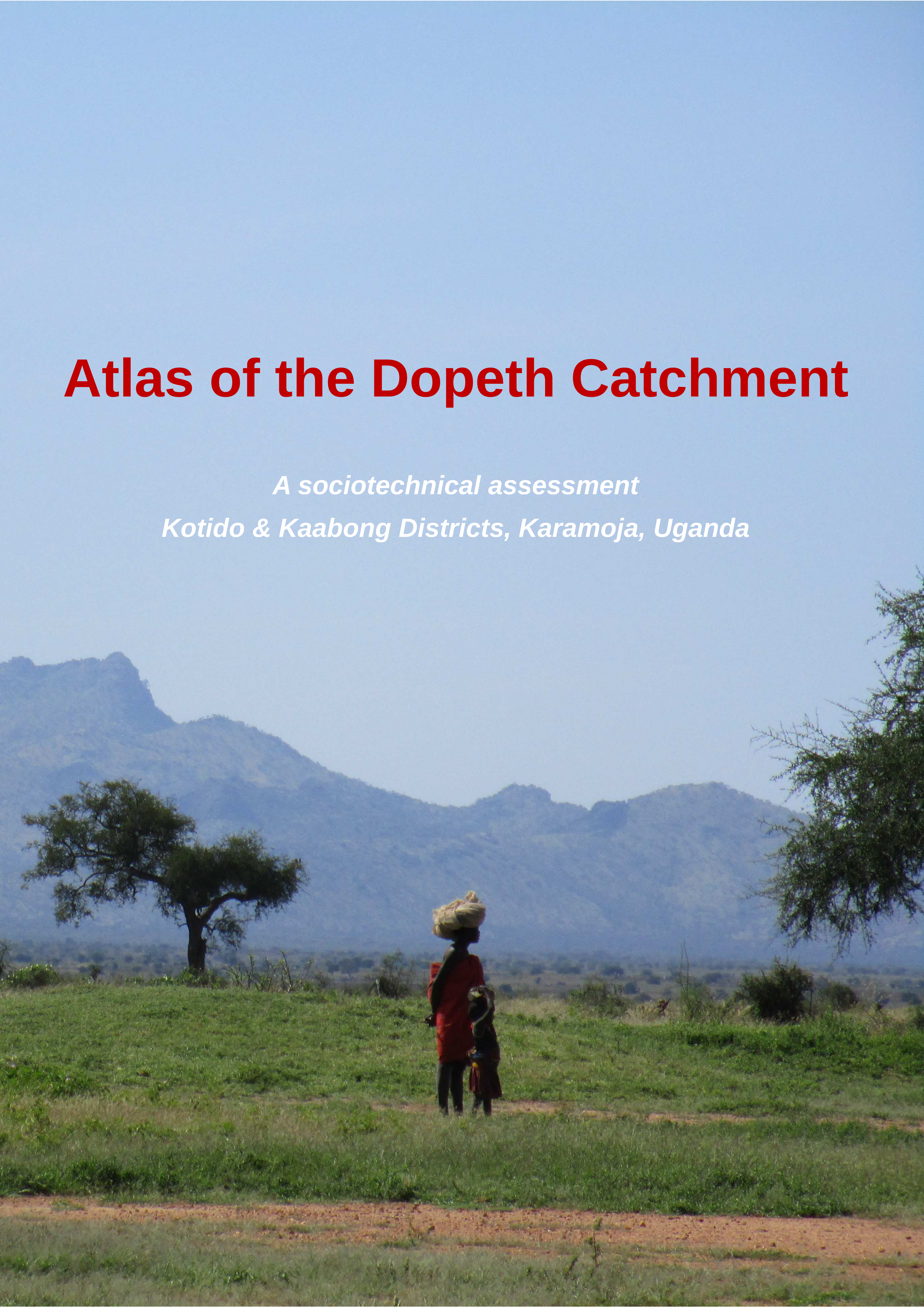
# Atlas of the Dopeth Catchment

***A sociotechnical assessment***

***Kotido & Kaabong Districts, Karamoja, Uganda***



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**An assessment by**

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Project lead: Acacia Water. Content, analysis and reporting: Wetlands International, RAIN and Acacia Water. Map production: Acacia Water. Design and editing Atlas: Acacia Water. Review by all partners, including Cordaid and Caritas Kotido. With financial support of Cordaid.



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Additions and remarks are welcome via info@acaciawater.com

# Atlas of the Dopeth Catchment

***A sociotechnical assessment, Kotido & Kaabong Districts, Karamoja, Uganda***

Karamoja is characterized by acute poverty and has the lowest social and economic development of Uganda. The situation improved over the past years, but the region was unable to successfully implement and manage long term sustainable development processes. The many disaster risk reduction, capacity building and other support projects proved helpful, but the region remains disaster prone. Much too often hazards still result in food insecurity, disease and conflict (e.g. UNDP 2014a, UNDP 2014b, FAO 2013, FAO et al. 2015)).

The underlying sociotechnical asssessment is part of a larger project that aims to formulate a development strategy towards building livelihood resilience. This sociotechnical assessment includes an analysis of the current biophysical situation of the Dopeth Catchment, the identification of linkages, challenges and opportunities, and the formulation of the most effective, practical and realistic solutions. In agreement with the IUCN guidelines and the policies adopted by the Government of Uganda (MWE - Directorate of WRM 2012), a catchment perspective is adopted and integrated ecosystem based disaster risk reduction approach is pursued.

In this Atlas, the results of the sociotechnical assessment are presented in the form of thematic maps. A description of the current biophysical landscape and the potential for improved land management, sustainable water resources use and use of other ecosystem services is given. Based on the assessment, at the end, the main challenges are summarized and possible solutions are provided.

We are confident  that the data and analyses presented will assist  to guide informed decision making in Karamoja, upon building more resilient livelihoods.

Gouda, The Netherlands, November 2015

*The Project Team*

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# Table of contents



**General legend**

In this Atlas, the main findings are presented on thematic maps. Each map comes with its own subject specific legend. However, there is a number of items that is presented on all map for orientation purposes. These items are included in the generalized legend on the right.

Country boundary
District boundary
Dopeth Catchment

**Towns**

Town
Regional Growth Centre
Village/Trading Centre

**Roads**

Motorable track
Secondary road

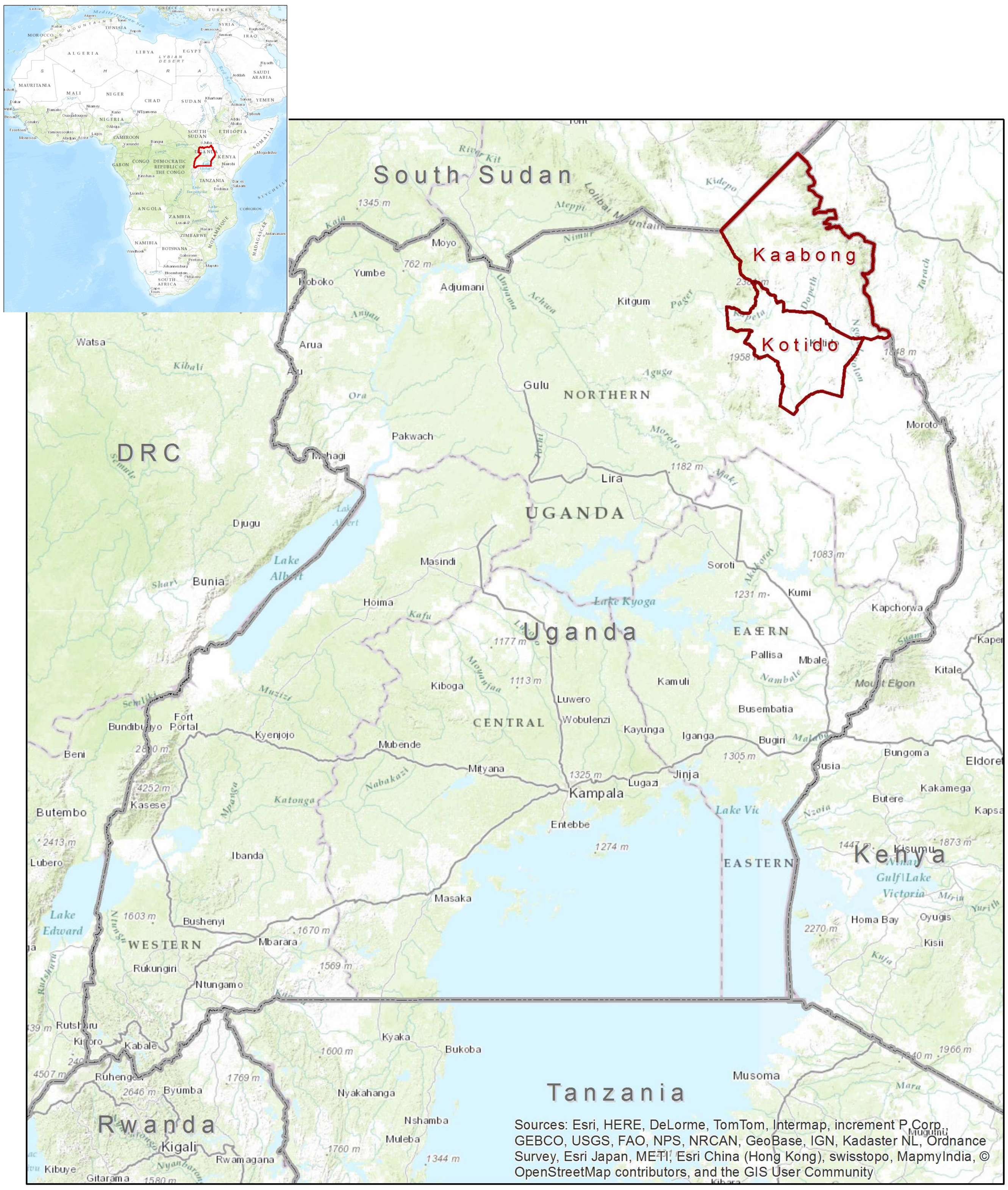
**Rivers**

Main seasonal river
Small seasonal river
Wetlands

# 1

# Background

# Project context and approach




**A. Location of Kaabong and Kotido Districts in Uganda**

## Karamoja

The project area is situated in Karamoja Region, more specifically in Kaabong and Kotido Districts (A), a vast semi-arid landscape in the Northeast of Uganda and some 550 km from Kampala. Karamoja (B) is characterized by acute poverty and has the lowest social and economic development of Uganda. Over 80% of the population lives below the poverty line of one dollar a day (Avery 2014). Factors contributing to the situation in the region are insecurity, environmental issues, marginalization, illiteracy , limited opportunies in marketing, poor health and poor infrastructure. Problems are largely attributed to droughts, flooding and disease outbreaks. The region is marked by a long-term dependency on external aid programmes. Recently, peace has returned following the disarmamament programme of the government. Economic and social development are slowly setting in.

In total 1.2 million people live in Karamoja, less than 3.5% of the total population of Uganda. The total area of Karamoja region is 27 900 $km^2$, 12% of the country's total surface (Avery 2014). Average population density is low, equalling 43 person/$km^2$.

**B. Cattle, maize cultivation and grasslands in Karamoja (Wetlands International 2015)**

## Project Approach

The underlying Atlas presents the results of the sociotechnical assessment of Kotido and Kaabong Districts in Karamoja, Uganda. The assessment is one of the inputs to a larger project that aims to formulate a development strategy to wards building livelihood resilience. Next to this sociotechnical assessment, the project includes a social context study, a stake-holder mapping exercise and an assessment on knowledge and coordination, especially at district level. The ultimate goal of the project is to strengthen and diversify livelihoods, build community assets and strengthen systems and structures that promote resilience to hazards.

Since a few years programmes by international organizations are being phased out in Karamoja. There is a clear cut back on emergency operations and food distribution. Karamoja has to explore new strategies to sustain its growing population. To minimize the effects of hazards such as heavy rainfall and droughts, amongst others in the light of climate change, disaster risk reduction, capacity building and other development projects were initiated by authorities and non-governmental organisations. Though these investments had their positive effect at community level, the impact of programmes can be increased by coordinating activities at a larger scale. Such coordination will increase the efficiency, effectiveness and long-term sustainability, especially because the system's processes are all interlinked (e.g. higher runoff rates in the mountainous areas may result in flooding downstream). This study aims to showcase the importance of an in-depth and integrated assessment at catchment scale to understand and describe the current situation before looking at interventions. The project aims to determine where to focus on, especially with regard to infrastructure and natural resources management, to ensure long term sustainable development investments.

The project adopts a catchment based natural resources management approach, following the introduction of this framework by the Government of Uganda. The approach improves the analytical underpinning of conclusions and recommendations and provides an opportunity for stakeholders to participate in the formulation of plans and the development of new (water) infrastructure (MWE-Directorate of WRM 2012).

To put the catchment based approach into practice, first all relevant data was collected, calibrated and validated. The results presented in this Atlas (maps, figures and analyses) are the outputs of integrated sociotechnical assessment and aim to support the fact-based decision making processes that will follow. During these processes priority interventions will be short-listed and the development strategy will be developed in collaboration with all stakeholders.

**Building livelihood resilience**

The results presented in this Atlas are input to the formulation of a development strategy towards building livelihood resilience in a disaster prone area. Resilience is the ability of a system exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR 2009).

Hazards are natural phenomena that may cause property damage and loss of live, such as heavy or very low rainfall. A disaster (e.g. food insecurity) occurs when a system cannot cope with the effects of a hazard. Disaster risk reduction starts from the viewpoint that hazards can be prevented from turning into disasters. Disaster risk results from the chance for a hazard to happen, the vulnerability of a system at risk and its capacities to

$$Disaster\ Risk\ = \frac{[Hazard\ \times\ Vulnerability\ ]}{Capacity}$$

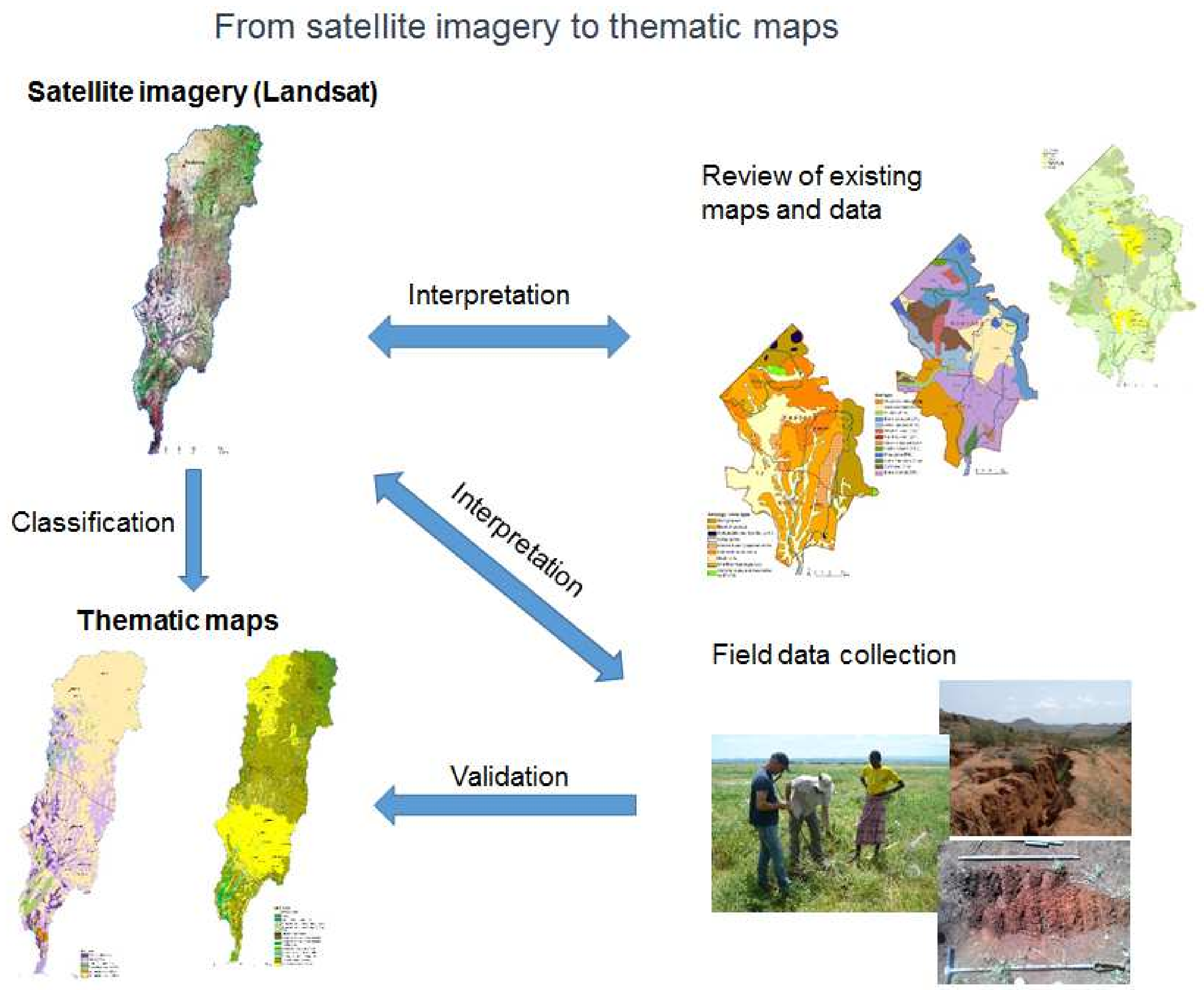
withstand or recover from a hazard event. High chance of hazard occurrence, coupled with high vulnerability and weak coping capacity, translate into high risks. Though hazards cannot be averted as such, vulnerability and capacity are factors that can be addressed, so that the system becomes more resilient, and disasters can be warded off. Vulnerability is herein defined as the susceptibility to the damaging effect of a hazard, while capacity refers to the collective strengths which allow people to survive and recover from a hazard event and transform the systems and structures to better withstand future events. If vulnerability can lowered and capacity improved, people become more resilient to catastrophes.

## Methodology

The results presented in this Atlas are the outcomes of a sociotechnical assessment on water resources, land and water management practices and ecosystem services, The focus is on the potential for improved land, water and other natural resources management that lead to disaster risk reduction. Results are presented in the form of thematic maps bounded by either Karamoja Region or the Dopeth Catchment (natural boundary, most suitable for integrated assessment), dependent on the availability and the level of detail of the data collected and the analyses performed.

The assessment started with a review of all readily available reports and data and preliminary GIS-analyses. The preliminary results provided a basic understanding of the biophysical context. The consecutive analysis of satellite imagery and field data collection was used to verify and validate the results of the desk(top) study and to fill the data gaps (C). Data collection in the field was organised along focus group discussions, interviews with key informants, surveys amongst stakeholders and field trips in the Upper, Middle and Lower parts of the Dopeth Catchment. The process of data analysis, refinement and validation is all but linear; myriad feedback loops and iterations were built into the study to ensure that the required level of detail was achieved and that no elements were over-looked. After refining and updating the results, a second field visit was undertaken to discuss the findings and the opportunities for intervention with key stakeholders.

Based on the assessment of the current situation and the thematic maps showing the potential for water resources, land and water conservation and use of ecosystem services, a simplified hazard-disaster assessment was performed and possible solutions/ interventions were identified.

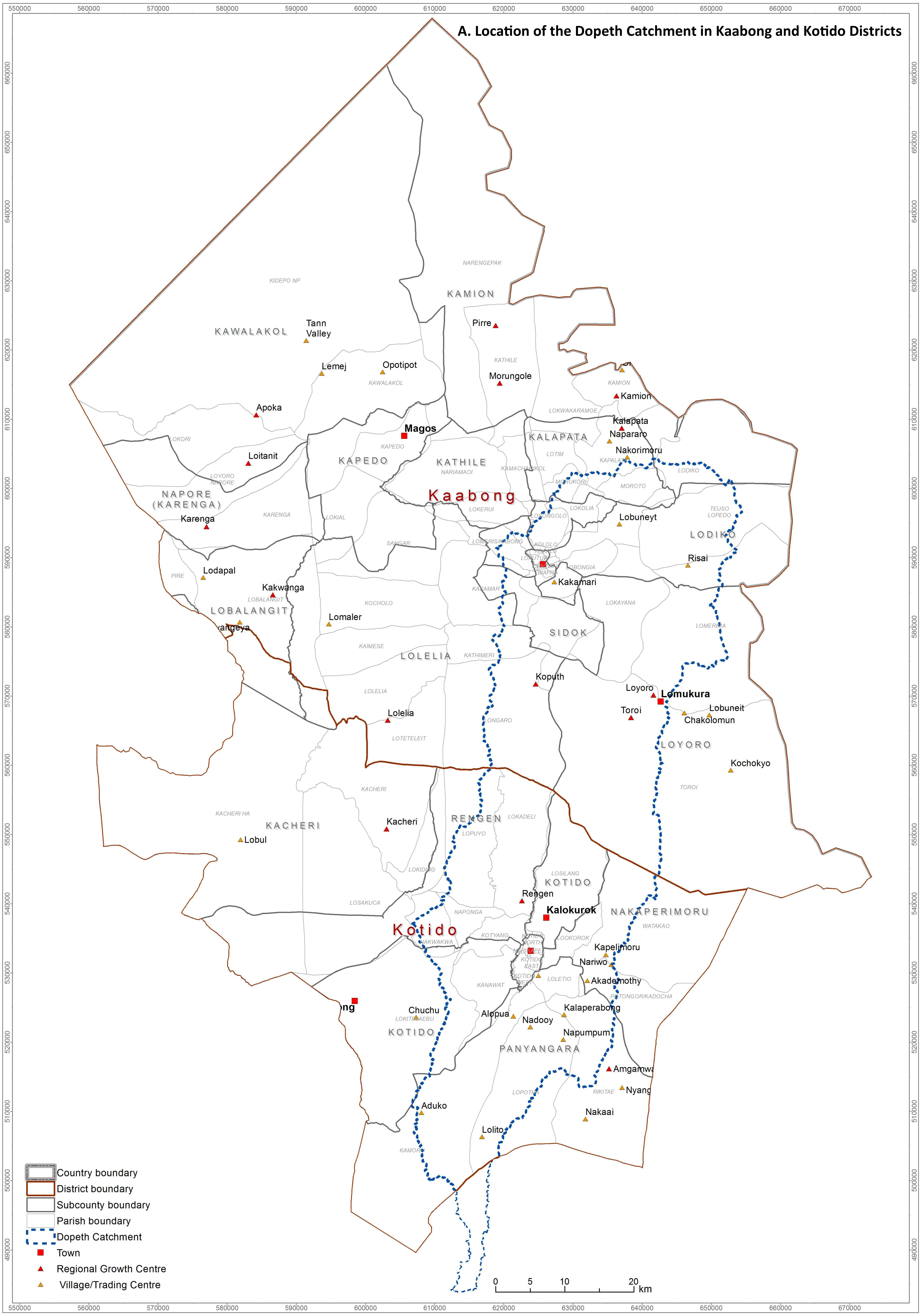



**C. Graphical representation of the methodology applied to produce the thematic maps presented in this Atlas**

## Organization of the Atlas

The aim of the underlying sociotechnical assessment is to identify the main challenges and opportunities and to prioritize interventions from a biophysical perspective. In the first chapter, the background to the project is provided. The location is further specified and the nature of the livelihoods is described. The second chapter addresses land use and its management. It starts with a description of the soils, includes information about current and potential land use and land cover, and ends with information on crop– and rangeland management strategies. Chapter 3 is dedicated to ecosystems. It provides an overview of the of the various ecosystems present in the project area and the ecosystem services provided, describes their inter-linkages and value to the communities. In Chapter 2 the water resources are discussed. The section describes surface water bodies, water sources, water demand and use, and an assessment of groundwater resources. Furthermore, it includes detailed maps that describe the potential for recharge and retention interventions. The fifth chapter emphasizes the need for and details on conservation strategies. In a simplified hazard and disaster assessment a cause-effect overview is provided, including the main challenges and opportunities. Chapter 5 also provides the main conclusions and recommendations.

# Boundaries




A. Location of the Dopeth Catchment in Kaabong and Kotido Districts

### Project area

Following from the river basin management approach, the boundaries of the project are set by the biophysical characteristics of the terrain. Focusing on the communities around Kotido and Kaabong Towns, the project is bounded by the Dopeth Catchment, the area of land where surface water converges in the Dopeth River near Kotido.

The administrative boundaries do not coincide with the catchment. The Dopeth River runs through Kaabong and Kotido Districts (A) passing the towns Kaabong and Kotido .

**B. Karamojong (Pluth 2013)**

### Karamojong

The population of Karamoja consists of a number of ethnic groups, such as the Jie, Dodoth, Ik, Matheniko, Tepeth, Bokora, Pian and Pokot. Together they form the Karamojong (B). The Karamojong live and die for cattle (C) — the determinant of seemingly everything in pastoral life. The Karamojong are constantly on the move to find enough water and pasture, and to defend and increase their herds. Women often stay at one central settlement called a *manyatta* (D), where they look over small farms and take care of the youngest children. Although much has improved, insecurity among tribes continues to threaten the viability of livelihoods and the ability of households to earn a living.

The Karamojong have developed tremendous adaptation potential that has enabled them to survive the harsh conditions in the semi-arid region. Whenever there are improvements in weather and security conditions, households adopt innovative approaches to maximize such opportunities, including re-activation of food crop production, marketing of agricultural produce, petty trade and rearing of small animals. These livelihood options have strengthened the adaptability of households despite the high poverty levels in the region (FAO et al. 2015).

Notwithstanding the pastoralist traditions, nowadays, an increasing number of people rely on largely sedentary agro-pastoral livelihoods, which combine livestock rearing with crop production. Depending on the socio-cultural and economic situation, the fertility of the land and rainfall, people make their living through combinations of nomadic livestock (cows and goats), agriculture (cereals, vegetables), keeping small livestock (goats, chickens) in the villages, and small-scale trade. Some smaller ethnic groups, like the Ik, live retreated in the mountains; they rely on hunting and gathering. Recently, the contribution of trading and mining to the regional economy is also increasing.

The reduction of the land carrying capacity due to population growth and changing livelihoods is, however, putting more pressure on natural resources, especially where both livestock and wildlife compete for pasture and water.

**C. Cattle (Premiere Group 2015)**

**D. Manyatta (Acacia Water 2015)**

### Changing conditions

Livelihoods in Karamoja are changing. The developments are complex and cannot be summarized in brief. However, it can be said that there are four processes that stand out amidst all the change: population growth, sedentarization, the development of new economic sectors and the improved security.

Although Karamoja is known for its remoteness, and low population density, the region has a population growth of  six to seven per cent per year. The development of infrastructure struggles to keep up with this growth.

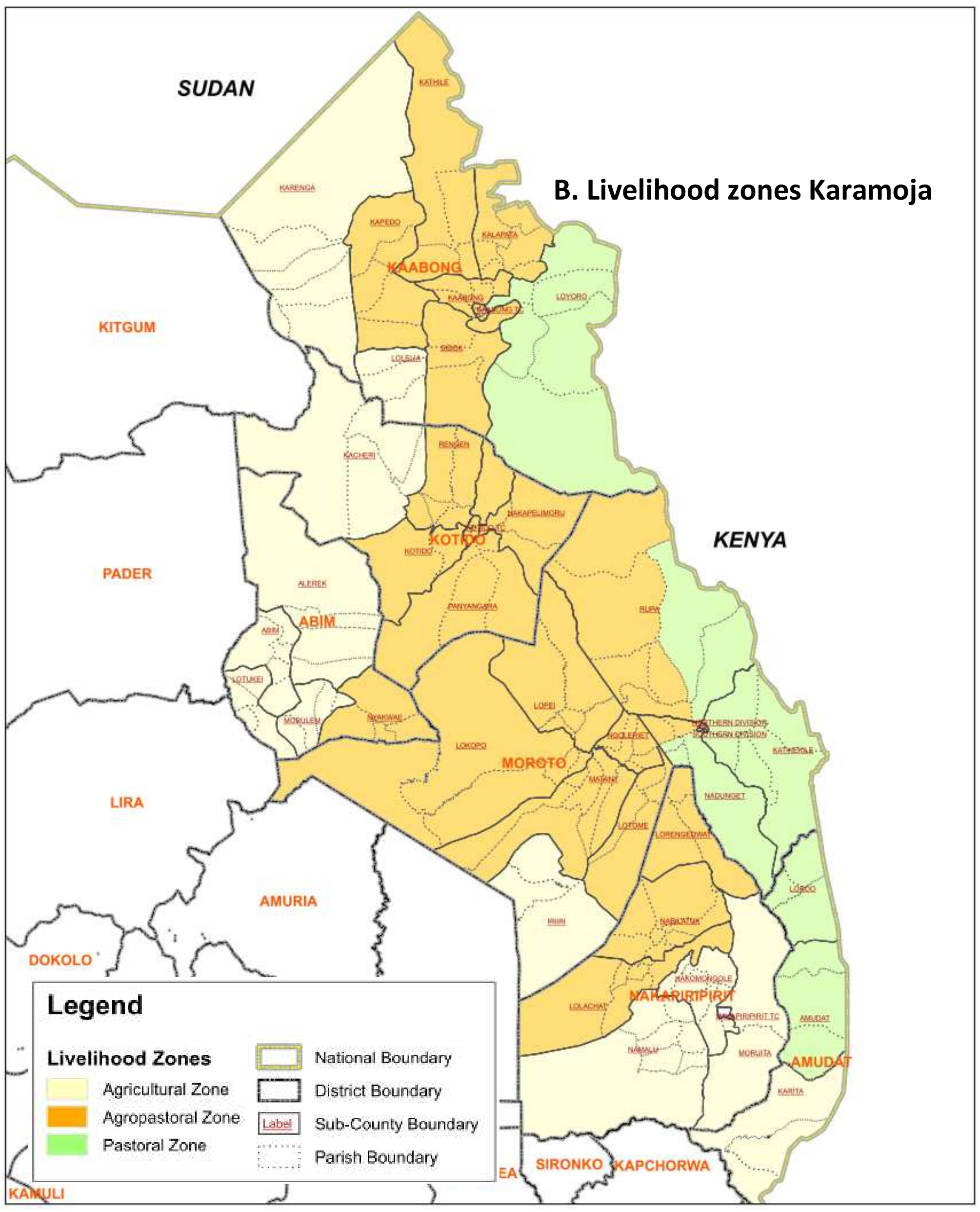
Sedentarization is seriously changing lives in Karamoja. In the former days the coping strategy of most of the people living in these areas was a mobile way of living. The community moved to places with sufficient water and other resources when needed. However, mobility has seriously decreased, on the one hand due to policies favouring communities to settle and on the other beacuse of the improved security situation.  The concentration of population in villages and towns is increasing pressure on land and water resources. Land degradation is aggravating, water shortages are perceived more intense and conflicts over pasture and water are aggravating. The value of land and water as a critical element for survival cannot be overestimated.

### Policies and investments

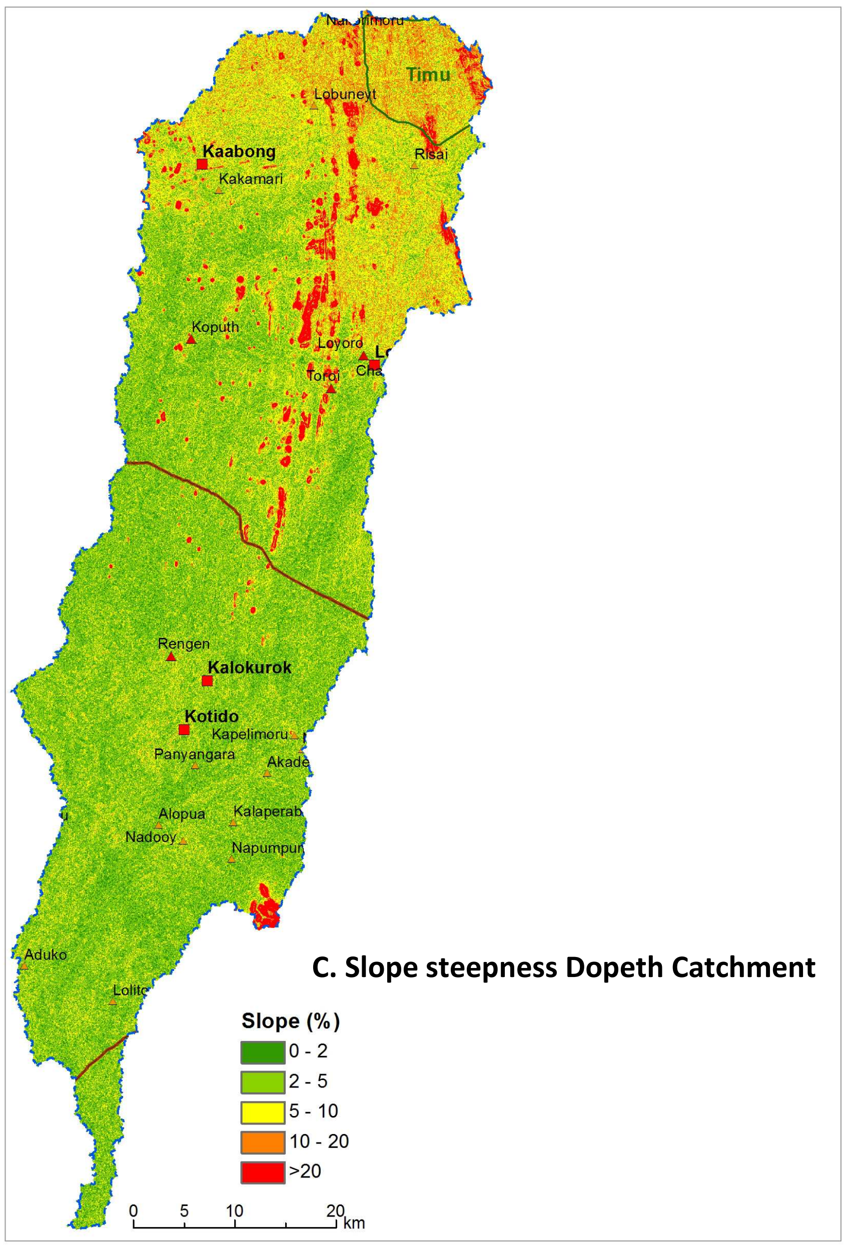
Karamoja was historically considered a marginal region. Although the situation has improved over time, eaducation, health care, housing, and water and sanitation services are below average. For many years, the general picture of Karamoja has been that of conflict and low human development as compared with other regions of Uganda.

The Government of Uganda has promoted crop farming as an alternative to pastoralism sources of livelihood. With the changes policy makers aimed to develop more modern, productive and environmental friendly practices. On the contrary, no significant institutional frameworks have been designed explicitly to promote pastoralism as a potentially viable livelihood system that contributes to national development. Generally, and in line with the national frameworks, few policies and investments have supported (agro-)pastoralism in Karamoja.

# Dopeth Catchment



B. Livelihood zones Karamoja



C. Slope steepness Dopeth Catchment

## Topography and livelihood zones

Topography alone tells a lot about Karamoja's remoteness (A). To its East stands the Rift Valley escarpment towering over the Kenyan plains and scrubland. To the North lie the pristine basin of Kidepo National Park and the mountainous vastness that leads into Sudan (B). To the south, there are the rugged peaks of Mount Elgon National Park, which were formed by volcanic eruptions millions of years ago. In the west, abundant swamps enter into the Acholilands. Many mountains in Karamoja's periphery are over 3 000 m, including Mount Kadam, Napaka and Moroto (Pluth 2007).

The region can be divided into three key livelihood zones (C), which are known as the Western agricultural zone, the Central agro-pastoral zone and the Eastern pastoral zone. This zoning applies to most geophysical characteristics of the region, including topography, soils, natural vegetation, precipitation and climate change scenarios. The Western wet green belt agricultural zone is characterized by hills, mountains and plains cut by valleys and rivers. The Central agro-pastoral zone is predominantly made up by undulating plains with isolated inselbergs (monolithic outcrops), seasonal rivers and gullies. The Eastern pastoral zone is a rugged terrain with gullies and rills.

The Dopeth Catchment runs from the Eastern pastoral zone in Kaabong District through and to the Central agro-pastoral zone in Kotido District. The source of the Dopeth River is located at an altitude of approximately 2 000 m asl. Almost 100 km downstream, where the Dopeth River converges with the Loporokochia River, the altitude is between 1000 and 1250 m asl. The slopes are steepest at the source of the river (C,D).

**D. Landscape Upper Dopeth (Acacia Water 2015)**

**E. Landscape Middle and Lower Dopeth (Acacia Water 2015)**

## Precipitation

Karamoja's climate is semi-arid. The total average annual rainfall varies between 300 and 800 mm per year (B). The precipitation pattern is highly variable in space and time, with high peak events and long dry periods.

The rainfall pattern is unimodal. In general, the rainy season runs from April to October with the desert winds and the hot dry season taking over from November to March. However, the length of the dry season varies between four and nine months depending on the exact location. June is often characterized by a typical three week dry spell.

Precipitation data has been acquired from rainfall stations in the area. However, few stations are available and data series are incomplete. To complete the precipitation data, all available daily precipitation records of the Africa Rainfall Climatology dataset (ARC-2) from the Famine Early Warning System Network (FEWS-NET) have been downloaded. This resulted in a dataset of daily precipitation from 1983 to 2014 on a 0.1 arc-degree grid (10 by 10 km cells).

With regard to the spatial variability (A), the Western zone is sub humid, with an average yearly rainfall of more than 800 mm/year. Rainstorms are most common in April, July and August.

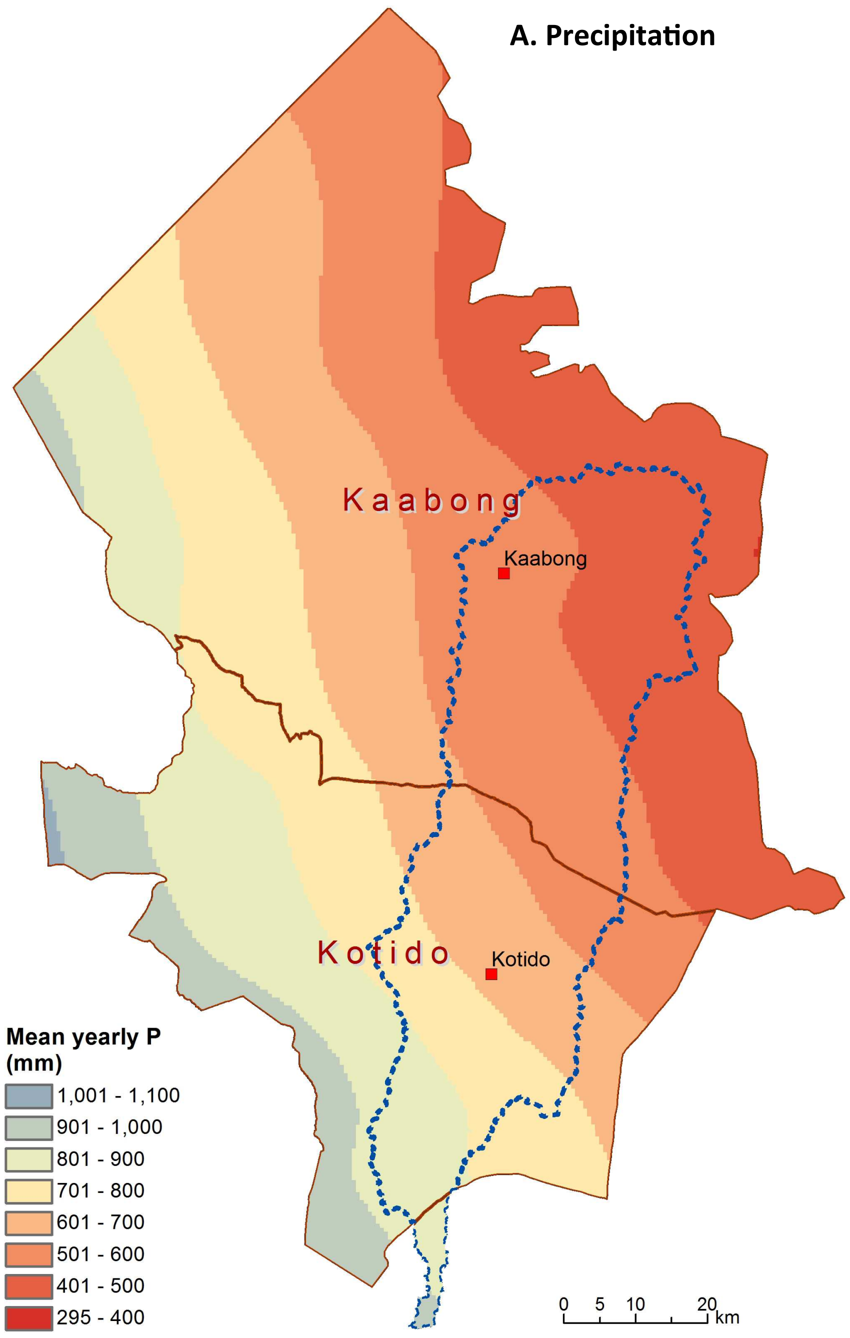
In the Central zone average rainfall varies between 500 and 800 mm/year, becoming more erratic to the East. Rainstorms of more than 25 mm and floods are common during the rainy season, but those are comparatively less intense than in the Western zone.

The Eastern zone is characterized by highly erratic and unreliable rainfall, varying between 300 and 700 mm/year. Rainfall is concentrated on a few rainy days between March and September (UN FAO 2009, Maimbo and Malesu 2014).

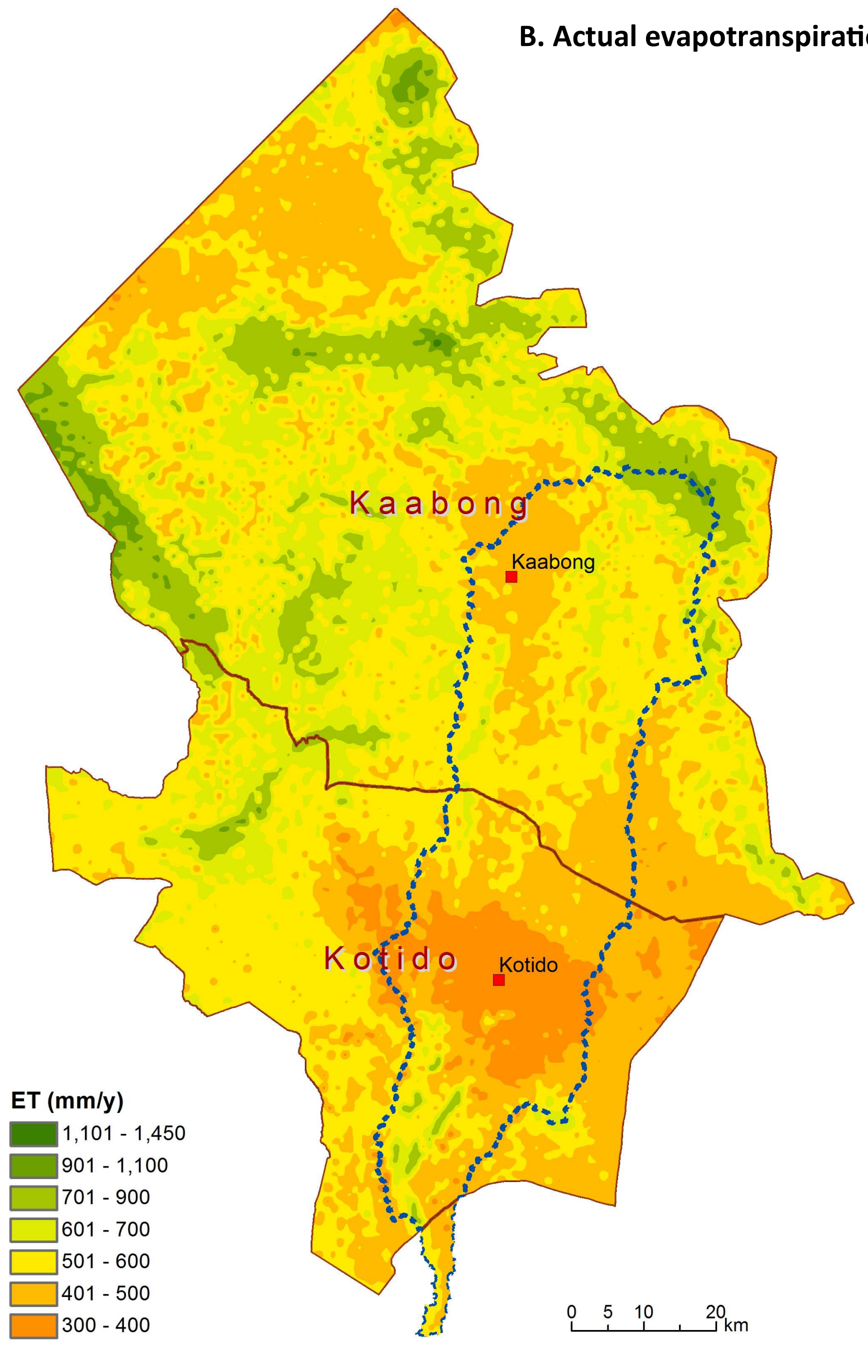
Note that rainfall is lowest in the upper part of the Dopeth Catchment; it increases along the course of the river.

As a result of erratic rainfall, the whole region suffers from acute water shortages during the dry season and heavy flash floods during the rainy season. Shortage of pastures, water scarcity, food insecurity and destruction of infrastructure are all strongly related to this variability in rainfall.

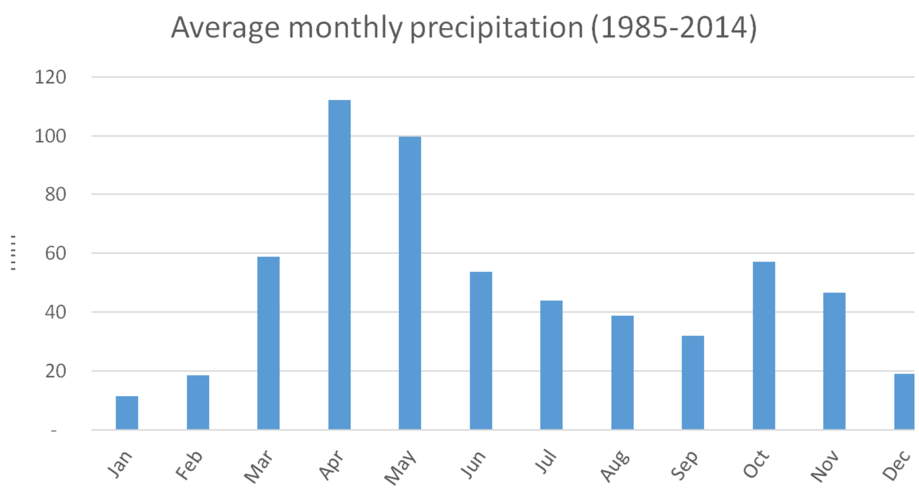
**A. Precipitation**



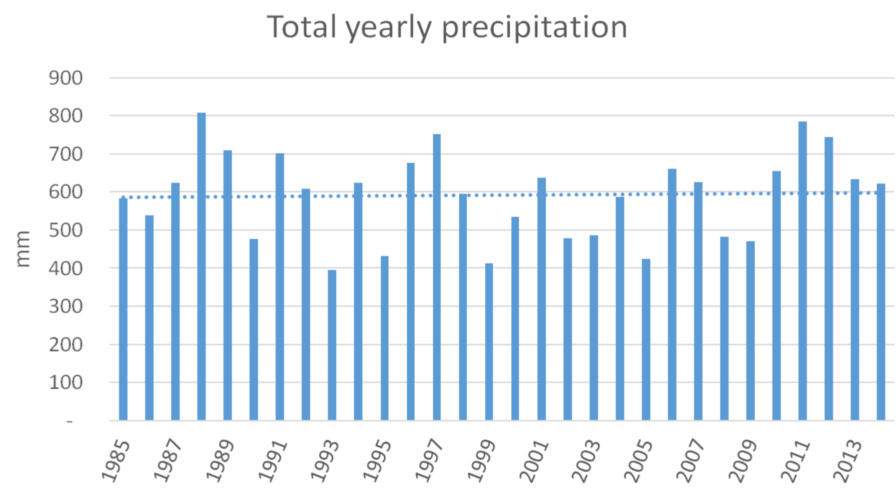

**B. Actual evapotranspiration**



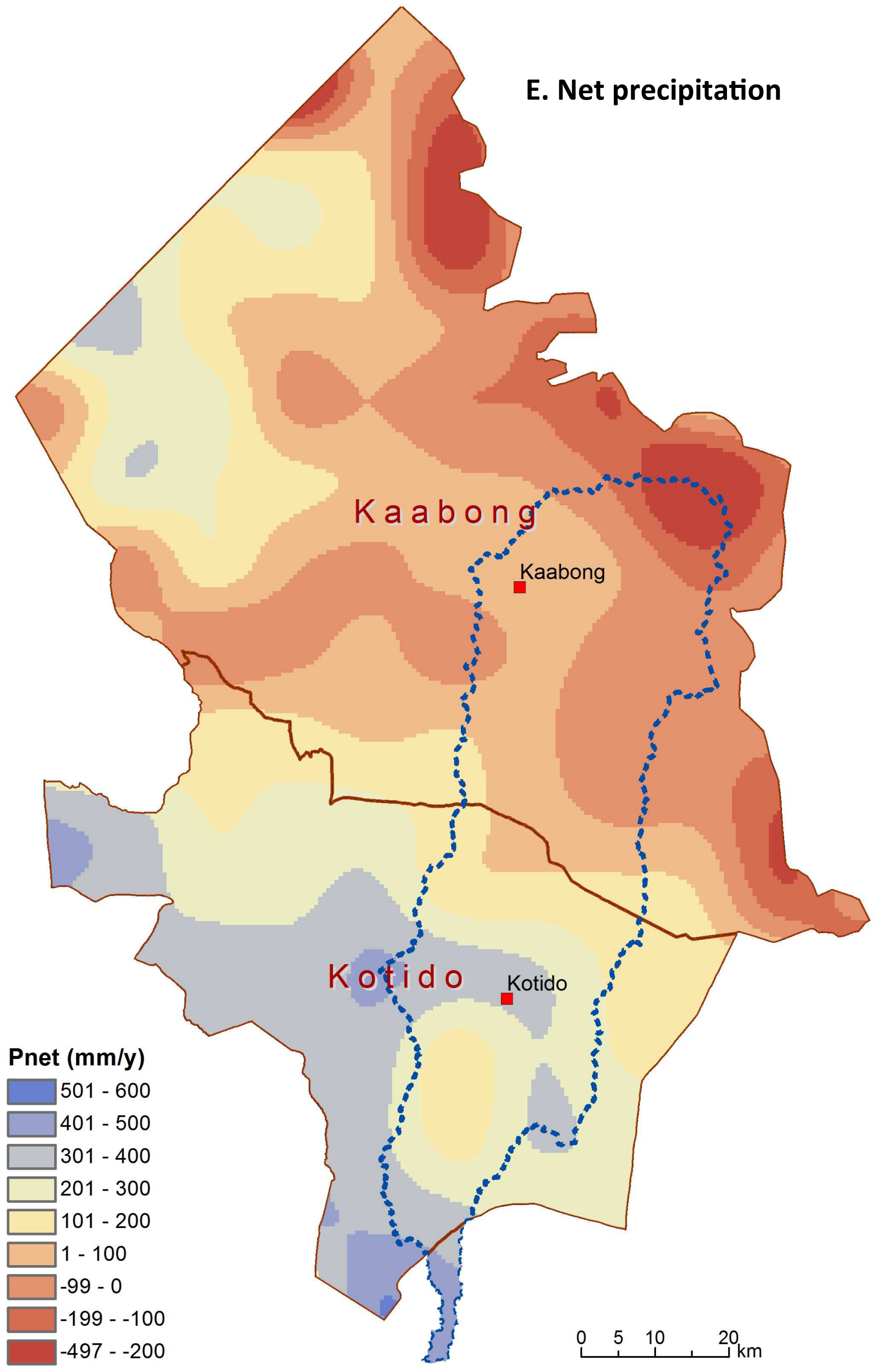

**C. Monthly precipitation averaged for the Dopeth Catchment**




**D. Yearly precipitation averaged for the Dopeth Catchment**



**E. Net precipitation**




## Evapotranspiration

In Karamoja, actual evapotranspiration, based on MODIS-data, varies between approximately 350 and 900 mm/year (B). Moderate temperatures during the rainy season result in limited evapotranspiration rates. On the contrary, the high to very high temperatures and strong winds that are typical for the dry season lead to high evapotranspiration rates, spread of bush fires and wind erosion (UN FAO 2009, Mubiru 2010).

The spatial variability of actual evapotranspiration is highly related to vegetation cover. Evapotranspiration is the sum of all water moving to the air from the soil, canopy and water bodies, and the loss of vapour through plant stomata. In the project area, evapotranspiration is highest in the forested areas. Along the river courses and at the rangelands that are in fair to good condition evapotranspiration is reasonable to high. These figures indicate that large amounts of water leave the system through canopy interception and transpiration. When modelling the region and developing water management plans it is important to include these losses.

In the highly eroded areas around Kotido and Kaabong and over the agricultural areas, evapotranspiration is low. Since the temperatures during the dry season are as high in these areas as elsewhere in the region, the low rates indicate that there is little water to evaporate: the vegetation cover is limited, soil moisture is low and there are no surface water bodies during the dry season.

## Net Precipitation

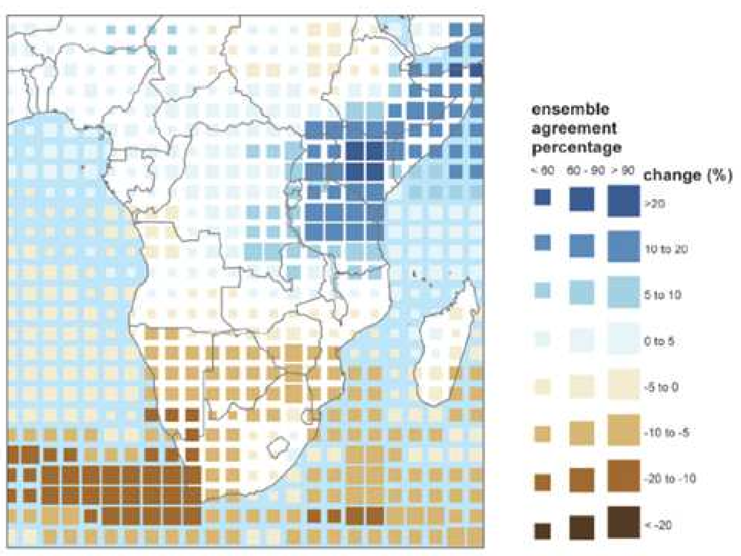
The average annual net precipitation (E) was calculated by deducting the actual evaporation from the precipitation. In over 80% of the project area annual precipitation exceeds evapotranspiration, meaning that there is a net surplus of water. It should be noted that the evapotranspiration dataset used is calculated using an algorithm that is based on the Penman-Monteith equation and incorporates surface stomatal resistance and vegetation information. Open water evaporation is not included.

## Climate Change and droughts

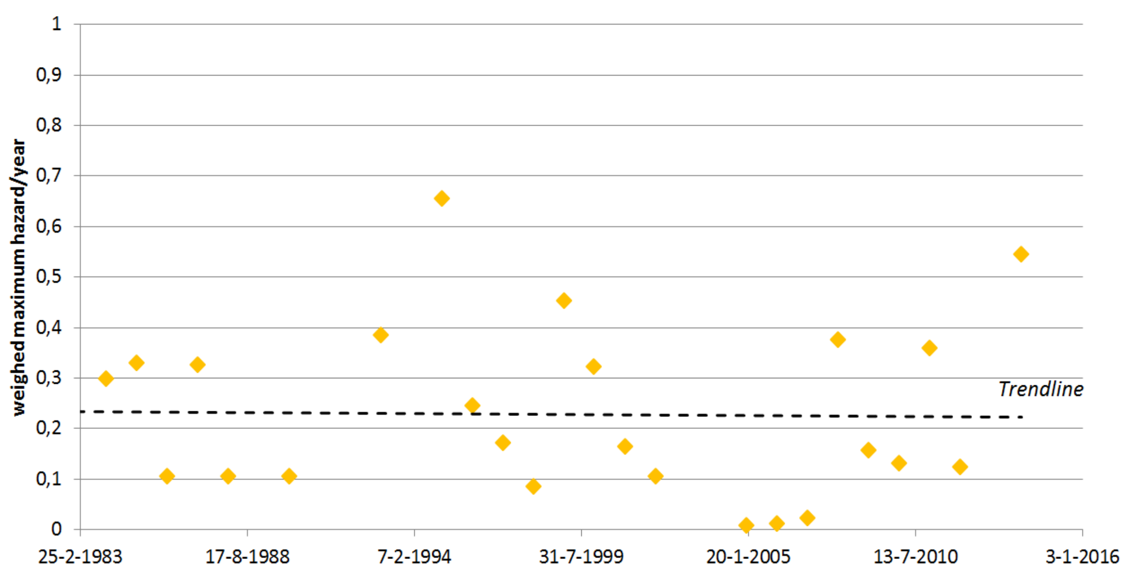
Models developed by the UNDP and UK Met Office, and refined by UK Met Office/Hadley Centre (2010), indicate that it is likely that in the future temperatures and rainfall intensity will increase in Karamoja. Average temperatures are projected to increase by up to 1.5 degrees Celsius in the next 20 years (USGS 2012, Mubiru 2010). Rainfall is expected to increase with 10 to 20 per cent over the coming 100 years (UK Met Office 2010) (G). Furthermore, all models agree that precipitation will become more intense and erratic and that the incidence of extreme dry spells, lightning strikes, floods and storms will increase.

The definition of 'drought' is subjective. Some figures and interviewees indicate that droughts have already become more frequent and severe in recent years. The way in which rain falls has changed with precipitation now being characterized by intense events of 20 to 35 mm separated by long periods of no effective rain (Magunda 2010, Office of the Prime Minister – Department of disaster preparedness and refugees 2008, and USGS/USAID 2012). On the contrary, a trend analyses of rainfall intensity, average amounts, and precipitation drought duration and intensity of droughts, using the TLM-method as described by Huijgevoort et al 2012, does not show an increase in drought frequency, duration or intensity nor of their combination (F). The most plausible explanation for this discrepancy is that the disasters induced by the same climate have increased over the years due to e.g. an increased number of water users, degradation of the catchment and mismanagement of resources.

**G. Projected changes in precipitation (UK Met Office 2010)**




**F. Trend in combined drought duration and hazard (for Kalapata)**

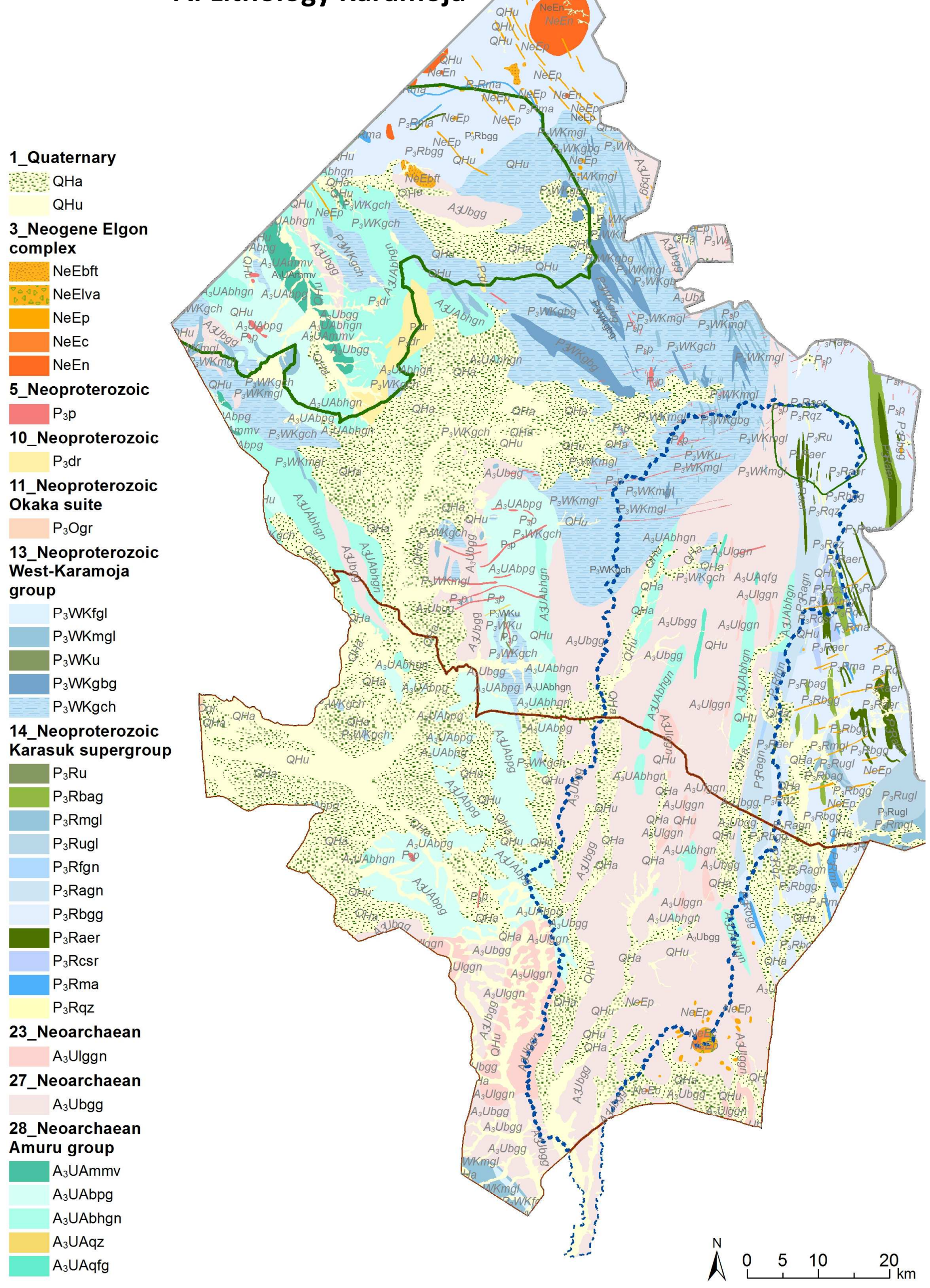


# 2

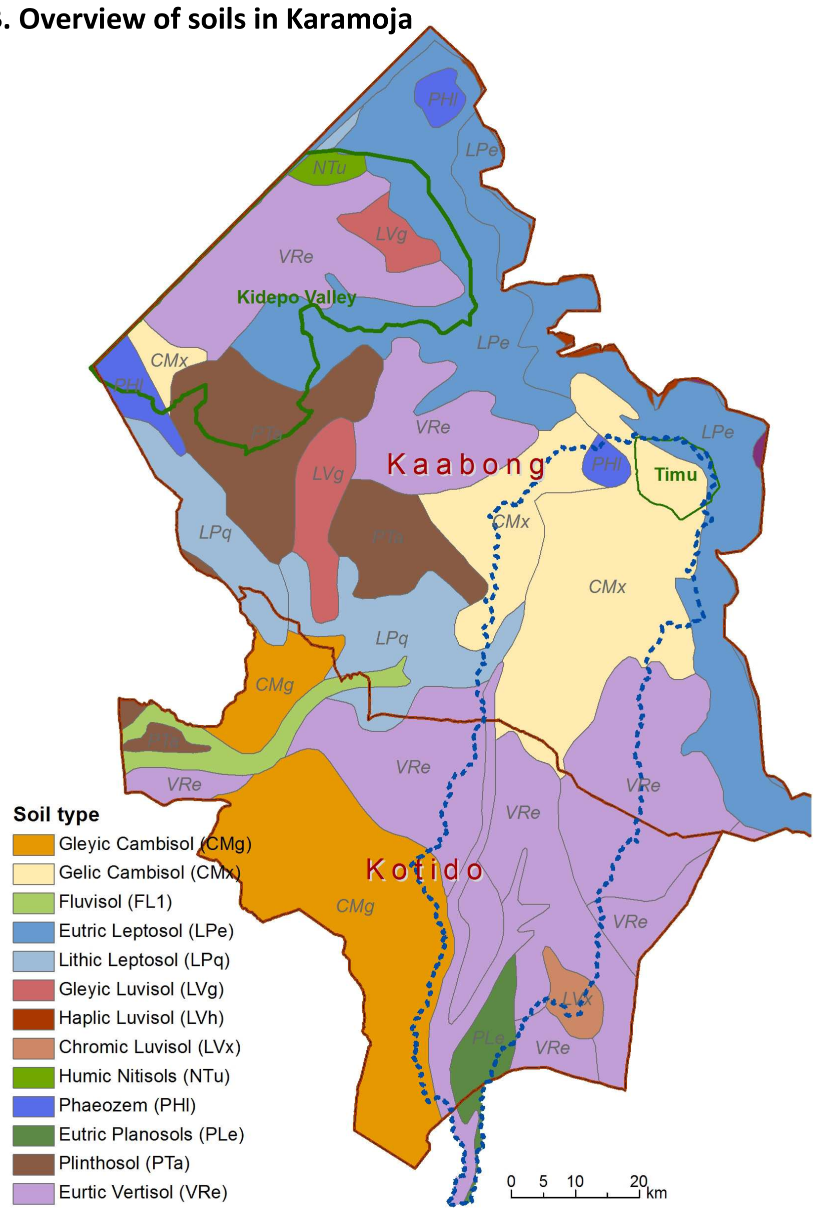
# Land use and management

# Soils

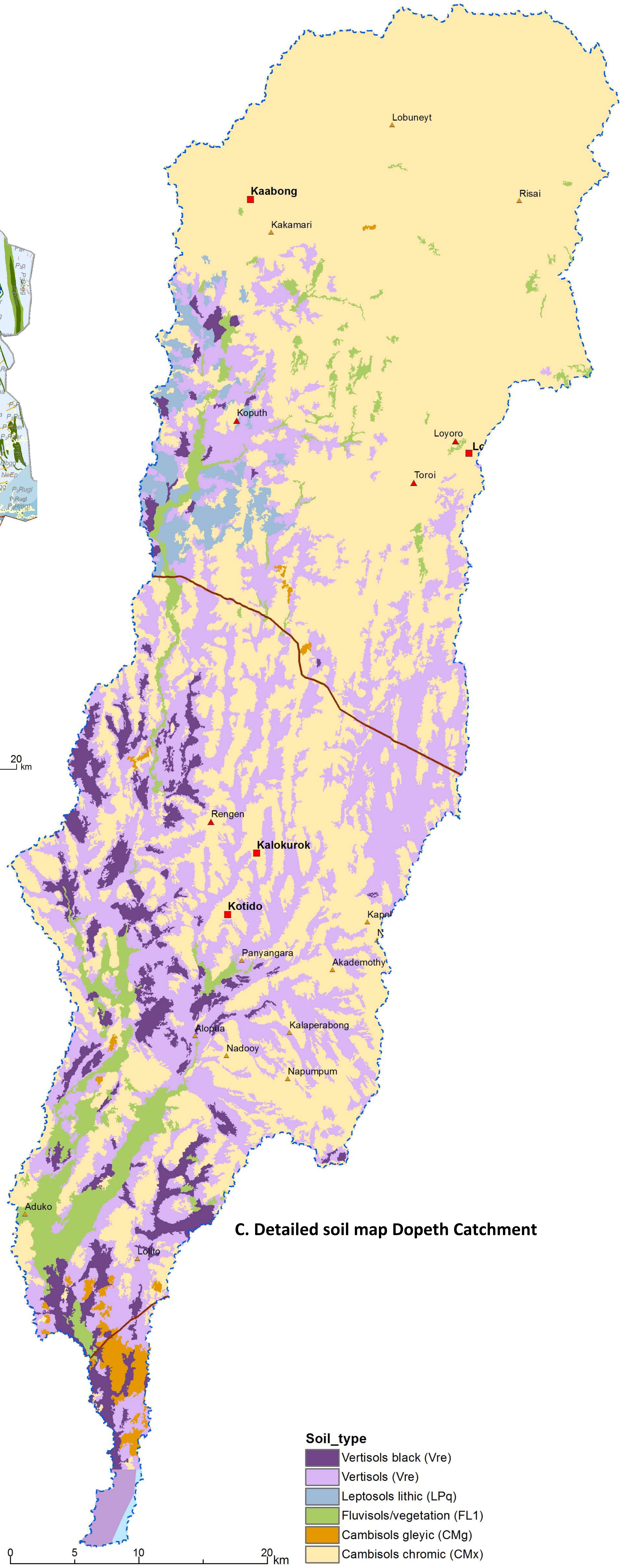
A. Lithology Karamoja




B. Overview of soils in Karamoja




C. Detailed soil map Dopeth Catchment



### Soil classification and suitability

Partly because of lithological differences (A), the soil types in Karamoja are highly variable (B). In the West, cambisols (D) predominate. These soils are typically well drained sandy loams, loams and sandy soils, which are known for their reasonable fertility and suitability for mechanized agriculture (UN FAO 2009). The valleys and flood plains are covered with a mixture of cambisols and vertisols (E). Vertisols are black and dark grey soils with a very high clay content. In general, these soils are low in organic matter, have a medium moisture storage capacity and a poor drainage capacity, and are very prone to erosion. In the far eastern highlands, at the border with Kenya, soils are mostly sandy gravels and red sandy loams (leptosols, F), all with a notable very low fertility. These soils hardly support any vegetation and are most suitable for extensive (migrant) pastoral activities. Inselbergs, outcrops of basement rocks, are present throughout the landscape.

The Dopeth River originates on the highly degraded ragged terrain with sandy gravels and red sandy loams in the Eastern pastoral zone. The soils in the Upper Dopeth Catchment belong to the cambisols class (C), which is characterized by the absence of accumulated clay, humus or oxides. The texture is sandy loam or finer. Cambisols are well drained and provide opportunities for a wide variety of agricultural uses.

In the lower part of the catchment, closer to Kotido, the Dopeth River flows through well-developed soils; almost half of the area is covered by vertisols. Vertisols are also known as black cotton soils after their dark grey to black color. The heavy soil texture and domination of expanding clay minerals result in a narrow soil moisture range between moisture stress and water excess. These soils are sticky when wet, crack when dry and are very prone to erosion.

**G. Soil erosion on vertisols**

**D. Cambisols**

**E. Vertisols**

**F. Leptosols**

### Erosion

Erosion in Dopeth Catchment is mainly concentrated in the agricultural areas. Erosion is a physical process that entails the detachment, transport and deposition of soil particles. The process can be either forced by water or wind energy.

In the Upper part of the catchment, on the steep slopes, deep rillls, gullies and mass movements are visible. In the Middle and the Lower Catchment, predominant problems are river bank degradation, sheet, rill and gully erosion, and wind erosion. On-site impacts of erosion inlude reduced soil fertility because of detachment of the upper nutrient-rich soils layers, loss of arable land and reduced soil water as the groundwater drains into gullies. Off-site, where the transported sediments are deposited, the process results in the sedimentation and eutrophication of the water bodies, and siltation of dams and ponds.

The erosion processes in the Dopeth Catchment are the result of a combination of the natural biophysical characteristics of the landscape, and anthropogenic activities. Close and upstream Kaabong, slope steepness is a major contributor. In the Middle and Lower Catchment, the soil type (vertisols) forms the major challenge. Due to swelling, the infiltration capacity of vertisols is extremely low, which results in high run-off rates. As a consequence, particles are easily detached and transported.

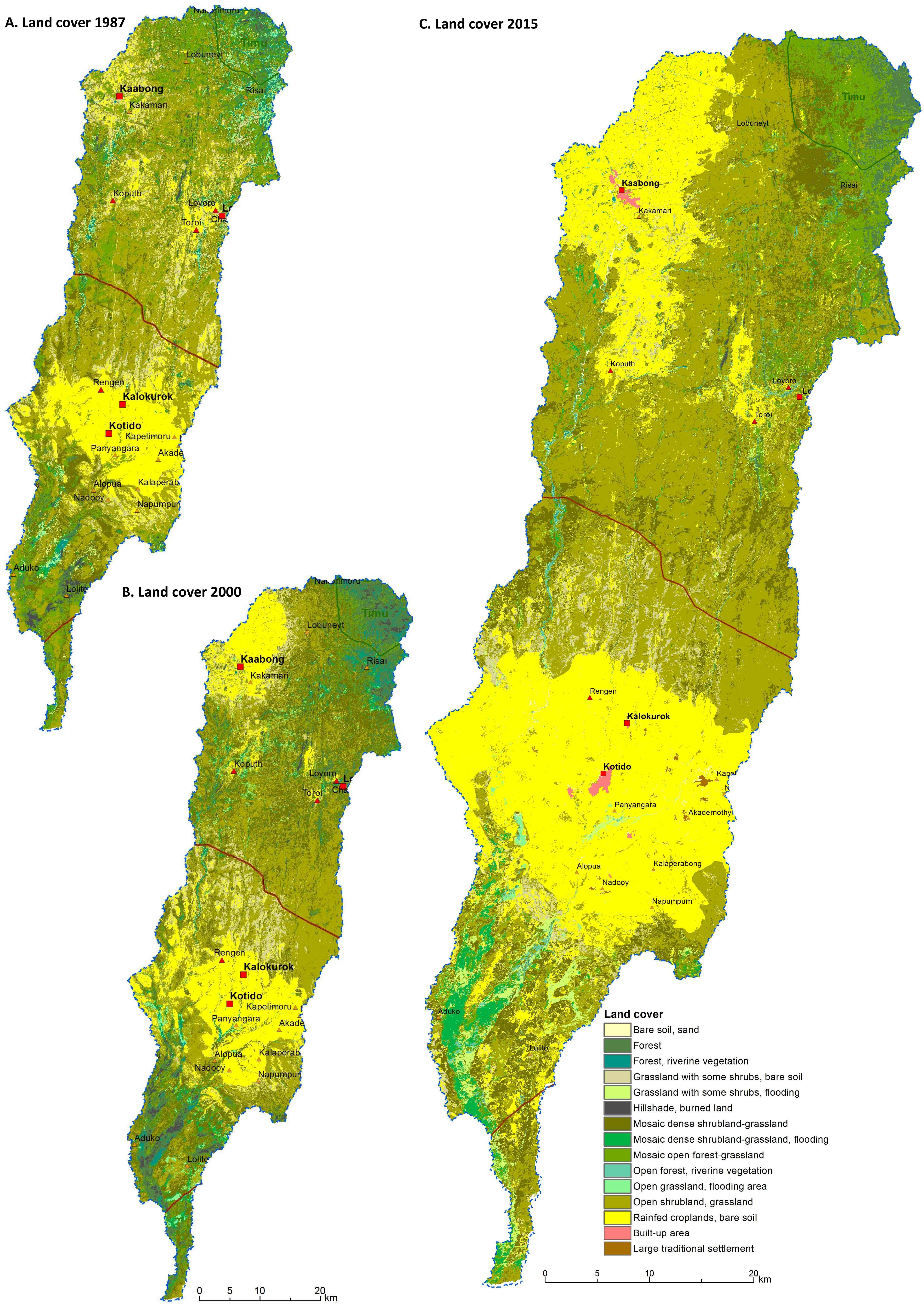
Despite the natural challenges, soil erosion would not have to be a problem were adequate management practices implemented. A number of anthropogenic activities is accelerating the erosion process: deforestation, cattle movements, loss of organic material and expansion of agricultural land. Deforestation is the consequence of charcoal production for use in town, land clearing for agriculture, and use of wood for construction, fencing and cooking. The movement of cattle results in the formation of tracks that form preferential flows though bare soils with high runoff rates. This is especially problematic on steep slopes and and close to settlements and watering points. Further, because manure is not recycled for agricultural purposes, organic material is lost, while the expansion of agricultural lands, especially on the slopes is adding to the problem. Together the factors lead to a loss of vegetation cover, declining soil structure, higher run-off rates, and therewith to higher erosion rates.

### Soil management

To address erosion, retain water and improve agricultural productivity in the Dopeth Catchment, sensitization on and investments in adequate soil management are fundamental. It is recommended to

- Promote conservation tillage and contour ploughing;
- Use fanya juu terracing and cut-off ditches on shallow slopes (1-10%) and bench terracing on steeper slopes (10-25%);
- Return manure and residue of crops to the agricultural fields, and plant nitrogen fixing crops;
- Introduce and promote crop rotation, inter-cropping and agro-forestry;
- Encourage crop diversification and introduce drought resistant crops such as cow peas and millet;
- Invest in soils conservation techniques such as soil bunds, demi lunes, etc.;
- Construct wind breaks; and
- Construct micro-dams on vertisols to keep the subsoil moist and, therewith,avoid cracking.

# Land cover


A. Land cover 1987
B. Land cover 2000
C. Land cover 2015
Timu
Lobuneyt
Kaabong
Kakamari
Risai
Koputh
Loyoro
Toroi
Rengen
Kalokurok
Kotido
Kapelimoru
Panyangara
Akademothyi
Alopua
Kalaperabong
Nadooy
Napumpum
Aduko
Lolito
Land cover
Bare soil, sand
Forest
Forest, riverine vegetation
Grassland with some shrubs, bare soil
Grassland with some shrubs, flooding
Hillshade, burned land
Mosaic dense shrubland-grassland
Mosaic dense shrubland-grassland, flooding
Mosaic open forest-grassland
Open forest, riverine vegetation
Open grassland, flooding area
Open shrubland, grassland
Rainfed croplands, bare soil
Built-up area
Large traditional settlement
0 5 10 20 km

## Land cover

The Dopeth River springs in the Timu Forest, a reserve predominantly covered by forest and open forest with grassland (C). Towards the west and south, around Lobuneyt and Koputh and past the district boundary, the landscape is dominated by open shrubland, consisting of acacia shrubs and thickets in open grassland. In a 15 km radius around Kaabong the land cover is dominated by small-scale agriculture. Past the district boundary towards Kotido, the shrubland becomes more open, and open grasslands with short thickets become dominant. As in Kaabong, an extensive area of small-scale farmland developed of the past years around Kotido town. Downstream of Kotido, the map shows two large green patches with a mosaic of dense shrubland and grassland, these are seasonal flooding areas along the Dopeth River. Smaller stretches with flooding areas are visible along upstream the Dopeth. The patches indicate the location of large wetlands.

## Normalized Difference Vegetation Index (NDVI)

The type of land cover and vegetation influences evapotranspiration, water use, susceptibility to erosion and the availability of pasture. An analysis of the vegetation cover was made with NDVI , based on satellite imagery from MODIS. The maps below provide the mean (E) and the variance in NDVI over the period 2000-2014. The mean NDVI of the Timu forest area is high (E), with a small variance (F), which means that the cover is present throughout the year. The Middle Catchment is covered with open shrubland and grassland (C). The greenness index in this area is not very high, and its variance medium (E,F).

Outstanding in both maps are the agricultural areas around Kaabong and Kotido, where both the mean and variance NDVI are very low compared to the surroundings. This indicates very low vegetation cover, and/or bare soil throughout most of the year. Along the Dopeth River, open forests and riverine vegetation are dominant. In the wetlands both the average and variance NDVI are high. The vegetation in the wetlands is always relatively green, but becomes even denser during the rainy season. In the upper reaches of the river, the average NDVI is high, but the variance low, meaning that the trees are green throughout the year.

## Land cover changes

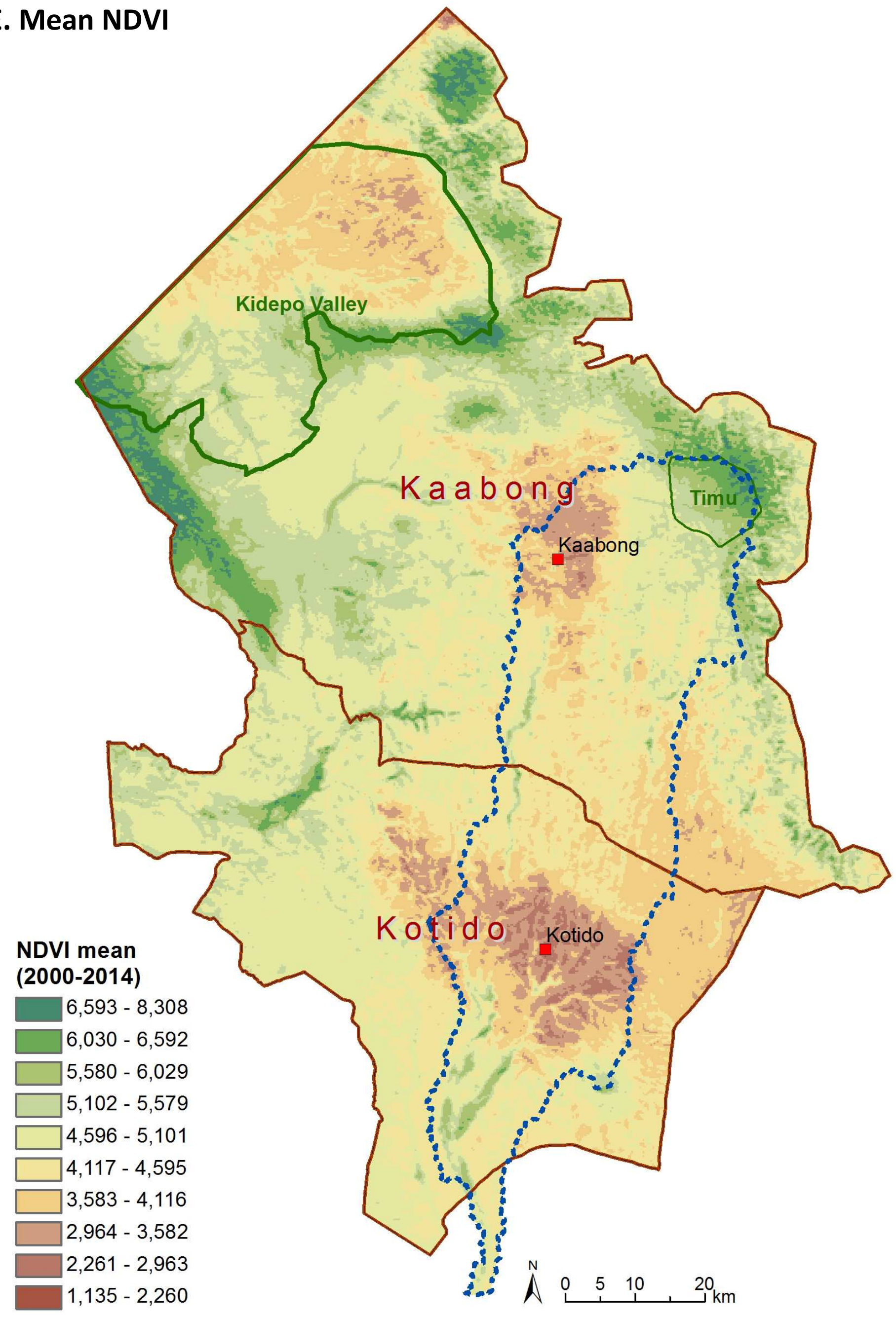
Standing out in all maps are the agricultural areas around Kaabong and Kotido. The area under croplands is ever expanding (A,B ,C ,D) into the shrulands and forests. Between 1987 and 2015 the area under cropland doubled, while the largest changes took place in the last 15 years (D). With the expanding farmlands, there seems also to be a shift in surrounding land cover types. The changes took place in especial detriment of the forested and dense shrub land areas. The shrublands directly sorrounding the settlement and agricultural areas, are becoming of poor quality, with some bare soil, while dense shrublands and forest are transforming into open shrubland.

As shown by the NDVI analysis, the average vegetation cover in the agricultural areas is extremely low, with the soil being exposed for most of the year intensifying erosion processes. Around Kotido vertisols are prone to severe gully erosion, while exposed cambisols are prone to water and wind erosion. In areas laying bare, soil fertility and land are lost, and infiltration and soil moisture are minimal (see also the sections on Soil and Agriculture).

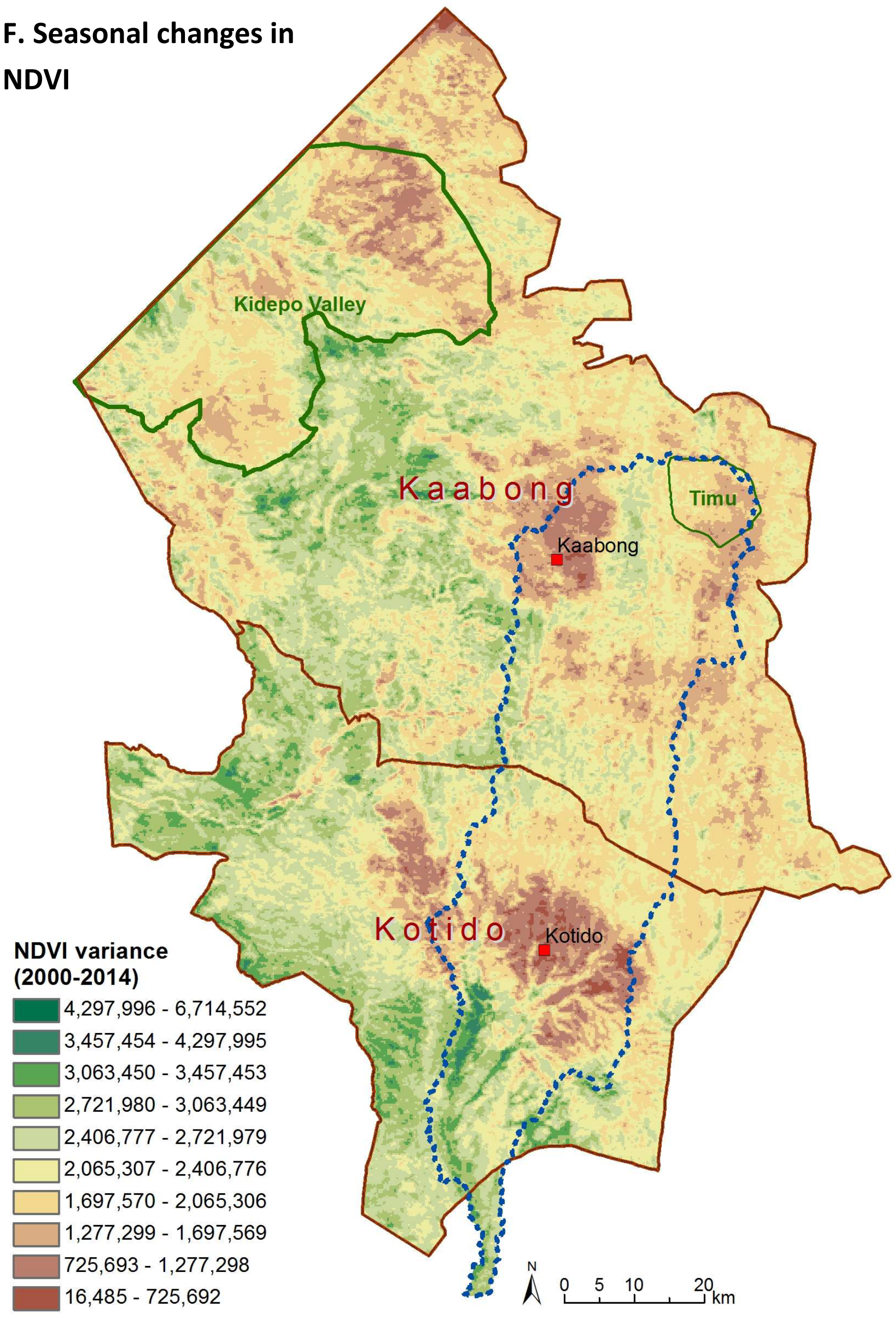
**D. Change of land cover over the period 1987-2015**

| Main land cover type | Area km2 | | | Area % | | |
|---|---|---|---|---|---|---|
| Year > | 1987 | 2000 | 2015 | 1987 | 2000 | 2015 |
| Croplands | 429 | 501 | 903 | 16 | 19 | 33 |
| Shrublands, grasslands | 1326 | 1089 | 1122 | 49 | 40 | 42 |
| Forest, dense shrubland | 926 | 1079 | 664 | 34 | 40 | 25 |
| Other | 22 | 34 | 14 | 1 | 1 | 1 |

**E. Mean NDVI**

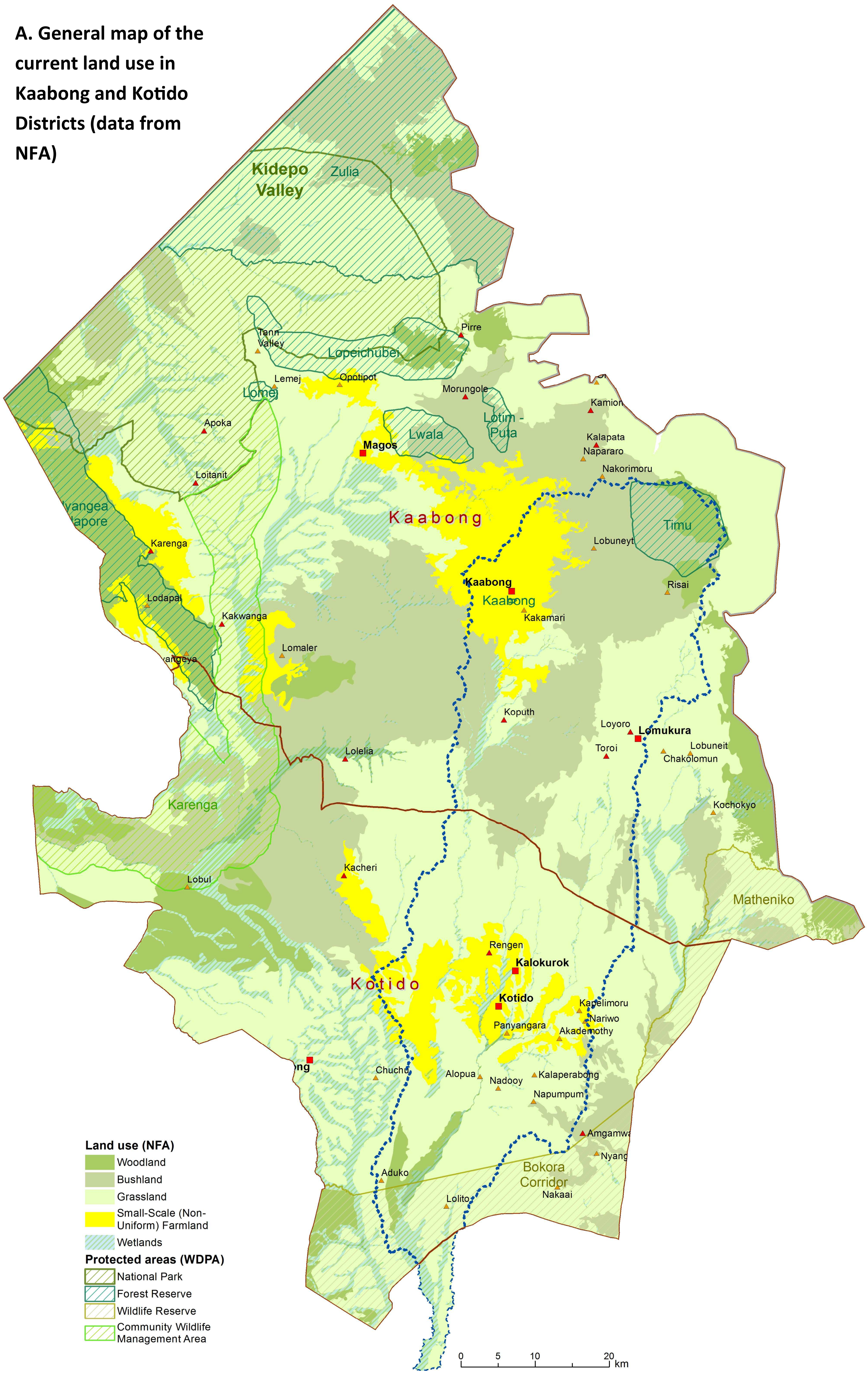



**F. Seasonal changes in NDVI**

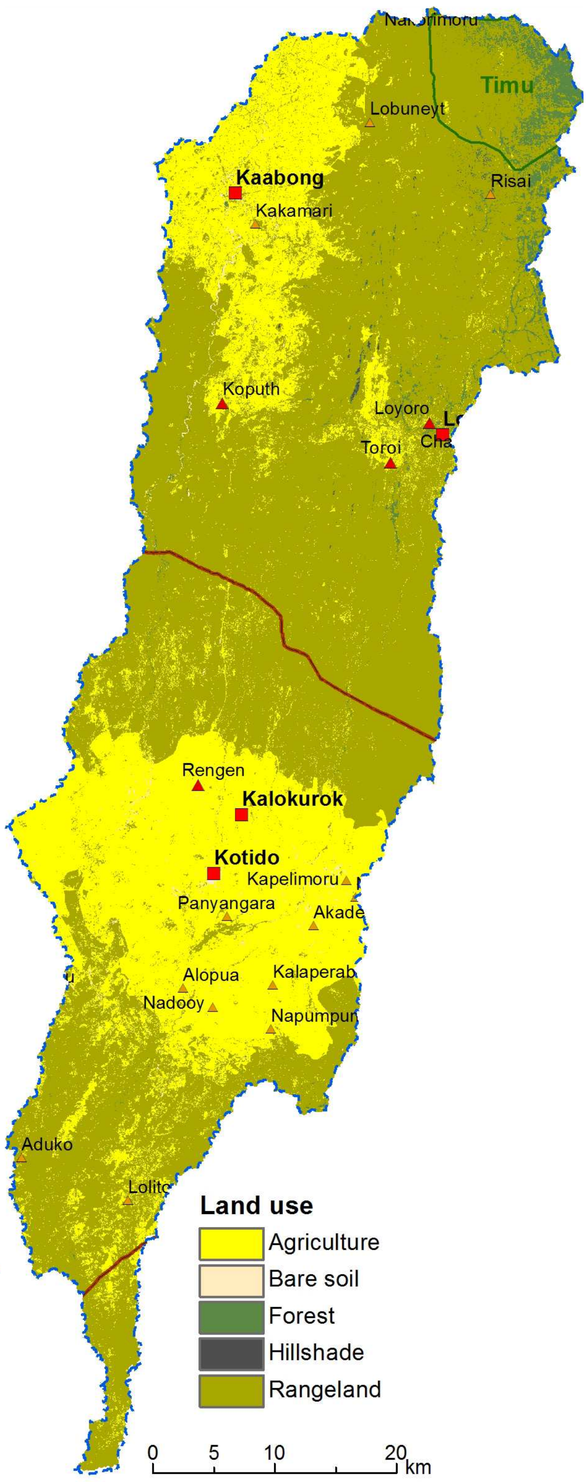


# Land use

**A. General map of the current land use in Kaabong and Kotido Districts (data from NFA)**




**B. Detailed map of the current land use in the Dopeth Catchment based on satellite imagery from 2015**




## Land Use

Most of Karamoja is used as rangeland by pastoral communities. Also within the Dopeth Catchment this is the main land use type (42%), while agricultural land use is increasing (33%). Forests and dense shrublands make up 25% of the land use. Local communities collect wood from the forest, woodlands and shrub lands. Grass- and shrublands are mostly used for grazing. Agriculture is mainly rain fed.

**C. Landscape impression of the agricultural area in Kotido District**

## Livelihood changes

Land use and land cover have changed over the years. Socio-economic, environmental and political factors have shaped livelihood conditions and opportunities in Karamoja. Improved security conditions, registration of land rights, government guidelines and access to markets have promoted the shift from livestock husbandry to agro-pastoralism. The movement toward households with an (additional) income from crop production is still on the way.

In the past, the Karamojong made a living from pastoralism, hunting and gathering of fruits, vegetables and other natural products. Nowadays, however, they are increasingly migrating toward urban centres and supplementing their income with crop production. Farming, mainly rain fed, is expanding especially since the security situation improved in the past 5 years. Traditional pastoralist communities are also moving toward agriculture. They realize crop production in the direct vicinity of the *manyattas.*

Expansion and poor agricultural practices are exhausting the natural resources, especially the soils. Farmers are resorting to cultivation on virgin lands, including steep slopes, wetlands, riverbanks and other vulnerable areas. As a consequence valuable ecosystems are being lost and the resilience of the system is decreasing. In addition, increased sedentarisation and reduced migration has reduced the capacity of the population in coping with climate extremes. When hazards occur, these elements add up and create disaster. For example, during an extreme drought, crops fail, while natural resources are weakened and communities are unable to migrate.

## Livestock

The Karamojong are herders; they live and die for cattle. Cattle raids used to be common, partly because the Karamojong believe they own all cattle by a divine right, but also for its use in dowries. Nowadays, livestock is increasingly also seen as an asset. Marketing of cattle is therewith becoming an extra source of income.

By day, men and boys move around with the cattle for grazing and watering. During the rainy season they often find these resources close-by so they do not have to move that far, but during the dry season they often have to move further away. At night, cattle are kept in the middle of the *manyatta* for security reasons. With regard to grazing, gazetting for wildlife is often mentioned as a problem because it reduces the availability of pasture for livestock. Gazetting is often imposed by government without proper consultation of communities.

Another major problem with livestock is keeping them pest and disease free, especially during the dry season when pasture and water availability are limited and the condition of cattle is suboptimal. The prevalence of pests and diseases in this period frequently results in reduced productivity and loss of cattle. The major transmitters of diseases are tsetse-flies and ticks.

## Protected areas

A large part of Karamoja has a protected status, 40.2% of Karamoja's total land is under protection of Uganda Wildlife Authority (UWA). Kotiodo and Kaabong Districts have a number of areas that have a protected status (A). The most important area is Kidepo Valley, which has the status of a National park. Within the Dopeth Catchment, there are two reserves, Timu Forest Reserve in the far Northeast and the wildlife reserve Bokora Corridor in the South.

National Parks are an important source of revenue for the government and important for biodiversity and conservation of ecosystems. However, for communities living close to these protected areas, conservation often translates into problems, such as loss of access to resources, crop damage caused by wildlife, conflicts over resources, etc. This creates conflict between the National Park authorities and the communities neighbouring them. Within Timu Forest Reserve large areas have been burned, in 2014/2015 and recent NGO activities promote settlement and agriculture which is not in line with the with the reserves management objectives.

Conservation and protection of high value ecosystems and wildlife can be an effective way of protecting ecosystem services and increasing resilience. However, it can only be sustainable when communities are actively involved and share in the benefits. A collaborative management between UWA and the communities could solve the issues, and create a win-win situation, where communities benefit from healthy ecosystem systems, and can make controlled use of its services, while UWA benefits from the communities efforts for conservation and reduced conflicts. This could also be applied outside the protected areas through Ecosystem-based Adaptation (EbA) approaches. The EbA approaches are elaborated in the section: Ecosystems and their services - Ecosystem based Adaptation.

## Deforestation

Deforestation is a major problem in Karamoja. Wood and timber are used for a large number of purposes in traditional households, therewith reducing the tree cover. Population growth and land use changes toward expansion of farmland are accelerating deforestation. The main drivers of deforestation are clearance for cultivation, thick fencing of cattle kraals and construction of *manyattas*, charcoal production, brick killns and communal landownership (tragedy of the commons) (D). Deforestation results in habitat destruction, loss of biodiversity and pressure on ecosystem services and aggravates erosion processes. The latter is especially becoming a problem on the steep slopes in Kaabong District. There, clearing of forested areas for expansion of farmland leads to accelerated erosion and therewith to loss of soil fertility, increased runoff and ultimately to flooding problems downstream because interception and retention are minimized.

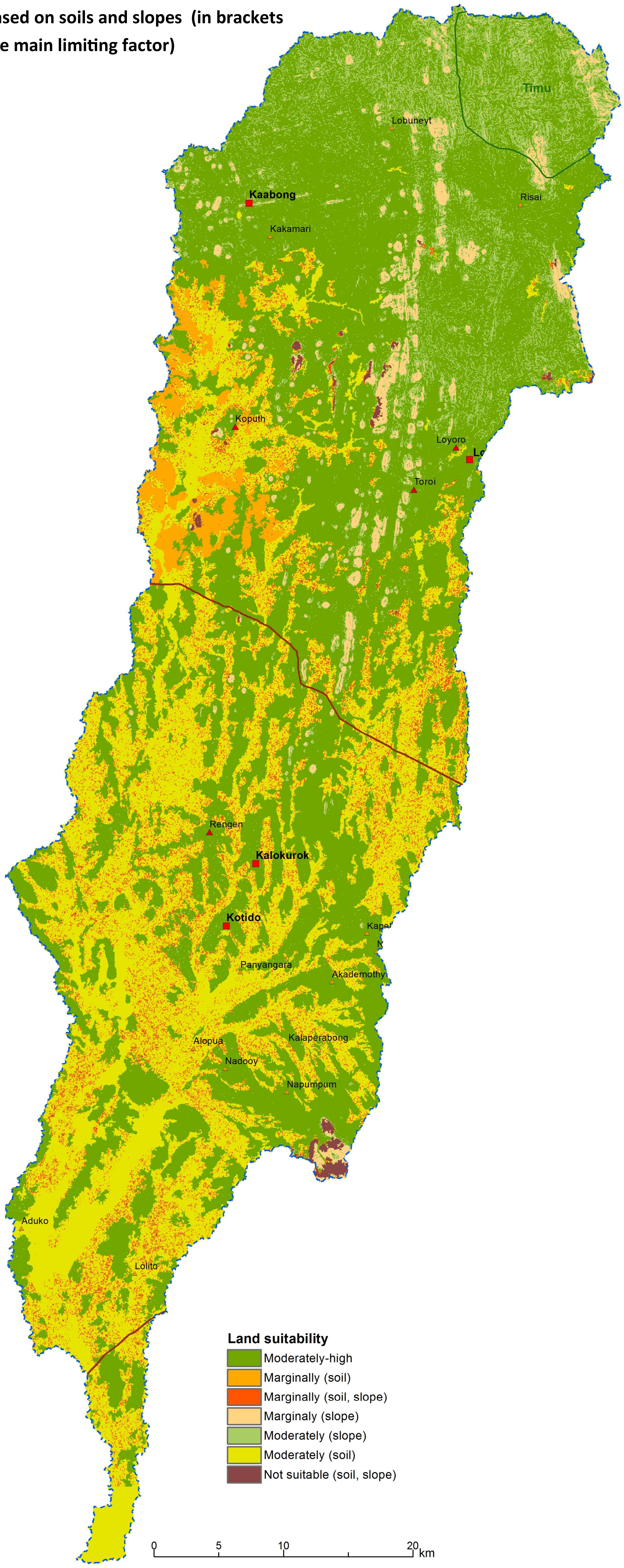
Management of communal lands, including the allocation of grazing rights, historically was the responsibility of tribal elders, but in recent decades their influence has dwindled.

There is no one solution to the land degradation problem. However, if dealt with in an integrated manner it should be possible to achieve some successes. Addressing the deforestation should be on the priority list; opportunities include the expansion of Akiriket (traditional shrines surrounded by trees), afforestation, introduction of alternative energy sources for cooking, and promotion of live fences for manyattas, kraals and other sites to be protected. The restoration of traditional systems and the influence of tribal elders is to be encouraged, especially in the introduction of bye-laws to manage burning, charcoal production and protecting steep, vulnerable slopes.

**D. Deforestation (from top to bottom): thatching manyattas, tree cutting, wood collection, brick killns and fencing with dead wood**

# Agriculture

**A. Land suitability for agriculture based on soils and slopes (in brackets the main limiting factor)**




## Agricultural suitability

Land suitability for agriculture is highly dependent on soil characteristics and slope steepness. Following the framework for land evaluation of the FAO (1976), soil moisture storage capacity, availability of oxygen, depth to impermeable layer, possibilities of mechanization, availability of nutrients and resistance to erosion are determinant to assess the potential for agriculture. Slope steepness is especially important because of the sensitivity to and impact of erosion.

The analysis shows that, based on slope steepness and soil type approximately 50% of the land in the Dopeth Catchment is suitable for agriculture (A). The potential for expansion is highest in between the valleys and in the region north-northeast of Kaabong. Note, however, that care should be taken that wetlands and forest are protected, the availability of sufficient grasslands ensured and that there adequate soil and water interventions are implemented to avoid environmental degradation.

**B. Agricultural practices, Upper: Recently plowed land in Kotido District, and Lower: ox plowing in Kotido district.**

### Challenges with current agricultural practices

Farming, mainly rain fed, is expanding rapidly within the Dopeth Catchment. The area under cropland has almost doubled over the past 15 years. More and more sorghum, millet, maize, wheat, groundnuts, sunflowers, simsim and beans are being produced, while some famers are even investing in horticulture to earn additional income.

However, expansion and current poor agricultural practices are exhausting the natural resources, especially the soils. Due to lack of or limited crop rotation, removal of all trees, and the absence of (appropriate) soil and water conservation measures, fertile soils and water are being lost, biodiversity is decreasing and regulations services are being disturbed (see also the chapter Ecosystems).

### Afforestation, reforestation and tree protection

Trees are at the heart of Karamoja's ecology, providing myriad services, such as nutrition to livestock and people, allowing for cultural practices, promoting infiltration and limiting soil erosion. Deforestation, however, is severely threatening these ecosystem services (Mobogga et al. 2014). Land is, for example, cleared for agricultural purposes (C). Maintaining and increasing tree coverage can significantly contribute to improving the resilience of livelihoods in Karamoja. To that end, deforestation rates have to be slowed down, and afforestation, reforestation and tree protection projects have to be implemented.

Field observations and discussions with communities and key stakeholders point out two elements are crucial to improve tree cover. On the one hand, the understanding of which species are already grown and valued by local people and how they use the products is very important. Trees that can be used for fuel, fodder, food, construction, medicines, mulching and soil conditioning are very much appreciated. E.g. Acacia spp, balanites (desert date), grevellea, teak, pondo, arambola (star fruit) and citrus trees. Furthermore, care should be taken when introducing exotic species and for agroforestry purposes trees should have roots deeper than the main crops and offer shade and nutrients.

On the other hand, a key success factor is giving farmers an incentive so that they benefit from their labour. Giving farmers either outright ownership of the trees they protect, or tree user-rights makes large scale farmer-led reforestation possible. Encouraging, for instance, farmers to fence off small areas to protect young trees against browsing by livestock and allow for sprouting of indigenous trees turns out to work well. During the field visits it was observed that mature trees, especially Balanites and Tamarind, are surviving on farmlands. It was understood that, because of the multiple benefits from these trees, farmers make a deliberate effort to make a fence around a seedling.

### Irrigated crop production

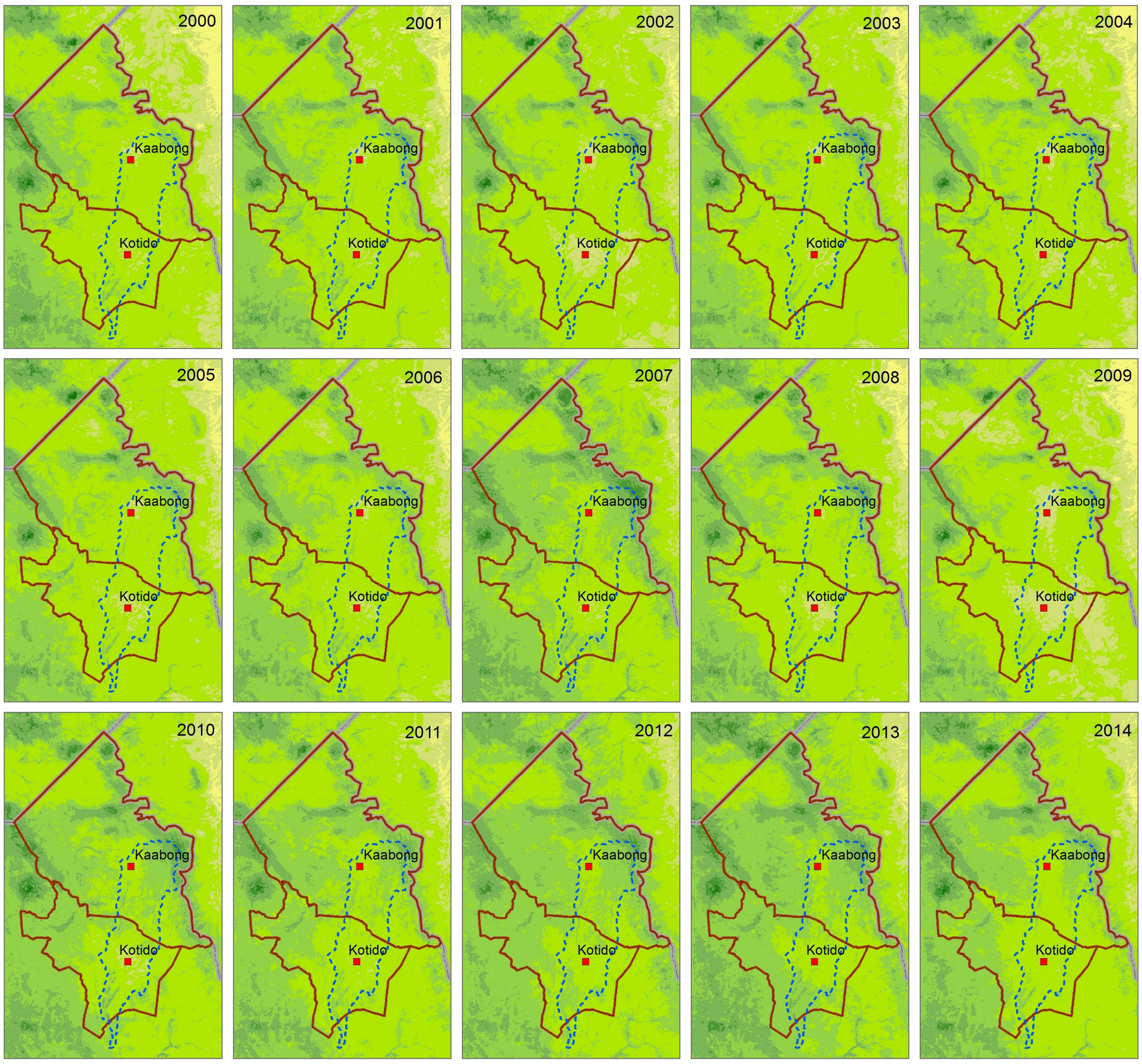
Current crop production in Karamoja is rain fed, except for some pilot projects and demonstration plots ran with external support. Assessments and evaluations indicate that the projects are not very promising. Pests, blocked drip outlets and water supply system that are damaged by fires and UV turn out to be serious challenges that cannot easily be overcome. Experts also point out that there is minimal potential for large scale irrigated agriculture because:

- There is insufficient water
- Groundwater depletion might threaten shallow wells
- Operation and maintenance are invariably problematic
- Registration of land rights is weak and could result in the displacement of people and restrictions to grazing and
- Soil salinization will lead to productivity losses
- The links to national and international markets are too weak to support commercial farming

On the contrary, there are viable opportunities for small-scale irrigated gardens. Runoff water stored in ponds could be used on rain fed crops and supplement rain during the dry periods and for small-scale horticulture. Complementary irrigation reduces exposure to more erratic rainfall patterns. Where a year round water source (such as a productive shallow well or abstraction from seasonal rivers) is available community gardens growing high value crops during the dry season could be established. Examples are found on the banks of the Dopeth close to Kaabong, but there is large potential to expand.

**C. Issues with current agricultural practices (from top to bottom): Gully erosion on farmlands in Kaabong District, Land clearing for agriculture on steep slopes within Timu forest reserve, Barren agricultural land in Kotido District highly susceptible to wind erosion, Google Earth image showing agriculture encroaching into a wetland area in Kotido District.**

### A. Average NDVI-series from 2000-2014




### NDVI analysis

The vegetation patterns in the area were analyzed with the use of the Normalized Difference Vegetation Index (NDVI). NDVI is a simple graphical indicator that can be used to assess whether the target area contains live green vegetation or not. The NDVI data was obtained from MODIS Terra Vegetation Indices (source: USGS and NASA). Table B provides an indication of the major land cover/ vegetation classes in the dry and wet season (scale factor 0.001).

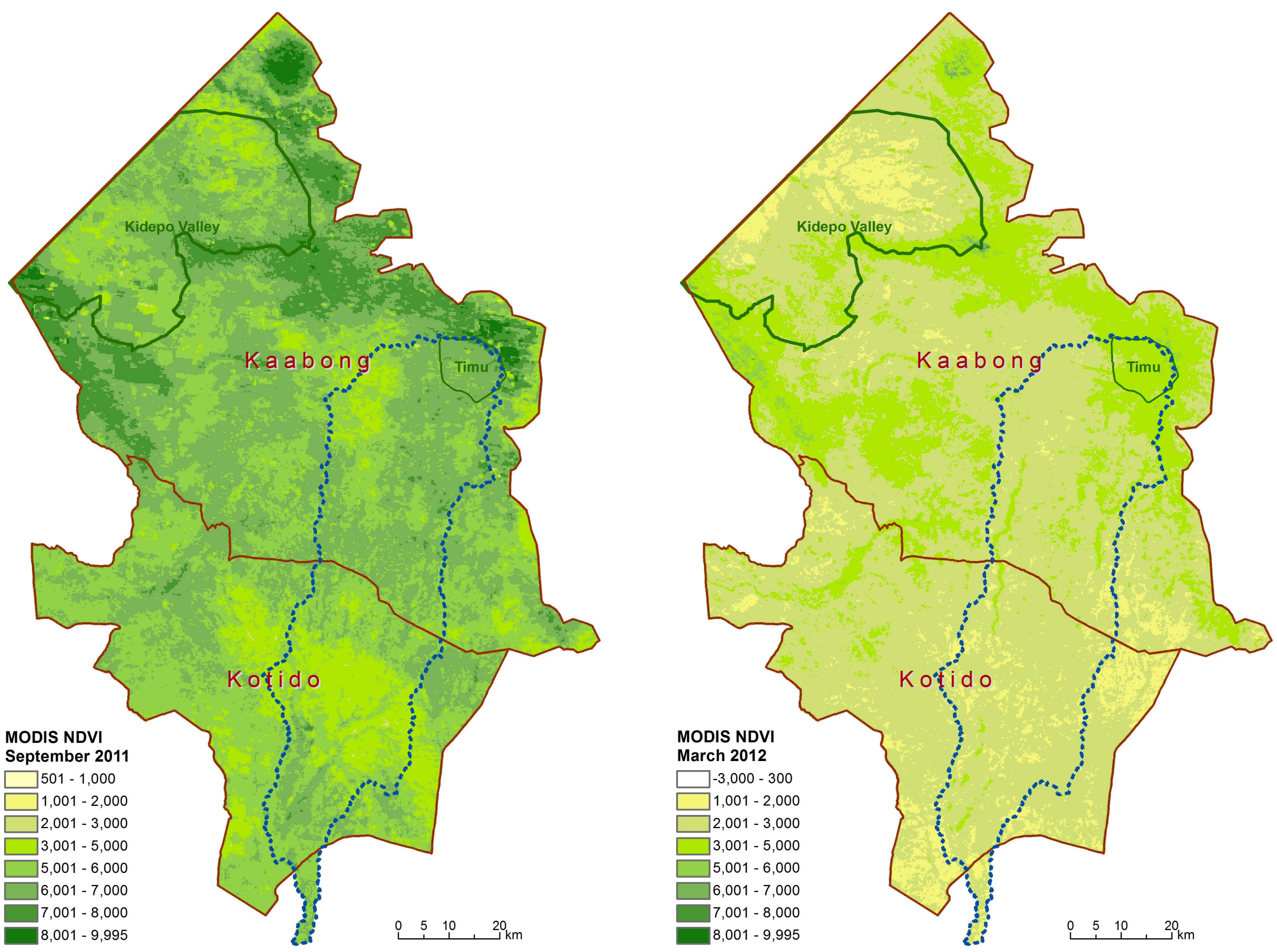
### B. NDVI Claasification

| Land Cover | Dry season values | Wet season values |
|---|---|---|
| Water, burnt soil | <300 | <300 |
| Barren land | 700-1000 | 700-1000 |
| Sparse grassland | 1000-1500 | 1000-2000 |
| Open grassland | 1000-2000 | 2000-5000 |
| Shrubs | 1700-2500 | 3500-6000 |
| Forest | 6000-8000 | 7000-9000 |

**Mean NDVI**

- -3,000 - 300
- 301 - 500
- 501 - 1,000
- 1,001 - 2,000
- 2,001 - 3,000
- 3,001 - 5,000
- 5,001 - 6,000
- 6,001 - 7,000
- 7,001 - 8,000
- 8,001 - 9,995

### C. Vegetation index during the wet (left) and dry (right) season




### Vegetation cover throughout the year

A comparison between the greenness index in September 2011 and March 2012 indicates that the vegetation in the Dopeth Catchment shows a strong response to rainfall (C). For the whole project area, independent of the biophysical characteristics of the landscape, vegetation cover is more intense during the wet season than during the dry season. However, the maps also show that the vegetation cover in the forested areas (along the borders of Kaabong), along the rivers and in the wetlands is always medium to high, suggesting that (some) (shallow groundwater is available throughout the year. This fact is confirmed by field observations and discussions with stakeholders: the moisture content in the forested areas is above average, water is fetched from scoop holes in the river beds and the pastures in the wetlands are always lush and green - also during the dry season.

## Vulnerability to droughts

The greenness index (NDVI - Normalized Difference Vegetation Index) statistics reflect many characteristics of the landscape. In A the mean NDVI over the period 2000-2014 is shown. In general, the maps show that the forested and dense shrubland areas (upper Dopeth Catchment, eastern boundaries Kaabong District) have the highest greenness indices. These high indices are constant throughout the series; seemingly the vegetation cover in these areas is (to a large extent) independent of rainfall amounts. The lowest vegetation cover is measured outside the project area, in Turkana Region (Kenya), upper left corner of the maps. The differences between the maps can be linked to the average yearly precipitation. In the four driest years (2002, 2004, 2008 and 2009), the agricultural areas around Kotido and Kaabong Towns show very low vegetation cover and the dry areas in Turkana become even drier. This vulnerability to low rainfall stresses the low resilience of the system in these areas.

Most communities in the project area rely on agriculture and pastoralism as major sources of income and livelihood. Severe drought results in crop failure and loss of livestock. This leaves the communities vulnerable to starvation, malnutrition and poor health. Literature report statistics indicate that total crop failure occurs every two to three years. Climate change is expected to result in even more crop failures. Coffee and maize production is already being negatively affected.

The introduction of water recharge and retention measures is suggested to cope with the decreasing resilience of the ecosystems (see section on water resources).

**D. Coping with droughts in Karamoja (Cordaid 2013)**

## Migration patterns

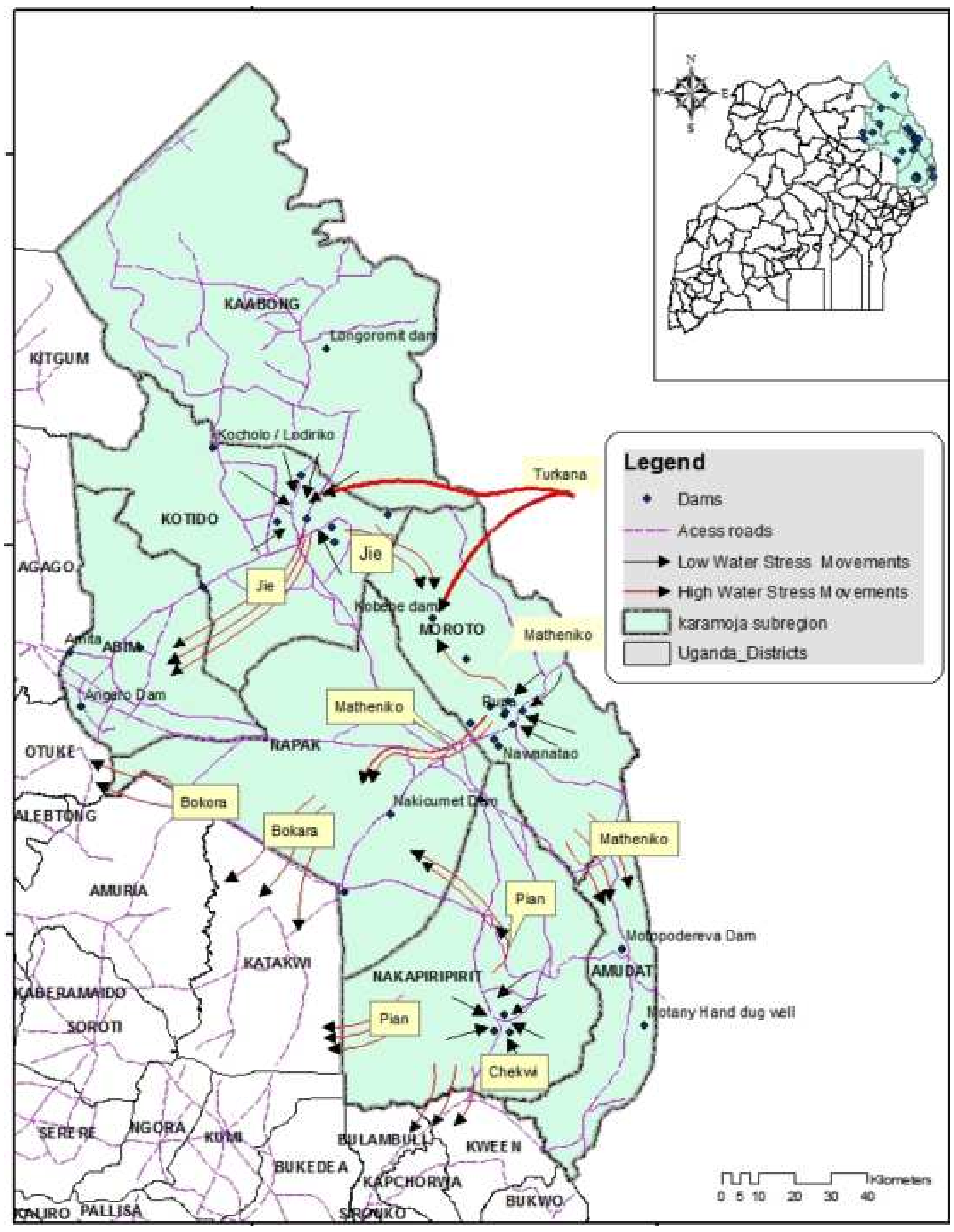
Kotido and Kaabong lie in the cattle corridor extending from Southwestern Uganda to Karamoja, and beyond through Kenya to Somalia. Endowed with 20% of Uganda's cattle, the Karamojong are used to droughts and know very well their traditional sources of water and pasture (Uganda National Census Report). In the rainy season, multiple sources of water and pasture are available and livestock grazing and watering are not restricted by water availability. During these periods, livestock is often closer to manyattas and ponds, rivers, and pools for watering.

As the rains finish and the grazing areas become more restricted, livestock move slowly in a pattern that takes them to from the Central zone more to the west (E). The traditional dry season water points are close to the Western green zone, and further away from permanent settlements. Because of the dependency of water and pasture, the productivity of the pastoral system is strongly linked to mobility. When rainfall fails, the herders have to move to water and pasture areas further away. This mobile exploitation proved sustainable in (semi) arid environments, where traditionally the best pastures were preserved for the end of the dry season (Mugerwa 2014).

In 2008 the Ugandan Government introduced kraals, i.e. fenced areas where cattle are protected by security guards. In many ways these kraals have been successful. The kraals improved veterinary services, provided protection against theft and regulated grazing according to guidelines. However, the kraals also led to extra stress on the cattle corridors, gazetted areas and water points. The over-concentration of animals increased soil compactation, runoff, erosion and proliferation of diseases (Magunda 2010).

Experts claim that the negative impacts of kraals are mainly a consequence of the lack of linkages and dialogue with local communities. Integration of traditional management practices into governmental guidelines through discussions with tribal leaders is currently missing (Rugadya et al. 2010, Ministry of Local Government 2001).

**E. Migration routes livestock (Mugerwa 2014)**



## Rangeland management

Rangeland is by far the predominant land use type in Karamoja and the Dopeth Catchment (C); in 2015 rangeland made up 65% of land use in the Dopeth Catchment. The condition of rangelands in the Dopeth Catchment is fair to good. Short perennial grasses predominate. However, the quality of rangelands close to the main settlement areas is decreasing due to increased grazing pressure, deforestation, and expanding agricultural land. The two most important rangeland management strategies are burning and mobility.

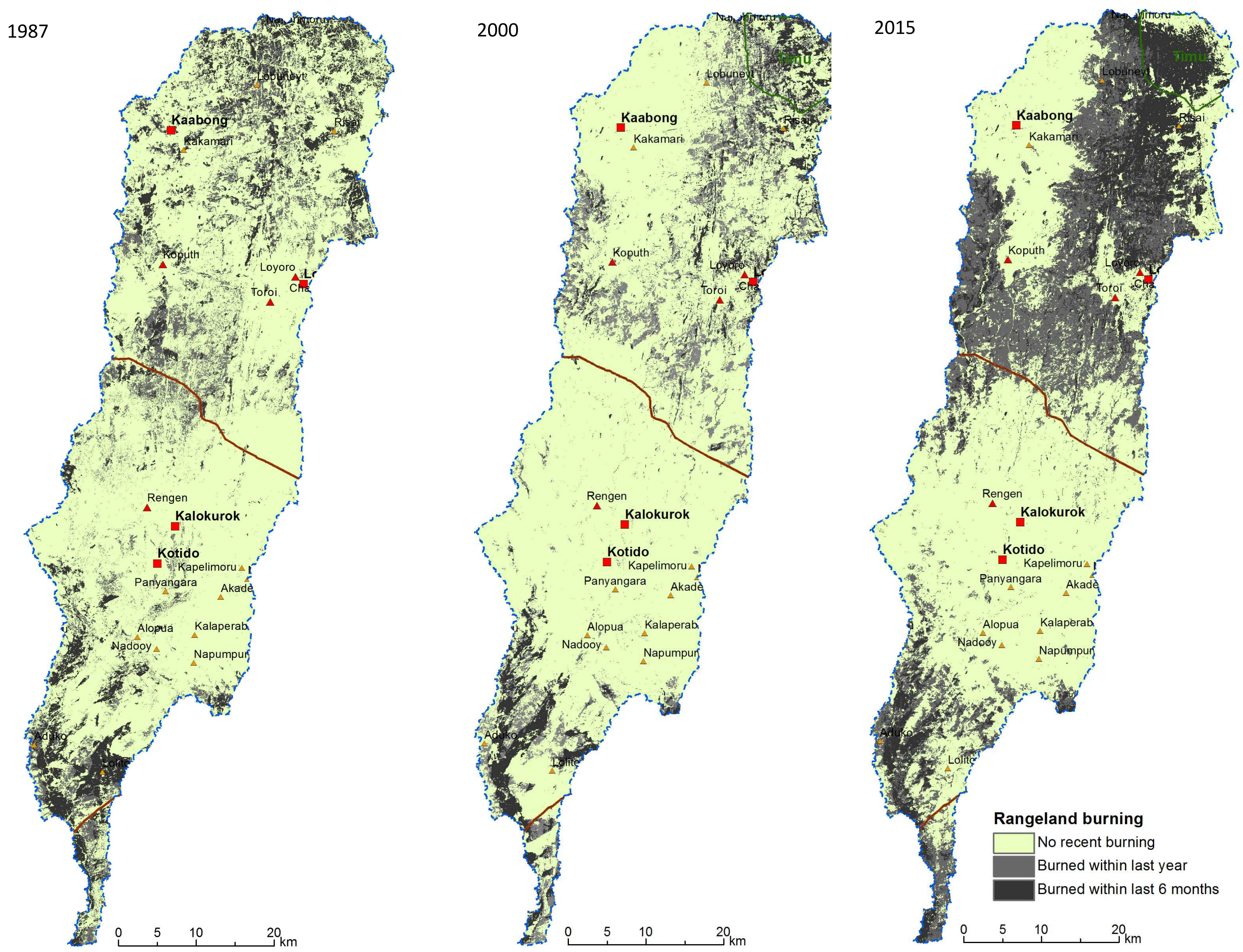
## Burning

Bush burning is applied extensively in Karamoja for a number of reasons, including: pest control (it is very effective at controlling parasites, especially tsetse fly), stimulating fresh grass growth (A), clearing land for cultivation, and hunting. During the field visits interviewees mentioned pest control as the main incentive for burning. Tsetse transmitted trypanosomiasis (sleeping sickness) affects both humans and livestock and is a major constraint to improved livestock production and productivity in Uganda (MAAIF-UTCC 2014). In addition to these traditional reasons for burning, research shows that the production of ash increases the amount of plant available water (Stoof et al. 2010) and avoids bush encroachment (Solomon et al. 2010). Most of the burning is done before the onset of the dry season, in the period October-December, when short rains stimulate the growth of lush pastures.

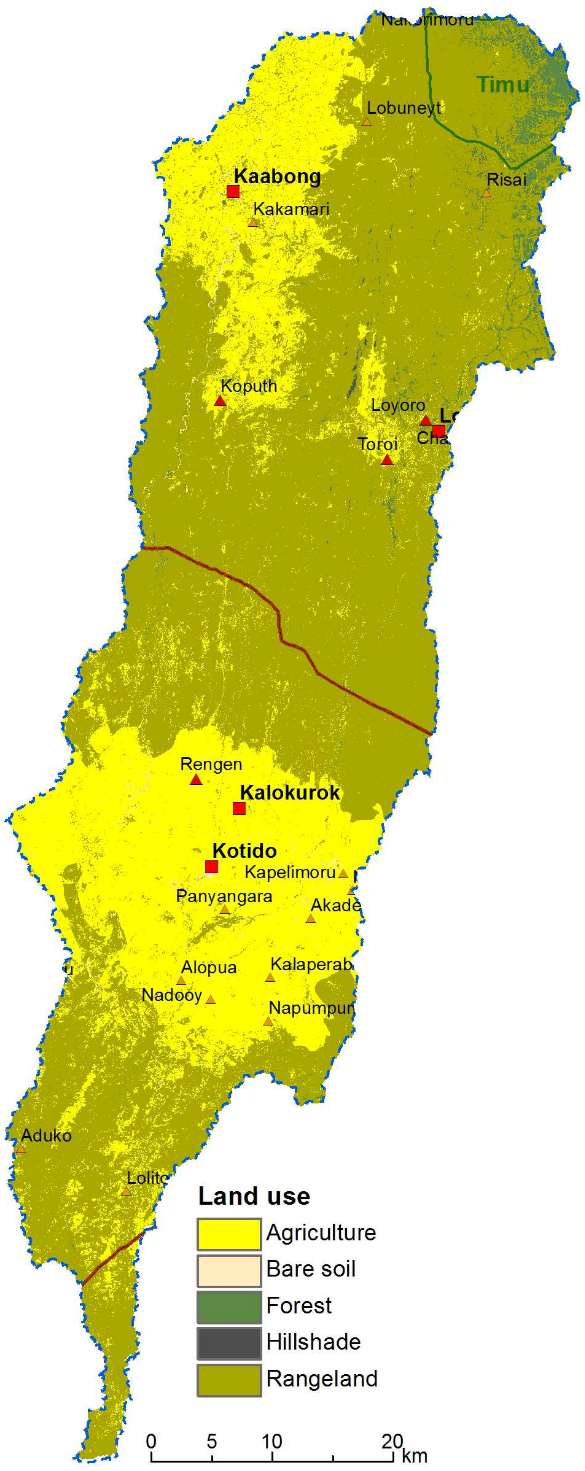
In the old days, tribal leaders would direct grazing patterns and migration routes and this would result controlled burning of certain areas whilst protecting other areas. However, with the rise of formal structures, armed youth and government/military directives the influence of tribal elders has reduced. As a result, control over burning has almost disappeared. Although the government has tried to control burning, analysis of satellite imagery indicates that vast areas of land have been burned. The total are burned in 2014/2015 is much larger than in 2000 and 1987 (B). The disadvantages of burning relate to:

- Ecological and environmental concerns (WHO 2015);
- Changes in the hydrological processes (run-off coefficients, stream flow increase) leading to flooding and erosion (Stoof et al. 2011)
- More rapid drying of topsoil after rainfall events, increased soil water repellency and decreased surface water storage (Stoof et al. 2010)
- Decreased survivorship and growth of seedlings (Dublin, 1995)
- Loss of useful insects and small animals thereby disrupting the ecosystem
- Caking of soils with sealing of pores resulting in higher run-off, which increases soil erosion

**A. Lush green grasslands after burning**




**B. Rangeland management: burned areas**




**C. Land use 2015**

## Controlled burning

Despite these challenges, a ban on burning is no solution because there are no good alternatives for parasite control. Furthermore, most trees do survive so that their regeneration is rather quick, and the overall rangeland quality is good. It is deemed that controlled burning, in patches, supported by other forms of tsetse control to limit reinfestation is a more logical way to go for. An analysis of traditional rangeland management systems compared with new systems is recommended, to determine how traditional systems can be strengthened and aligned with government programmes and policies. Specific areas will have to be designated for burning while the animals are grazed in other areas. This will kill the ticks and tsetse and encourage fresh grass to regenerate. Also, it will create a natural cycle whereby small animals and insects can thrive in the unburned areas and later easily recolonize the burned areas.

## Tsetse control

Although the regeneration of grass and bush control are important, the main reason for burning is tsetse-control. Therefore, if alternatives to tsetse control were available the need for burning becomes much lower. Only controlling tsetse has proven ultimately difficult throughout (semi-)arid countries. Transmission can only be effectively addressed through an area-wide and integrated approach, wherein a series of pest control techniques is combined (MAAIF-UTCC 2014), and even then only to a limited extent.

Currently, the following vector control interventions are available

- Insecticide ground-spraying: seldom used because of residual insecticides and operational demands
- SAT (Sequential Aerosol Spraying Technique): can be very effective, efficient and accurate (thanks to recent advances in aircraft guidance systems) to clear large areas of tsetse flies, but requires substantial economic and infrastructure support
- Pour-ons, cattle dips and selective spraying of legs and belly: effective and a means to save funds and minimize the distribution of pesticide in the environment
- Odor baited traps and screens: simple and effective to reduce tsetse population by almost 99% and cheap, but labour and management intensive and have to be implemented at large scale to avoid re-invasion.
- SIT (Sterile Insect Technique): effective but ecological islands are a needed for success to avoid re-invasion; logistically, management and cost intensive

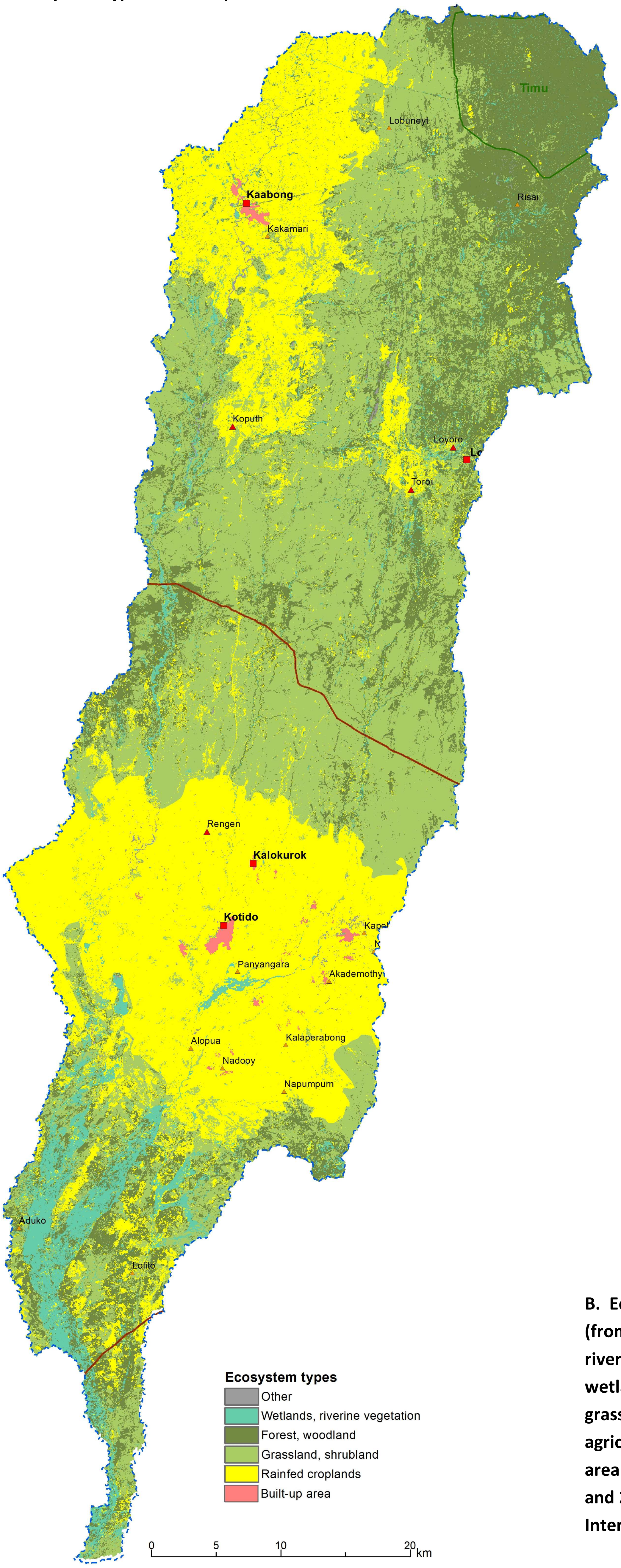
Full-provision of above interventions is not likely to be a feasible option because of the many cattle, large area and limited resources available. Combining controlled burning with one or more of the above techniques when– and wherever possible seems the best option.

**D. Rangelands (clockwise, from top left): Mosaic dense shrubland-grassland near Timu Forest Reserve, Open shrubland - grassland in southern Kaabong, Open grasslands-bare soil (rangeland in poor condition) in Kotido District, Grazing livestock in a seasonal wetland in Kotido District.**

# 3

# Ecosystems

**A. Ecosystem types in the Dopeth Catchment**






**B. Ecosystem types (from top to bottom): riverine vegetation, wetlands, forest, grasslands, rainfed agriculture and built-up area (Acacia Water 2014 and 2015, Wetlands International 2015)**

## Ecosystem services

An ecosystem is formed by the interaction of communities of living organisms with the physical environment. Ecosystems have no fixed boundaries and vary in size and the elements that make them up - from a single raindrop, to a lake, a watershed, or an entire region. Their boundaries may overlap and depend upon the purpose of analysis, the processes being studied or the scope of questions to be answered. Ecosystem services are defined as the benefits that people receive from ecosystems (MA, 2003). Ecosystem functions are defined as the capacity or the potential to deliver ecosystem services (EU 2013). Various ecosystem services typologies have been developed in the recent years. In this study we apply the most recent typology such as defined by the CICES v.4.3 (2013):

1. Provisioning services: Includes all material and biota-dependent energy outputs from ecosystems; they are tangible things that can be exchanged or traded, as well as consumed or used directly by people in manufacture. Within the provisioning service section, three major divisions of services are recognised:

- Nutrition includes all ecosystem outputs that are used directly or indirectly as foodstuffs (including potable water). Provisioning of water is either attributed to nutrition (drinking) or materials (industrial etc.) It is considered as ecosystem service because its amount and quality is at least partly steered by ecosystem functioning.
- Materials (biotic) that are used directly or employed in the manufacture of goods (including water from non-drinking purposes)
- Energy (biomass) which refers to biotic renewable energy sources and mechanical energy provided by animals

2. Regulating and maintenance services: Includes all the ways in which ecosystems control or modify biotic or abiotic parameters that define the environment of people, i.e. all aspects of the 'ambient' environment. These are ecosystem outputs that are not consumed but affect the performance of individuals, communities and populations and their activities. Within the regulating and maintenance section, three major service divisions are recognised:

- Mediation of waste, toxics and other nuisances: the services biota or ecosystems provide to detoxify or simply dilute substances mainly as a result of human action
- Mediation of flows (air, liquid, solid masses): this covers services such as regulation and maintenance of land and snow masses, flood and storm protection
- Maintenance of physical, chemical, biological conditions: this recognises that ecosystems provide for sustainable living conditions, including soil formation, climate regulation, pest and disease control, pollination and the nursery functions that habitats have in the support of provisioning services.

3. Cultural services: Includes all non-material ecosystem outputs that have symbolic, cultural or intellectual significance. Within the cultural service section, two major divisions of services are recognised:

- Physical and intellectual interactions with biota, ecosystems, and land-/ seascapes
- Spiritual, symbolic and other interactions with biota, ecosystems, and land-/ seascapes

Biodiversity is the variety of living organisms that live in a particular ecosystem including, inter alia, terrestrial, marine and other aquatic ecosystems. It includes diversity within and between all species and of ecosystems within which they live and are a part of. Biodiversity is therefore explored at 3 levels: genetic (variety of genes within a species) , species (variety of species) and ecosystem (variety of ecosystems in a given place) diversity. Species diversity could be seen as a very high order regulatory ecosystem service as it helps to protect the diverse gene pool which we think is needed to be able to constantly adjust to changing climatic conditions over long time periods or to major sudden differences in these conditions. However, from a more local (Dopeth) scale and in the short-term there is only limited demand for gene pool protection.

Biological diversity at the same time also supports the ecosystem functioning, e.g. existence of various plant species help to develop various habitats which are occupied by other species, in the food chain lower order species acts as forage for the higher order species, bacteria play an important role in bio-chemical processes and help to breakdown toxic substances in less harmful products, numerous insect species are responsible for pollination processes, essential such that ecosystems are able to deliver edible goods.

## Ecosystem based adaptation

Ecosystem-based adaptation (EbA) approaches include sustainable management, conservation and restoration of ecosystems as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits of local communities. EbA approaches tap on ecosystem services as propellers of socio-ecological system resilience and are particularly useful in supporting vulnerable communities that are highly dependent on natural resources for their livelihoods. Ecosystems provide functions like storing water, reducing erosion and siltation and purifying polluted water sources; they are therefore able to provide means to reduce the occurrence and intensity of natural hazards like flash floods, droughts and dust storms.

Hence, intervention in terms of ecosystem management and restoration (EMR) are essential for increasing sustainability. For example, a degraded, deforested, hilly upstream area is less able to store water and thus reduce the runoff of water. The loss of this sponge function (absorbing and slowly releasing water) may lead to increased runoff and eventually result in flash floods downstream. Reforestation will slow down the runoff and reduce the probability of a rainfall event turning into downstream hazardous flooding. Similarly, a sparsely vegetated pasture (e.g. as a result of overgrazing) will more likely result in a soil moisture deficit area (and hence an agricultural drought with the remaining vegetation wilting and dying even faster) in times of meteorological drought (less actual rainfall than the climatic average). Then re-vegetation of that degraded ecosystem (for example by allowing less grazing for a certain period of time and in certain designated zones) could possibly reduce the occurrence of agricultural droughts.

To plan such ecosystem based adaptation interventions, the state of ecosystems and their services have to be assessed at multiple spatial and temporal scales.

## Ecosystem types

As mentioned above, the definition of ecosystem applies to various scales, from a water drop to the entire world. However from a practical point of being able to map and assess their services, we consider ecosystems of the scale of landscapes. To be able to spatially and functionally differentiate between a number of different ecosystem types in the Dopeth Catchment covering Kotido and Kaabong districts, we assessed how various regions show greater or lesser similarities in climatic conditions, geophysical conditions, dominant use by humans, surface cover (vegetation), species composition and natural resources management system.

Based on this assessment, we categorized and spatially delineated the Dopeth Catchment in following ecosystem types (B):

- Wetlands/riverine areas (including marshes, swamps, fresh water bodies),
- Forest/woodland (including forested habitats, broad leaved woodland, forested grassland),
- Grassland/ shrub-land (including open grassland, dense grass and shrub-land, inland rock, acacia savannah), rain-fed croplands ( farmlands, agro-pastoralist areas) and
- Built-up areas (settlements, sand sediments, bare soil)

## Land tenure

Land in Karamoja is under common, state and private property regimes. Most land is communally owned except in town centres (Kaabong and Kotido) where individuals possess title deeds. Where the land is owned by the community, its use is traditionally controlled by a hierarchy of clan elders. The communal land is collectively managed by the clan and is characterized by a common pool of resources such as grazing fields and water sources. Land use is practiced under a dual system of both customary law and statutory legal systems. The communal land tenure system is, however, susceptible to the “tragedy of the commons”. Increased human pressure on the landscape level (partially resulting from population growth), lack of environmental law enforcement, low level of awareness on environmental degradation and shortage of capacities and resources for monitoring and community-based natural resources management (e.g. for water and rangeland) have resulted in the overexploitation of natural resources at various locations.

# Ecosystem services in the Dopeth Catchment

**A. Evaluation ecosystem services**


## Mapping ecosystem services

To promote the understanding, monitoring and evaluation of ecosystems services, including their synergies and trade-offs, the services in the Dopeth Catchment were mapped and assessed. In order to do so, a number of provisioning and regulating services were valued on a scale ranging from 0-3, whereby 0 is low and 3 is high. The identification and assessment of the services was based on the land cover map (2015) with validation of the scores during the field work. In the field, data was collected through interviews with key informants and field observations. The categorization of the ecosystem types was also validated in the field.

## Ecosystem functions and services in the Dopeth Catchment

The evaluation of various important ecosystem functions and services in the Dopeth Catchment is shown in Figure B. The combined ecosystems services scoring  is provided in Map A.

The combined scoring map clearly shows that the forested and shrub land areas in the northwest and the riverine vegetation, including the wetlands, provide multitude of ecosystem services and, therefore play a fundamental role in the resilience of the system. It is of uttermost importance to avoid (further) degradation of these systems. On the other hand, the map also makes clear that the cropland areas provide limited combined services. The croplands obviously play a fundamental role in food provision, but at the same time undermine the availability of multiple other services to communities. The availability of the various ecosystem services, however, differs greatly throughout the Dopeth Catchment. This is a result of the very specific characteristics of the various landscapes (ecosystem types, see previous pages) present in the project area.

Food provision service: covers crop production, livestock rearing, fisheries and agro-pastoralist livelihood systems. It turns out that all ecosystem types contribute in some way or another to food provision. Croplands stand out obviously with regard to this service. However wild fruits are also gathered for human consumption and for use in holy rituals. Honey and ants are highly valued for their taste and nutritional value.

Water provision service: the availability and quality of water is highest in woodland, forested areas, wetlands and grassland habitats. Intact soils and good vegetation coverage promote water infiltration, limit soil erosion and trap sediments. Water is used for watering animals, drinking water purposes, hygiene and sanitation, cooking and brewing, building infrastructure, smearing huts and cultural activities.

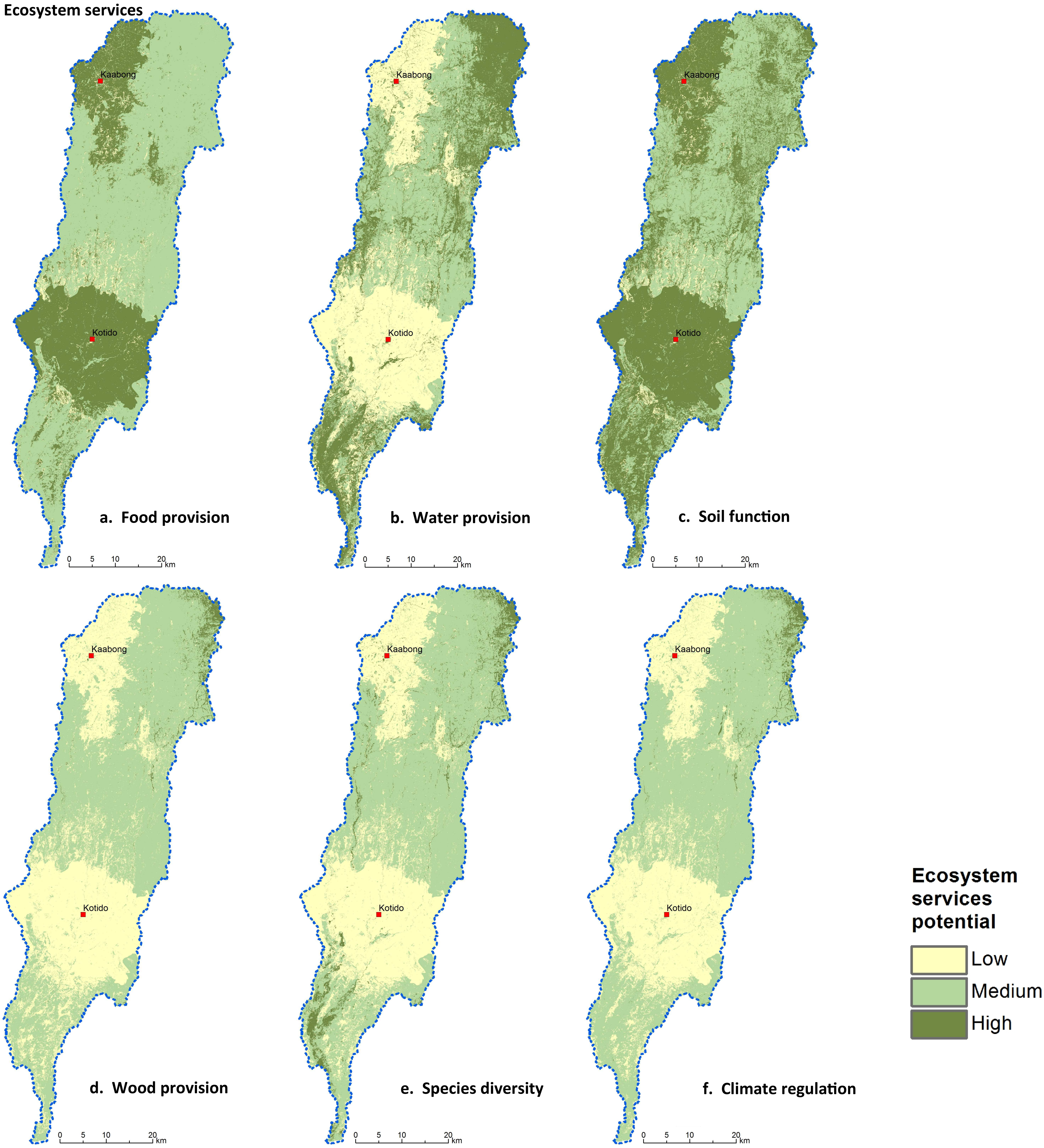
Soil function: soil quality is related to nutrient cycling, biomass production, water retention and percolation; soils have the capacity to filter, buffer and transform. Soil is a fundamental resource for crop cultivation, plastering walls of *manyattas*, cultural ceremonies and burying the dead. The undisturbed soils in the Upper Dopeth Catchment provide highest support to these ecosystem services. In the middle and lower Dopeth, soil functions are more limited because the soil has been disturbed by a number of activities, such as intensive farming, grazing and deforestation.

Wood provision service: wood is used for fuel, fencing and timber, and can be extracted from forests, woody grasslands and acacia savannahs. Within the Dopeth Catchment, the upper catchment has the highest potential for wood provision servicesForests and trees are important for firewood and charcoal production, shade, to make fences for kraals, manyattas and water troughs, produce gum, edible leaves and fruits and in some cases with medicinal properties. In addition, trees are often considered sacred. The Akiriket trees, for example, are symbol of a holy places which are used for prayers.

Species diversity function: Forested and riverine ecosystems have the highest potential for species diversity, including wildlife and endemic plant species. While such species diversity is assumed to positively contribute to ecosystem health and its ability to deliver services, these are also potential places of human–animal conflicts (e.g. hunting, competition for pasture and water and vector-based diseases).

Climate Regulation: shrub- and grasslands contribute to climate regulation, but the most important role is played by (dense) forests. Forests regulate temperature, rainfall, evapotranspiration and humidity, and lower wind speeds at surface level. Furthermore, forests provide sinks for greenhouse gases and are a source of aerosols regulating regional and local climate conditions.

**B. Ecosystem services**




## Environmental degradation

Environmental degradation is increasing the vulnerability of communities in the Dopeth Catchment. The degradation reduces the ability of the various ecosystems to deliver ecosystems services and results in higher disaster risks. The degradation of the ecosystems in the Dopeth Catchment is manifested by erosion (rills, sheet, gullies, hard crusts), patches of non-vegetation areas, litter dams, degraded river catchments, mud slides, siltation and flooding.

At present, the observed environmental degradation seems to be mainly caused by localized watering of cattle, reduced pastoral mobility, increased grazing intensity, deforestation and, more in general, by overexploitation of all natural resources. The concept of protected kraal system and the placement of permanent watering and drinking water points have caused localized overgrazing and loss of thorny bushes, shrubs and trees. This has exacerbated erosion and sedimentation problems. Traditional grazing patterns have been much less of a problem. Paradoxically, severe over-grazing observed in the zones several square kilometres around the kraals, have supported a parallel conservation of pasture in adjacent outlying areas.

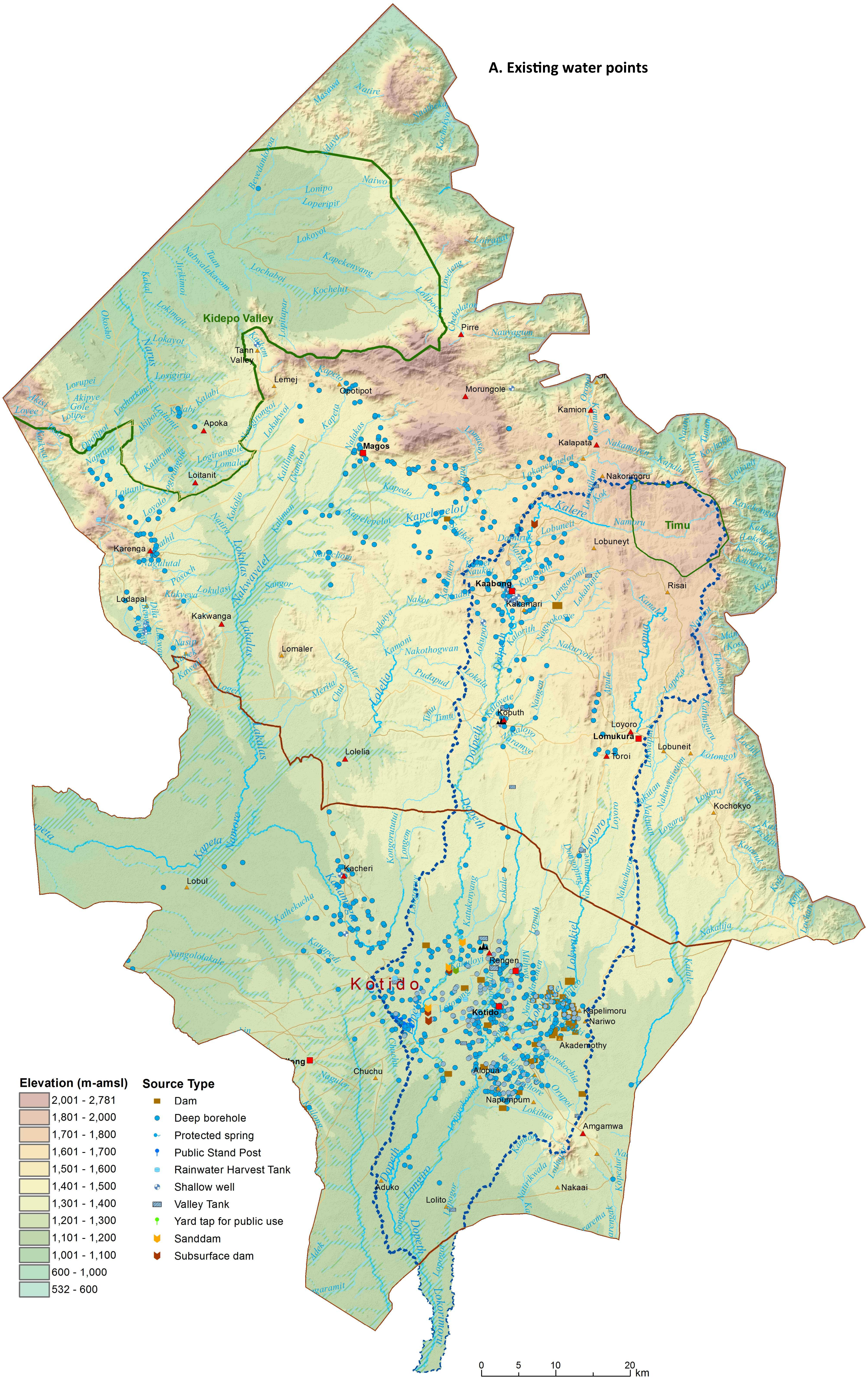
After years of repeated and extended droughts, many people in this region tend to revert to short-term coping strategies. Communities are shifting to new methods of survival, many of which are neither sustainable (such as those based on over exploitation of natural resources) or appropriate for the fragile and variable ecology of the region. People's survival seems to overrule customary protection regulations as people are substituting long-term gains for short-term benefits.

The continued loss and degradation of natural resources in the Dopeth sub-catchment presents a serious challenge to livelihoods, economic growth and human well-being. Various earlier reports and plans quote severe environmental degradation. However, District Development Plans do hardly include any interventions to address environmental degradation. Although environmental and/or natural resources management officers exist within the governmental structure, hardly any soil and water conservation mechanisms are put in place and are operational.

# 4

# Water resources

# Water sources



## Access to water

The regular supply of clean and safe water for domestic, agricultural and industrial use remains a key for development. Data, and its accuracy, on water access are, however, limited; an update of the Uganda Water Atlas (MWE) is expected in 2015-2016. Based on the currently available reports and databases, access to safe water rates in Karamoja vary between less than 20 and 60 per cent, depending on the sub county (MWE 2010) (A, B, C, D). Averaged over whole Karamoja, less than 20% of the population has access to safe drinking water (Mapping a healthier future 2009). The main water supply technology around the towns Kotido and Kaabong is the deep borehole. Rural communities often make use of shallow wells and ponds. Kaabong District has 263 and Kotido District has 283 safe water points (boreholes, shallow wells, protected springs, piped water systems and rainwater harvest tanks) (A).

In the past water provision in Karamoja has been hampered by a combination of low funding, remoteness and poor roads, insecurity, high drilling costs and weak institutional capacity. However, since 2010 there has been significant investment in the water sector and both access and functionality have improved significantly, although admittedly from a very low base (MWE 2010).

B. Fetching water: borehole (top) and scoop holes (bottom)

## Water supply

Boreholes are the predominant source of water for domestic use, especially in and around (small) towns (A, B). Around Kaabong and Kotido boreholes are equipped with electric or diesel power pumps, whilst around *manyattas* and villages hand pumps are used. A high percentage (over 50% of those visited) of the hand pumps were non-functioning. Away from towns, it is common to see children and women collecting water from ponds during the wet season or from scoop holes in the riverbed during the dry season (B). During the wet season, men can be seen washing clothes or taking a bath by the river or pond. All this could point to the fact that sources of water for home use are either not enough or far from where they are needed.

On average, seven additional boreholes are developed per district per year, but the District Engineer of Kaabong reports that around 60% of the boreholes run dry during the dry season. The reduced yield of boreholes could be the result of low groundwater potential, seasonal fluctuations, over abstraction or poor maintenance. This brings into question the process of siting such boreholes and their development, pump testing and monitoring. Obviously, the absence of or difficulty to access past data (for instance on ground water potential, drilling depths, pump testing, etc.) makes borehole siting a complicated and costly process.

## Operation and maintenance

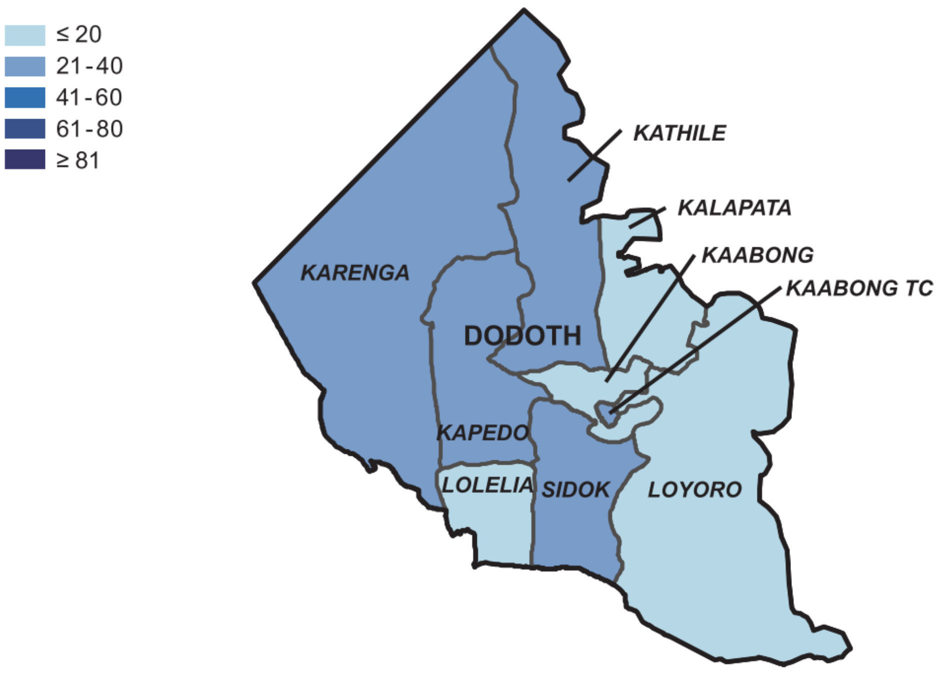
Clearly, functionality of water sources is challenge. Infrastructure is non-functioning as a consequence of poor design, construction and/or maintenance, and to a lesser extent water resource problems. The main reasons for non-functionality are electro-mechanical problems, vandalism and siltation, which in most cases could have been prevented had proper O&M been carried out. Partly, this is due to the limited functioning of the community based Water source User Committees (WUCs). An even bigger problem might be the lack of structural support to the WUCs. The focus of many organizations active in the water sector is still on the development of new water supply systems, while little attentions is paid on the long term sustainable service delivery of water sources. After implementation and training the community is expected to have the full ownership of the water sources and is held responsible for its management. Reality shows that it is often unrealistic to expect a small rural community to take full responsibility for management of a water supply system, especially the more complex systems such as motorized boreholes with a generator, wind or solar power or water treatment facilities. The most feasible management form depends on the local situation, institutional structures, capacity and regulations. There is a need for local structural support to the WUCs, to ensure sustainable and reliable water supply. This support can be in many forms, and can include support to periodic larger maintenance, monitoring, financial management, establishing a supply chain of fast moving parts, quick response to breakdowns, or even a different ownership or service provision model.

## Water source development planning and design

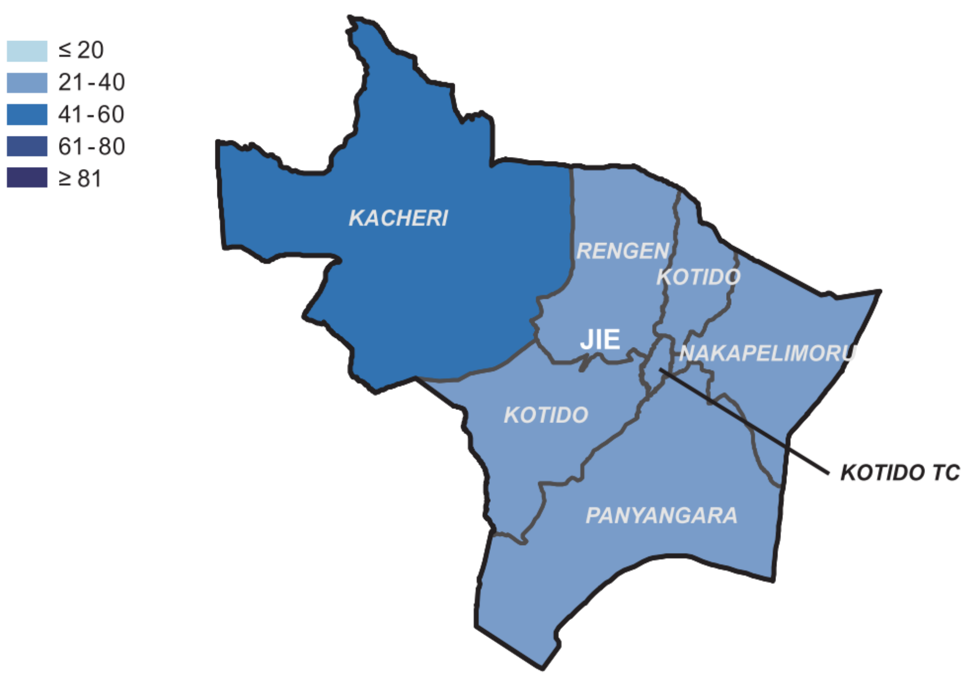
Coordination and planning are seriously hindered by the lack of monitoring data for rainfall, groundwater levels and river flows, and more in general the availability of knowledge on the bio-physical characteristics of the area. As a consequence, critical policy decisions are made based on limited evidence. For example, the decision not to promote hand dug drilling and to move away from shallow boreholes towards larger and deeper boreholes can be appropriate in some parts of the catchment, but in many others it might not be the most cost-efficient and sustainable solution.

A clear understanding of water resources characteristics is needed to improve water source development. In addition, technical guidelines and standards are required to improve design and construction quality. The district officers are willing to improve the situation, but currently lack the data, capacity and the resources to do so.

C. Access in % of population to water in Kaabong (MWE 2010)

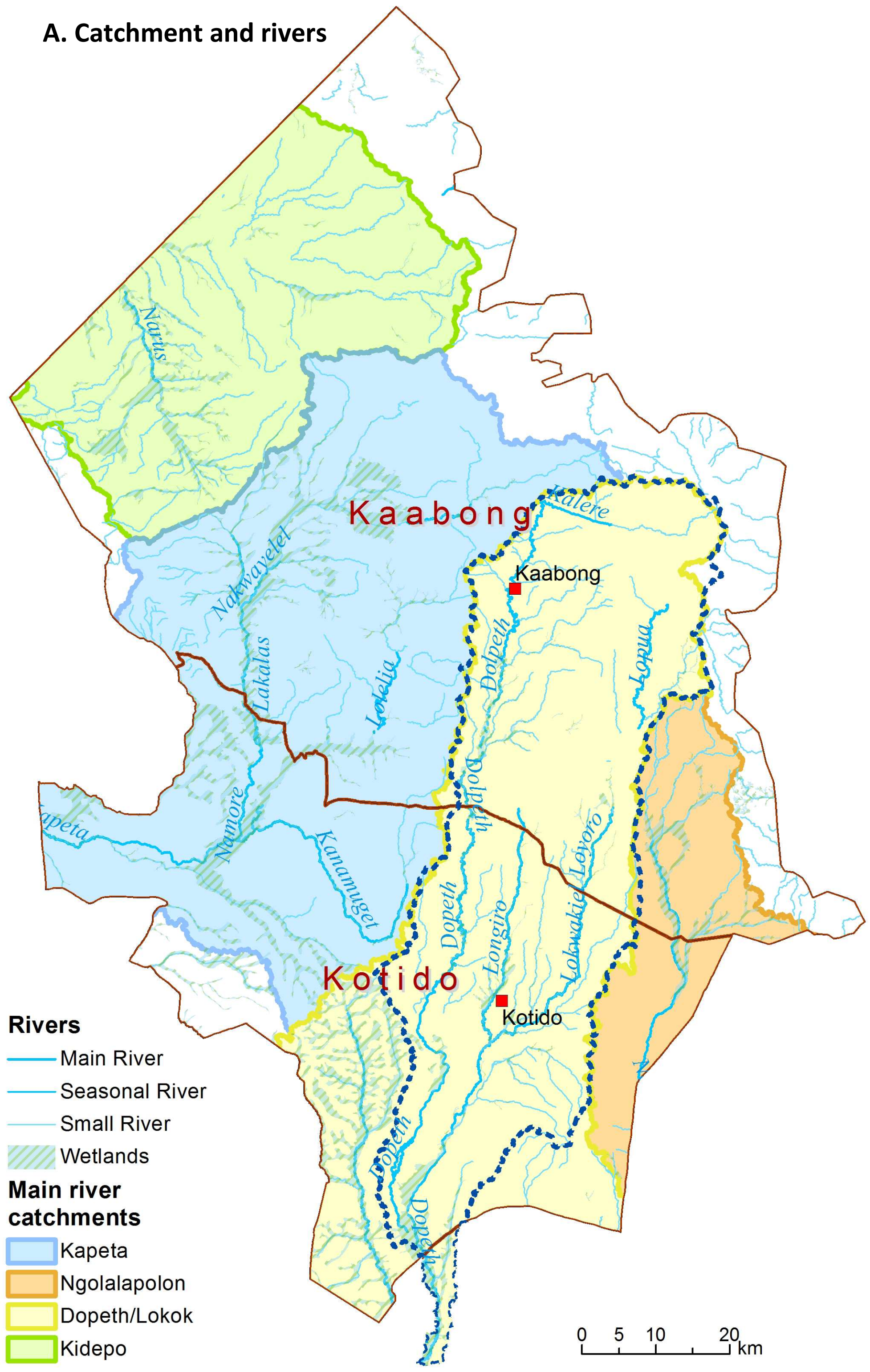



D. Access in % of population to water in Kotido (MWE 2010)



# Surface water

## A. Catchment and rivers




### Surface water in Kotido and Kaabong

Karamoja region is well-drained with a dense network of meandering seasonal rivers and streams filled with sand and silt. No permanent notable surface water features are present (A). Ultimately, most rivers drain into Lake Kyoga in Central Uganda. The rivers are characterized by large variations in low and peak flow, with a very quick response to rainfall events (Vries and Ghawana 2012). During the rainy season the rivers flood and form temporary swamps. After the rainy season, water is stored in the river beds. During the dry season the Karamojong dig up 10 m deep to get water for domestic use and livestock watering purposes.

### Dopeth Catchment area

The project focuses on the Dopeth River catchment area up to the Kaputh River. The total catchment area 2708 $km^2$. The Dopeth River runs from North to South. Most of the catchment is within Kaabong and Kotido Districts, the furthest southern part is located in Abim District.

### Floodplains in the Dopeth Catchment

In the area between Kaabong and Kotido near Koputh shallow groundwater is available throughout the year. In the large flooding areas in the southern part of the catchment at the confluence of the Dopeth and the Longiro River water availability if highly dependent on the season; this is also reflected in the variation of the greenness index (refer also to page 23). From Kaabong southwards the Dopeth River enters a flatter area with alluvial deposits. From this point onwards, the river starts to meander and has a very wide river bed of over 200 meters at some places.

The flooding areas and seasonal wetlands have a major impact on the discharge characteristics. The discharge of the Dopeth decreases significantly in this area. It is expected that the river water recharges shallow aquifers in the alluvial sediments surrounding the river. Potentially, recharge to deeper groundwater and/or paleochannels also occurs here.

The discharges are further reduced in the large floodplains downstream; it is expected that this is mostly due to the high evaporation.

### B. Dopeth River during the dry (left) and wet (right) season

### Dopeth River

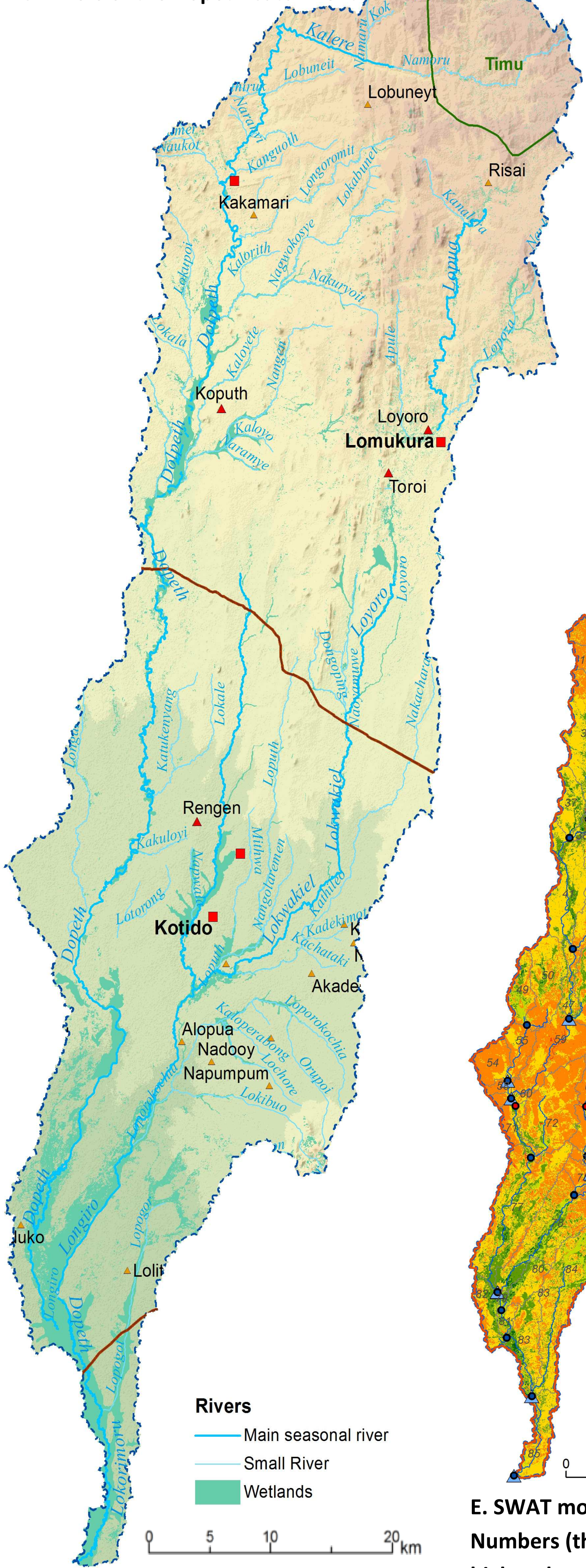
The Dopeth is a typical seasonal river (B). The source of the river lies high in the mountains, at the border with Kenya in the rugged terrain of Kaabong District. There is one main course, but many tributaries add water and sediments to it before it reaches the wetlands South of Kotido. The branches in the upper part of the catchment are often gully-like features, a couple of meters wide. Downstream the river widens up, its cross-section at times being over 200 meters wide. In these downstream sections, the river is filled-up with medium to coarse sediments, which serve as valuable safe water reservoirs to the communities settled close to the river. Water availability is especially high where natural barrier (rock outcrops), bridges and drifts block the subsurface water flow.

During the rainy season, the river floods the surrounding plains increasing soil moisture content and improving the fertility of the soils.

## Hydrological model

A hydrological model was prepared for the Dopeth Catchment to acquire an insight into the water balance, i.e. to get an understanding of the water flow through the catchment (flow regimes, flood hydrographs). The modelling software Soil and Water Assessment Tool (SWAT) was used. This is an open source model that was developed to quantify the impact of land and water management practices in large and complex watersheds. The model uses land use, soil, slope and climatological data to simulate hydrological processes in a catchment. The model combines land use and soil into SWAT curve numbers (CNs). High curve numbers indicate high runoff-infiltration ratios. Map E shows that CNs are highly dependent on land use. Deforestation and expansion of croplands result in higher runoff, and hence increased flood risk and reduced infiltration. The catchment was divided into 85 sub catchments. The input data to the model was based on the high resolution datasets developed for the Dopeth Catchment. The input and output data are both in daily time steps. No river flow gauging data was available for any of the rivers in the catchment to calibrate the model outputs. River profiles were measured at ten locations in the catchment, maximum water levels and other river flow characteristics were estimated in the field and obtained from local knowledge through interviews. This information was combined with remote sensing data. The manning formula was applied to estimate average and maximum river discharge. The summarised outputs for some of the key modelling nodes for the period 1985-2009 are given in Table D. These are simulated model outputs which intend to provide an order of magnitude of the discharge characteristics. These figures should be taken as indication and not hard figures.

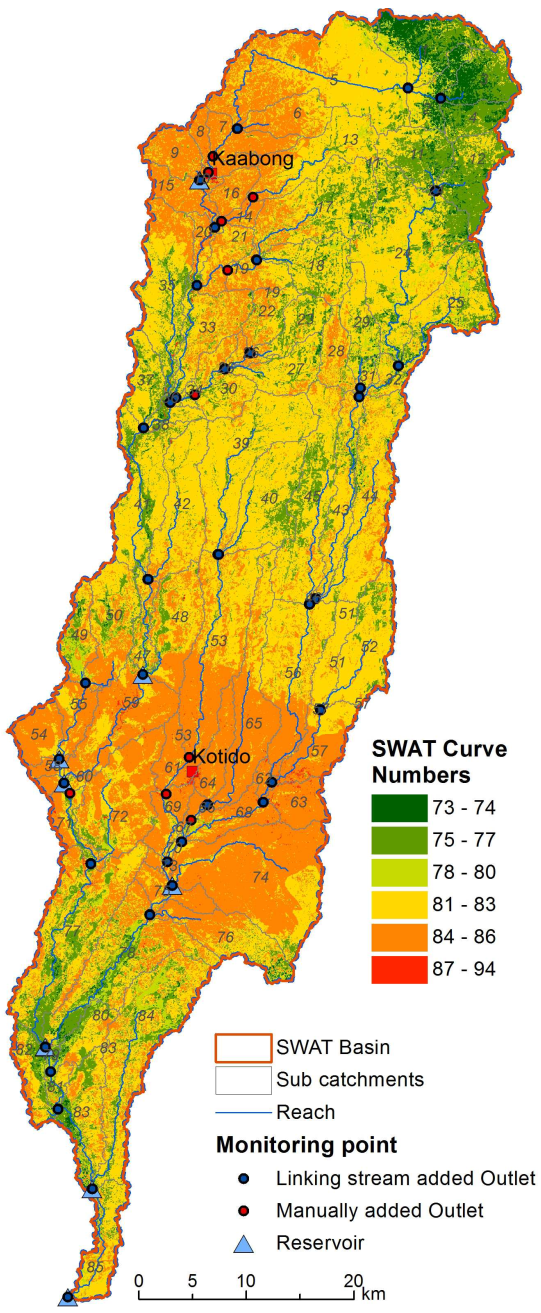
**C. Rivers of the Dopeth Catchment**




**D. Summary of SWAT-model results, indicative and not calibrated.**

| Main River | Tributary | Location | Sub catch-ment | Qmax (m3/s) | Qmax average (m3/s) | Q annual average (Mm3/y) | Q annual max (Mm3/y) | Q annual min (Mm3/y) |
|---|---|---|---|---|---|---|---|---|
| Dopeth | Dopeth | Bridge at Kaabong | 10 | 180 | 78 | 36 | 84 | 4 |
| Dopeth | Nakuryoit/ Nagwokosye | Bridge at main road | 19 | 59 | 15 | 8 | 24 | 1 |
| Dopeth | Longoromit | Bridge near Kaabong | 14 | 46 | 12 | 15 | 34 | 1 |
| Dopeth | Nangen | Bridge at main road | 34 | 106 | 17 | 14 | 36 | 2 |
| Dopeth | Dopeth | Dopeth Kaidila | 60 | 273 | 37 | 18 | 73 | 0 |
| Dopeth | Dopeth | Dopeth downstream wetlands | 77 | 476 | 66 | 31 | 128 | 0 |
| Longiro | Loyoro | Near Loyoro | 32 | 142 | 37 | 22 | 111 | 1 |
| Longiro | Longiro | Bridge near Kotido | 69 | 229 | 36 | 21 | 70 | 1 |
| Longiro | Loputh | Bridge main road | 67 | 43 | 7 | 1 | 8 | 0 |
| Longiro | Lokwakiel | Junction Longiro | 68 | 402 | 72 | 35 | 107 | 2 |
| Longiro | Longiro | Junction Dopeth, after wetland | 78 | 828 | 129 | 63 | 214 | 4 |
| Dopeth | Dopeth | Endpoint, after wetlands | 85 | 107 | 16 | 6 | 45 | 0 |

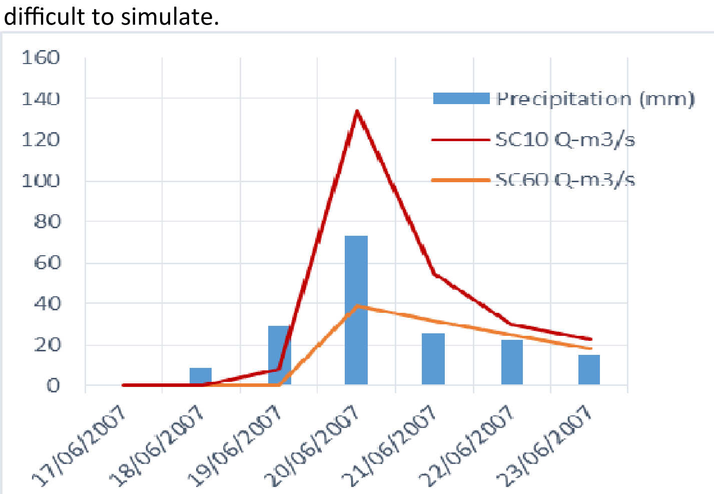
*Qmax: Maximum discharge in m3/s for the entire model period.* ***Qmax average:*** *Average yearly peak discharge in m3/s.* ***Qannual average:*** *average annual discharge in million m3/year.* ***Qannual max:*** *maximum annual discharge in million m3/year.* ***Qannual min:*** *lowest annual discharge in million m3/year*




**E. SWAT model setup and Curve Numbers (the higher the number the higher the run-off and the lower the infiltration rate)**

## Results

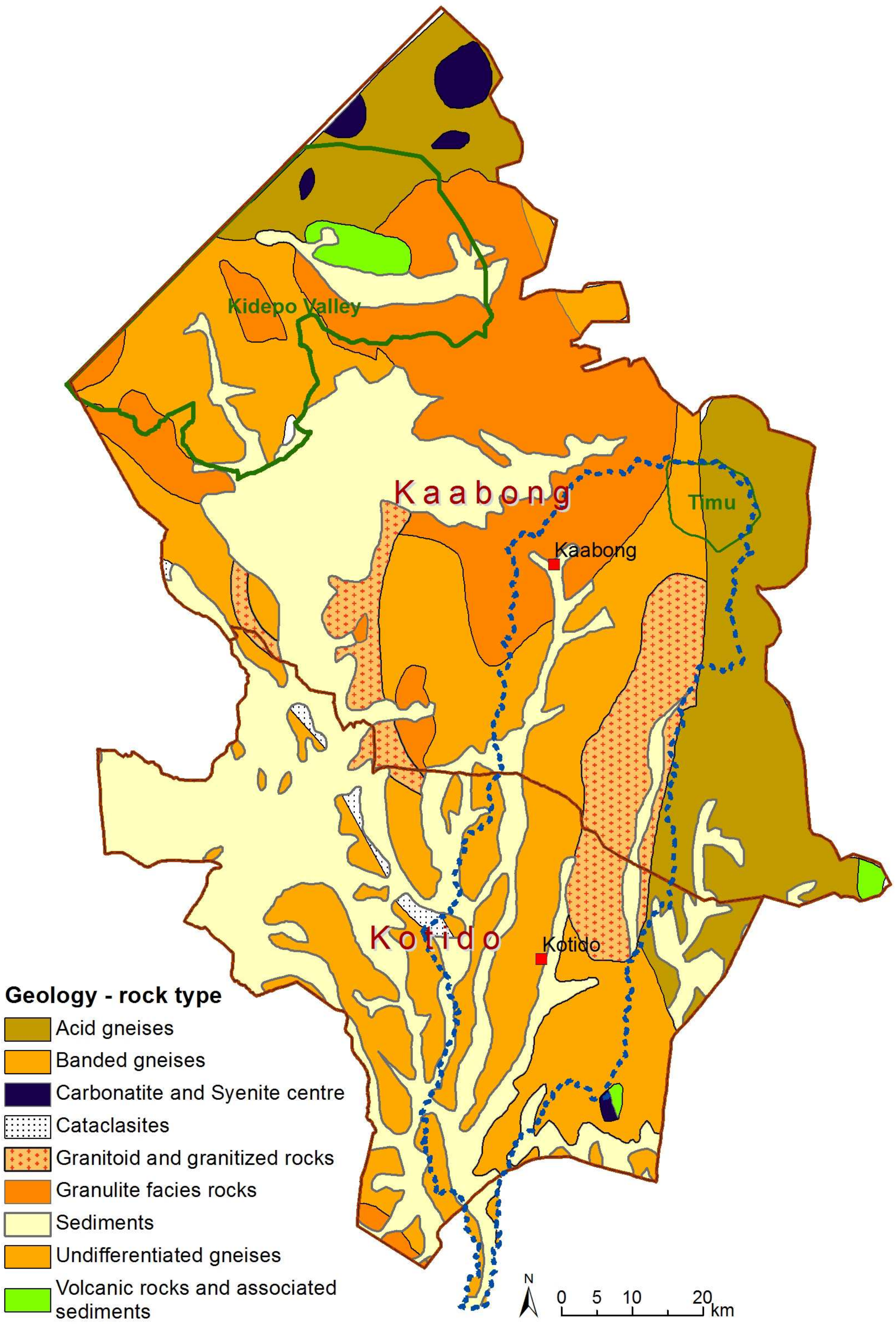
The simulated outputs indicate high peak discharges, especially in the upper catchment where the river responds quickly to heavy rainfall. Field observations indicate high flood discharges in the year 2012, when severe flooding occurred and even old bridges were washed away. It is likely the discharge has even been higher than indicated in the table (D) at some locations. In the lower catchment, the effect of rainfall in the upper catchment is mitigated by the wetlands. The hydrograph (F) provides the simulated discharge for a single rainfall event at the upper catchment (SC10 at Kaabong) and at the middle catchment (SC60 near Kotido). Although the wetlands have been included in the model, flooding, evaporation and infiltration processes proved difficult to simulate.



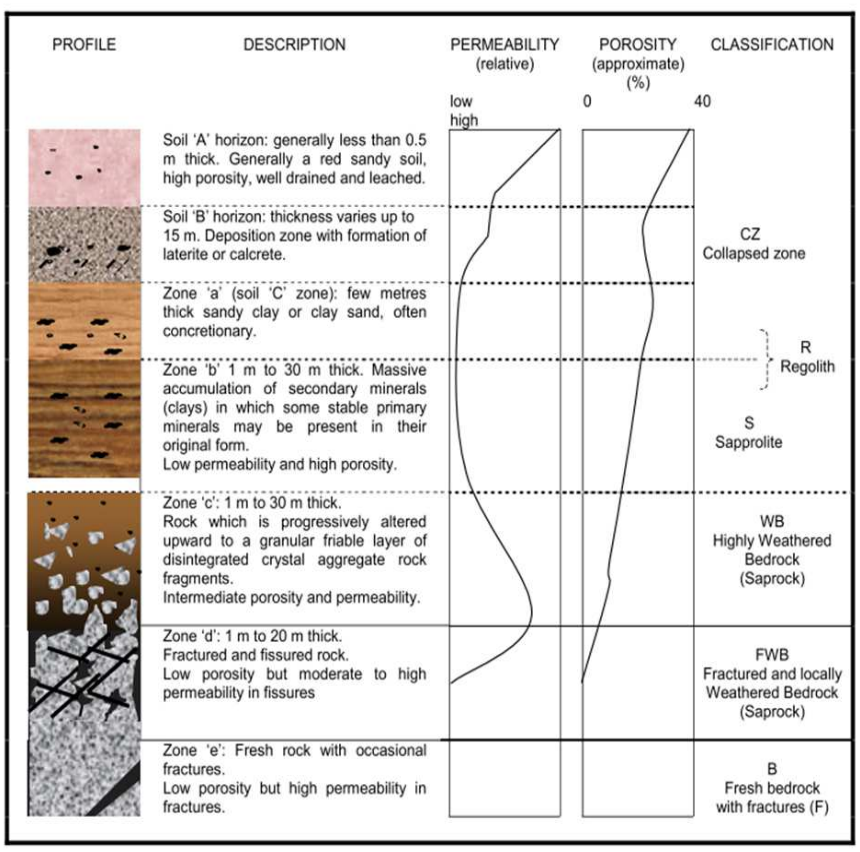

**F. Hydrograph Dopeth River**

## Future use of the model

The current model provides a first insight in the water balance of the catchment. When further improved and calibrated, the model could be used for scenario studies, including the implementation of interventions such as water storage interventions, soil and water conservation, land use change (deforestation, increasing agriculture in wetlands etc.), and effects of climate change. In addition, the model can decision making on support water allocation, development and integrated management.




A. Geological map




B. Indicative geologic profile Central plains (MEDAIR/WeConsult 2009)

## Geology and deep groundwater

The main determinant to groundwater potential is geology. Therefore, to identify the areas where groundwater can be found, it is essential to look at the characterization of the geological formations and their relation with each other (A).

Karamoja is underlain by Precambrian basement rocks. The Upper Dopeth Catchment, the area around Kaabong and the inselbergs in the Middle and Lower Catchments are made up of metamorphic rocks, including granitoid, highly granitized and gneissic formations. The centre of the valley consists mainly of sediments, alluvium, black soils and moraines (WE Consult 2014).

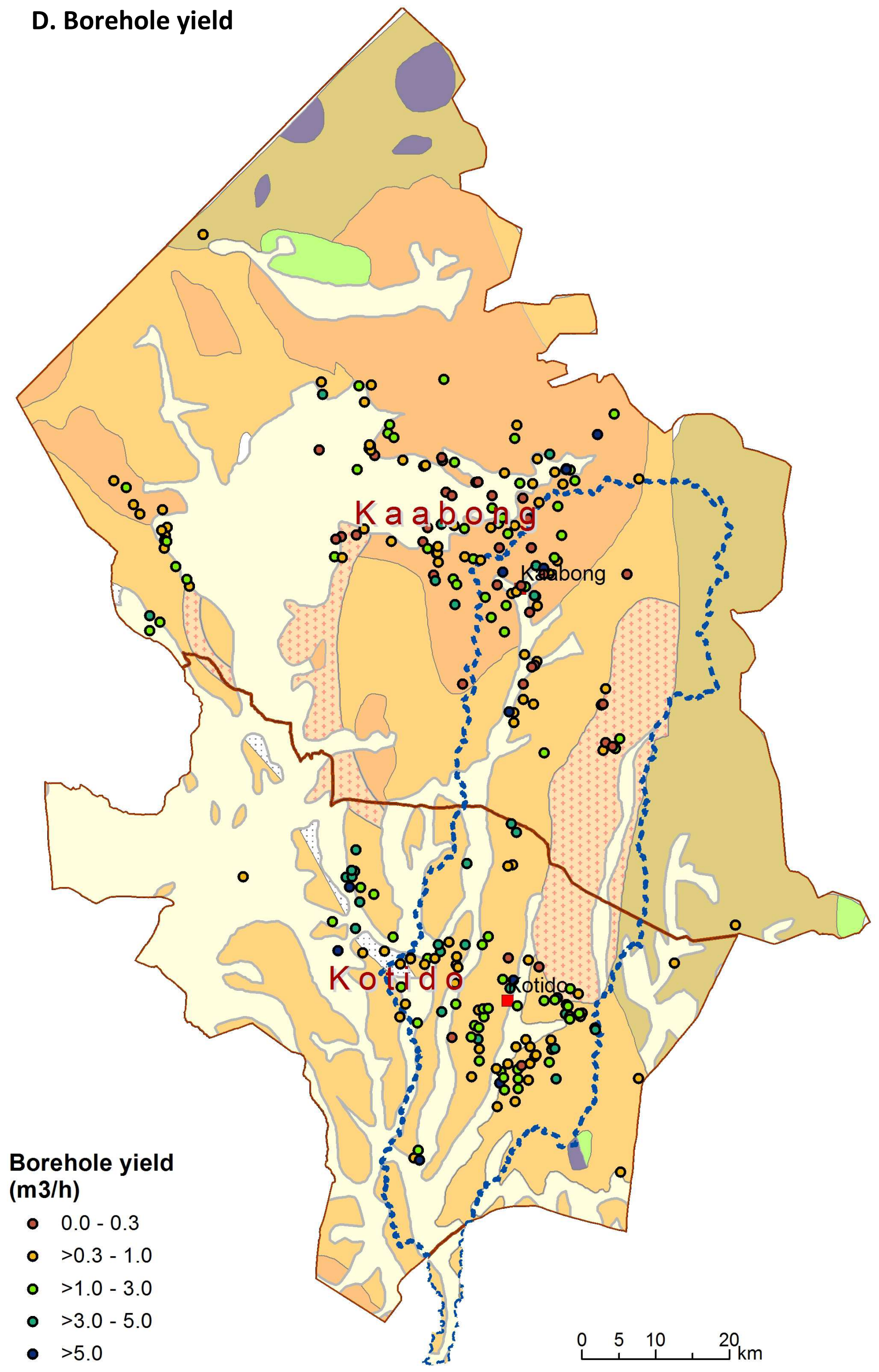
The basement formations contain little to no water. Groundwater is concentrated in fractured and weathered rock, and in the topping regolyth (MEDAIR/WE Consult 2009) (B). In general, porosity decreases with depth, while the variation of hydraulic conductivity is more complex depending on clay content and fracturing (Lahmeyer International 2012a and 2012b). The potential for groundwater resources and the hydraulic conductivity is highest in the zones where rocks disintegrated and fractured due to decompression features and where the weathered material directly overlays the basement rock. These zones often contain little clayey material and, therefore, have a higher hydraulic conductivity. In general, In the Dopeth Catchment, however, the deep aquifer is not well developed because fracturation of rocks due to decompression is limited. Existing deep aquifers are probably associated with geologic fault lines. As a result, when siting for deep groundwater abstraction, in-depth hydrogeological studies and geophysical soundings are imperative (MEDAIR/WE Consult 2009).

## Paleochannels

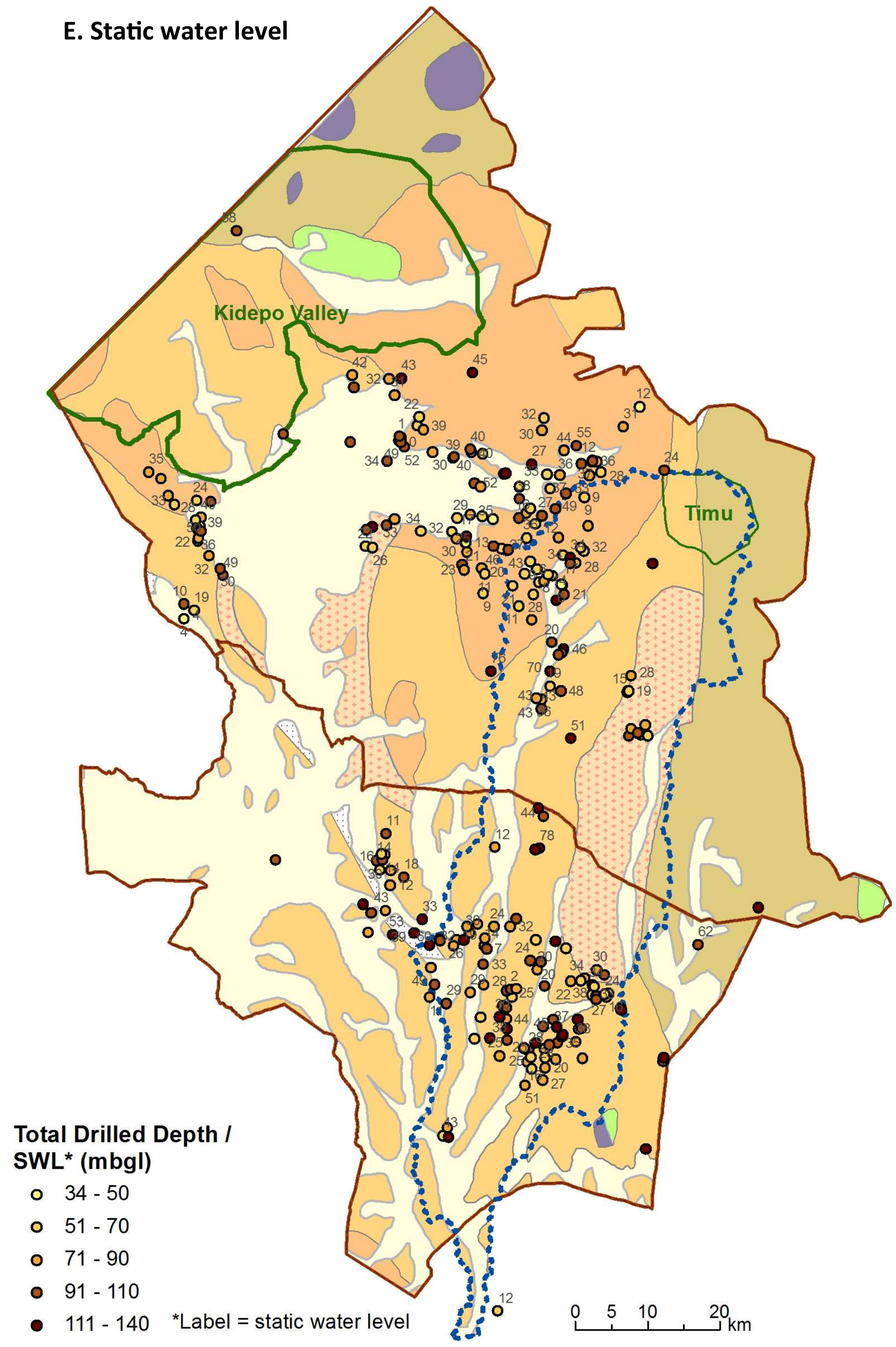
Paleochannels are old buried riverbeds of ancient river networks truncated by Miocene and Pleistocene rifting. While paleochannels did not get much attention for a long time, recent investigations (Tindimugaya 2008) suggest the existence of these highly productive - up to 50 $m^3$/hour pump yield- aquifers east and west of the Western Rift Valley. Although not confirmed, the hypothesis has been formulated that water is seeping down into these paleochannels in areas where the discharge of the Dopeth River decreases suddenly. To understand and tap groundwater from these potential aquifers detailed groundwater studies would have to be carried out.


C. Drilling boreholes (thewaterproject.org 2013)

D. Borehole yield




E. Static water level




## Boreholes

Boreholes are the main source of safe drinking water in Karamoja (C). A previous study on groundwater in Kaabong District, indicates that groundwater levels are deep and drilling success rates (average 68%) and borehole yields (average 1.2 $m^3/h$) low. The presence of some high yielding wells, however, indicates that spatial variability is high (D) (MEDAIR/WE Consult (2009)). The study shows that, on average, in Kaabong District, the first groundwater strike is at 41 m below groundwater level (bgl), main water strike is at 49 m bgl and thickness of the weathered layer is 27 m. During the preparatory phase of the Karamoja Livelihoods Programme, groundwater was found to be at 60 to 100 m bgl in the Eastern zone and between 20 and 60 m bgl in the Western and Central zones. Both WE Consult and Lahmeyer International found in various studies that, in Karamoja, drilling below a depth of about 100 m is not productive.

Overpumping is mentioned by some stakeholders, but there insufficient data on pumping rates and groundwater levels available to check whether the claims are founded. Mostly hand pumps with 1$m^3$/hour to 10$m^3$/day at full capacity are used. Such hand pumps have a small cone of influence and limited drawdown. Hence it is not likely that they are affecting the yields of neighbouring boreholes.

Apart from water quantity, water quality sometimes also forms a constraint to water use. Groundwater measurements in Kaabong District, however, show that neither pollution nor toxicity seem to be a serious threat (F). Salinity, though, at times is somewhat higher, but in the large majority of cases without being problematic.

The figures (D, E) indicate that groundwater potential is high at many places in Karamoja, but careful siting is required. Furthermore, experts point out that databases with drilling data, monitoring programmes, mapping on an on-going basis, detailed hydrogeological assessments and training are much needed.

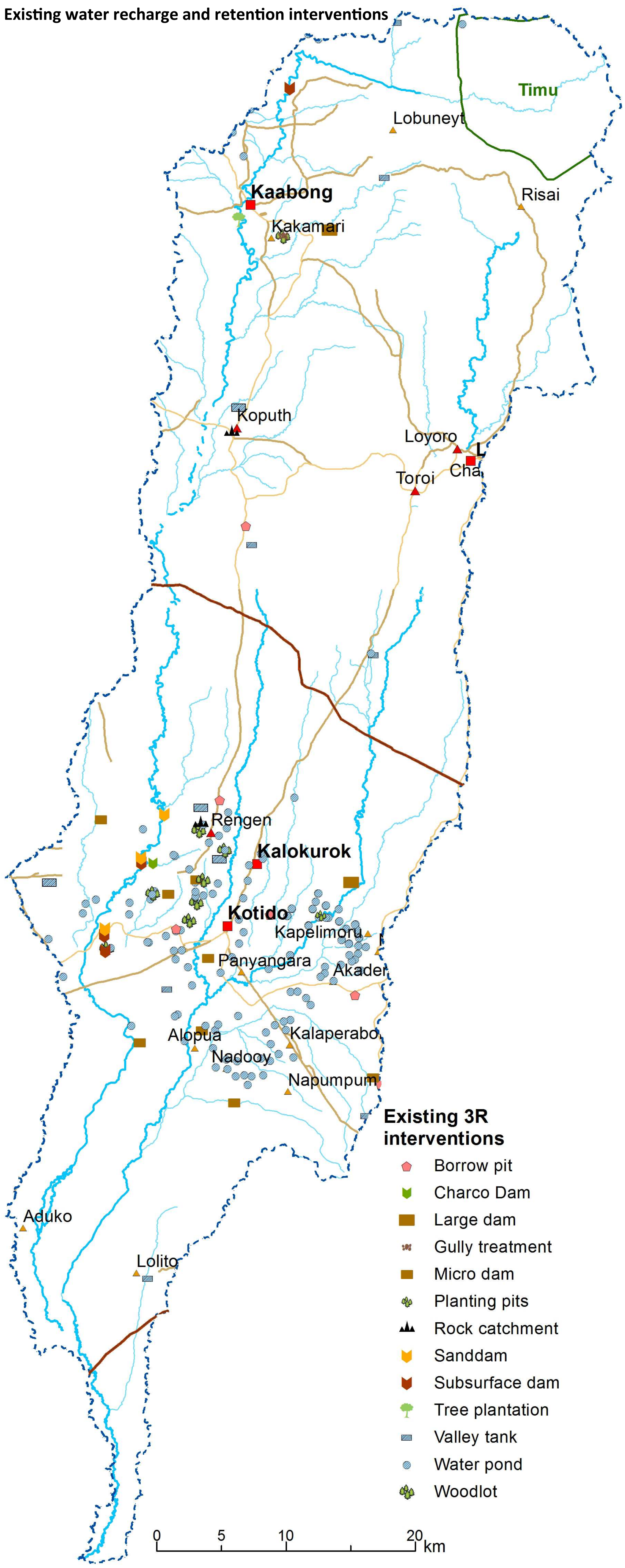
### Shallow groundwater

Throughout Karamoja, groundwater is present in the river beds as is shown by the existence of traditional scoop holes and dug wells in and next to river beds (Vries and Ghawana 2012). Scoop holes and dug wells exist mainly at points where the river encounters rocky outcrops, bridges and road drifts. Groundwater flow is blocked and stored behind the rocks and infrastructure. To increase recharge the implementation of sand and subsurface dams can be considered. For a more detailed description on the opportunities for recharge and retention infrastructure refer to the following sections

### F. Water quality (based on MEDAIR/WeConsult 2009, WHO 2003 and WHO 2011)

| Hydrochemical parameter | Minimum measured | Maximum measured | Toxicity/pollution threshold value |
|---|---|---|---|
| Electrical conductivity | 603 µS/cm | 1120 µS/cm | n.a. |
| Chloride concentrations | 1 mg/l | 81 mg/l | Taste 250 mg/l, no health based guideline |
| Total dissolved iron | 0 mg/l | 0.3 mg/l | 1 to 3 mg/l |
| Fluoride concentrations | 0.1 mg/l | 0.5 mg/l | 1.5 mg/l |
| Nitrate concentrations | 0.2 mg/l | 0.4 mg/l | 50 mg/l |
| Sulphate concentrations | 2 mg/l | 94 mg/l | Taste 250 mg/l, no health based guideline |

**A. Existing water recharge and retention interventions**




**B. Broken/degraded water infrastucture, from top to bottom: broken handpump, cattle erosion along water pond and failed sand dam (RAIN 2015)**

## Sustainability of interventions

Soil and water conservation infrastructure is implemented to improve water availability throughout the year and preserve soils and land for production purposes. The sustainability and effectiveness of this infrastructure in Karamoja is, however, low (A, B). At district level, there are good approaches to field activities and a good understanding of the issues, but in the field it is clear that there is no mechanism for translating ideas into practice. Though there are good initiatives such as consultation of the communities, formation of water user's committees, training of mechanics, results are meagre. The sense of ownership varies from place to place, but is low in most communities. Repair and maintenance of the facilities is often either absent, poor or inadequate. The limited sustainability of the interventions can, in general, be linked to a limited understanding of pastoral livelihoods and their dynamics of the implementing organisations, and, more in general, to the weak enabling environment.

## Recharge and retention - The Approach

The implementation of recharge and retention interventions offer a great opportunity to improve food and water security, limit the impact of droughts, reduce the frequency of destructive erosion and flood events and improve livelihood resilience.

In practice, recharge and retention means collecting and storing water during periods of water excess, making it available during periods of drought. Recharge and retention interventions use buffers like shallow aquifers, the soil profile, open water reservoirs and tanks to store water. The ultimate aim of the interventions is to create secure water buffers, which can fulfill the water demand for different uses in the area. This translates into an increased resilience during droughts, higher productivity, increased access to drinking water and extension of the chain of uses. The recharge and retention approach can be used to make water available in areas with otherwise low water availability. The focus of the approach is on small low cost interventions that add to the resilience of local livelihoods, with no or very limited negative impacts. Sustainable management of natural resources is at the core of the approach.

Recharge and retention includes multiple techniques, such as soil and water conservation measures, subsurface dams, sand dams, water harvesting from roads, ponds, but ‘soft measures’, such as controlled grazing. The most appropriate combination of measures is selected by means of integrated assessments. These assessments include in-depth biophysical analyses and discussions with stakeholders on the needs, opportunities, operation and maintenance.

The strength of recharge and retention techniques is reinforced when the biophysical opportunities are combined with local priorities. By making use of the site’s natural hydrogeological characteristics, the most effective and efficient interventions can be selected. Resilience and water access at regional scale can only be reached through a combination of local interventions appropriately working together.

## Conservation farming programmes

Recharge and retention starts at field level. Appropriate soil management interventions reduce erosion and promote the infiltration of water into the subsoil. Though being labour intensive, conservation farming programmes require very few external inputs. Community groups typically require technical support, tools and transport for learning exchanges between farmer groups. The simplest way for farmers to harvest water and enhance and maintain soil moisture in their fields is in-situ rainwater harvesting, such as zai pits, half moons, soil bunds and stone lines. Several NGOs, including Caritas Kotido, Oxfam, ACF and ZOA, have recently included these methods in their programmes. The projects support terracing, tree nurseries, small (<0.2 ha) community gardens and learning exchanges and provide tools, seeds, micro-savings support and watering cans and recently started trials on half-moon crescents.

## Existing interventions

Knowledge and adoption of recharge and retention and soil and water conservation measures is limited in Karamoja. Farmers have little experience with the techniques because traditional livelihoods were pastoralist.

Currently, there are subsurface dams, valley tanks, water pans, road water harvesting and a few sand dams (A). Bridges and in-stream rocks narrow down the streambed and also improve retention. Shallow wells, dug wells and scoop holes are being used to access the water. The existing water infrastructure was designed and constructed by external organizations, such as NGOs, Ministry of Water and Environment and the Office of the Prime Minister.

In-field soil and water conservation measures are mostly absent. Contour ploughing, soil bunds, mulching and composting, for example, are either not or to a very limited extent applied.

The functionality of water infrastructure is low. There are numerous examples of broken pumps, damaged sand dams and eroded and silted ponds. Most interventions fail due to inadequate site selection, (cattle) erosion, absence of silt traps, vandalism and because tanks and ponds are not lined (B).

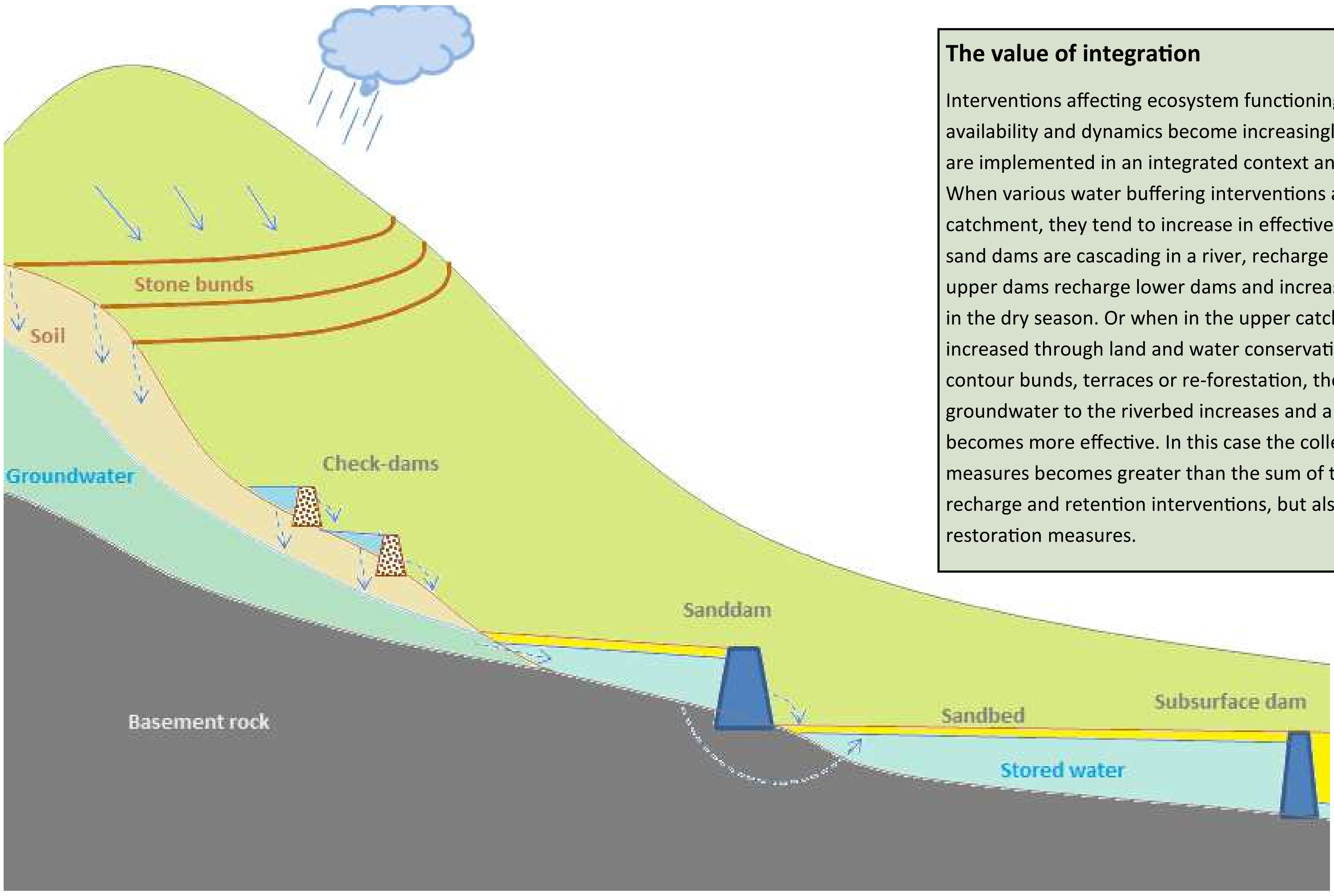
Furthermore, water quality is often low. In open ponds and pans water is subject to pollution through sedimentation, watering of cattle and open defecation, while roof water harvesting systems are often polluted because proper flushing is missing. To ensure good water quality, all collected water from open sources has to be treated or boiled to avoid the proliferation of salmonella and other microbes.

The Ministry of Water and Environment is currently establishing one valley tank for every sub county of Karamoja. The design and construction of this infrastructure seem to meet all requirements. For long term sustainability, however, the linkages with communities and local authorities could be further improved, so that demand, operation and maintenance aspects are sufficiently taken into account.

Altogether, to promote the effectiveness and long term sustainability of the interventions it is most important that theory and practice, demand and supply, and operation and maintenance are matched.

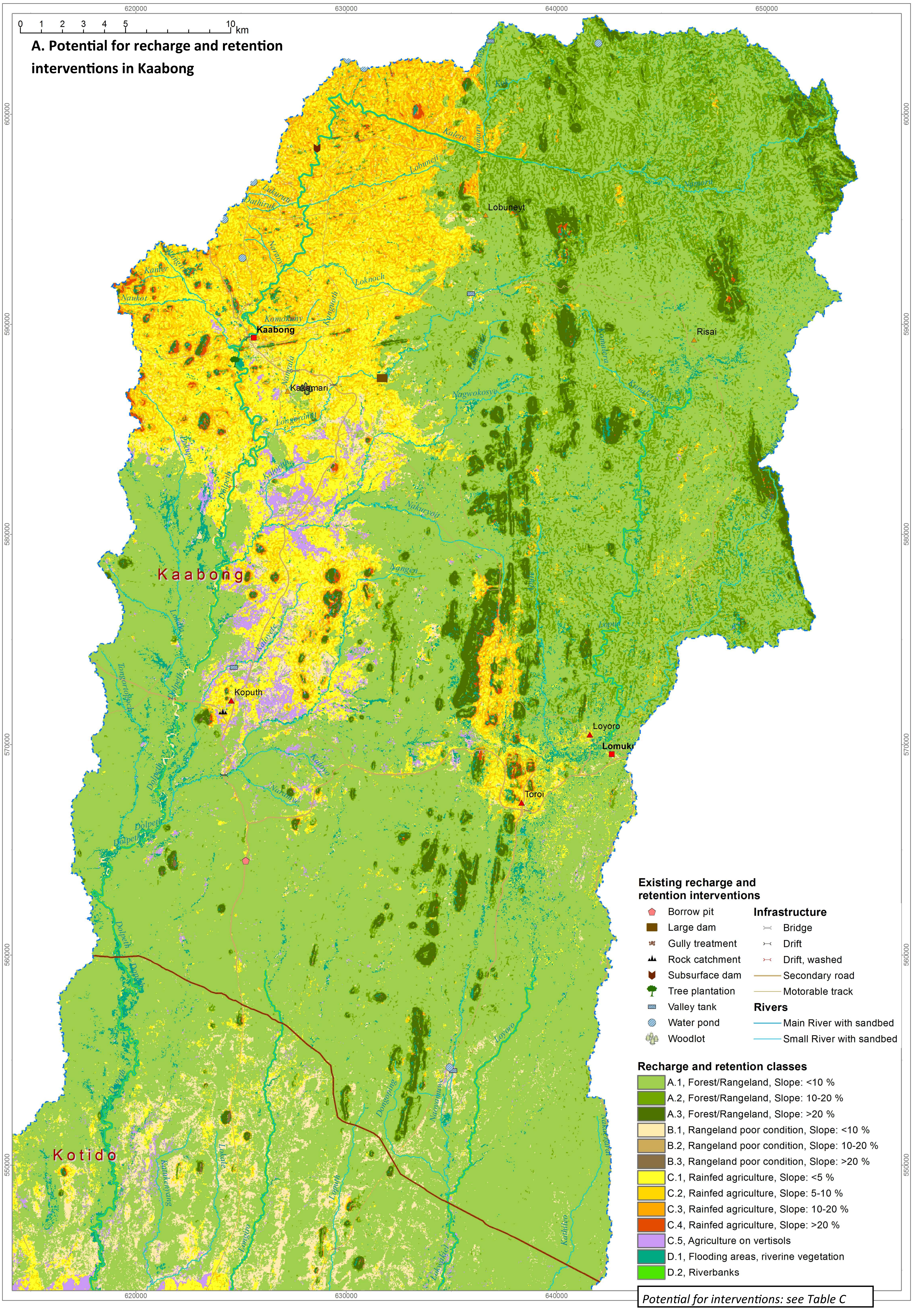
## The value of integration

Interventions affecting ecosystem functioning and water resources availability and dynamics become increasingly effective when they are implemented in an integrated context and at landscape scale (C). When various water buffering interventions are implemented in one catchment, they tend to increase in effectiveness. For example when sand dams are cascading in a river, recharge and leakage from the upper dams recharge lower dams and increase the water availability in the dry season. Or when in the upper catchment infiltration is increased through land and water conservation measures, such as contour bunds, terraces or re-forestation, the recharge of groundwater to the riverbed increases and a sanddam downstream becomes more effective. In this case the collective advantage of the measures becomes greater than the sum of the parts. This applies for recharge and retention interventions, but also for other ecosystem restoration measures.




**C. Illustration of integrated recharge and retention interventions**

# Recharge and retention potential - Kaabong



## Recharge and retention potential maps

Recharge and retention interventions aim to improve water availability during water scarce periods, thus increasing the resilience to droughts. Locally, recharge and retention interventions are already implemented in the project area and the interventions are, in general, well-known to implementing organizations, donors and communities. However, selection of interventions is not straightforward and at catchment level it is difficult to adequately integrate various measures such that the combined result is larger than simply the sum of its parts.

In the Dopeth catchment, as elsewhere, the selection of the specific kind of intervention is, in general, based on community preferences, local knowledge of the implementing partner, or governmental advice. An in-depth technical assessment and siting study are often either missing or incomplete. As a consequence, on the one hand, the sustainability of the interventions is very limited and, on the other, the full scope of viable interventions is not exploited.

To empower organizations with hands-on information based on the specific biophysical limitations and opportunities of the landscape recharge and retention potential maps were developed. The recharge and retention potential maps presented on these pages for the Dopeth Catchment are based on an in-depth assessment of all collected and analyzed data (literature, reports, remote sensing and GIS-files). The maps show practical categories of recharge and retention classes with an indication of recommended land use, opportunities for land and water conservation and possibilities for improving water storage (see next page for examples).

## Users of recharge and retention maps

Recharge and retention potential maps can be used by multiple partners and organizations:

1) Policy makers and coordinating bodies: to plan, advise and evaluate the choice and implementation of soil and water conservation and water provision interventions;

(2) Funding organizations: to indicate different options to provide funding for and examples of measures that are considered feasible in the area under consideration as part of project calls;

(3) Implementing organizations: an indication of the options to consider when applying for funding.

**B. Live fences (Acacia Water 2015)**

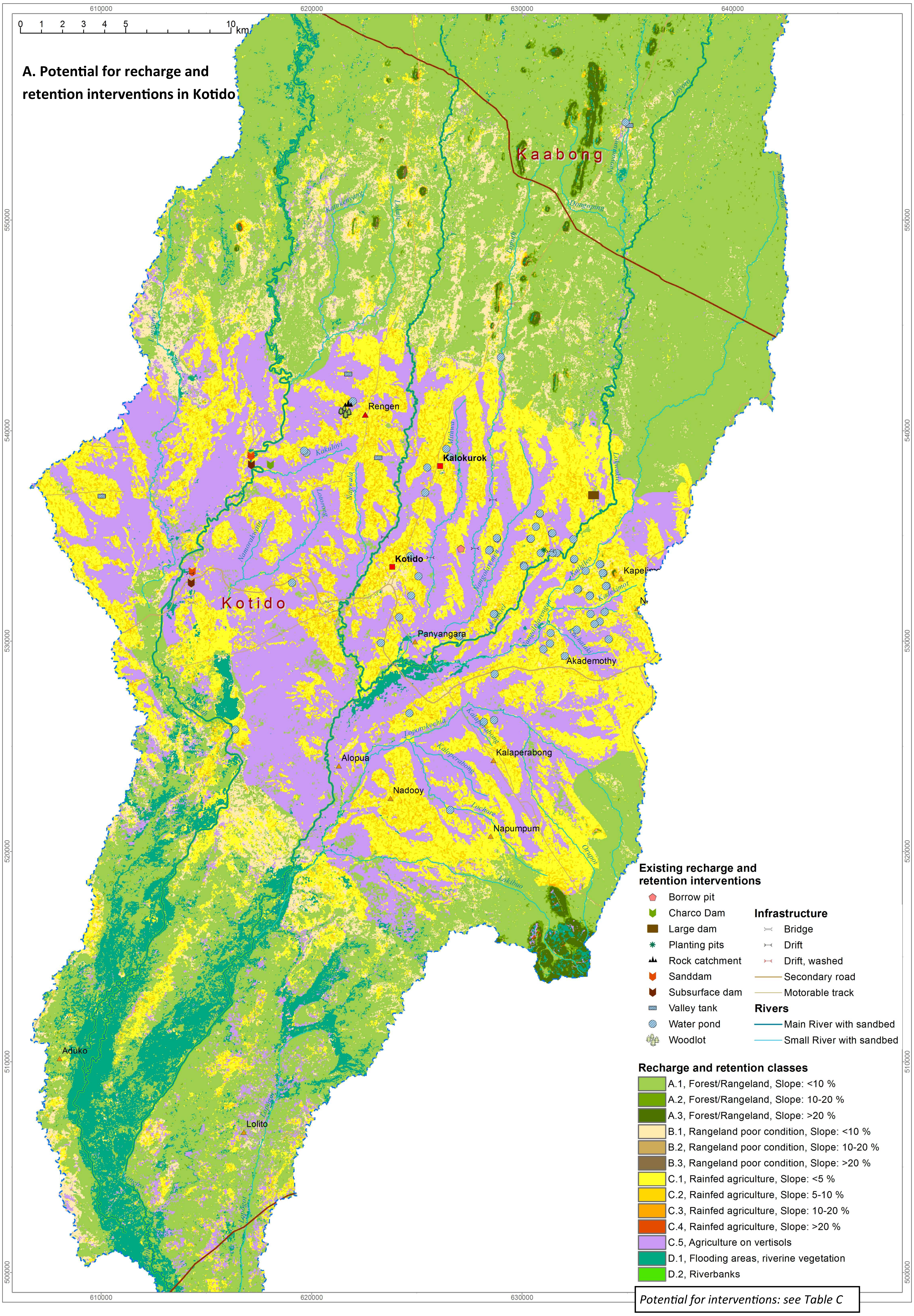
## Wind breaks and live fences

Traditionally fencing of homesteads was typically done with dead wood. Families would cut and collect branches of thorny acacia trees to protect their property and belongings. Nowadays, more and more live fences are used. It is recommended to support this movement, also when protecting water tanks and other infrastructure. The use of live fences, such as Euphorbia *tirucale*, has many advantages: it slows down the deforestation rate, is more sustainable (the plants are not susceptible to termites and putrification) and serves other functions, such as providing shade and fodder for livestock, preparation of natural medicines and construction.

**C. Potential for recharge and retention interventions in the various zones**

| Zone | Area, current land use | Slope | Recommended land use | 3R Interventions for land and water conservation | 3R interventions for storage |
|---|---|---|---|---|---|
| A.1 | Forest/ Rangeland good condition | Slopes < 10% | Forest, rangeland, agriculture | No specific interventions required, controlled burning | Valley tanks, ponds, sanddams, subsurface dams |
| A.2 | | Steep slopes (10-20%) | Forest, rangeland | No specific interventions required, controlled burning | Valley dams, hill-side dams, (leaky) sanddams, rock catchments |
| A.3 | | Very steep slopes (>20%) | Forest | Forest protection, ban on burning | Valley dams, (leaky) sanddams, rock catchments |
| B.1 | Rangeland, poor condition | Slopes < 10% | Rangeland, controlled grazing | Rangeland management, protection of trees, controlled burning, in eroded areas: stone bunds, tied ridges and trenching | Valley tanks, ponds, sanddams, subsurface dams |
| B.2 | | Steep slopes (10-20%) | Rangeland, extensive grazing | Rangeland management, protection of trees, controlled burning, in eroded areas: stone bunds, tied ridges and trenching | Valley dams, hill-side dams, (leaky) sanddams, rock catchments |
| B.3 | | Very steep slopes (>20%) | Forest | Forest protection, area closure, ban on burning, tree planting, in eroded areas: stone structures above ground | Valley dams, (leaky) sanddams, rock catchments |
| C.1 | Rainfed agriculture | Flat to gentle sloping areas (<5%) | Agriculture | Tree planting as wind breaks, mulching, floodwater spreading, spate irrigation | Valley tanks, ponds, subsurface dams, sanddams, pans, MAR |
| C.2 | | Gentle slopes (5-10%) | Slope adapted agriculture | Tree plantations, terracing, contour bunds, tied ridges, grass-strips, tree planting as windbreaks | Valley tanks, ponds, hillside dams, subsurface dams, sanddams, pans, MAR |
| C.3 | | Steep slopes (10-20%), | Forest or rangeland, slope adapted agriculture | Tree plantations, bunds and ridges to cut of runoff before the gully, tied ridges, trenching, planting pits, gulley treatment | Valley dams, hillside dams, rock catchments, (leaky) sanddams |
| C.4 | | Very steep slopes (>20%) | Forest | Forest protection, area closure, tree planting, in eroded areas: stone structures above ground | Valley dams, (leaky) sanddams, rock catchments |
| C.5 | | Agriculture on vertisols | Conservation agriculture | Soil moisture management, runoff and erosion control | Sanddams, subsurface dams, water pans |
| D.1 | Riverbanks and wetlands | Flooding areas and seasonal wetlands | Controlled grazing | Wetland protection, floodwater spreading, and floodwater storage | Water pans, valley tanks |
| D.2 | | Riverbanks | Protected areas, no grazing and tree cutting | Protection of riverine vegetation, floodwater spreading, regulation of sand harvesting, | Sanddams, subsurface dams |

# Recharge and retention potential - Kotido




*Potential for interventions: see Table C*

**Overview recharge and retention potential Dopeth Catchment**

The recharge and retention potential maps on this (A) and the previous pages in combination with the corresponding table (C)provide an overview of the landscape categories present in the Dopeth Catchment and the recommended land use, the opportunities for soil and water conservation measures and the potential for construction of water storage interventions.

Approximately 1/3 of the Dopeth Catchment is under forest or rangeland in good condition. The need for interventions in these areas is minimal. Mostly, these areas provide great opportunities for water storage both in open water reservoirs (tanks, ponds and rock catchments) and in the form of groundwater (by means of subsurface and sand dams). Degradation processes threatening rangelands in poor condition can best be slowed down by means of strict rangeland management, including controlled grazing and burning, and physical structures slowing down runoff, such as stone bunds, tied ridges and trenches.

Rain fed agriculture predominates in the areas around the towns of Kotido and Kaabong. On the steep slopes it is recommended to limit agriculture. In all other areas it is advised to adapt agricultural practices: a combination of multiple soil and water conservation measures should be implemented to limit erosion caused by runoff, wind breaks and increased vegetation cover are suggested to limit wind erosion and early gulley treatment is advised to limit the loss of fertile lands (B). Vertisols are especially vulnerable to erosion and require additional soil moisture management measures to improve infiltration.

Riverbanks and wetlands should be protected at all times. Controlled (or even no) grazing policies are recommended, while floodwater spreading could reduce erosion and improve soil moisture conditions.

**B. Examples of recharge and retention measures, from top to bottom and from left to right: mulching (afarminafrica 2013), tree plantation (RAIN 2015), terracing (Tuinhof et al. 2012), valley tank (Acacia Water 2015), pond (Acacia Water 2015) and sand dam (Tuinhof et al. 2012)**

**C. Potential for recharge and retention interventions in the various zones**

| Zone | Area, current land use | Slope | Recommended land use | 3R Interventions for land and water conservation | 3R interventions for storage |
|---|---|---|---|---|---|
| A.1 | Forest/ Rangeland good condition | Slopes < 10% | Forest, rangeland, agriculture | No specific interventions required, controlled burning | Valley tanks, ponds, sanddams, subsurface dams |
| A.2 | | Steep slopes (10-20%) | Forest, rangeland | No specific interventions required, controlled burning | Valley dams, hill-side dams, (leaky) sanddams, rock catchments |
| A.3 | | Very steep slopes (>20%) | Forest | Forest protection, ban on burning | Valley dams, (leaky) sanddams, rock catchments |
| B.1 | Rangeland, poor condition | Slopes < 10% | Rangeland, controlled grazing | Rangeland management, protection of trees, controlled burning, in eroded areas: stone bunds, tied ridges and trenching | Valley tanks, ponds, sanddams, subsurface dams |
| B.2 | | Steep slopes (10-20%) | Rangeland, extensive grazing | Rangeland management, protection of trees, controlled burning, in eroded areas: stone bunds, tied ridges and trenching | Valley dams, hill-side dams, (leaky) sanddams, rock catchments |
| B.3 | | Very steep slopes (>20%) | Forest | Forest protection, area closure, ban on burning, tree planting, in eroded areas: stone structures above ground | Valley dams, (leaky) sanddams, rock catchments |
| C.1 | Rainfed agriculture | Flat to gentle sloping areas (<5%) | Agriculture | Tree planting as wind breaks, mulching, floodwater spreading, spate irrigation | Valley tanks, ponds, subsurface dams, sanddams, pans, MAR |
| C.2 | | Gentle slopes (5-10%) | Slope adapted agriculture | Tree plantations, terracing, contour bunds, tied ridges, grass-strips, tree planting as windbreaks | Valley tanks, ponds, hillside dams, subsurface dams, sanddams, pans, MAR |
| C.3 | | Steep slopes (10-20%), | Forest or rangeland, slope adapted agriculture | Tree plantations, bunds and ridges to cut of runoff before the gully, tied ridges, trenching, planting pits, gulley treatment | Valley dams, hillside dams, rock catchments, (leaky) sanddams |
| C.4 | | Very steep slopes (>20%) | Forest | Forest protection, area closure, tree planting, in eroded areas: stone structures above ground | Valley dams, (leaky) sanddams, rock catchments |
| C.5 | | Agriculture on vertisols | Conservation agriculture | Soil moisture management, runoff and erosion control | Sanddams, subsurface dams, water pans |
| D.1 | Riverbanks and wetlands | Flooding areas and seasonal wetlands | Controlled grazing | Wetland protection, floodwater spreading, and floodwater storage | Water pans, valley tanks |
| D.2 | | Riverbanks | Protected areas, no grazing and tree cutting | Protection of riverine vegetation, floodwater spreading, regulation of sand harvesting, | Sanddams, subsurface dams |

# 5

# The way forward

**Problem - flow chart**

In the previous chapters, the results of the sociotechnial assessment of the Dopeth Catchment were presented. Experts judge that the high vulnerability and disaster risk in the project area can, to a large extent, be attribute to the failing natural resources management.

The flow chart with the socio-technical problem analysis (A) shows how the context, core problem, hazards, effects and disasters are linked to each other. The failing natural resources management forms the core problem. In the next phase of this strengthening community resilience project, this analysis presented in this Atlas will be held against the the socio-economic, knowledge and coordination studies to check whether the findings match with each other, and how these can best inform the strategic intervention plan.

Considering once again the disaster risk reduction formula (see page 6), it is, on the one hand, important to build capacity and, on the other, to decrease the vulnerability of the system.The data and analyses in this study show that the current natural resources management in the Dopeth Catchment does not suffice. The environment is being degraded and ecosystem services lost. The resilience of the system is being undermined at an alarming pace.

However, this study also shows that natural resources management can be improved through the implementation of, for example, integrated (water) resources management, capacity building programs and rangeland management policies.

**A. Flow chart problem analysis**

| EXPLANATION | SOLUTIONS |
|---|---|
| Livelihood and lifestyles are transforming due to increased security and outside influences: from pastoralism to agro-pastoralism, increased sedentarisation and less migration, while still heavily dependent on natural resources. | Outside scope of this project |
| Increased and concentrated use of NR, transformation of rangeland to agriculture, tree cutting for cooking charcoal production and fencing, permanent grazing | Awareness and training, farmer schools |
| Weakening traditional social structures for natural resources management (agreements on dry/wet season grazing etc.), and failing alternative systems for NRM (government strategies and NGO programs). This also includes management of water sources | Most effective level of intervention : NRM, IWRM, capacity building, rangeland management |
| Degradation of ecosystems, such as forests, wetlands, grasslands | Recharge and retention interventions for soil and water conservation measures, reforestation, zoning with land use regulations |
| Loss of ecosystem services such as rangeland capacity, wood, water regulation, climate regulation and soil fertility increases vulnerability | Recharge and retention interventions for water storage |
| Natural phenomena of this climate zone, such as droughts and intense rainfall become problematic because of decreased resilience of the ecosystem and reduced adaptation strategies (migration) of the communities. Climate change can intensify these hazards. | Early warning systems, food stocking and water supply |
| The weakened system is vulnerable. Hazards result in high runoff rates and flooding in the rainy season, and strong winds and wild fires in the dry season. Less infiltration leads to reduced soil moisture and groundwater recharge. As a consequence, crops and infrastructure are lost due to flooding, while natural resources are quickly depleted in the dry season. | Large dams and water regulating infrastructure, deep boreholes, irrigated agriculture |
| Disasters occur and become more intense | Emergency aid |

## CONCLUSIONS

Karamoja Region in the northeast of Uganda is characterized by acute poverty and has the lowest social and economic development of the country. The situation improved over the past years, especially in terms of security, but the region was unable to successfully implement and manage long term sustainable development processes. Many disaster risk reduction, capacity building and other support projects proved helpful, but the region remains disaster prone. Frequently, hazards still result in food insecurity, disease and conflict.

Hazards lead to disasters when the vulnerability of a system is high, and its coping capacity low. The project looked at this hazard-disaster link from a sociotechnical perspective. Concepts and models from the fields of integrated water and ecosystem-based management were used. In accordance with guidelines set by the Government of Uganda, an assessment at catchment level was pursued. The project included a literature review, remote sensing and GIS analyses, field surveys, interviews and discussions with key stakeholders; the collected data was refined, calibrated and validated in the field. The main objectives of the assessment were the development of a knowledge base, the pinpointing of key challenges and the identification of opportunities to support priority setting and development of planning and development strategies.

In the following paragraphs first the main findings are presented. Thereafter, follows a short note on the overarching challenges beyond these findings.

***Climate.*** The climate in the project area is semi-arid, with an unimodal rainfall pattern and erratic precipitation. Net precipitation is positive. There are claims that, possibly due to climate change, droughts are becoming more severe. Our analysis, however, shows that climatological droughts have not become more frequent, more intense or longer in the past decennia. The findings, however, suggest that the impact of droughts is increasing because of degrading natural resources, reduced resilience of the system and reduced adaptation strategies.

***Surface water.*** There are no permanent natural surface water bodies in the catchment. Runoff and river discharge are seasonal and in direct response to rainfall. It was found that wetlands and riverine vegetation play an important role in the system attenuating peak discharges. Water is stored in the riverbed, evaporates and infiltrates toward the deep groundwater system. Current expansion of agriculture into the wetlands is, therefore, increasingly leading to higher peak discharges and flooding downstream.

***Groundwater.*** Access to safe and clean water is limited. Boreholes are the predominant source of domestic water in towns; in the rural area villagers collect water from ponds and scoop holes. Large percentages of the water infrastructure are non-functional due to either design, construction or maintenance problems. There is some potential for deep groundwater, but depth and yield are highly dependent on weathering and fractures; proper siting is a thus a must. Locally, e.g. in the alluvial deposits of the Dopeth River, the potential for shallow groundwater is high.

***Recharge and retention.*** Due to pastoralist and nomad traditions there is little knowledge in the project area on soil and water conservation measures and recharge and retention interventions. The high levels of degradation, especially on the agricultural lands, indicate the need for measures such as mulching, soil bunds and tied ridges. Rangeland degradation could be slowed down through controlled grazing and burning, and protection of trees. Furthermore, locally, there is high potential for in-stream water storage intervention such as sand and subsurface dams.

***Land use and management.*** Erosion and deforestation are major challenges in the Dopeth Catchment. Land use changes and management issues play a major role in these problems. The crop production area in the catchment has almost doubled over the past 15 years, while forest cover was reduced by approximately 15%. Deforestation is mostly a consequence of charcoal production, firewood collection, tree cutting for fencing and land clearance for cultivation. Increased dependence on rain fed agriculture is reducing the system's resilience and the effectiveness of traditional coping mechanisms. Rangeland management traditions have been lost over the past decades; as a consequence, pastures shortages, burning and erosion are becoming problematic in the dry years. The land use and management challenges are in part compounded by weak or non-existent formal land registration, which acts as a barrier to smallholders investing their time in conserving soil and water.

***Ecosystems.*** Wetlands and forests have the highest value in terms of ecosystems services, providing a multitude of provisioning and regulating services. Wetlands, riverine vegetation and forests contribute to climate and hydrologic regulation, and provide a multitude of products including water, reed and good quality pasture. On the contrary, agricultural areas play an important role in food provision, but have limited value in terms of water provision, climate regulation and wood provisioning services. At the same time, there are limited policies in place to protect vulnerable ecosystems and habitats. The increasing environmental degradation is reducing the ability of the various ecosystems to deliver ecosystem services, therewith increasing the chance of hazards leading to disasters.

***Overarching challenges.*** The findings show that the core problem is at the level of natural resources management. Livelihoods and –styles are changing due to improved security and outside influences: from pastoralism to agropastoralism, with increased sedentarisation and less migration, while still being heavily dependent on natural resources. The weakening of traditional resources management in absence of good alternative systems results in environmental degradation and, therewith, in the loss of resilience. There is a number of clear overarching challenges that is compounding to environmental degradation:

- Population growth, sedentarisation and dependency on aid programmes
- Limited consideration of ecosystem services and opportunities provided by the landscape
- Weak linkages between policies, plans and frameworks, implementing organizations, and communities' needs and demands
- Lack of knowledge and technical capacity
- Lack of coordination and dialogue between government agencies and village leaders
- Shortage of monitoring data (on for example rainfall, groundwater levels and river flows)

## RECOMMENDATIONS

To effectively reduce disaster risk the overarching challenges have to be tackled in an integrated manner. Improved natural resources management is crucial and should be at the core of any approach. High value ecosystems such as forests and wetlands should be protected, and ecosystem services of rangelands and agricultural lands should be expanded and managed, so that resilience is build and hazards can be prevented from turning into disasters.

***Wetlands.*** Wetlands and riverine vegetation are of greatest importance to the resilience of the Dopeth Catchment system. It is recommended to control sand harvesting, address gulley erosion, ban burning practices and, foremost, avoid further expansion of agricultural practices into wetlands; existing crop production in the areas should become more sustainable.

***Agricultural practices.*** Due to lack of or limited crop rotation, removal of trees, and absence of (appropriate) soil and water conservation measures, fertile soils and water are being lost, biodiversity is decreasing and regulations services are being disturbed. The system's resilience is being undermined by the transformation of other land cover types into agricultural land. It is, therefore, recommended to regulate the expansion of agriculture and start a 'damage control' series of measures shortly. Measures should aim for the improvement of agricultural practices, including the adoption of drought resistant crops, crop diversification, promotion of crop rotation, implementation of agro-forestry practices, tree planting and widespread implementation of soil and water conservation measures. In addition, at locations where water is available, small scale irrigation systems can be introduced, to enable production of high value crops and more reliable harvests.

***Forest.*** Forest management efforts should focus on the inventory of current cover and long term planning as a means of preventing further soil erosion. Reforestation with drought tolerant species in zones with observed and potential erosion is recommended. Alternative cooking, building and fencing practices should be promoted to avoid or limit tree cutting.

**A. Karamojong girls**

***Enabling environment.*** The enabling environment for good management practices should be strengthened. There is a dire need for policy adjustments, regulatory measures, stakeholder involvement, creation of a knowledge centres, coordination and dialogue, and integration of traditional management practices into governmental guidelines.

***Rangeland management.*** Rangeland management, including restrictions on burning practices, should be improved. Promising strategies include the incorporation of bye laws into regulation, strengthening the role of elders in and improving coordination with the government agencies.

***Water provision.*** Water availability could be improved through the large scale implementation of small scale water recharge and retention measures tailored to the local conditions and geography (e.g. sand and subsurface dams, water harvesting from roads), strengthening of water use associations and improved siting of boreholes. Further, when implementing infrastructure, in-depth understanding and full-consideration of pastoral livelihoods is needed.

***Planning, design, operation & maintenance.*** Currently, many water sources such as boreholes, water ponds and sanddams fail due to poor site selection, design and construction, while their functionality remains a challenge due to poor operation and maintenance practices. Partly, this is due to the poor functioning of community based Water source User Committees (WUCs), but an even bigger problem might be the lack of support to communities and WUCs. To address the challenges, it is recommended to support the WUCs, strengthen the capacity of authorities, structure the role of the private sector and NGOs.

***Coordination and planning,*** Coordination and planning are seriously hindered by a lack of monitoring data on rainfall, groundwater levels and river flows, and more in general the availability of knowledge on the bio-physical characteristics of the area. As a consequence, critical policy decisions have to be made based on limited evidence. A clear understanding of water resources characteristics is needed to improve water source development planning. In addition, technical guidelines and standards are required to improve design and construction quality.

***Knowledge centre.*** In order to improve site selection, design, construction and O&M of water infrastructure a regional knowledge centre could be established. The knowledge centre could be a platform of government agencies (DWO, WMZ etc.), NGOs and private service providers, aiming for improved coordination, effectiveness, efficiency and professionalism in the sector. The centre could

- Support water governance
- Back capacity building programs
- Develop planning tools
- Organize knowledge, information and data sharing
- Maintain a list of registered, qualified consultants and contractors
- Develop guidelines and standards for implementation
- Improve coordination between organizations

Alongside the project's other studies, the Atlas of the Dopeth Catchment will inform strategic planning and decision making. Building resilient livelihoods in the Dopeth Catchment is feasible. Karamoja is endowed with pro-active communities, and the government and NGOs are very willing to contribute. The project team is convinced that with multiple small but practical interventions, in parallel with improved coordination, capacity building and monitoring, good steps can be set toward more sustainable and effective natural resources management and, therewith, toward more resilient livelihoods and disaster risk reduction.

# Credits and references

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