THE COUNTY GOVERNMENT OF KITUI **SOUTH EASTERN KENYA UNIVERSITY**

KITUI COUNTY SUBSURFACE/SAND DAM DEVELOPMENT PROGRAMME

Technical report on identification of the potential sites for construction of subsurface dams and sand dams in Kitui County, Kenya

Submitted to Kitui County Government, Ministry of Agriculture, Water, and Irrigation

Project Report

EXECUTIVE SUMMARY

Kitui County Sand Dam Project was implemented as a joint venture between the Kitui County Government and the South Eastern Kenya University through the School of Water Resources Science and Technology in this programme. The main goal of the project was to carry out an objective process of assessing sites for the construction of sand dams in Kitui County. The project was implemented between July 2015 and May 2016. The South Eastern Kenya University provided technical support while the County Government through the Ministry of Water, Agriculture, and Irrigation provided financial resources for the implementation of the project. A team of experts drawn from the two institutions implemented the project based on mutually agreed terms of reference. The technical team provided technical information that would allow the county government to make informed decision on the suitable locations for construction of sand dams and subsurface dams projects with the support of the local communities. In addition to providing technical/scientific information, the study also included surveys to gather lessons and best practices in the sustainability of similar projects that have been undertaken in Kitui County with support from various non-governmental organizations. The later socio-economic survey also assisted in establishing challenges in sustaining sand dam projects on long term basis and the remedial measures that can be undertaken to address the most critical challenges.

The project involved field-based investigations as well as desk-top review and analysis of secondary data and information generated through various processes. The sites proposed by the local communities were visited by the team of experts who proceeded to conduct thorough verification exercises based on an agreed technical criterion. The local communities were sensitized through sub-County Water Officers before verification exercises in order to ensure they are able to identify sites within their villages. To achieve this, the Sub-County Water officers also liaised with the Ward Development Committee members who mobilized local community members to identify the potential sand dam sites that were later visited by the technical experts for further scientific assessment. The entire process involved participation of the Members of County Assembly (MCAs), Sub-County Commissioners, Chiefs, Water Field

Officers who worked jointly with the Village Administration and Village Councils to identify the suitable sites for construction of sand dams.

A total of 2,573 sites were suggested by the local communities from all the eight Sub Counties at ward levels and these were subjected to the agreed technical criteria for verification of sand dams. Out of this, a total of 2,029 sites were found to be suitable for construction of sand dams following an assessment exercise carried out in all the eight (8) Sub Counties in Kitui County. This represents 79% of the total number of sites suggested by the local communities.

The implementation of the 2,029 sites will supply Kitui County with an approximated 2,426,400m^3 of clean and safe water for multiple uses.

It should however be noted that, the technical team only selected those sites that passed the technical test criteria as opposed to the many that had been suggested by the community. The reasons for the failure of their proposed sites were also clearly explained.

Table 1: Summary of the results of the assessment of sites for construction of sand dams in Kitui County

S/N	Name of Sub County	Name of Ward	No. Proposed Sites	No. Visited Sites	No. Viable Sites
1.	Kitui central	Township	59	59	46
		Mulango	60	60	51
		Miambani	51	51	43
		Kyangwithya East	46	46	45
		Kyangwithya West	47	47	45
	TOTAL	**-**	**263**	**263**	**230**
2.	Kitui east	Chuluni	71	71	51
		Endau/Malalani	78	78	38
		Voo/Kyamatu	41	41	35
		Nzambani	72	72	37
		Mutito/Kaliku	82	82	36

		Zombe/Mwitika	60	60	31
	TOTAL	**-**	**404**	**404**	**228**
3.	Kitui rural	Kisasi	70	70	62
		Mbitini	48	48	35
		Kanyangi	58	58	46
		Yatta/KwaVonza	51	51	30
	TOTAL	**-**	**227**	**227**	**173**
4.	Kitui south	Mutomo/Kibwea	60	60	41
		Athi	52	52	40
		Kanziko/Simisi	60	60	51
		Ikanga/Kyatune	70	70	52
		Mutha	60	60	47
		Ikutha/Kasaala	42	42	37
	TOTAL	**-**	**344**	**344**	**268**
5.	Kitui west	Kithumula/KwaMutonga	66	66	57
		Mutonguni	73	73	65
		Matinyani	89	89	84
		Kauwi	84	84	79
	TOTAL	**-**	**312**	**312**	**285**
6.	Mwingi central	Mwingi Central	65	65	56
		Mui	61	61	61
		Kivou	60	60	57
		Nguni	22	22	21
		Nuu	55	55	46
		Waita	57	57	52
	TOTAL	**-**	**320**	**320**	**293**

7.	Mwingi north	Mumoni	84	84	65
		Kyuso	60	60	59
		Ngomeni	59	59	25
		Tharaka	59	59	55
		Tseikuru	59	59	45
	TOTAL	**-**	**321**	**321**	**249**
8.	Mwingi west	Kyome/Thaana	105	105	91
		Nguutani	100	100	95
		Migwani	60	60	59
		Kiomo/Kyethani	117	117	58
	TOTAL	**-**	**382**	**382**	**303**
TOTAL			**2,573**	**2,573**	**2,029**

Financial Implication

Considering an approximate average cost of KShs. 800,000 for each sand dam site, then the cost estimate for the implementation of 2,400 sites is KShs. 1,920,000,000**.** However other suitable sites may in future be explored for construction of sand storage dams. This will depend on the available resources, both in monetary value and personnel. This report therefore details on all the possible approaches that may be adopted to accomplish the implementation of the programme.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASAL	Arid and Semi Arid Lands
NGOs	Non Governmental Organizations
SSDs	Sand Storage Dams
SASOL	Sahelian Solutions
DEM	Digital Elevation Models
GIS	Geographic Information System
GPS	Geographic Positioning System
UTM	Universal Traverse Mercator
EIA	Environmental Impact Assessment
NEMA	National Environment Management Authority
USD	United States Dollar
ADRA	Adventist Development and Relief Agency
GoK	Government of Kenya
CGoK	County Government of Kitui
SEKU	South Eastern Kenya University
SWRST	School of Water Resources Science and Technology
DFID	Department of International Development
FAO	Food and Agriculture Organization of the United Nations
CDF	Community Development Fund
UNDP	United Nations Development Programme
SIDA	Swedish International Development Cooperation Agency

DEFINITION OF TERMS

Village- The decentralized unit of the county government delimited in accordance with section 48 of the County Government Act 2012.

Sand Storage Dam- A masonry or concrete structure constructed across a seasonal stream to impound sand and consequently obstruct surface and base flow.

River- A natural flowing watercourse towards an ocean, sea, lake or another river.

Stream- A small narrow river.

Open well- A scooped sandhole dug into the river/stream bed using hand tools and left uncovered.

Shallow well- A hole drilled to less than 50 feet deep drawing water from a shallow aquifer.

Borehole- A hole drilled into the earth for the purpose of extracting water from deep aquifers.

Earth Dam- A dam built of compacted soil materials (sand, loam or clay) mostly with trapezoidal cross sections.

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1. INTRODUCTION

1.2 Background to the study

Kitui County is one of the semi-arid counties in Kenya (Figure 1). The county is characterized by highly erratic and seasonal rainfall which is considered to be one of the major factors limiting agricultural production and therefore food security. The chronic shortage of water in the county is also considered to be a major drawback for rural and urban development. The county is one of the water scarce regions with inadequate water supply to meet both domestic and agricultural requirements. The current existing water resource structures in the county (Table 2), the problem of water scarcity has not yet been eliminated. But although the perennial surface water resources in the county are limited, there are found numerous sandy seasonal rivers traversing most areas in the county. These systems have been sources of water for most of the people and livestock in the county for many generations. However, rapid population growth coupled with increased demand for water to meet both human and livestock needs have meant that the traditional sources of water in the county are no longer adequate. In order to address the chronic shortage of water to rural communities in the county, the government of Kitui County has initiated the subsurface/sand dam programme. The goal of the programme is to increase accessibility to good quality water through construction of subsurface/sand dams in the seasonal rivers traversing the county. It is expected that the construction of the sand dams will increase the storage of water in sandy river beds and this would make water to be available to the local communities, particularly in dry seasons of the year when chronic shortage of water is experienced. Figure 1 shows the distances people walk to access water resources across the county. Previous studies in Kitui County have established the potential of sand dams as sources of water supply to the local communities (Borst and De Haas, 2006: Beimers et al., 2001a-b; Burger et al., 2003; Munyao et al., 2004; Puttemans, 2004).

Table 2: Existing water resources in Kitui County

S/N	TYPE OF WATER RESOURCE	NUMBER
1.	Rock Catchments	103
2.	Sand Storage Dams	482
3.	Shallow wells	286
4.	Springs	34
5.	Earth dams	539
6.	Boreholes	376

In order to facilitate the implementation of the programme, the Kitui County Government worked jointly with the South Eastern Kenya University, School of Water Resources Science, and Technology in a process of assessing the suitability of sites recommended by the local communities. The project assembled a team of experts drawn from the School of Water Resources Science and Technology and the County Government's Ministry of Water, Agriculture and Irrigation who implemented the project based on mutually agreed terms of reference detailed in the previous document. The provision of technical information allowed the county government to make informed decision on the suitable locations for construction of sand dams and subsurface dams projects with the support of the local communities. In addition to providing technical/scientific information, the study also included surveys at ward level to gather lessons and best practices in the sustainability of similar projects that have been undertaken in Kitui County in the past with support from various non-governmental organizations. The socio-economic survey also assisted in establishing challenges faced by communities in sustaining sand dam projects on long term basis and the remedial measures that can be undertaken to address the most critical challenges.

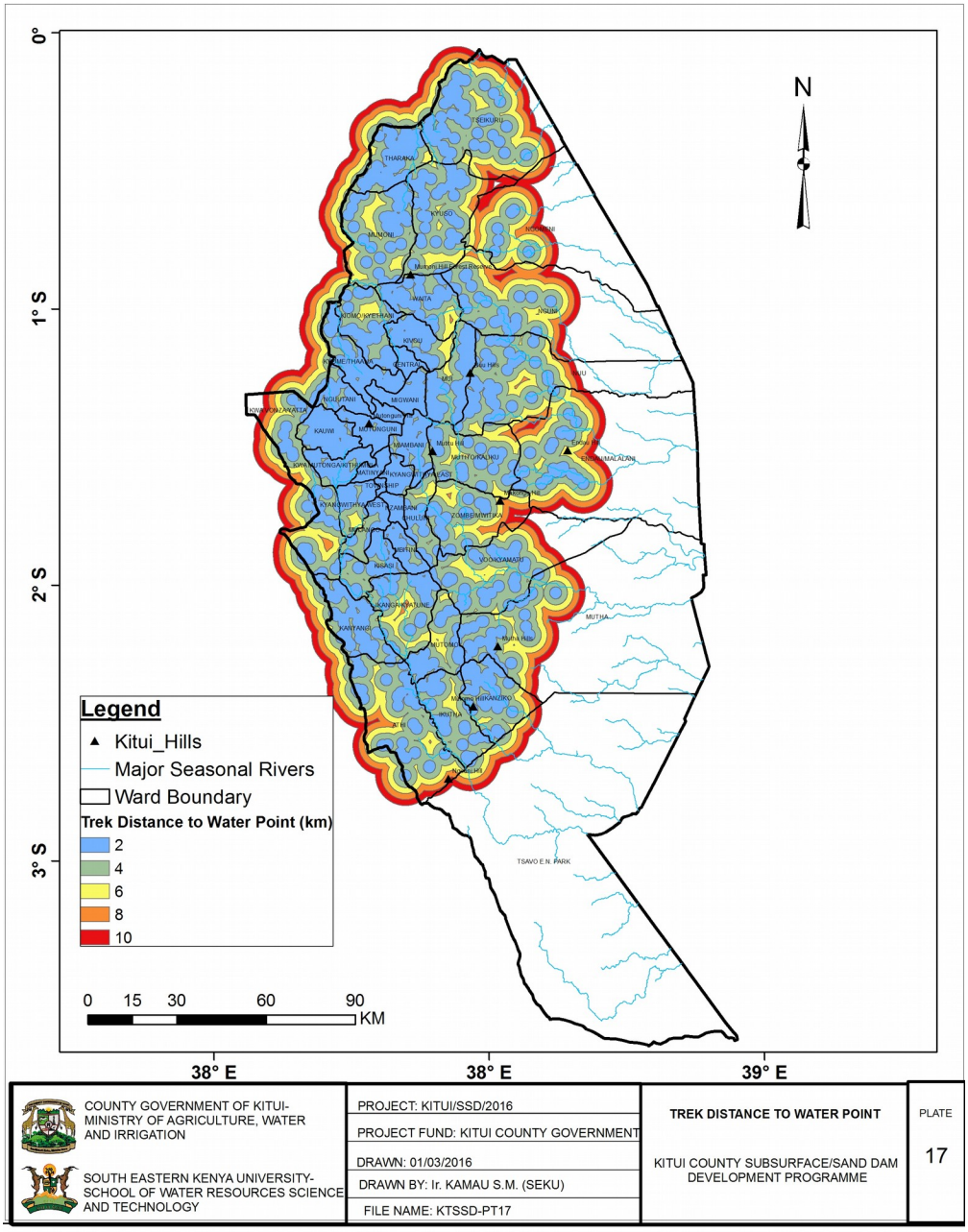

Figure 1: Average trek distances to access water resources across Kitui County

1.2 The nature of sand dams and subsurface dams

A sand storage dam is a masonry or concrete structure constructed across a seasonal stream to impound sand and consequently obstruct surface and base flow. The structure is usually located on a channel site with well defined banks and a stable basement. This enhances retention of sand

and water. Sand storage dams facilitate the obstruction of the groundwater in the riverbed and retention of water between the pores in the sand, making it available to the people and livestock during the dry season (Figure 2). Subsurface water storage has some certain advantages as compared to the open water storage. There is reduction in water loss from sand dams due to evaporation since most of the water beneath the sand dam is not subjected to direct solar radiation and hence very little is lost through capillary action. The water quality particularly salinity in sand dams is less variable due to reduced evaporation and or evapotranspiration. In addition, water in the sand dam is less affected by contamination as compared to the open water. As water infiltrates through the sand medium, it is filtered and the bacteria and other biological agents are reduced. Since the water is in the soil, it is also much less contaminated by solid waste. Sand dams also reduce the breeding of mosquitoes and thus in the long run reduce incidences of malaria in a locality. Sand storage dams are slightly different from subsurface dams. The latter are structures that are constructed across a sandy river bed below the surface to enhance retention and recharge from the base flow. These also differ from Earth dams which are compacted earthen embankments with a nearly trapezoidal shape that impound surface flow from seasonal streams. Sand dams and subsurface dams are normally referred to as '*ming'eeto'* in the local Kamba dialect.

Figure 2: Women drawing water from a sand dam. Note the high water level in the dam.

1.3 The Objectives and Goals of the Project

1.3.1 Main Goal

The broad goal of the programme is to provide Kitui County Government with technical information on the suitable sites for the development of subsurface/sand dams including also suitable sites for locating small-scale irrigation and aquaculture projects. This will ensure that Kitui County Government implements the sand dam programme in sites that are technically suitable and that will ensure sustainable realization of benefits to the local communities and the county as a whole.

1.3.2 Specific Objectives

The specific objectives of the assessment were as follows:

1. Using a technical/scientific criteria, conduct an assessment of the sites recommended by the local communities and recommend sites that can be targeted for construction of sand dams in all the sub-counties.

2. Produce GIS/electronic maps of Kitui County and sub-counties showing the location of the sites for sand dams including the stream network and the classification of different streams according to their morphometric characteristics and suitability for construction of subsurface/sand dams.

3. Prepare a detailed technical report containing among others Bills of Quantities and Budget for the implementation of the programme.

4. Prepare a detailed proposal on the construction of subsurface/sand dams and irrigation projects that can be used by the County Government to mobilize funds for the implementation of the sand dam programme.

5. Examine the lessons, best practices and past challenges in the long-term sustainability of subsurface/sand dams and provide recommendations for addressing those challenges.

Examine the climatological and land use factors that may affect the long-term sustainability of the programme including the potential impacts of climate change and suggest how the effects can be addressed.

1.3.3 The Terms of Reference

The specific Terms of Reference (TOR) of the assessment were as follows:

a) Produce a GIS/electronic map of Kitui County showing the stream network including classification of different streams according to their morphometric characteristics and suitability for construction of subsurface/sand dams and irrigation.

b) Identify the potential sites for the construction of earth dams to be recommended for further detailed investigations.

c) Prepare a detailed technical report containing among others Bills of Quantities and Budget for the implementation of the programme.

d) Provide recommendations for catchment protection and/or conservation to enhance the sustainability of subsurface/sand dams programme.

e) Prepare a detailed proposal on the construction of subsurface/sand dams and irrigation projects for submission to donors for funding.

f) Examine the lessons, best practices and past challenges in the long-term sustainability of subsurface/sand dams and provide recommendations for addressing those challenges.

g) Examine the climatological and land use factors that may affect the long-term sustainability of the programme including the potential impacts of climate change and suggest how the effects can be addressed.

1.3.4 The expected outputs of the assessment

The following are the expected outputs of the assessment exercise:

(i) A GIS map of Kitui County showing the drainage network and suitable sites for construction of subsurface/sand dams, irrigation and fishponds. The map should present a classification of streams according to their suitability based on the established suitability criteria.

(ii) A technical report providing details on the above mentioned including details on the methodology, findings, bills of quantities, conclusions and recommendations on the mechanisms for the implementation of the sand dam programme by the County Government.

(iii) A technical proposal for mobilization of financial resources for the implementation of the sand dam programme.

1.3.5 Why carry out technical assessment of proposed sites?

The sites for most of the sand dams that were previously constructed in Kitui County were not subjected to a detailed scientific assessment. This resulted in location of sand dams in unsuitable sites with the result that nearly 70% of the constructed dams failed within a short period of time (Figure 3). It is therefore important that proposed sites are subjected to detailed technical assessment applying scientifically agreed criteria. In this respect, the carrying out of this study on the identification of the potential sites for the construction of sand dams is considered invaluable because it will ensure that:

1. Sand dams are located in suitable locations with high chances of long–term sustainability and delivery of intended objectives.
2. Sand dams are located in areas with suitable sediment materials and can therefore retain sufficient quantities of water of suitable quality.
3. Sand dams are located in areas with suitable hydrological conditions and there will be replenishment of water stored within the sand media.
4. Sand dams are located in areas with suitable geological materials that ensure integrity of constructed structures.

5. Sand dams are located in areas that are not prone to contamination and therefore there is no possibility of endangering public health through consumption of polluted water.
6. There are no conflicts that would later arise due to biase associated with non-scientific selection process.
7. Unnecessary and unforeseen costs are identified early and are avoided during the implementation of the project.
8. Risks associated with the implementation of the project are identified and corrective actions are undertaken.

Failure to carry out detailed scientific evaluation or assessment of sites proposed by local community can lead to location of sand dams in unsuitable sites meaning that the long term sustainability of the constructed sand dams will not be realized. In addition to waste of funds, the County Government could also loose the much needed support of the local communities who will continue to be frustrated by shortage of water and county investments that do not yield intended benefits. This project is therefore important in that the County Government of Kitui will be assured that the funds will be channeled to investments that have high potential of benefiting the targeted local communities. According to the work done in the county by the Sahelian Solutions (SASOL) Non-Governmental Organisation, sites for sand dams that are subjected to detailed technical assessment results in successful sand dams.

Figure 3: A sand dam located in unsuitable site that was swept away by flashfloods in Ikutha ward, Kitui South Sub County.

2.0. BASELINE INFORMATION ON THE KITUI COUNTY

2.1. Location in Eastern Kenya

The Kitui County is found in Eastern Kenya. The county extends roughly 200 km from north to south and 120 km from east to west. The county has a surface area of 30,496 km^2. The county is bordered by Nyambene and Tharaka counties to the North, Taita-Taveta County to the South, Mbeere, Machakos and Makueni counties to the West and Tana River County to the East (Figure 4). The county's capital Kitui town is located about 160 km South East of Nairobi. The Southern part of the county covers the Tsavo East National Park. The topography of the county can be divided into an Upland and Lowland area. The Upland area includes the Yatta Plateau in the west and the Kitui Mountains in the East. Elevations in the Kitui Upland area vary between 600 and 1800 m above sea level. The Lowland area which covers the majority of the county is a gently eastward-sloping peneplain with elevation varying from 400 to 600 m above sea level. Few isolated inselbergs are found in this zone (Borst and de Haas, 2006). The central part of

Kitui County consists of an undulating plateau with an elevation of 1100 m. Within the central plateau are found deep ridges and mountains that rise to an elevation of 1800 m above sea level.

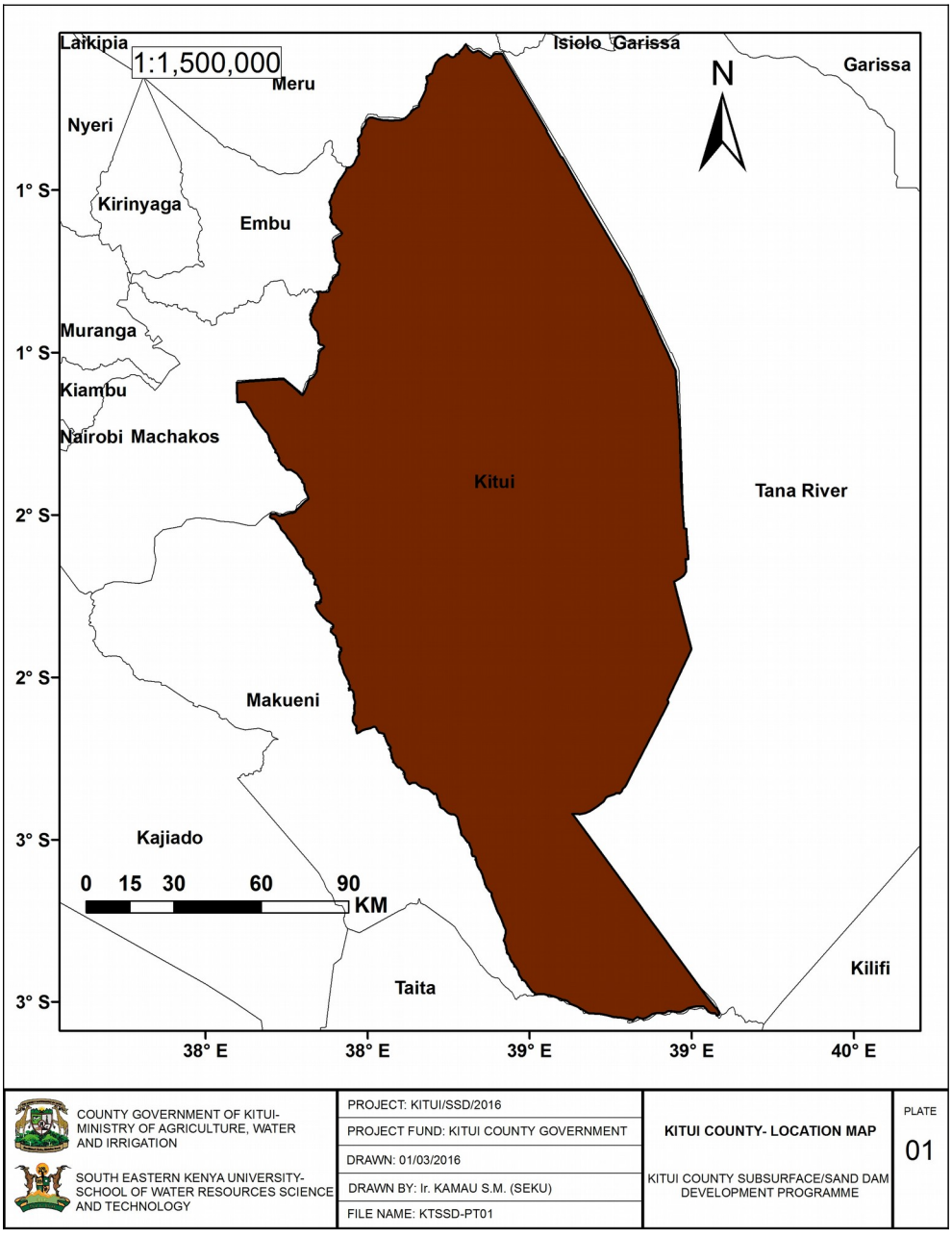

Figure 4: Location map of the Kitui County

2.2. Climatic conditions

The climate of Kitui County is generally hot and dry with erratic and unreliable rainfall typical of arid and semi-arid climatic zones. The county experiences two rainy seasons with two peaks in April-May (long rains) and November-December (short rains). The rest of the year is hot and dry. The total annual rainfall average is between 750 and 1150 mm with 40/60 percent reliability. Air temperature ranges between 16^{o}C and 34^{o}C with mean maxima of 28^{o}C and minima of 22^{o}C. The average temperature is 24^{o}C (Horst and de Hass, 2006). Relatively lower temperatures are experienced between June and August while high temperatures are experienced in January-March and September-October periods. The highest temperatures (of the order 34^{o}C) are experienced in February. The prevailing winds are the north and south easterly monsoon winds. The direction of monsoon winds is often influenced by Kitui Mountains found in the central region of the county.

Most of the Kitui region receives less than 730 mm of rain per year (Figure 5). The Kitui upland areas however receive relatively higher rainfall ranging between 760 and 1270 mm due to the orographic effects of the Kitui Mountains. Rainfall amounts decline to the South and Eastern regions of the county. Annual rainfall totals in the eastern lowland areas bordering Tana River County are usually less than 500 mm. The average annual potential evaporation is approximately 1800 mm per year, implying most areas of the county experiences water deficit in most periods of the year.

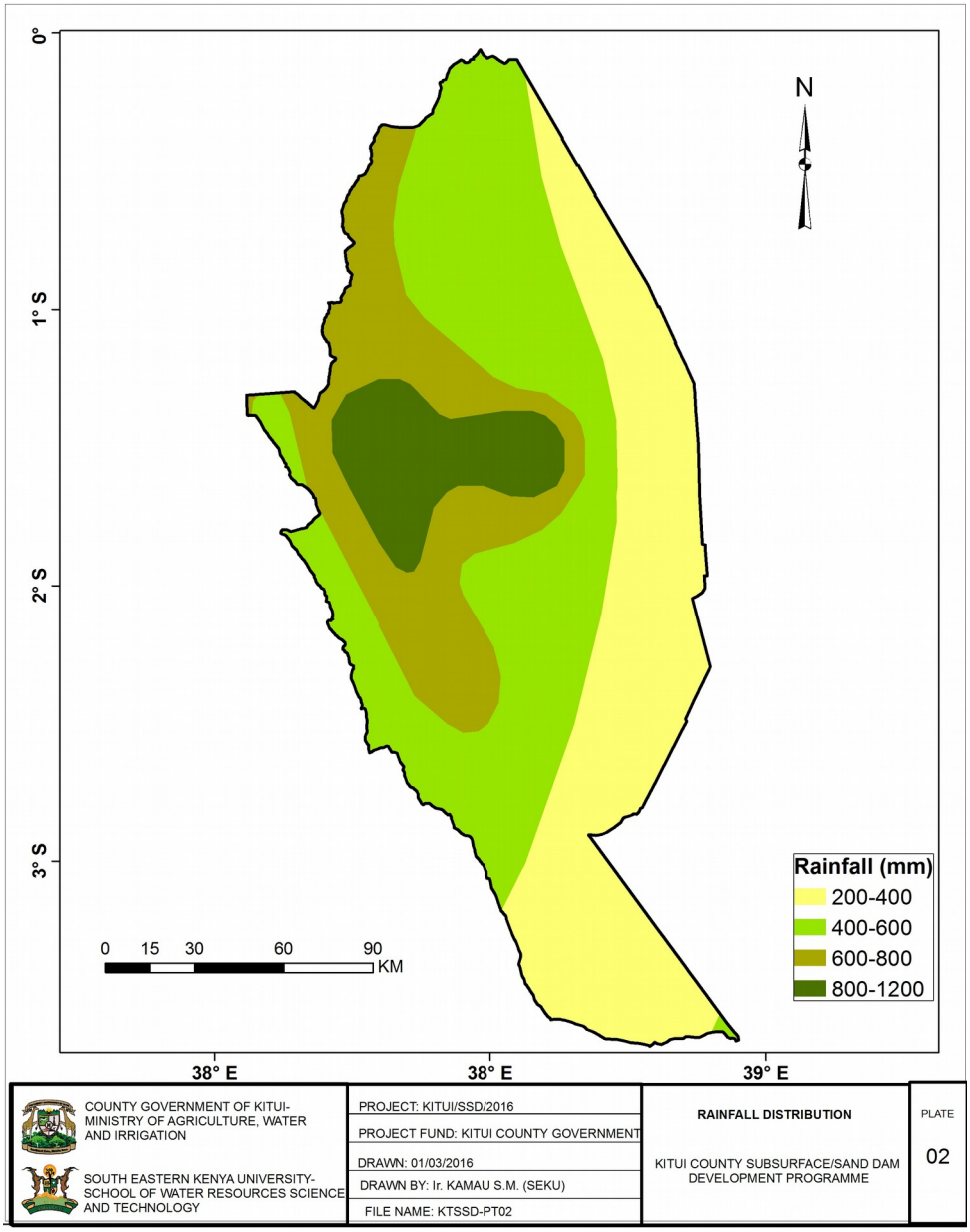

Figure 5: Distribution of rainfall in Kitui County

2.3. Vegetation and biodiversity hotspots

Vegetation in Kitui County is characterised by scrublands and wooded bushland (Figure 6). The hilltops are usually characterised by upland dry forest ecosystems dominated by *Drypetes*, *Combretum*, *Vepris* and *Croton* species (Lind & Morrison, 1974). Early in the 19th century before the forests in the Kitui Upland regions were gazetted, people settled on the hills and cultivated them. Examples of hills that were affected and still form main biodiversity hotspots in Kitui

County are: Mutitu (1958.7 ha), Engamba (3222.3 ha), Makongo (3431.8 ha), Endau (6717.8 ha) and Mutha in Kitui County (GoK, 2002), and Mumoni (11,031 ha), Gaikuyu/Nuu (2,532 ha), Chakuyu/ Imba and Maai forests in Mwingi Sub-County (Waas, 1995) and Musengo hills. The majority of these are protected as trust land and few as government gazetted forests. In the last few decades, degradation of biodiversity in these areas has continued owing to anthropogenic effects such as illegal harvests of timber, medicine, charcoal burning, and clearance for cultivation among others.

Over 748 different plant vascular plant species in 116 families and 420 genera have been recorded in Kitui County. Such high plant diversity is remarkable as it represents close to 15% of the dryland flora in Kenya, and way above the well-known Kakamega rainforest with about 420 plant species. The dominant plant families in the two regions are Leguminosae Mimosaceae, Papilionaceae, Caesalpiniaceae), Euphorbiaceae, Acanthaceae, Gramineae, Rubiaceae, Compositae, Malvaceae and Labiatae. These are represented by 87 (11.6%), 48 (6.4%), 38 (5.1%), 38 (5.1%), 38 (5.1%), 26 (3.5%), 21 (2.8%) and 20 (2.7%), different species, respectively. Common genera include *Acacia, Ficus, Euphorbia, Hibiscus, Crotolaria, Commiphora* and *Combretum species.* Endau is the most diverse botanically in the Kitui County with 508 (67.9%) species.

Kitui south National Reserve which was first established in 1979 forms one of Kenya's reserves with wonderful flora and fauna. It is well known for its multiple species of notable primates. Most of these primates relocate between the Tsavo National park and the South Kitui National Reserve making the place worth preservation to protect the primates from getting into extinction. The main fauna include mammals like lions, leopards, black rhino, zebra, waterbuck, dikdik, gazelle, gerenuk, gemsbok among others. Some of these species are also found in Mwingi North Game Reserve. A total of 45 species of reptiles and amphibians have also been recorded from the forests of Kitui County. These comprise of 21 species of lizards, 12 species of snakes, 1 species of tortoise and 11 anurans. These fall under six families of lizards, seven families of amphibians, five families of snakes and only one family of tortoise.

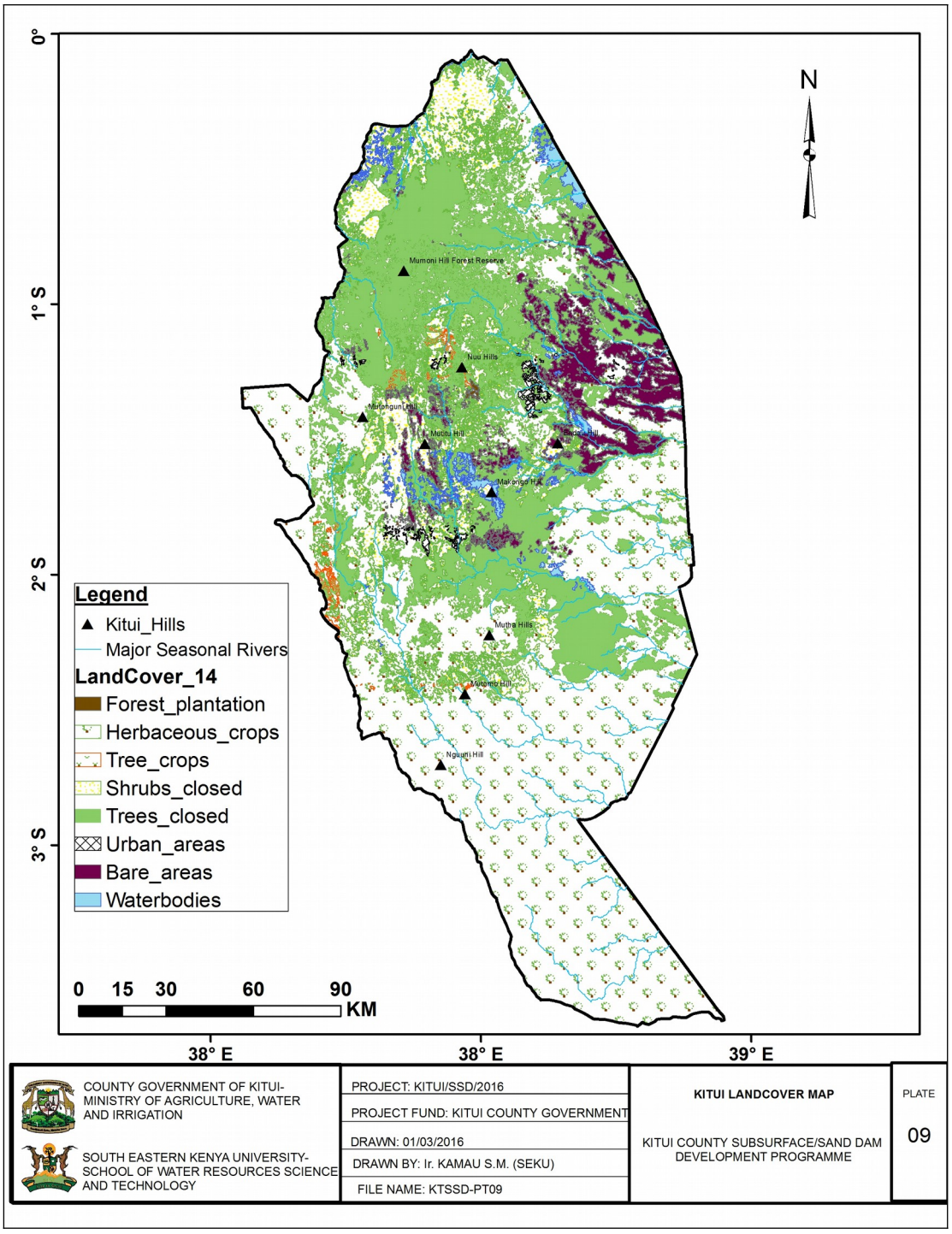

Figure 6: Landcover map of the Kitui County

2.4. Agro-ecological zones of Kitui County

The central part of Kitui County consists of an undulating plateau about 1100 m in altitude, surounded by ridges and hills, which rise to 1700 m (Figure 7).

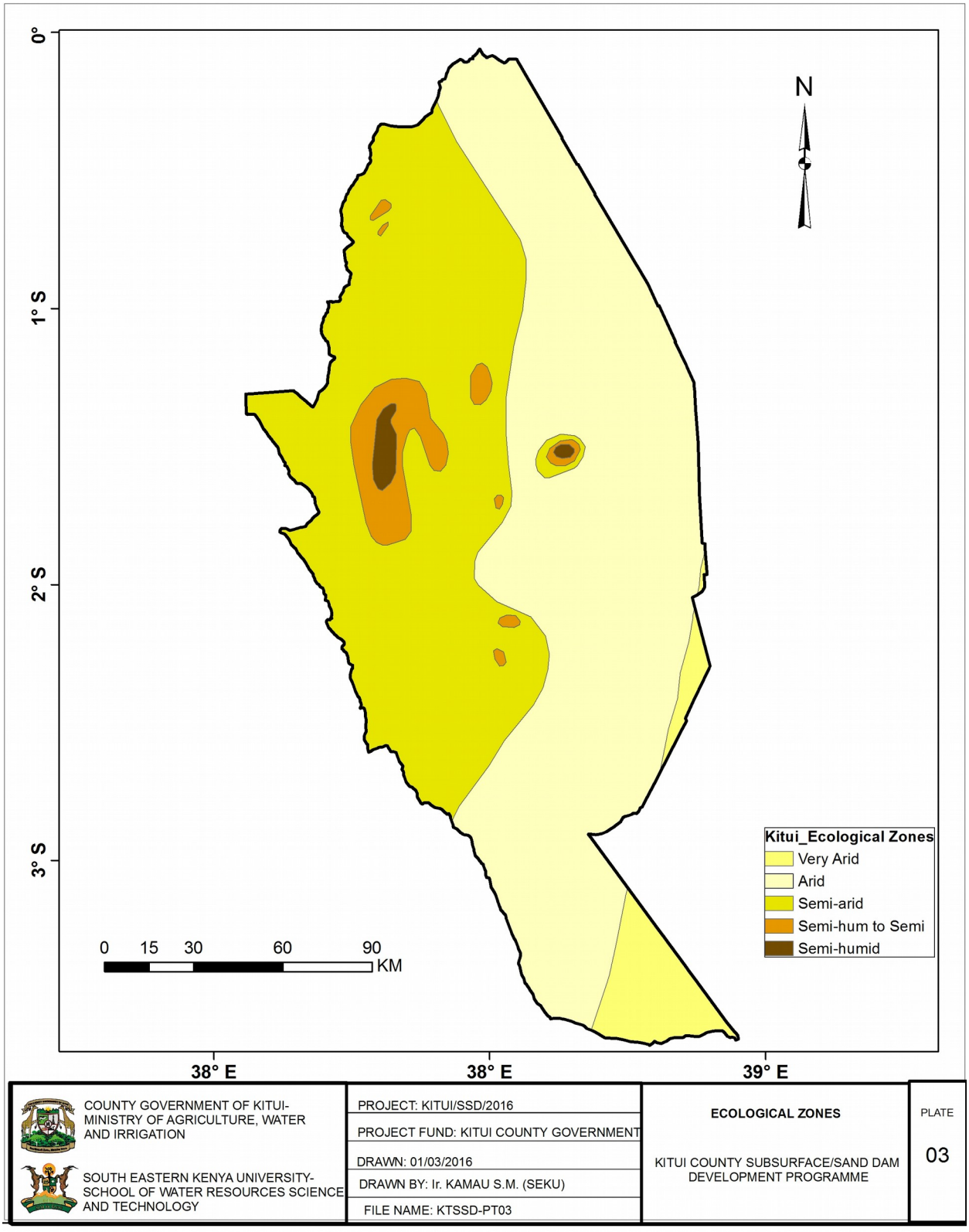

Figure 7: Kitui County map showing the main ecological zones

Kitui County is divided into nine Agro Ecological Zones but seven are more pronounced

1) UM3- Marginal Coffee Zone. This is found in very small pockets within the Nzeluni hills in Mwingi West. The crops suitable for this agro ecological zones includes Maize, Coffee, beans

2) UM3-4 - transitional to Zone 4 with a short to medium and short cropping Season around the Kitui township ward, Mutitu Forest, Kavonge Forest Reserves a and Matinyani ward. The crops grown are Maize, Sunflower Vegetables, Sorghum, Millet, and Avocado, Sisal, beans, sweet potato, Cabbage, Paw-Paws, Citrus, Passion fruit, bananas, Mangoes, pasture and forage

3) UM4 - the sunflower- maize zone. The prominent crops are maize, Sorghum, Millet, Vegetables, Avocado, Sisal, beans, sweet potato, Cabbage, Paw Paws, Citrus, Passion fruit, bananas, Mangoes, pasture and forage. These areas are around Migwani Health Centre, Kyome Secondary School, Kitui Dam and Kiluilu in Kyanika among others

4) LM3 the cotton zone which is Very small and in steep slopes of Makongo and Muumoni hills. LM3 has a Potential nearly that of LM 4 but Katumani Composite B maize, sweet potatoes, beans and cotton can do well on the few patches of good soils.

5) LM4 is marginal cotton zone with a short cropping season. Crops grown are millets, Dry land Maize, sorghum, Beans, Ground nuts on sandy soils, cowpeas, sunflower vegetables, Dolicos lab lab, pigeon peas, pumpkins, sweet potatoes. These are areas around Mwingi Town, Tharaka Chief's camp, parts of Kyuso ward, Tulia market, Mulango Girls Sec. School, Mbitini ward, Parts of Kisasi ward, Mui Chief's camp, Mutitu Chief's camp

6) LM5 is a livestock-millet zone. LM5 covers the entire county but more pronounced in Mutomo, Mwingi Central, parts of Kyuso ward, Kavisuni area. Nguuni area, Maliku and Tiva. In LM5 runoff-water harvesting methods are important especially for agriculture. The zone has a very short cropping season. More fodder reserves are necessary as palatable shrubs, silage of fodder sorghum.

7) IL5 has a very short cropping season. It is suitable for both livestock and millet production. These are areas around Thaana Nzau, Tseikuru ward, Ngomeni ward, Zombe, Mwitika, Kanziko, Voo, Mutha Chief's camp, Endau Dispensary, Inyuu Dispensary, Ikutha Agric. Office

8) LM6 and IL6 are the ranching zones (no rain-fed agriculture is suitable except with runoff-catching techniques).This covers Mwingi North Natural Reserve, Mulangoni, Malalani,

Kalambani, Inyali, Kitui South Game Reserve, Kalalani Shopping Centre and all other areas bordering Tana River

The semi-arid zones in Kitui County are potential for agricultural development and are currently either cultivated or lying fallow. Due to population pressure the less fertile semi-arid ranching areas are currently used for food crops production and livestock keeping which leads to frequent crop failures as these areas are not suitable for growing of certain crops under rain-fed agriculture.

2.5. Environmental degradation

The expansion of human settlement and rapid population increase has led to high rate of land sub division in some parts of the County, especially in the densely populated Kitui Central region. Cultivation of land is done with little application of soil conservation measures and this has lead to increased soil erosion in most area of the county. In some areas, fire is used to open land for cultivation and this has destroyed both fauna and flora (Figure 8).

The major cause of environmental degradation in the County is inelastic nature of Land. The rapid population increase over the years is against a constant supply of land. This trend has caused people to inhabit environmentally inhabitable places such as hilly tops, water catchments areas, and wet lands accelerating degradation of such environment. Most forests in the county have been encroached. Such encroachment will eventually lead to clearing of forests leading to the destruction of the water catchments areas.

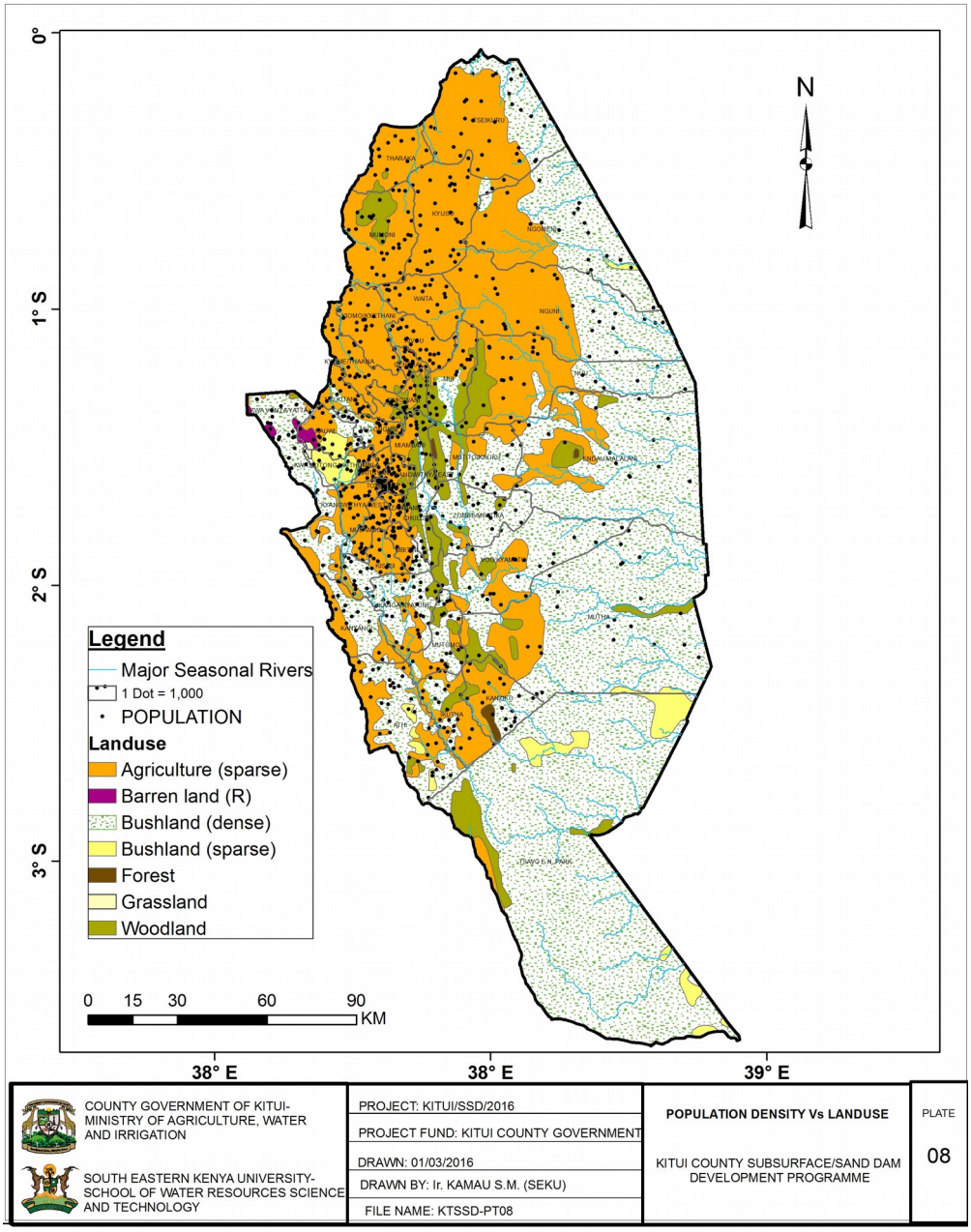

Figure 8: Land Use map of the Kitui County

2.6 Geology

Kitui County is located within the Mozambique belt and is generally occupied by the basement complex system consisting mainly of metamorphic rocks (Nyamai et al., 2003). The rocks are dominated by massive metamorphic granulites which are highly impermeable. These are usually composed quartz and feldspars, red garnets and pyroxenes or less). Some rock outcrops are

composed of high grade metamorphic granulites composed of quartz and feldspars, mafic pyroxenes, biotite and red almandine garnets

The sandy river beds usually consist of well sorted and mature sand without or with minimal silt/clay content; hence these sands are ideal in tapping and retaining water in their sub-surface pores. Most of the river courses are composed of metamorphic granulites and gneisses. There are also found silt/clay floodplains with variable width. Mafic granulites rich in garnets and black minerals, iron ore and pyroxenes have weathered into deep fresh red soils rich in black heavy sands. The soils do not contain much quartz sands. These mafic granulites give in to felsic granulites consisting of 80% quartz and feldspars, mafic biotite and pyroxenes, ~ 5-10% and garnets ~10%. These are characterized by reddish sandy loam soils. These rocks which are medium grey in color are vertically dipping but foliation planes are tight and do not allow much water to disappear into the ground. In some places are found well foliated biotite gneissies which allow some water into the ground. Kunkar limestone and white patches of sodium chloride are common along the river beds making the water slightly brackish, particularly during periods of low flow.

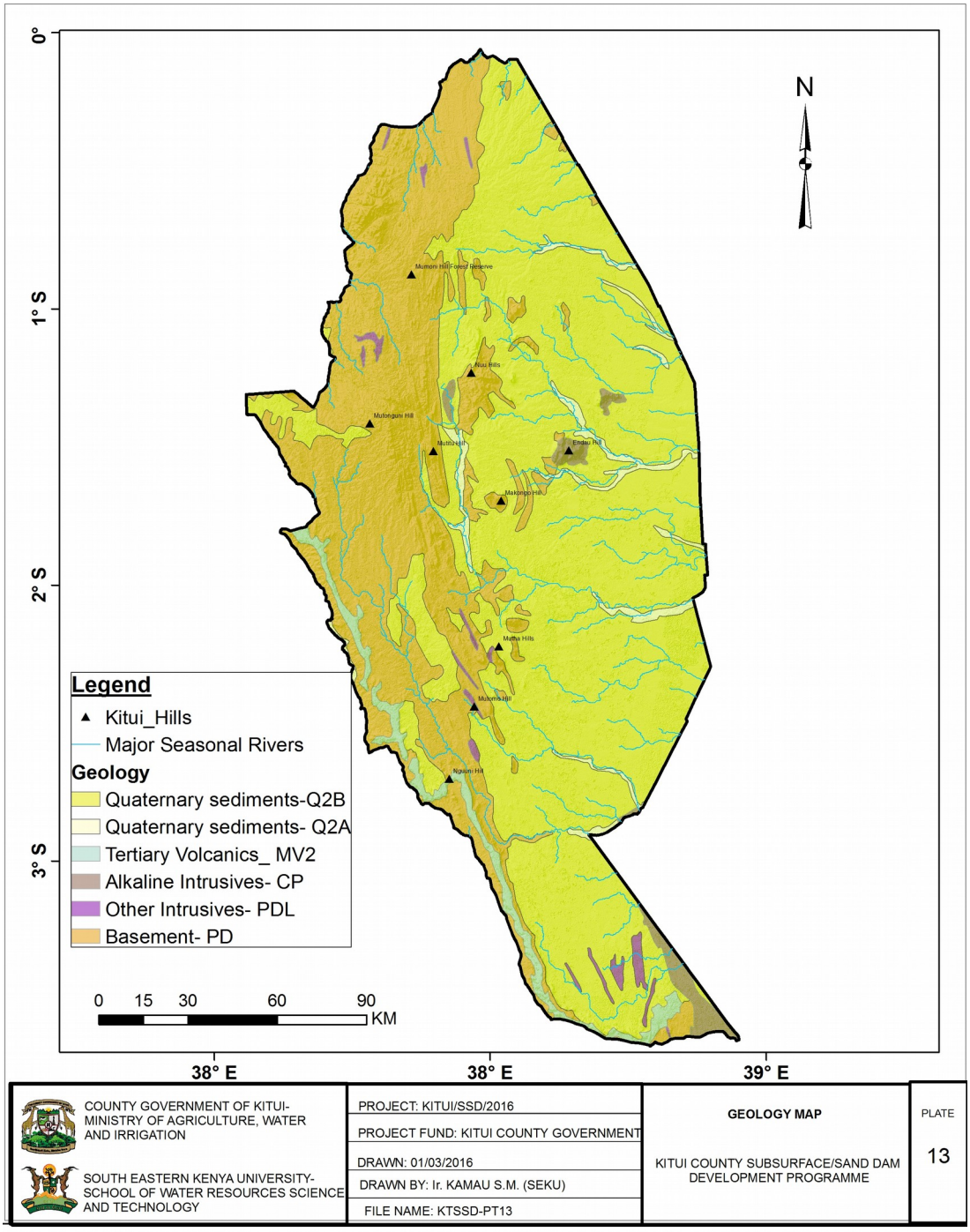

Figure 9: Geology map of the Kitui County

2.6 Hydrology and Water Resources

Due to limited rainfall, surface water sources are very scarce in the County. The major sources of water are seasonal rivers such as Tyaa, Thunguthu, Eenziu, Mwania, Thua, Tiva, Kalundu,

Nzeeu, Mikuyuni and Mwita Syano, among others that flow only during rainy seasons. The only perennial rivers are River Tana & Athi that flow partly within the county. Virtually all of the seasonal rivers in the project area drain into the Tana River and Athi river drainage basins. The river flows in the project area are characterised by very low flows (base flows) in dry season and high flows during rainy seasons, i.e. April-May and November-December. Most of the ephemeral streams generally become dry within one month after the rainy season (cf. Borst and De Haas, 2006). The flows are usually fast and turbid due to high sediment concentration associated with high rates of soil erosion in the catchment areas. There are also several sand dams along the courses of most seasonal rivers that play a significant role in providing water to the local community particularly during dry seasons. However, most of the dams are small and dry up during the extended dry seasons due to the high water abstraction and evaporation rates.

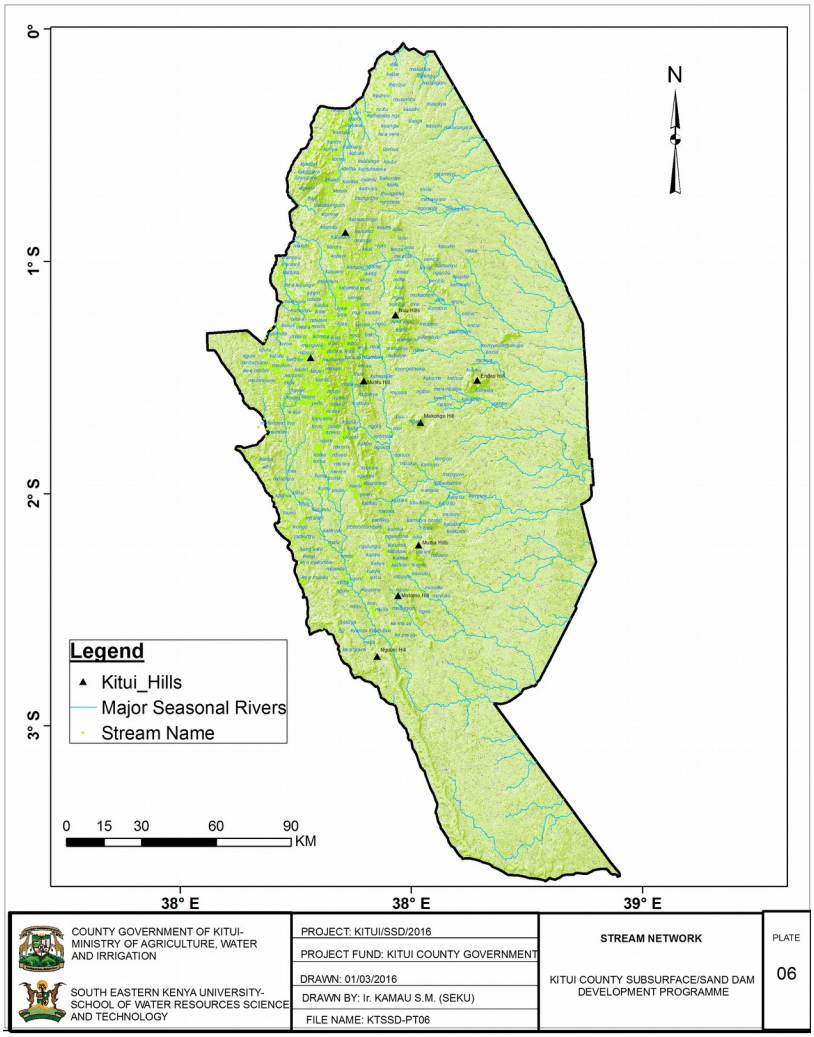

Figure 10: Kitui County Seasonal stream Network

2.7 Population

The population in the Kitui County according to the 2009 census was 1, 060, 00 (Male - 48%, Female - 52%). High population density is observed in Kitui Central and Mwingi Central wards (Figure 11). The population density is relatively low being 33 people per square km. The age distribution is characterized by a large proportion of people below the age of 14years who make 47% of the total population while those aged between 15- 64years make up 48% of the total population. The proportion of elderly people (above 65yrs) is small being 5.2% of the total population. The population is largely rural-based with only 10% of the people residing in the urban areas. The settlement patterns are greatly influenced by water availability and agricultural potential. The county has high proportion of females to males (112:100) and a dependency ratio of 100:1135. The labour force is robust as youth comprises 21% of the population. The life expectancy is 51 years as compared to 55 countrywide. More than 50% of the population lives below absolute poverty level.

Human activities such as clearing of land for agriculture, settlements, charcoal making and cutting of indigenous trees for carving has in the recent past promoted land degradation. Clearance of trees for charcoal production has reached commercial levels and is considered to be a major threat on the environmental sustainability in the county. This has been responsible forloss of biodiversity and severe degradation of the fragile arid and semi arid lands' ecosystem. Kitui County has eight (8) sub counties and forty (40) wards as shown in Table 3 below.

Table 3: Population sizes in Kitui County at sub-County and ward levels (source: Kenya Bureau of Statistics, 2009)

Sub-County	Population	Wards and their populations
i. Mwingi North	139,967	Ngomeni (18, 447) Kyuso (40,375) Mumoni (32,171) Tseikuru (35,890) Tharaka (13,084)
ii. Mwingi Central	122,361	Kivou (24, 886) Nguni (29,313) Nuu (27,644) Mui (19,628)

			Waita (20,890) Mwingi Central (23,743)
iii.	**Mwingi West**	122,620	Kyome/Thaana (22,443) Nguutani (27,265) Migwani (28,169) Kiomo/Kyethani (21,000)
iv.	**Kitui West**	102,314	Mutonguni (34,140) Kauwi (25,385) Matinyani (24,081) Kwamutonga (18,708)
v.	**Kitui Central**	131,715	Miambani (22,164) Township (26,016) Kyangwithya West (22,121) Mulango (28,573) Kyangwithya East (32,841)
vi.	**Kitui Rural**	104,443	Kisasi (26,759) Mbitini (24,858) Kwavonza/Yatta (30,732) Kanyangi (22,094)
vii.	**Kitui East.**	123,239	Zombe/Mwitika (25,452) Nzambani (18,126) Chuluni (22,046) Voo/Kyamatu (23,011) Endau/Malalani (15,506) Mutitu/Kaliku (15,506)
viii.	**Kitui South.**	166,050	Ikanga/Kyatune (36,185) Mutomo (24,450) Mutha (25,138) Ikutha (26,176) Kanziko (18,664) Athi (35,437)

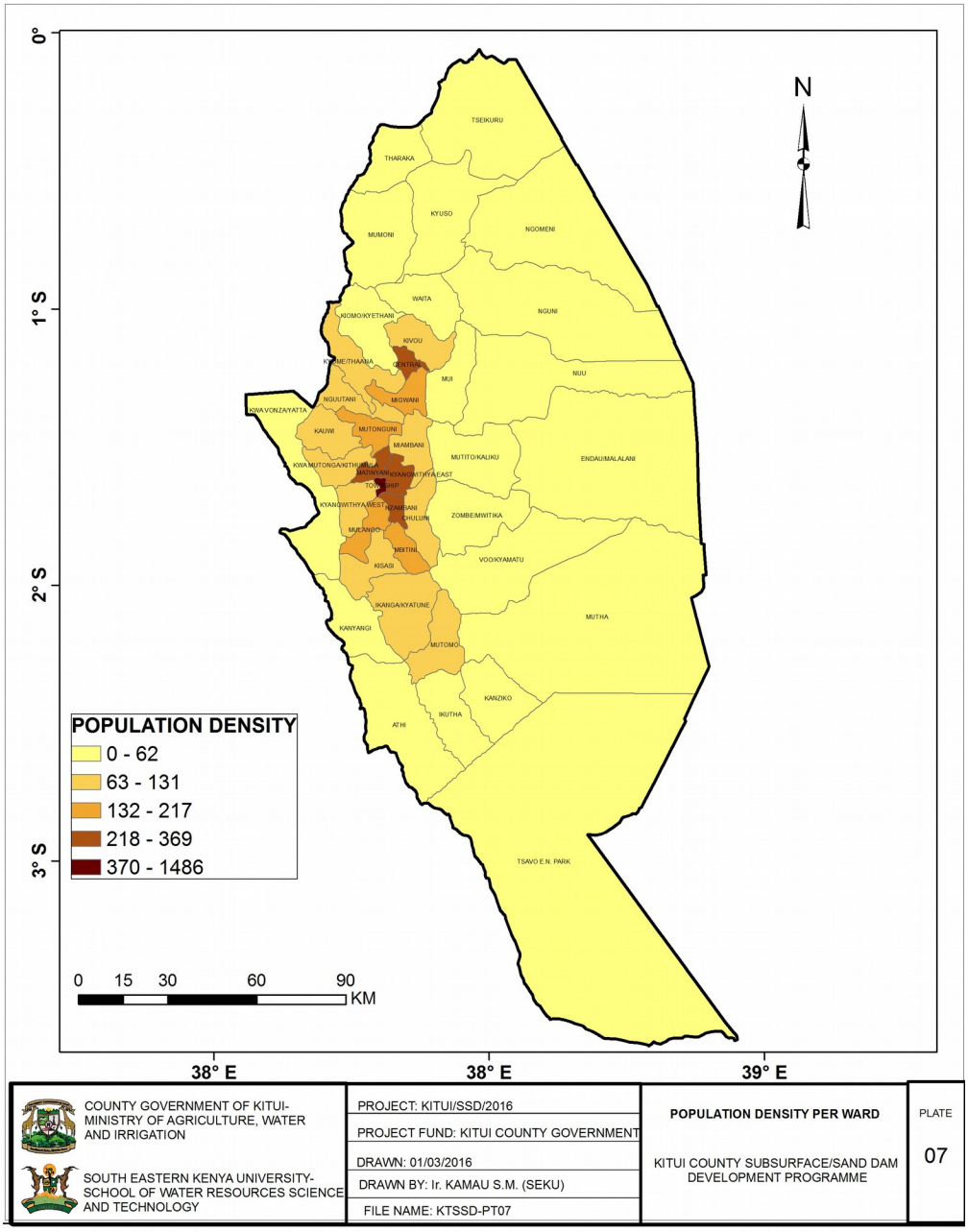

Figure 11: Population Density map of the Kitui County

2.8. Economy and Socio-economic activities

Kitui County is divided into six major economic zones (Figure 12). The vast majority of the local economy is based on subsistence agriculture with the practice of mixed farming being common in the county. Rainfed agriculture is an extremely challenging activity given the sporadic and low rainfall in the county which is often poorly distributed on spatial-temporary basis. Formal employment opportunities are normally experienced in rural trading centres. Also

in rural trading centres, businesses such as butcheries; food Staples; mini-markets; garages; hotels and restaurants, are common although most of them are small-scale enterprises with low earning levels. The income of 58 percent of the population in Kitui County is below the poverty line of 2 USD a day (PRSP, 2001). During prolonged dry periods, majority of the farmers are usually dependent on relief food from the government and donors. In some dry years when seasonal rain fails, up to 20 percent of the inhabitants of Kitui County rely on food aid for survival. Besides farming, the other main economic activities are retailing, bodaboda operations, charcoal making, sand harvesting, brick making and hawking.

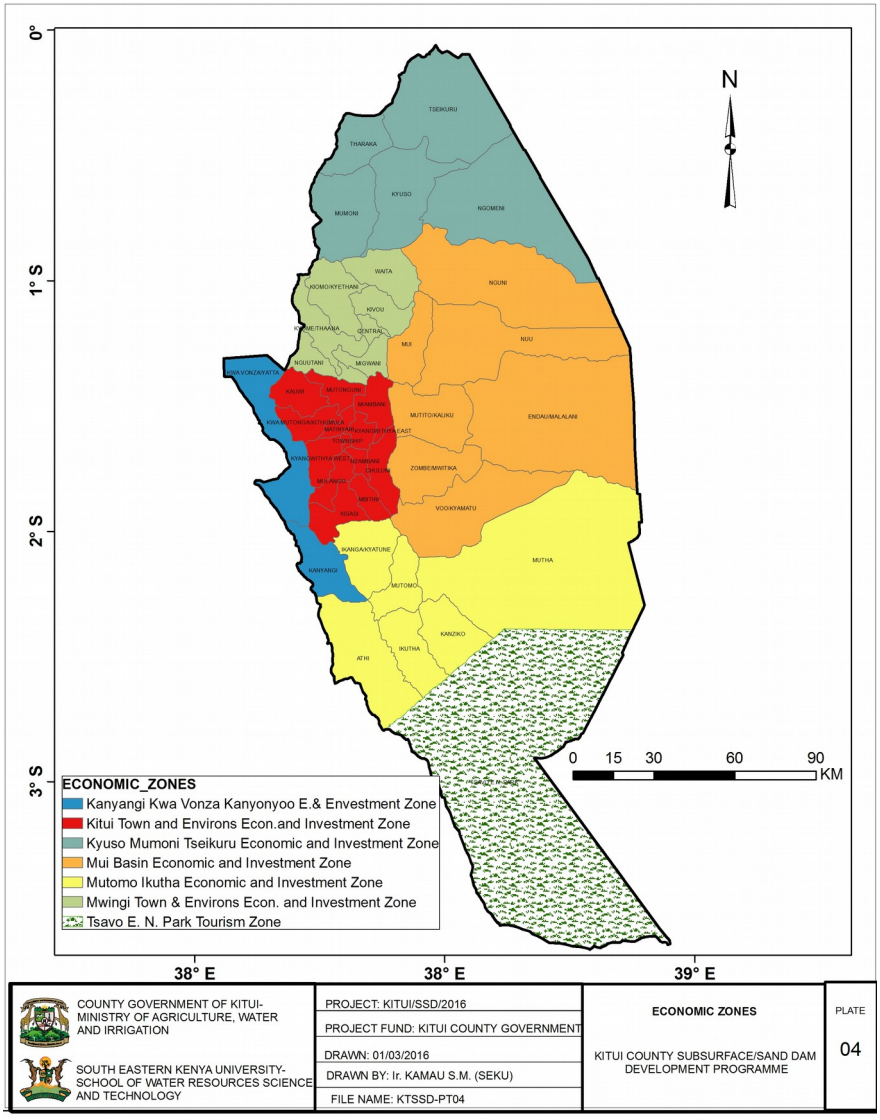

Figure 12: Economic Zones of the Kitui County

3.0. THE APPROACH APPLIED IN THE ASSESSMENT OF PROPOSED SITES

The process of identification and or assessment of sites proposed for the construction of sand dams involved application of approaches described in the following sections.

3.1 Sensitization of the local communities

The sensitization was carried out at ward level in order to obtain proposals from the local communities. The sensitization exercise was carried out through media announcement and distribution of pamphlets containing information on the intention by the County Government to construct sand/sub-surface dams in all the sub-counties and wards. The announcements and pamphlets also provided details on the ideal sites for the sand dams and it was expected that the communities would select their sites based on this guidance. The initial process of selecting the proposed sites was coordinated by the Sub-County Water Officers who liaised with the Ward Officers and Ward Development Committee members who subsequently mobilized their members to identify the potential sites that were later subjected to detailed verification and or suitability assessment according to the established criteria.

3.2 Involvement of sub-County Officers

The County Director of Water Services liaised with the Members of County Assembly (MCAs), Sub-County Commissioners, Chiefs and Water Field Officers who jointly with the Village Administration and Village Councils worked with the local communities to identify the sites for construction of sand storage dams that formed the basis for further detailed evaluation by the technical team. The community identified sites that met the established criteria were assessed and identified as having been agreed upon. Where the sites were found to be unsuitable, the technical team suggested other sites with the assistant of local community leaders and ward officers.

3.3 Field Identification of the sites

Lists of proposed sites with exact stream location and names were submitted to the Sub County Water Officers who forwarded them to the County Director of Water Resources and Services. A total of 2,490 proposed sites in all the eight Sub Counties and wards in Kitui County were subjected to detailed technical evaluation by technical teams drawn from the County Ministry of

Agriculture, Water and Irrigation and South Eastern Kenya University. The field based exercises were carried out between July 2015 and December 2015.

3.4 Application of the Technical Criteria

3.4.1 Establishment of stream morphology

The determination of stream morphology involved measurement of the width of the river channel and depth of banks. The depths and widths were measured using a tape measure and this was based on the highest water level. The bank depths were used to estimate the height of the reservoir that would be constructed at the site. The data on the fetch distance and banks depth of the river channel was used in the determination stream channel gradient as: Gradient- Computed as the ratio between the river bank depth and fetch distance i.e. = [bank depth (m)/fetch distance (m)] e.g. 2m/100m= 0.020 or 2%.

3.4.2 Determination of the nature of river banks

The nature of river banks is an important determinant in the siting of a sand dam. The river banks that consist of loose soil materials may not be suitable due to increased possibility of erosion of the banks and subsequent collapse of the sides of sand dams rendering the whole structure unstable. The ideal sites should consist of consolidated rocks. The nature of the river banks was established through observations. Notes were also made as to whether the river banks consists of loose soil or consolidated rocks, and whether there is evidence of river bank erosion.

3.4.3 Determination of the nature of river channel sediments

The sediment characteristics play an important role in enhancing water storage in a sand dam. The most suitable sediment types includes coarse sand and to an extent silt. Normally stream channels with coarse sand deposits are the most suitable. River channels with clay sediment deposits are not suitable because of low permeability and low water holding capacity. The nature of sediment deposits in stream channels were based on the particle size analysis of sediments.

3.4.4 Determination of potential water storage capacity

The water storage capacity within a given cross-section is an important consideration since it determines the ability of a sand dam to satisfy the desired local water needs. Thus, the sites must

provide an opportunity for storage of adequate amount of water to meet various water use needs within a given locality. The water storage capacity was based on the determination of the potential sand volume within the stretch of the river channel that is considered suitable. This was based on the maximum dimensions of the sand dam that can be constructed at the site. The volume of water held in a sand dam is a function of the volume of the sand and the portion occupied by pore spaces. A substantial volume of the sand dam (approximately 25-30%) is normally occupied by sand and the rest of the volume is occupied by water (Borst & Haas, 2006) Hence, storage capacity (m^3) = [banks depth (m) ×fetch distance (m) ×stream width (m) ×0.3] e.g. 2m×100m×18m×0.3=1,080m^3.

3.4.5 Establishment of infrastructure near the sand dams:

The use of water from the sand dam is influenced to a certain extent by the nature of infrastructure at or near the sand dam. The ideal sites for constructing a sand dam should be one that can easily be accessed by the local communities. Sites that are located far from villages may not be useful sources of water to the local communities and this will defeat the whole purpose of constructing sand dams. In this respect, an assessment was made on the roads and footpaths leading to the identified sites and nearness to population centres or villages. Also, sites located in heavily populated areas such as markets or within towns may not be suitable because of high possibility of contamination of water in the sand dam.

3.4.6 Determination of the sand accumulation rates:

Areas with a potential of high sand accumulation rates are most suitable for construction of high-yielding sand dams. Based on this, the rates were analysed in the scale of very high, high, moderate, low or very low. Areas with very low sand accumulation rates and/or high clay and silt deposits were rated as being unsuitable for construction of sand storage dams due to the high potential of siltation.

3.4.7 Determination of the location of proposed sites

The Geographical Positioning System (GPS) specifically ETrex model was used in recording the location coordiantes of the proposed sites for construction of sand dams. The GPS were used to record particularly the co-ordinate values for Latitude (E), Longitude (N) and Elevation (Z)

based on Universal Traverse Mercator (UTM) projection. A database showing the recorded data from every visited site is provided in both hard copy and soft copies in Microsoft Excel and Microsoft Access. The record were also used to create maps showing the distribution of the sand dam sites across the whole county and utilized in the final designs for the sand dams.

Datasets for Geographic Information System site suitability analysis

The criteria for evaluating suitability of the proposed sites for sand dams involved integration and evaluation of appropriate datasets such as the location, landuse/landcover, soil types, stream gradient, geology, stream order, height above sea level (elevation), slope and rainfall distribution. The Digital Elevation Model (DEM) (30m resolution) was utilized to derive the slope map of the Kitui County. Integration and site suitability analysis based on these datasets was done using the Geographical Information System (GIS) (ArcInfo). Erdas Imagine software was used to derive land cover and land use maps of the Kitui County based on the Landsat Satellite data which was acquired in January 2016.

The methodology used, to identify appropriate sites in the entire Kitui County for the proposed sand dams within the stream deposits, consists of the following steps using ArcGIS 10.3:

Mapping of the proposed sand dam sites and projecting the points on Kitui map. This involved all the records of the collected data based on the specified attributes defined in the data collection forms.

Digital Elevation Model (DEM) (30 meters resolution) was used to show the general terrain of the Kitui County area. High mountains and steep hills were considered less suitable since such areas experience minimal deposition of the stream deposits and more erosion

Stream network was derived from the Digital Elevation Model (DEM) of the area covering Kitui County followed by digitization of the major river channels. First order (at the river source) was not considered for evaluation. The derived stream network of the Kitui County shows the rivers and streams from the second to seven order level.

Slope (topographical gradient map) was derived from the Digital Elevation Model (DEM). Sites at the level ground surface to very gentle slope are recommended for the best results of sand dam. This allows more and enough time for water infiltration into the sand deposits hence rapid storage and increase of subsurface dam capacity. This means areas with zero (0) degrees to a

maximum of 10 degrees are the best for siting a sand dam. Sites located at point of higher slopes would be considered if showing favorable conditions other than the slope level.

Geological map to show the distribution of the different lithological units in the Kitui County. Sites located on firm rock, less fractured and less weathered are best for anchoring the structure across the river bed. Metamorphic and some igneous rock are best for this consideration. Metamorphic rock such the gneiss with high quartz content is eroded at the upstream to hence more sedimentation on the sand dams.

Soil map was provided to show the general distribution of the soils for engineering evaluation. Sites with minimal rock exposure were evaluated based on the engineering suitability of soils near the site

Land cover/ Landuse maps derived from Landsat Satellite data. Utilized in the evaluation of sites based on the vegetation cover and the land use practices near the proposed sand dam sites. Also used in establishing and recommending the possible measures and practices to maintain the sand dams.

Rainfall and Temperature data used in estimating the river discharge and assessing the sites with possible shallow groundwater level based on the rainfall experience. Areas experiencing heavy rainfall events especially from the high elevation areas are considered due to high overland flow that recharges the sand dam reservoir.

3.5 Legal and Socio – Economic Criteria

3.5.1 Determination of population distribution and size

The population size and distribution is an important determinant of the location of a sand dam since the overall aim is to provide water to the local communities. Thus, it would be desirable to locate sand dams in areas where local communities can benefit from increased water availability throughout the year. The ideal site should therefore be located near villages. Locations near market centres and within towns are not ideal because of high possibility of contamination of water. Also, thinly populated areas or areas where there are no people, are not suitable because the site will not serve the purpose of supplying water to the people. Thus, field surveys on population size and distribution were undertaken. The field officers analysed the population size of people to be served by a particular sand dam in terms of the number of Households. The

number of livestock to be served was also taken into consideration. With this data it was possible to calculate the water demand projections and the duration of water storage for each sand dam. This was done in terms of the number of months.

3.5.2 Establishment of land use types

Land use within the vicinity of the sites that are considered suitable for the construction of sand dams was assessed through field observations and surveys. Some land uses may be considered to be incompatible with the sand dams. As mentioned in the previous sections, sites that are near markets or those located within urban areas are not suitable due to high possibility of contamination of water in the sand. Also, heavily cultivated areas with high soil erosion rates may not be suitable due to potential for supply unsuitable sediment materials into the dam (materials that may eventual affect the water storage volume within the dam). Based on that, the land use characteristics at the area close to the proposed site were described as cultivation, grazing, settlements etc.

3.5.3 Consolidation of lessons from existing sand dam initiatives

The field based survey identified any existing sand dam within the target areas. The aim was to establish the extent to which the sand dam had contributed in alleviating shortage of water at a specific site. This survey also helped in determining whether there is a real need for a new sand dam intervention in the area. Also, lessons learnt in other existing sand dam initiatives within a target site were compiled in order to devise approaches that can enhance the long-term sustainability of sand dams. Opinions were also sought from other stakeholders in the development of sand dams within Kitui County. This was done through the use of questionnaires shared with several organizations including Sasol Foundation-Kitui, ADRA- Kenya, & Caritas-Kitui and feedbacks received. This was meant to share experiences and challenges in the similar initiatives undertaken.

3.5.4 General Conclusions on the overall suitability of the sites

The technical teams who visited the proposed sites rated each site visited based on the established criteria described in the previous section. All the information collected from the filed

and the supplementary GIS data were gathered to have a more integrated site suitability analysis using ArcGIS tool (Figure 13). The sites were rated as either excellent, very good, good, fair or purely not suitable for construction of sand dams based on the general physical condition. This rating criterion is considered important in defining the priority of each suitable site for construction of sand dams given that the County Government may not be able to proceed with all the assessed sites at once. In total **2,029** sites were found to be suitable at different levels for the construction of sand dams across the county. This represented about 79% of the sites proposed by the local communities. It should therefore be noted that sites described as very suitable exhibit negligible to no need for ground reinforcement during construction unlike sites described as less suitable. Less suitable sites showed the need to have preconsiderations such as reinforcement on the weak and less firm river banks among other factors.

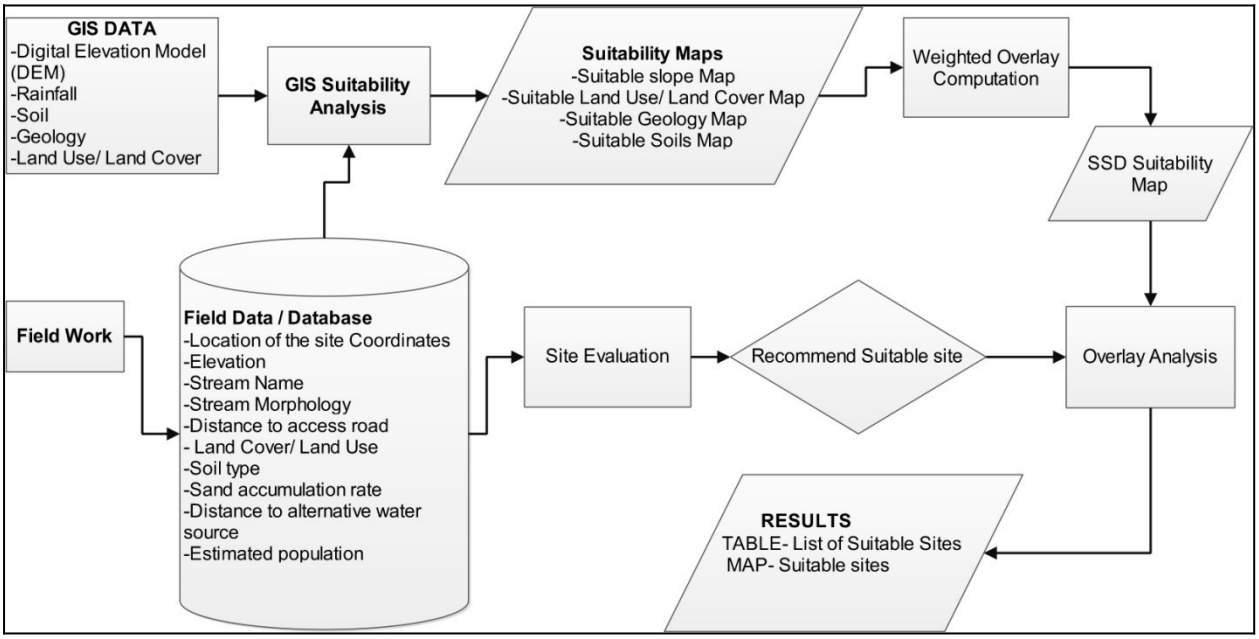

Figure 13: Procedure followed in the evaluation for sites suitable for sand dam construction.

4.0. POTENTIAL IMPACTS OF ENVIRONMENTAL DEGRADATION ON SAND DAMS

4.1. Sand harvesting

In Kitui County, sand harvesting is done along rivers and streams. Most of the sand harvesting activities were encountered in rivers in Kitui central (Kalundu and Nzeeu), Kitui west (Kaayo, Ngethya, Mutindi, Musuu, Mathata, Mutendea), Kitui rural (Tiva, Nzeeu, Mwiw'e) and

rivers/streams in Mwingi central (Tyaa, Kanginga, Kivou, Ndiuli, Kamuyu, Mangolomano). Tyaa and Tiva rivers (Figures 14 and 15) have been affected greatly by sand harvesting.

Figure 14: Sand harvesting on the Tiva river in Kwa Vonza/Yatta ward, Kitui Rural Sub County

Figure 15: High sand accumulation and moderate flow at Tyaa River in Mwingi central Sub County.

Fieldwork identified many cases of sand dams that have been constructed in the past but have failed to achieve their key purposes of sand and water storage because of excessive sand harvesting. Sand harvesting in many rivers contributes to slow sand accumulation in many of the failed sand dams. It is recommended that sand harvesting be regulated and harvesting only done in NEMA licensed sites after EIA has been done. Furthermore, the harvesting process should strictly follow the NEMA sand harvesting guidelines. There is need to sensitize the local communities on the impacts of sand harvesting on water resources and sustainability of the sand dams.

4.2. Modification of groundwater recharge areas

In many streams/rivers identified for proposed sand dams, the river beds were dry. Excavation of such river beds yielded no meaningful water (Figure 16). Lack of adequate sand to store the water was responsible for the dry river beds. Destruction of land as a result of sand harvesting was found to change the land surface and this affected the quantity and quality of water in nearby groundwater aquifers. Modification of the recharge area for groundwater by changing the land surface was prevalent in most areas visited. There have been changes on land vegetation cover that has decreased the recharge of groundwater through infiltration of rainwater. Also, short flow paths may increase susceptibility to contamination while re-directed flow paths may deplete total recharge of the aquifer (Peckenham, Thornton & Whalen, 2009). Where a riverbed was overlaid by deep alluvium or other erodible materials, significant interruption in downstream supply of bed-load, bed lowering was substantial and this can in turn lower the groundwater table, which can variously affect floodplain hydrology (Goodwin and others 1992) and habitat. A lowered groundwater table can kill riparian vegetation (Kondolf and Curry 1986). In many cases where bed lowering occurs, depending on vegetation and site conditions, it may take long for some riparian plants to colonize newly exposed stream banks and this could change the age and species structure of riparian communities. Groundwater lowering can also kill vegetation in floodplain wetlands and along sloughs, where trees might play important roles in providing cover, shade, and a supply of large wood for salmonid habitat. Groundwater table lowering can eliminate recharge to a stratigraphically higher aquifer or breach and contaminate a lower aquifer. This could in turn affect a river’s low-flow regime.

Figure 16: Dry river bed with very low sand accumulation in Mui Ward, Mwingi Central Sub County

To avoid dry river beds, it is strongly recommended that sand harvesting should be controlled. Some of the destructive activities include vegetation clearance and farming activities along the riparian corridor leads to the modification of the groundwater recharge. These destructive activities should be controlled as much as possible in areas targeted for construction of sand dams. Comprehensive catchment conservation programmes need to be put in place. The local community should also be sensitized on the implications of catchment destruction on sand dams and other water resources.

4.3. Modification of stream channels

In some of the sand harvesting sites in areas proposed for sand dams, the rate of extraction of sand exceeds the rate at which natural processes generate and replenish it. Sand harvesting results in lowering of the water table which, in turn, directly affects groundwater storage capacity (Kondolf *et al.*, 2001). Excessive harvesting also allows for saline intrusion into groundwater (Viswanathan, 2002). The lowered water table implies a rise in water pumping costs, thus restricting access to only those who can afford it (Hoering, 2008). It was also found to result in habitat loss including destruction and fragmentation of fragile semi arid lands ecosystems and reduced species richness and diversity.

The removal of sand from streams/rivers was found to cause a change in the cross section of the stream. Removing sand was also causing an increased gradient at the site of extraction. Increasing the gradient of the stream may cause upstream incision of the channel. Removing

sand from streams, particularly reaches of streams that are eroding or down cutting may cause a decrease in bed load. For example, human activities that accelerate stream bank erosion, such as riparian forest clearing or in-stream sand harvesting, cause stream banks to become net sources of sediment that often have severe consequences for aquatic species (Newell *et al.,* 1999). Sand harvesting, in some cases, has transformed the riverbeds into large and deep pits and as a result, the groundwater table has dropped leaving the water wells on the embankments of these rivers dry. Activities that leads to lowering of groundwater table and recharge capacity of ground water should be controlled as much as possible. It is strongly recommended that activities that result to destruction and fragmentation of fragile, endangered ecosystems and reduced species richness should be avoided. Enrichment planting especially using native tree species should be done on key catchment areas. Soil conservation structures should be constructed in neighborhood farms to reduce incidences of soil erosion and siltation of sand dams and rivers downstream.

4.4. Degradation of aquatic and riparian vegetation

In sites where sand harvesting was on-going, the aquatic and riparian habitats were greatly disturbed. Effects directly related to sand harvesting and to changes in geomorphology included increased sedimentation, turbidity, and bank full widths. Other effects that may arise include higher stream temperatures, reduced dissolved oxygen, lowered water table, decreased wetted periods in riparian wetlands, and degraded riparian habitat. Channel geomorphology changes, such as a wider and shallower streambed may consequently result in increased stream temperature (Kondolf, 1997). Loss of riparian habitat may result from direct removal of vegetation along the stream bank to facilitate the use of a dragline or through the process of lowering the water table, bank undercutting, and channel incision (Kondolf, 1997; Brown *et al*., 1998). Sand harvesting also imposed pressure on the biological communities thriving in the river environments. The riparian zone acts as resting and nesting ground for many migratory birds and the destruction of this valuable area affects those migratory birds. Local channel changes propagate upstream or downstream and can trigger lateral changes of the stream as well as the riparian zone. Alteration of the riparian zone affects the physical and biological functioning of the stream (Packer *et al*, 2005). Activities that result to changes on the channel geomorphology should be controlled as much as possible. Key among these activities is sand harvesting. Loss of riparian habitat through activities such as vegetation clearance should be avoided. Anthropogenic activities such as farming along river banks should be controlled. Tree planting using native and indigenous species should be undertaken in key catchment areas. Soil and water conservation on farmlands in the catchment should also be done. This could be undertaken through active community participation.

4.5. Land degradation and vegetation effects

Surface sand harvesting, widely practiced in many rivers in Kitui County, was found to disfigure the topography and surface drainage leading to deforestation and soil erosion, dust generation, long-term compaction and reduced agricultural productivity. The principal cause of environmental impacts from in-stream sand harvesting is the modification of channel characteristics especially the removal of more material than the system can naturally replenish. The effects that were found associated with excavation are channel bed lowering, migration of excavated pits and undermining of structures, bank collapse, caving, bank erosion, valley widening and channel instability. The impacts on water supply were reduced ground water recharge to local aquifers, reduction in storage of water for people and livestock especially during drought periods, contamination of water and conflicts between harvesters and local communities. Further, in-stream sand harvesting was found to result in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts included bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. Removing sand may cause an increased gradient at the site of extraction. Increase in the gradient of the stream may cause upstream incision. Erosion caused by in-stream harvesting can cause bank failure, which result to loss of riparian habitat and loss of shade along the stream banks (Meador and Layher, 1998). Anthropogenic activities such as farming on river banks, tree cutting, and sand harvesting among others should be avoided. The local community should be sensitized on conservation systems that should be put in place on their farms to reduce soil erosion and subsequent siltation of water points. Tree planting on farms and the riparian corridor should be encouraged.

4.6. Farming activities along riparian zones

Irrigated agriculture (Figure 17) was observed to be widely prevalent along riparian corridors of rivers/streams such as Nzeeu, Kalundu, Mutendea, Tiva, Ngethya, Mutindi, Kaayo, Musuu, Mathata, Kithyoko, Nguutani, Tyaa, and Kivou among others. Matinyani ward had the highest incidences of irrigated agriculture along the key rivers including small streams. Assorted horticultural crops such as kales, tomato, cabbage, pepper, onion among others are commonly planted. In some rivers/streams, such farming activities occurred along the banks thereby posing major environmental challenges such as soil erosion, increased water turbidity, collapse of river banks, widening of stream channels, among others.

Figure 17: Irrigated agriculture along river bank in Matinyani ward, Kitui West Sub County

To minimize environmental degradation due to farming activities, it is advisable that farming activities on the riverbanks be controlled as much as possible. Soil conservation structures such as terraces, cut-off drains among others should be constructed in areas where irrigation agriculture is practiced, particularly on slopy grounds. Enrichment planting with key riparian species such as *Acacia xanthophloea* and other riverine species should be done. Farmers should also be encouraged to plant fruit tree species along riparian corridors to minimize effects of soil erosion.

4.7. Charcoal production and vegetation clearance along riparian corridors

In some areas, it was noted that key riverine species such *Acacia xanthophloea* have been cleared for chacoal production. For instance, in Kitui rural, clearance of *Acacia xanthophloea* for charcoal making was on-going along Nzeeu river. Extraction of vegetation along riparian corridor was noted to have led to the collapse of river bank, caving of banks, bank erosion, channel widening and channel instability. Most of the rivers in Kitui County originate from the hills that characterize the entire county. However, most of these hills (Figure 18) have been subjected to heavy deforestation activities leaving them bare and predisposing the neighboring streams/rivers to environmental degradation. Enrichment planting using riverine species along riparian corridor can greatly increase the vegetation cover. Awareness should also be created among the local communities on the effects of vegetation clearance along the riparian corridors.

It is important to note that in Kitui County most poor and vulnerable communities engage in charcoal production as a source of livelihood.

Figure 18: Badly degraded hills in Mutito/Kaliku ward, Kitui East Sub County.

There is a need to control charcoal making activities in riparian corridors. If charcoal production is to take place, then process should be in line with the proposed Forests (charcoal regulations) bill 2016. According to the proposed bill, charcoal production should only be done by organized and licensed groups after carrying out an EIA. The county government of Kitui should work in liaison with the national government to implement the bill once it is published.

4.8. Brick making

Most of the sites proposed for the construction of sand dams are also used making bricks for various construction activities. Bricks are popular among the local community because they are relatively cheaper than quarry stones. However, in some rivers, brick making was observed to be done along the river banks leading to soil erosion and subsequent entry of silt and clay into the river system. This results in high turbidity of water. The brick making also leads to migration of excavated pits, bank collapse, bank erosion, valley widening and channel instability, reduction in storage of water for people and livestock, contamination of water and water use conflicts. There is need to sensitize the local people on the need to adopt new technologies of bricks making that

are environmental friendly. The local community should also avoid brick production near rivers/banks to avoid above problems.

5.0. FINDINGS OF THE ASSESSMENT

The following sections provide details on the results of the field verification exercises and assessments that were conducted in each of the sub-counties. It should be noted that some wards had more suitable sites that had not been suggested by community members. These were then visited by the technical team to ascertain their suitability. This is the reason for differences between the number of proposed sites and those visited by the team. Other wards had very flat river channels without suitable banks hence location of sand dams was not possible. The task force team avoided imposing sites to the communitity therefore only verified the sites proposed as alternative sites for investigation. All other factors held constant though, technical feasibility of the sites was the major attribute considered by the technical team. The total number of sites verified and found suitable was 2,029 across the County. Majority of the sand dam sites are located at a distance of 2km from one site to the other. According to the collected data, the average stream width is 20m wide; 2.3 bank depth; 70m fetch distance and an average sand dam capacity of 1300m^3.

Figure 19: Overall storage capacity of the verified sand dam sites with the respective bank depth. Majority of the sites have less than 3m of bank depth

5.1. KITUI CENTRAL SUB-COUNTY

5.1.1. Background Information

Most of the Kitui Central is covered by valleys with seasonal water courses. Good examples include Mutendea, Kalundu and Nzeeu seasonal rivers. The area is typically an upland zone with elevations reaching up to 1,700m a.m.s.l. There are hilly outcrops such as Ulonzo hills in Miambani ward. Land is used for agricultural activities. Crops such as maize, beans, cow peas, green grams, fruits and irrigated horticultural crops are grown in the area including river valleys. There is less herding of goats, cattle, and sheep since most of the land is used for cultivation and settlements. Settlement is permanent and individuals' land boundaries have been established. Areas near the town are mostly occupied by business class people, schools and colleges, shopping centres, among others. Most of the area has been subject of previous reforestation programmes that now make the Sub-County relatively green throughout the year except in some areas of Kyangwithya west. There is serious commercial sand harvesting in Nzeeu River which reduces the river water retention capacity. Brick making is also common along the river banks making banks very loose and prone to erosion. This also affects the quality of water flowing as surface runoff during rainy seasons. Streams draining near the town e.g. Kalundu stream are subjected to sewage disposal from the urban settlements making the quality of water from them unsuitable for domestic uses. Several sand dams have been built across the streams, some by the Government, NGOs and others by individual farmers.

5.1.2. Location and Population

The sub county is situated at the central part of the county and borders Kitui Rural Sub County to the north, Kitui West Sub County to the west, Kitui East Sub County to the east and Kitui South Sub County to the south. The SSDs verification exercise in Kitui Central Sub County was carried out by technical teams between 28th September & 7th October 2015. Table 4 below shows the sub county wards and their population sizes.

Table 4: Kitui Central Sub County Wards & Population sizes

Name	Human Population in 2009	Population (livestock)	Area (sq. km)	Human Population Density (persons per sq. km)	Livestock Population Density (heads per sq. km)
1) Miambani	22,164	4,500	215.10	103	21
2) Mulango	28,573	5,300	155.70	183	34
3) Kyangwithya East	32,841	7,000	105.00	313	67
4) Kyangwithya West	22,121	6,780	142.50	155	48
5) Township	26,016	2,980	17.90	1445	166
TOTAL	**131,715**	**26,560**	**636.20**	-	-

5.1.3. Outcome of SSD sites Identification

Table 5 below outlines the total SSD sites proposed by the community in Kitui Central, the number of SSD sites visited and the number of sites found suitable for SSDs. Detailed information on measured and computed parameters for suitable SSD sites is attached. A total of 230 sites were found to be viable for sand dam construction.

Table 5: Kitui Central Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited SSD Sites	No. of Suitable SSD Sites	Ratio Between No. Sites & Population
1. Township	59	59	46	1:565
2. Mulango	60	60	51	1:560
3. Kyangwithya East	46	46	45	1:729
4. Kyangwithya West	47	47	45	1:491
5. Miambani	51	51	43	1:515
TOTAL	**263**	**263**	**230**	-

All the verified sites were ploted on the Kitui Central (660km^2) (Figure 20). The sites in Miambani, Mulango, and Kyangwithya West were observed with high percentage of suitable sites. This outcome is majorly associated with good exposure of rock outcrop on the riverbed and well defined and firm river banks. Township Ward is dominated with fairly suitable sites. This ranking is as a result of minimal sand accumulation and several sources of water pollution. Other

sites which were ranked fairly suitable was as a result of lack of rock outcrops, no well defined river channels, and weak river banks especially at the sites located on the flooding prone areas.

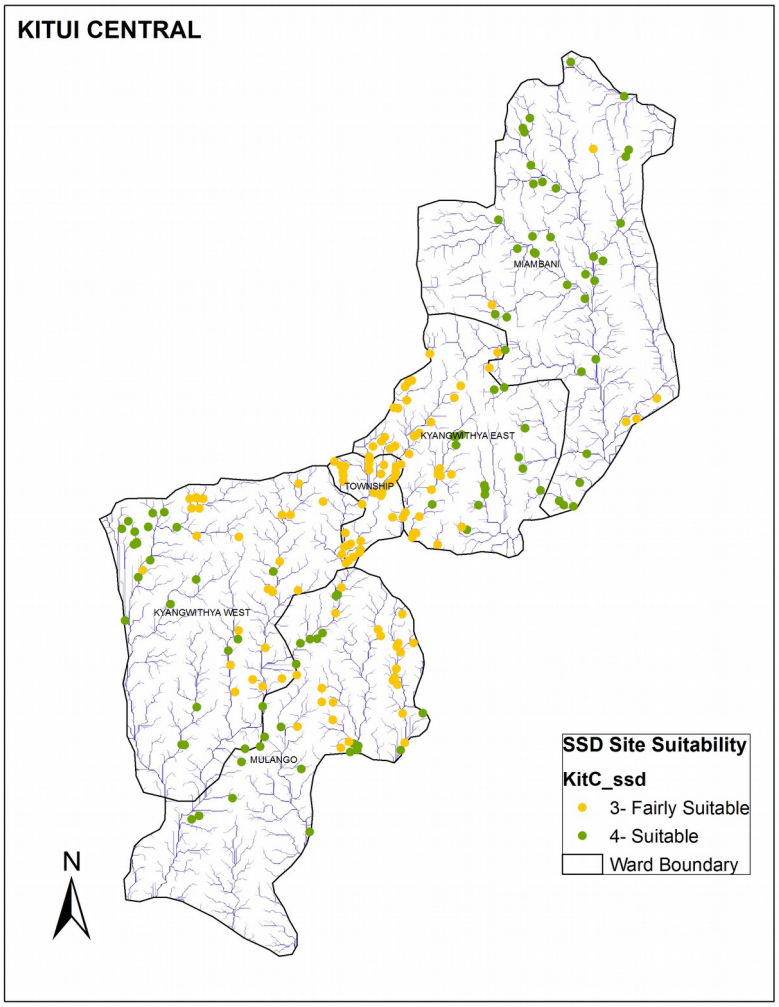

Figure 20: Distribution of the potential suitable sites for Sand dams construction in Kitui Central

5.2. KITUI EAST SUB-COUNTY

5.2.1. Background Information

Most of the Kitui East Sub-County is low laying grazing and farming plains criss- crossed by seasonal water courses. There are several hilly outcrops such as Mutitu, Endau and Kyoongwe which have water springs and have been protected and extended to surrounding communities through pipelines. Makongo and Kyango hills are rocky and dry. Land is used for agricultural activities with the cultivation of various crops such as maize, beans, cow peas, green grams, fruits and irrigated horticultural crops are grown on the suitable river basins. Livestock grazing is

important particularly in Endau/Malalani, Voo/Kyamatu, Zombe/Mwitika and Mutitu/Kaliku wards. Except in the grazing areas of the eastern parts of Endau/Malalani and Voo/Kyamatu wards, settlement is permanent and individuals' land boundaries have been demarcated. Land adjudication is however on process. A large extent of Mui river basin in Mutitu and Mwitika wards is within the Mui coal basin. The community also practices light businesses such as retail shops, hotels and restaurants and butcheries in many shopping centers.

Most of the area is covered by natural semi-arid vegetation of acacia trees, shrubs and bush and a variety of grass cover. Currently the trees are being cut for charcoal burning; the bushes and grass cover has been cleared to open the land for agriculture. There is cultivation on steep slopes which has led to serious soil erosion. Shifting cultivation is common in the area and the soil is usually left exposed following a period of cultivation. Overgrazing is also observable as some large extracts of land are bare and exposed to agents of soil erosion. There is serious sand harvesting at Nzeeu River in Nzambani ward which reduces the river water retention capacity of the river. Efforts are underway to train the community on proper land use by the agriculture and environment departments.

5.2.2. Location and population

Proposed SSD sites were visited and verified by technical teams from 7th December to 16th December 2015. The sub county is situated at the eastern part of the county and borders Tana River County to the east, Kitui central sub county to the west, Mwingi central Sub County to the north and Kitui south sub county to the south. Below is a tabulation of human and livestock population size as well as the ward sizes (Table 6).

Table 6: Kitui East Sub County Wards and their population sizes

Name	**Human Population in 2009**	**Population (livestock)**	**Area (sq. km)**	**Persons per sq. km**	**Livestock per sq. km**
1) Zombe/Mwitika	25,452	70,000	580.50	44	121
2) Nzambani	18,126	10,000	64.00	284	157
3) Chuluni	22,046	50,000	235.00	94	213
4) Voo/Kyamatu	23,011	90,000	1,114.80	21	81
5) Endau/ Malalani	15,506	95,000	2,528.00	7	38
6) Mutitu/Kaliku	19,098	90,000	596.00	32	151
TOTAL	**123,239**	**605,000**	**4,118.30**	**-**	**-**

5.2.3. Outcomes of SSD Sites Identification

The total number of sites proposed by the community was 404 and 228 sites were found to be suitable for SSDs (Table 7). Detailed information on measured and computed parameters for suitable SSD sites are contained in the appendices.

Table 7: Kitui East Sub County findings

Name of Ward	**No. of Proposed SSD Sites**	**No. of Visited SSD Sites**	**No. of Suitable SSD Sites**	**Ratio Between No. Sites & Population**
1. Chuluni	71	71	51	1:433
2. Endau/Malalani	78	78	38	1:408
3. Voo/Kyamatu	41	41	35	1:658
4. Nzambani	72	72	37	1:489
5. Mutito/Kaliku	82	82	36	1:530
6. Zombe/Mwitika	60	60	31	1:821
TOTAL	**404**	**404**	**228**	**-**

Figure 21 shows Kitui East an area of 5029 km^2 divided in six wards represented in Table 7. Most of the sites in Nzambani Ward are ranked fairly suitable with evidence shallow river bed of an average river bank depth of 1.5m. Other sites ranked suitable are well distributed in Mutito, Zombe, Chuluni, and Voo Wards respectively. Endau Ward is a lowland area with minimal rock outcrop on the river beds and poorly defined river banks. This observation explains the distribution of the fairly suitable and less suitable sites in this ward. There is a possibility of ground water occurrence in Endau Ward due to high sedimentation of coarse sands that allow water infiltration and storage with high underground interflows.

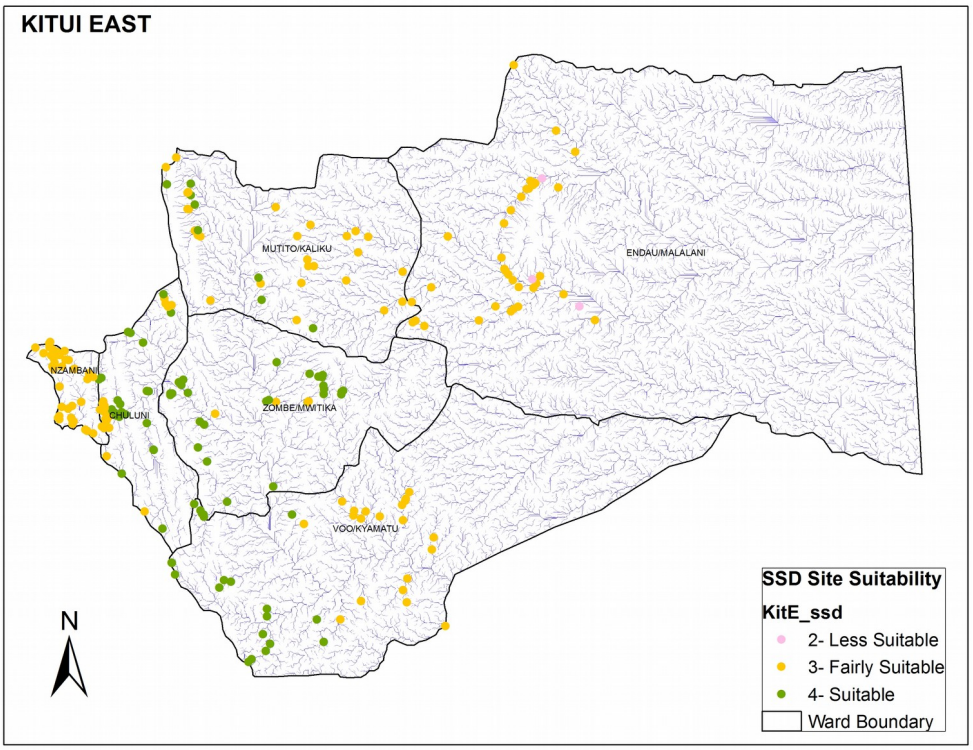

Figure 21: Distribution of the potential suitable sites for Sand dams construction in Kitui East

5.3. KITUI RURAL SUB COUNTY

5.3.1. Background Information

Most of Kitui Rural Sub-County is low lying grazing and farming plains mostly the Yatta plateau. There are few rock outcrops and hills e.g. Kwa Vonza hills. Most rivers flowing through here have their origins in the Kitui central upland areas. The major rivers include Mwitasyano and Tiva Rivers. Land is used for agricultural activities where maize, beans, cow peas, green grams, fruits, and irrigated horticultural crops are grown on the suitable river basins. There is livestock herding of goats, cattle, and sheep. This is predominant in Kanyangi and Yatta wards. Settlement is mostly permanent and individuals' land boundaries have been set. Land adjudication is on process. Brick making and charcoal burning are also practiced here. Most of the area is covered by natural semi-arid vegetation of acacia trees, shrubs and bush and a variety of grass cover. Majority of tree cutting is carried out to pave way for cultivation and also for charcoal burning. Ground water levels in major rivers such as Nzeeu, Mwiwe & Tiva is very high as these rivers have high flows. Also several sand storage dams have in the past been

constructed. Among the most successful ones is Ngaasani SSD in Kisasi ward built in the early 1970's. Overgrazing is also observable as some large extracts of land are bare hence exposed to erosion. Sand harvesting, charcoal burning and brick making are some of the major negative activities carried out along the rivers. Efforts are in place to train the community on proper land use by the agriculture and environment departments.

5.3.2. Location and Population

The sub county is situated at the northern part of the county and borders Kitui South Sub County to the south, Makueni County to the west, Machakos County to the north and Kitui Central Sub County to the east. The SSDs verification exercise was carried out by technical teams from 27th July to 5th August 2015. Table 8 shows the wards and population sizes.

Table 8: Kitui Rural Sub County Wards& population sizes

Name	Human Population in 2009	Population (livestock)	Area (sq. km)	Persons per sq. km	Livestock per sq. km
1) Kisasi	26,759	44,600	253.60	106	176
2) Mbitini	24,858	11,000	131.10	189	84
3) Yatta/Kwa Vonza	30,732	50,650	757.40	41	67
4) Kanyangi	22,094	74,456	418.70	53	178
TOTAL	**104,443**	**180,706**	**1,560.80**	**-**	**-**

5.3.3. Outcomes of the exercise

From the exercise, one hundred and seventy three sites were found suitable for sand storage dams. Table 9 below shows the general breakdown.

Table 9: Kitui Rural Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited SSD Sites	No. of Suitable SSD Sites	Ratio Between No. Sites & Population
1. Kisasi	70	70	62	1:432
2. Mbitini	48	48	35	1:710
3. Kwa Vonza/Yatta	51	51	30	1:1024
4. Kanyangi	58	58	46	1:470
TOTAL	**227**	**227**	**173**	**-**

Kitui Rural Sub-County is divided into four (4) wards (Figure 22). Kwa Vonza is the largest ward located on the Northern part of the Sub-County. This is the Ward that hosts the South Eastern Kenya University and several ranches which take a relatively higher percentage of the land. There were 51 proposed sites in Kwa Vonza Ward but only 30 quite well distributed sites were found suitable (97%) and fairly suitable (3%). The average stream width in this Ward is 30m and river bank depth of 2m. This ward is characterized with low laying land hence minimal rock exposure, most parts dominated with black cotton soils on the river banks and moderate sand accumulation in most of the visited sites. This observation explains the high number of beneficiaries on the sites that were found suitable in this ward (Table 9). Kisasi and Kanyangi Wards were observed with well distributed sites ranked suitable and one site ranked very suitable is located at Maviani along Kanaani stream in Kiseuni Village at the south eastern parts of Kanyangi Ward. About 50% of the visited sites in Mbitini Ward were ranked fairly suitable (Figure 22) especially of the high hills of the northern parts with an average gradient of 0.03, 20m stream width and 2m river bank depths.

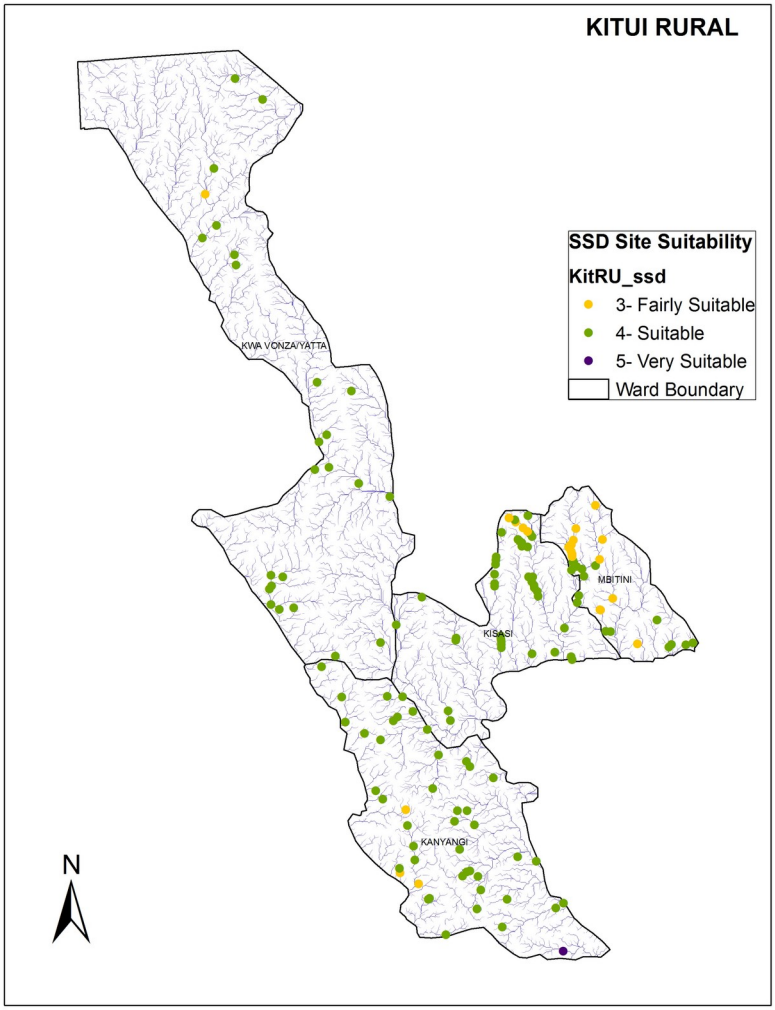

Figure 22: Distribution of the potential suitable sites for Sand dams construction in Kitui Rural

5.4. KITUI SOUTH SUB-COUNTY

5.4.1. Background information

Most of the Kitui South Sub-County area is low laying grazing and farming plains criss- crossed by seasonal water courses. There are a number of hilly outcrops such as in the Mutomo ward which have been protected and extended to form good rock catchments for water harvesting. These serve the surrounding communities with water especially during the dry seasons. As in other sub-counties, most of the hills are rocky and with dry degraded vegeation. Land is used for cultivation of crops such as maize, beans, cow peas, green grams, fruits and irrigated horticultural crops are grown along river valleys. The herding of goats, cattle, and sheep is important in the area particularly in Mutha, Athi and Kanziko wards. Except for some few areas, most of the settlement is permanent. Charcoal burning is widely practiced leading to degradation

of the semi arid bushland. This has also made the land bare and unproductive. Most of the area is covered by natural semi-arid vegetation of acacia trees, shrubs and bush and a variety of grass cover. Charcoal burning has left most of the land bare exposing it to high soil erosion. Cultivation takes place on steep slopes which has also led to serious soil erosion problem. Shifting cultivation is also common in the area. Overgrazing is also observable as some large extracts of land. There is uncontrolled harvesting of sand in major rivers which reduces the river water retention capacity during dry seasons.

5.4.2. Location and Population

The sub county is situated at the southern part of the county and borders Kitui Rural Sub County to the north & west, Kitui East Sub County to the east and Tana River County to the south.

The SSDs verification exercise was undertaken by technical teams from 2nd November to 11th November 2015. Table 10 below shows the sub county wards and particular populations.

Table 10: Kitui South Sub County Wards & population sizes

Name	Human Population in 2009	Population (livestock)	Area (sq. km)	Persons per sq. km	Livestock per sq. km
1) Ikutha/Kasaala	26,176	87,234	433.90	61	201
2) Mutomo/Kibwea	24,450	78,567	325.40	75	241
3) Mutha	25,138	95,670	3,477.10	8	28
4) Ikanga/Kyatune	36,185	67,890	491.60	74	138
5) Kanziko/Simisi	18,664	84,780	453.40	42	187
6) Athi	35,437	86,120	952.30	38	91
TOTAL	**166,050**	**500,261**	**6,133.70**	-	-

5.4.3. Outcomes of the exercise

From a total of three hundred and forty four (344) proposed sites, only two hundred and sixty eight (268) qualified for construction of sand storage dams. Table 11 below gives the general breakdown.

Table 11: Kitui South Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited SSD Sites	No. of Suitable SSD Sites	Ratio Between No. Sites & Population
1. Mutomo/Kibwea	60	60	41	1:596
2. Athi	52	52	40	1:886

3. Kanziko/Simisi	60	60	51	1:366
4. Ikanga/Kyatune	70	70	52	1:695
5. Ikutha/Kasaala	42	42	37	1:708
6. Mutha	60	60	47	1:534
TOTAL	**344**	**344**	**268**	**-**

Kitui South is the largest Sub-County in Kitui County covering an area of about 5986 km^2. Mutha Ward is the largest among the six wards in the sub-county but observed as the third highest populated ward but with lowest population density (8 persons per km2). The average stream width and bank depths in Mutha are about 20m and 2.4m respectively. Around 80% of the visited sites in the Western parts of Mutha Ward were ranked fairly suitable for sand dam construction. The central and entire western parts of this ward are not suitable for sand dam contruction due to lack of rock out crops, very shallow stream banks, and weak soils. However this ward can be supplemented with underground water. Shallow wells are deemed reliable in this area since there is possible enough recharge from the uphills. The western parts of the Kitui South are well distributed with sites ranked suitable to very suitable sites for sand dam constructions. Areas at the foot of Mutomo hills and the rocky areas in Ikanga wards were found with excellent sites as shown in Figure 23.

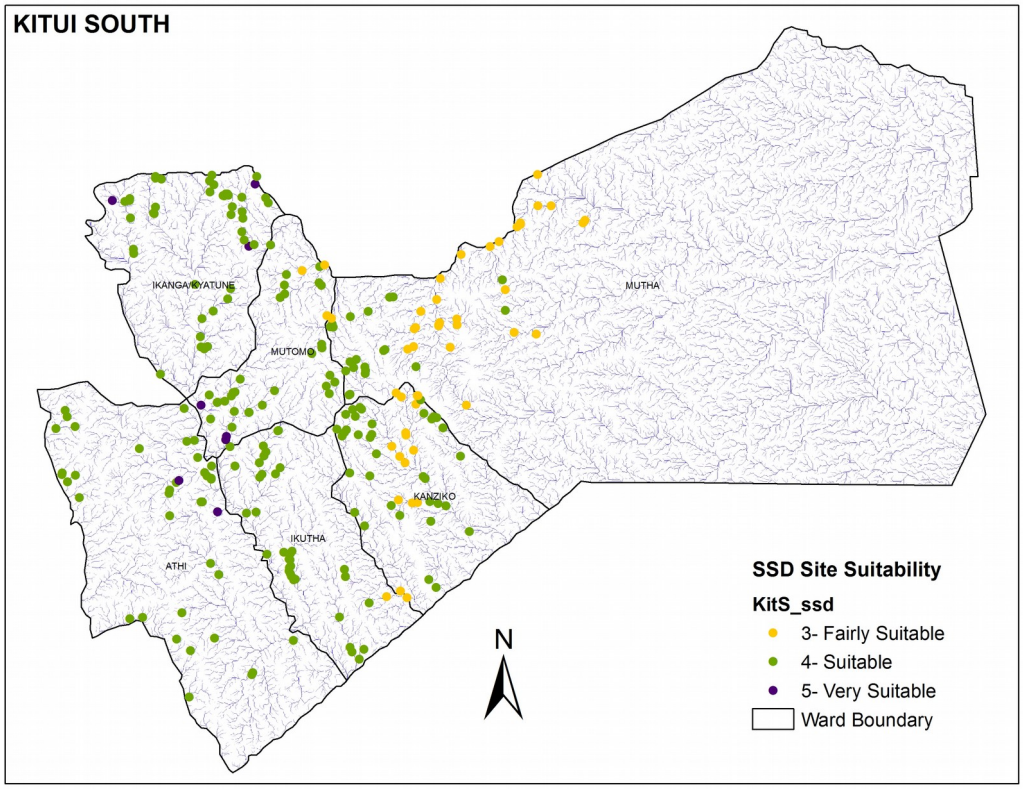

Figure 23: Distribution of the potential suitable sites for Sand dams construction in Kitui South

5.5. KITUI WEST SUB COUNTY

5.5.1. Background information

Most of the area is covered by valleys with seasonal water courses originating from them e.g. Mutendea and Ndiang'u. There are hill outcrops e.g. Muthale hills in Mutonguni ward. Land is used for agricultural activities where maize, beans, cow peas, green grams, fruits and irrigated horticultural crops are grown on the suitable river basins. There is less livestock herding of goats, cattle, and sheep since most of the land is used for cultivation. Settlement is permanent and individuals' land boundaries have been set. Most of the area is covered by grown forest trees that make the sub county very green throughout the year except in some areas of Kauwi ward that are covered by semi-arid shrubs. There is farming on steep slopes on the hills which has resulted to serious erosion. There is serious commercial sand harvesting in Mutendea River which reduces the river water retention. Brick making is also common along the river banks which the banks very loose and prone to erosion. This also affects the quality of water flowing as surface run off during rainy seasons. Several sand dams have been built across the streams, some by the Government, NGOs and others by individual farmers.

5.5.2. Location and Population

The sub county is located at the western part of the county and borders Machakos County to the north, Mwingi West Sub County to the west, Kitui Central Sub County to the east and Kitui Rural Sub County to the south. The SSDs verification exercise for the proposed sites was carried out by technical teams from 7th September to 16th September 2015. Table 12 below shows the wards and their specific population numbers.

Table 12: Kitui West Sub County Wards and population sizes

Name	Human Population in 2009	Population (livestock)	Area (sq. km)	Persons per sq. km	Livestock per sq. km
1) Matinyani	24,081	20,500	72.10	330	281
2) Mutonguni	34,140	23,700	157.80	216	150
3) Kithumula/ Kwa Mutonga	18,708	31,455	192.00	98	164
4) Kauwi	25,385	29,670	245.30	104	122
TOTAL	**102,314**	**105,325**	**667.20**	-	-

5.5.3. Outcomes of the verification exercise

A total of 271 proposed sites were visited and verified. Sites found unsuitable were replaced with others and other unproposed sites were also found very suitable for establishment of sand storage dams. A total of 285 sites were found to be suitable for SSDs. Table 13 below shows the sub-county wards and their specific populations.

Table 13: Kitui West Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited Sites	No. of Suitable Sites	Ratio Between No. Sites & Population
1. Kithumula/Kwa Mutonga	66	66	57	1:328
2. Mutonguni	73	73	65	1:534
3. Matinyani	89	89	84	1:287
4. Kauwi	84	84	79	1:322
TOTAL	**312**	**312**	**285**	-

Kitui West is divided into four (4) wards and Kauwi located on the north western parts of the sub county being the largest. The central parts of Kauwi are obsvered with relatively high ground where most stream orginate and drain toward the south and northern parts. The low laying land in Kauwi area exhibit relatively low to moderate accumulation of sands along the river beds and around 50% of the sites have no rock exposure hence the observation in Figure 24. The average stream width in this ward is about 10m and a stream bank depth of 2.4m

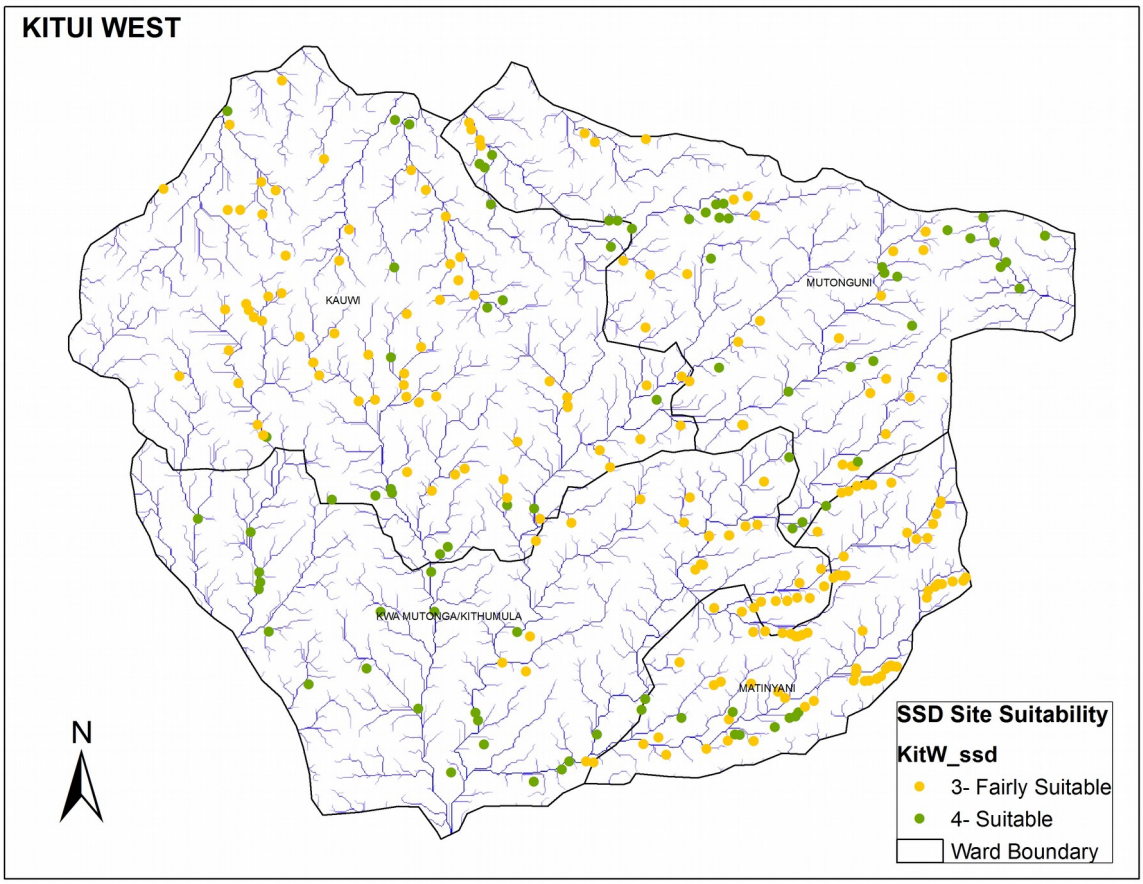

Figure 24: Distribution of the potential suitable sites for Sand dams construction in Kitui West

5.6. MWINGI CENTRAL SUB COUNTY

5.6.1. Background information

The majority of the inhabitants in Mwingi Central Sub-County practice cultivation except during dry periods when grazing is the common activity especially in Nuu and Nguni wards. Charcoal burning is also practiced in the area leaving the land bare and very prone to soil erosion.

5.6.2. Location and Population

Mwingi central sub county is found in the northern region of Kitui County bordering Mwingi west Sub County to the west, Mwingi North Sub County to the east and Garissa County to the south. The SSDs verification exercise for the proposed sites here was undertaken from 12th October to 21st October 2015. The sub-county has six wards. Table 14 below provides details on the sub-county wards and their specific populations.

Table 14: Mwingi Central Sub County Wards & population sizes

Name of Ward	Human Population in 2009	Population (Livestock)	Area(km^2)	Persons per sq. km	Livestock per sq. km
1. Mwingi Central	18,846	23,460	248.40	76	94
2. Kivou	24,886	22,390	252.70	99	89
3. Nguni	29,313	39,450	1,758.00	17	23
4. Nuu	27,644	73,567	1,324.00	21	56
5. Mui	19,628	67,789	369.40	54	183
6. Waita	20,890	36,560	377.40	56	97
TOTAL	**141,207**	**263,216**	**4,329.90**	**-**	**-**

5.6.3. Outcome of the exercise

Table 15 shows the proposed sites by the community, the number visited and the number of sites found suitable for construction of SSDs. A total of 293 sites were found suitable for sand dam construction.

Table 15: Mwingi Central Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited SSD Sites	No. of Suitable SSD Sites	Ratio Between No. Sites & Population
1. Mwingi central	65	65	56	1:336
2. Mui	61	61	61	1:321
3. Kivou	60	60	57	1:436
4. Nguni	22	22	21	1:1396
5. Nuu	55	55	46	1:600
6. Waita	57	57	52	1:401

TOTAL	**320**	**320**	**293**	**-**

Mwingi Central is the home of Mwingi town located in Central ward on the western part of the sub-county (Figure 25). The rugged terran and rock exposure in the western parts of the sub-county favors the occyurence of suitable sites dominating these areas with moderate to high accumulation of sand deposits along most of the river beds. The sand dam sites in Central, Kivou, Waita, and Mui Wards are well distributed with moderate number of beneficiaries (Table 15) as compared to Nguni and Nuu wards where few sites were found fairly suitable for sand dam construction. Most of the and streams in western parts of the sub-county have an average width of 20m, bank depth of 2.5m, and fetch distance of 65m while the streams on the eastern parts especially in Nguni and Nuu wards have an average stream width of 25-30m, bank depth of 2m, and fetch distance of 70m. Nguni and Nuu areas are low laying lands as compared to the western parts of the Sub-County. This factor contributed to identification of less suitable sites at the flood zones with minimal rock exposure and lack of firm river banks.

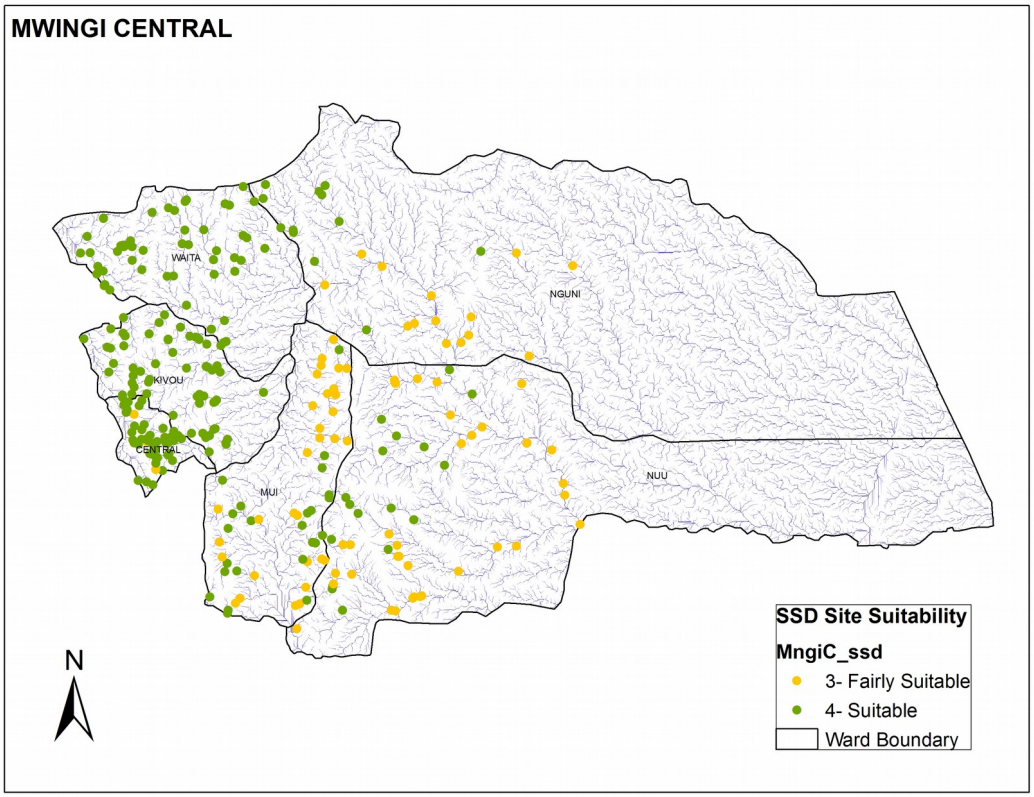

Figure 25: Distribution of the potential suitable sites for Sand dams construction in Mwingi Central

5.7. MWINGI NORTH SUB COUNTY

5.7.1. Background information

Land in the Mwingi North Sub-County is mainly livestock grazing and mixed farming which mainly depends on seasonal rainfall. Agricultural activities where maize, beans, cow peas, green grams, fruits and irrigated horticultural crops are grown on the suitable river basins. The land is also used for small scale irrigation schemes along major rivers among other rivers, Katse, Thunguthu and Wikithuki irrigation scheme. There is livestock herding of goats, cattle, and sheep. This is predominant in Tseikuru and Ngomeni wards where vast extents of land lie idle and unproductive due to the harsh weather conditions experienced here. Tana River offers a great advantage to the people living closer to it as it is a permanent river. Activities for communities living near the river include fishing, irrigation, and brick making. Most of the area is covered by natural semi-arid vegetation of acacia trees, shrubs and bush and a variety of grass cover. Charcoal burning is also widely practiced here leaving most of the land bare and unproductive. There is farming on steep slopes on the hills which has resulted to serious erosion. Shifting cultivation is common in the area and the soil is usually left exposed to denudation. Overgrazing is also observable as some large extracts of land are bare hence exposed to erosion. There is serious sand harvesting at the seasonal rivers in which reduces the river water retention. Land degradation activities have adversely affected the area in terms of productivity. Factors affecting land degradation include: Poor agricultural practices e.g. down slope cultivation & shifting; Deforestation e.g. charcoal burning; Overstocking – keeping of many livestock units; Run – offs due to road excavation and Brick making along water sources. One way of conserving degradation of the land is to educate the communities on methods employed in combating the effects of environmental degradation. Such methods as Soil conservation; Effects of brick making along river backs; Tree planting after charcoal burning; Terracing to check run offs from slop cultivation; Reduce livestock keeping (overstocking) and increase construction of dams/ pans which besides providing water act as control measures for run offs.

5.7.2. Location and Population

Mwingi North Sub County is situated in the Northern part of Kitui County. Tana River County borders it to the east, Mwingi Central Sub County to the west and Tharaka & Embu Counties to the North. The total land area is about 4768.8 km^2. The land in Mwingi North Sub County is gently sloping towards east. The sub county has diverse physical features which are the major

sources of water. These include Tana River which runs from North West to the East which has provided potential for irrigation schemes e.g. Wikithuki Irrigation Scheme. Mumoni hill is the highest peak in Kitui County and from it most of the seasonal rivers in the county originate. Hills also have forest cover. The sub county also has many big seasonal rivers like Thunguthu, Katse River, Mataka, Nziitu, Manzolo and Musavani. Rock catchments, which are sources of rain-harvested water, are many in the Sub County. The climate in the sub county is semi-arid. The rainfall in this region is bio modal due to its disparity in distribution in time and space. Most of the area is low lying grazing and farming plains criss- crossed by seasonal water courses. There are large rock outcrops e.g. Kyuso rock which have been protected and extended to form good rock catchments for harvesting rainwater. These serve the surrounding communities with water. Most of the hills here are rocky and dry hence don't have spring water fissures. Table 16 outlines the sub county wards with their particular population sizes. The SSDs verification exercise for the proposed sites was carried out from 16th November to 25th November 2015. Table 17 shows the general breakdown of the findings from the sub county.

Table 16: Mwingi North Sub County Wards& population sizes

Name	**Human Population in 2009**	**Population (livestock)**	**Area (sq. km)**	**Persons per sq. km**	**Livestock per sq. km**
1) Ngomeni	18,447	78,000	1,619.00	12	49
2) Kyuso	40,375	79,034	751.50	54	105
3) Mumoni	32,171	79,000	659.60	49	120
4) Tseikuru	35,890	80,136	1,328.00	28	61
5) Tharaka	13,084	79,000	410.70	32	193
TOTAL	**139,967**	**395,170**	**4,768.80**	**-**	**-**

5.7.3. Outcomes from the exercise

From the verification exercise, some proposed sites were found to be suitable while others were not. Table 17 shows the general breakdown.

Table 17: Mwingi North Sub County findings

Name of Ward	**No. of Proposed SSD Sites**	**No. of Visited SSD Sites**	**No. of Suitable SSD Sites**	**Ratio Between No. Sites & Population**
1. Mumoni	84	84	65	1:495
2. Kyuso	60	60	59	1:684

3. Ngomeni	59	59	25	1:737
4. Tharaka	59	59	55	1:238
5. Tseikuru	59	59	45	1:798
TOTAL	**321**	**321**	**184**	-

Mwingi North is located on the Northern part of the Kitui County with Tana River as the major river flowing along the North Western border of the Sub-County. Tharaka Ward has well distributed sand dam sites with majority ranked suitable and fairly suitable at the lower lands. Kyuso and Mumoni Ward are also dominated with potential suitable sites for sand dams. Tseikuru and Ngomeni show high number of beneficiaries per site due to limited favorable conditions especially at the North Eastern region of the subcounty. All the visited sites in Ngomeni Ward were ranked fairly suitable for sand dam construction therefore; necessary engineering measures should be taken during construction of the sand dams to minimize failure. Other water resources such as ground water from shallow wells should be explored to supplement water from the sand dams.

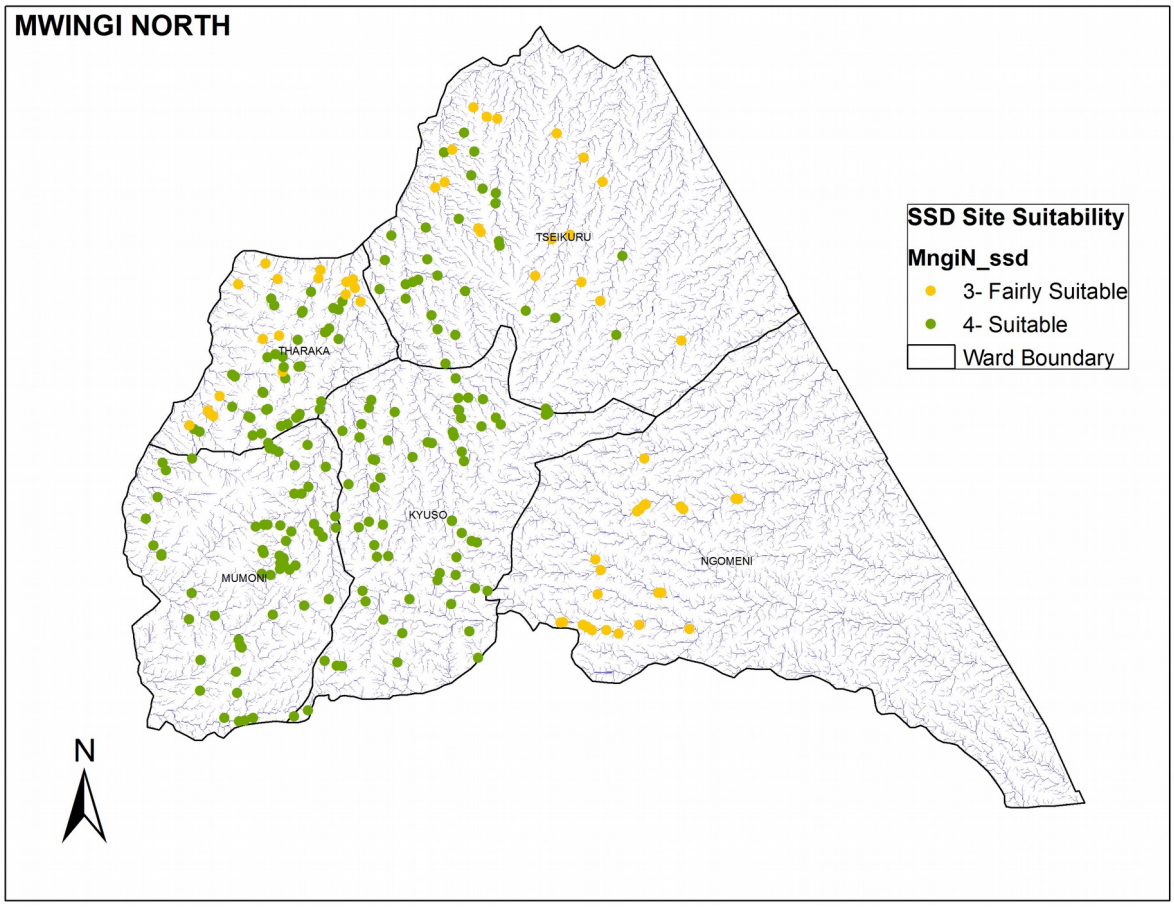

Figure 26: Distribution of the potential suitable sites for Sand dams construction in Mwingi North

5.8. MWINGI WEST SUB COUNTY

5.8.1. Background information

Most of the area is covered by deep valleys with several seasonal rivers having their origin from them e.g. Ikoo river. Areas to the west are however flat with few hill outcrops. Land is used for agricultural activities where maize, beans, sorghum, millet, sisal, cow peas, green grams and fruit trees. Major livestock kept include cattle, goats, sheep and donkeys. Zero grazing is practiced on the higher areas of the sub county mostly in areas around Migwani ward. Brick making is also common in areas bordering rivers. Most of the area is covered by natural semi-arid vegetation of acacia trees, shrubs and bush and a variety of grass cover. Areas near valleys remain green for greater part of the year compared to other flat areas. There is uncontrolled sand harvesting, farming on steep slopes of rivers & hills and charcoal burning leading to serious soil erosion. Key conservation activities include re-afforestation, construction of terraces and measures to control sand harvesting & charcoal burning. Efforts are in place to train the community on proper land use by the agriculture and environment departments. Several sand dams have also been built to conserve water and control gulley erosion (Figure 27).

Figure 27: existing sand dam in Migwani ward, Mwingi West Sub County

5.8.2. Location and population

Mwingi West is one of the three sub counties in the larger Mwingi region of Kitui County. It borders Mwingi Central Sub-County to the north, Machakos County to the west, Kitui East/Central Sub County to the east and Kitui West Sub County to the south. The SSDs verification exercise for the proposed sites was carried out from 28th September to 7th October 2015. Table 18 below gives the sub county details including its four wards and their population sizes.

Table 18: Mwingi West Sub CountyWards& population sizes

Name	Human Population in 2009	Population (livestock)	Area (sq. km)	Persons per sq. km	Livestock per sq. km
1) Kyome/Thaana	22,443	11,012	308.00	73	36
2) Nguutani	27,265	5,481	209.70	130	27
3) Migwani	28,169	14,390	685.10	41	21
4) Kiomo/Kyethani	23,011	7,000	385.40	60	19
TOTAL	**122,620**	**37,883**	**1,588.20**	**-**	**-**

5.8.3. Outcomes from the exercise

Table 19 below shows the outcomes from the sub county. A total of three hundred and three sites were found to be suitable.

Table 19: Mwingi West Sub County findings

Name of Ward	No. of Proposed SSD Sites	No. of Visited SSD Sites	No. of Suitable SSD Sites	Ratio Between No. Sites & Population
6. Kyome/Thaana	105	105	91	1:247
7. Nguutani	100	100	95	1:287
8. Migwani	60	60	59	1:486
9. Kiomo/Kyethani	117	117	58	1:396
TOTAL	**382**	**382**	**303**	**-**

All the suitable sites were ploted on Mwingi West Map (Figure 28) with different ranking based on the site evaluation from fairly suitable to suitable. Majority of the sites ranked fairly suitable are found in the hilly southern parts of the Sub-County around Migwani and Nguutani. Most of the sites in all the Wards in this Sub-County are well distributed to the befeciaries in this region. Ground water can also be explored in the norther parts of Kiomo/Kyethani areas since there is

relatively adequate recharge from the uphills. Streams in this Sub-County have relatively small bank depth at the norther parts (2.5m) as compared to the streams at the southern parts near the Migwani hills (1.8m). Approximately 80% of the sites in the Sub-County are located in rocky riverbeds which are considerably good for anchoring the sand dam strutures and moderate to high accumulation of sands.

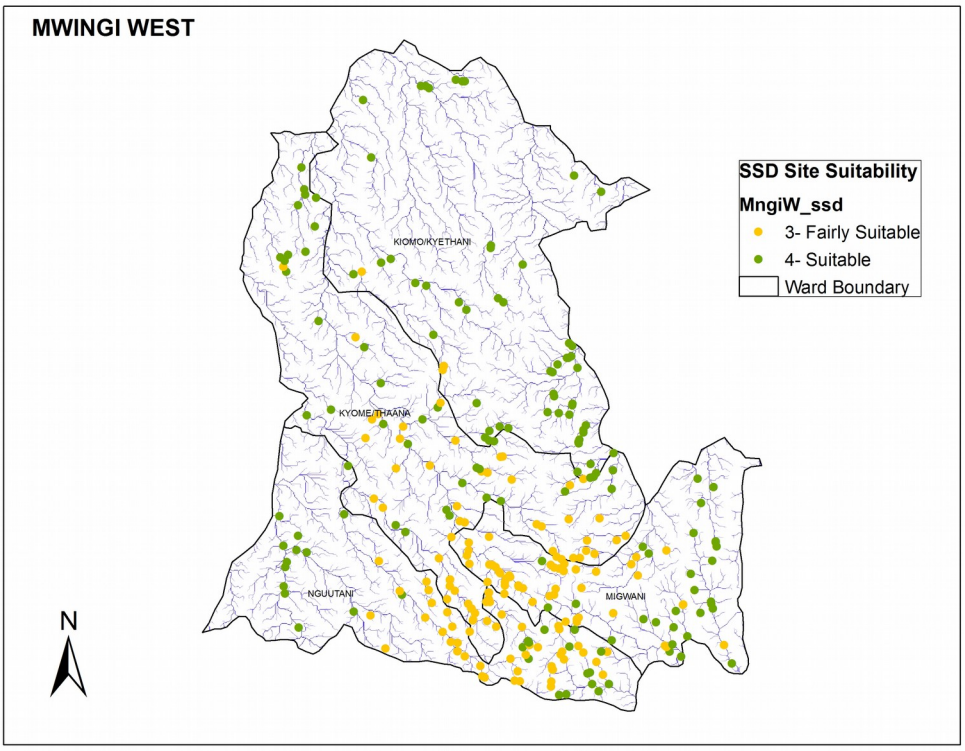

Figure 28: Distribution of the potential suitable sites for Sand dams construction in Mwingi West

5.9. CHALLENGES FACED IN THE EXERCISE

During the exercise for field verification of the proposed sites for construction of sand dams, the task team faced a number of challenges. These challenges are cross-cutting and were faced in virtually all the areas visited.

a) Most of the sites have poor infrastructure with no access roads such that many sites were inaccessible by car or field vehicle.

b) Lack of proper mobile networks making phone communication difficult in some areas.

c) Several streams have very gentle banks with loose soils.

d) Some community guides were selfish and preferred sites which they had interests in.

e) Lack of proper links between the area chiefs and the ward development committee members.

6.0. BEST PRACTICES IN THE IMPLEMENTATION OF SAND DAM PROJECTS

The construction of sub-surface dams is an important means of solving water storage problems, particularly in arid and semi-arid land (ASAL) Kitui County. This is primarily because sand dams are considered to be relatively low cost water harvesting technologies with minimal construction and environmental costs. The sand dams also minimize evaporation losses as well as downstream sedimentation and they have also to be known to improve water quality as a result of the filtration effect of the sand matrix. As a result, water in most sand dams is usually clear as compared to the highly turbid water found in most streams in wet seasons.

Any dry sandy riverbed, seasonal stream which receives some flow during the rainy season, is considered to be potentially suitable for the development of sub-surface dams (Thomas, 1999). The sand retains water for relatively long periods after the flow in the river has ceased. The volume of water stored varies depending on the grading of the sand and the gravel. Generally, the available volume of water is about 25% to 30% of the total volume of sand. This water is retained behind the dam structure, which forms a seal across the width of the river and down to foundation, built on an impermeable layer of rock or clay (Nyamai et al., 2003). A pumping well or any other suitable outlet structure can be located upstream for drawing water and delivering to the consumers to avoid damage caused by direct access to the dam. The water quality in sub-surface dam is usually much better than water from open surface reservoir, since it is protected from contact with animals and humans and has undergone some form of filtration through the sand. In rivers with only seasonal flow it is often possible to abstract water from the riverbed in the dry season if a structure is built across the riverbed under the surface to retain the sub-surface flow. This method is particularly suitable in areas where the groundwater is generally saline or has high fluoride content. The water is generally withdrawn through infiltration galleries up-stream the sub-surface dam (Kibiiy et al, 2003). However, this technology is labour and capital intensive and most communities cannot implement it without external aid.

Key lessons learnt in other sand dam projects implemented in Kitui County are:

a) Ensure that the sites targeted for construction of sand dams are subjected to further site-specific technical assessment studies to ensure the sand materials and site conditions are ideal for the construction of sand dams.

b) Ensure that local communities are fully involved in the implementation of the programme, through sensitization and awareness creation. This will ensure project ownership by the local communities and this will in the long run help in maintenance and operations of sand dams.

c) Create an effective system of monitoring and evaluation of the process of implementation of the project at county, sub-county, ward and village, so that challenges in implementation can be identified and dealt early enough.

d) Ensure catchment areas are protected through implementation of various soil and water conservation programmes, to control the destruction of vegetation and the resultant soil erosion. This will reduce entry of unsuitable sediment materials in sand dams and in the process ensure the constructed sand dams are able to provide water on sustainable basis.

e) Conduct training to sand dam contractors to ensure that all the contractors that will be engaged in the construction of sand dams are able to construct sand dams according to the set technical specifications and standards. Engagement of trained constructors will ensure that constructed sand dams are robust and able to withstand even the largest flashfloods.

f) Engage South Eastern Kenya University in research and consultancy works to ensure best practices and lessons learnt are documented and disseminated widely. The university could work with the County Government to establish monitoring stations in seasonal rivers aimed at establishing weather the constructed sand dams are performing as earlier envisaged.

7.0. SUGGESTED IMPLEMENTATION FRAMEWORK

The implementation of the Kitui Sand Dam Programme would be coordinated at various levels as described below.

7.1. Mechanisms at County Level

The County Government will establish the Kitui County Sand Dam Programme Implementation Committee at county level to coordinate the implementation of the programme at county level. The Committee will be headed by the Director of Water in the County Ministry of Water, Agriculture and Irrigation. The Committee will be multi-disciplinary involving membership of the Directors or Chief Officers in the County Ministries responsible for the environment, forestry, agriculture, water, rural development, lands and settlement. The Committee can also include representation of elected community leaders. The Committee will hold meetings on monthly or quarterly basis to discuss progress in the implementation of projects and deal with challenges faced in the implementation process.

7.2. Mechanisms at Sub-County Level

The County Government will ensure that in all the 8 sub-counties, Sub-County Sand Dam Implementation Committees are established. The Sub-County Committees will be chaired by the Sub-County Administrator and the Sub-County Water Officers will provide secretariat support. The members of the Sub-County Committee will be heads of sub-county departments responsible for rural development, water, environment, forestry, agriculture, lands and settlement. The Sub-County Committees will be meeting on monthly basis to discuss issues related to the implementation of projects.

7.3. Mechanisms at Ward Level

In each of the 40 wards, the County Government will establish Ward Sand Project Committee that will work closely with the Ward Development Committee. The Ward Committee will be chaired by the Ward Administrator and the Chairman of Ward Development Committee will provide secretariat support. The functions of the ward committee is to ensure that sand dams projects are implemented as planned and all major challenges will be communicated to the Sub-

County Committee for action where they cannot be addressed at ward level. In this respect the Ward Committee will provide an important oversight function on the implementation of sand dam projects at grassroot level.

7.4. Mechanisms at Village level

The Village Committees headed by the local Assistant Village Administrator will play a role of making sure that contractors undertakes construction works in sites that have been assessed and agreed with the local communities. The village committees will also play an important role in the mobilization of community support and labour where necessary.

8.0. MOBILISATION OF FINANCIAL RESOURCES FOR CONSTRUCTION OF SAND DAMS

8.1. Resources required

Considering that construction of a typical sand dam in Kitui County costs approximately KShs. 800,000, thet estimated cost for the construction of 2,400 sand dams is KShs. 1,920,000,000. The funds for the implementation of the programme would be obtained from various sources as indicated below. In view of the fact that the County Government of Kitui is limited in terms of human technical personnel, it would be important for the County Government to build the required capacity to enable full implementation of the programme. This will entail recruitment of additional staff at various technical cadres including water resources management, water engineering, project management, monitoring and evaluation, among others.

8.2. Funding by the County Government

It is expected that part of the funding for the implementation of the Kitui Sand Dam programme would be derived from the budgetary allocations to the County Government. In the current financial year, the County Government of Kitui is implementing 200 sand dams across the county. It is expected that with proper funding 2,400 sand dams will be implemented in the next three financial years.

8.3. Funding by the National Government

The national government, either directly to the County Government or through various national government ministries responsible for issues related to water and rural development is expected to channel some funds for the implementation of the programme.

8.4. Funding by Development Partners

Kitui County government will mobilize resources from various development partners. These include various non-governmental organizations (NGOs), including bilateral and multilateral sources. The major donors that would be approached include the Department of International Development (DFID), African Development Bank (AfDB), Japan International Cooperation Agency (JICA), USAID, FAO, UNDP, SIDA, SNV among others. Major NGOs that could be approached to support the implementation process includes Catholic Aid, SASOL, ADRA, Action Aid, among others.

8.5. Funding by the Community

The local communities will be expected to support the implementation of the programme through provision of labour and materials during the construction of sand dams. This will supplement resources that will be provided either by the County Government or the National Government through various ministries. It is also expected that well endowed members of the community will take the initiative of implementing some of the sand dams using their individual resources.

8.6. Other Sources of Funding

The County Government will also explore other possible sources of funding. For instance, the County Government will work closely with the local Members of Parliament to ensure Constituency Development Funds (CDF) are channeled to the construction of sand dams. It is also expected that Members of County Assembly will also mobilize for public contributions to enable construction of some sand dams at ward level.

9.0. MONITORING AND EVALUATION

The monitoring and evaluation of progress in the implementation of the Kitui Sand Dam Programme will be guided by the specific results-based indicators that will form part of the M&E Plan. The project will follow standard monitoring and evaluation procedures. The Project's Results Framework will include SMART indicators for each expected outcome and mid-term and end-of-project targets. These indicators along with the key deliverables and benchmarks will be the main tools for assessing project implementation progress. The means of verification will be summarized in the log frame. Monitoring and evaluation includes a series of linked activities, including annual project reports, mid-term evaluation and terminal evaluation.

Quarterly & Half-Yearly Progress Reports: These will be prepared by the County, Sub-County and Ward Committee and the reports will be assessed based on the projects Results Based Framework. The detailed half-yearly reports will be prepared and submitted to the Director of Water Services covering the periods 30thJune and 31stDecember of each year of implementation. The reports will include a summary of progress made since the previous biannual report and provide details of any unforeseen impediments to project implementation. The report will also include up-to-date financial information on the expenditure of project funds. These reports will be reviewed, amended as required and approved by the County, Sub-County and Ward Committees.

Annual Project Reports (APR): This report will be prepared by the Director of Water Services in consultation with the relevant Stakeholders and will be submitted to various committees at county level. The report will enable the partners of the project to obtain information on the performance of the project with regard to the implementation of agreed activities. The APR will also provide details on the project achievements, initial evidence of success, including constraints in the implementation of agreed activities and how those constraints/shortcomings will be addressed in subsequent years. The report will also include a compilation of lessons learned and financial expenditure statement. The review of APR will be based the logical framework matrix and the agreed performance indicators.

Mid-Term Evaluation (MTE): The project will undergo an independent Mid-Term Evaluation at the mid-point of project implementation. The mid-term evaluation will take place as indicated in the project milestones. The mid-term project evaluation will focuses on relevance, performance (effectiveness, efficiency and timeliness), issues requiring decisions and actions and initial lessons learned on the project design, implementation and management. The Terms of Reference for the Mid-term review will be prepared by the Director of Water Services and must be approved by the County Committee. The recruitment of a consultant to carry out mid-term evaluation will be undertaken following normal procurement procedures.

Terminal Evaluation (TE): An independent final evaluation of the programme will take place at least six (6) months prior to the final year of the project. This terminal evaluation will be undertaken in accordance with established procedures and will focus on the same issues as the mid-term evaluation but in addition it will also examine the early evidence of project impact and sustainability of results. The terminal evaluation will focus on the delivery of the project's outputs and outcomes. The final evaluation will assess the impact and sustainability of results. The Terms of Reference for this evaluation will be prepared by the Director of Water Services and will be approved by the County Sand Dam Programme Committee

Periodic Site Visits (PSV): The Kitui County Sand Dam Committee will conduct periodic visits to project sites in all sub-counties and wards. The purpose of site visits will be to assess the progress in the implementation of specific project activities in the field. A field visit report will be prepared by the County Director of Water Services within a period of one month after the visit to the field. The Audit Service may also undertake ad hoc site visits.

10.0. CONCLUSIONS

This study aimed at verifying the sites for the construction of sand dams that were proposed by the local communities at sub-county and ward levels. The study applied objective technical criteria to determine the suitability of the suggested sites. A total 2,573 sites were verified by the technical team of experts drawn from South Eastern Kenya University and the Kitui County Government. A total of 2,029 sites were found to be suitable for the construction of sands and it is recommended that further detailed site specific assessments be carried out before construction works begins. It is also recommended that the Kitui County commences with the implementation of sites that have been categorized as being excellent and very good. Once adequate funds have been obtained, the other sites that have been categorized as being good can be considered for implementation. The study has also recommended the mechanisms for implementation of the project to ensure benefits accrues to the local communities on sustainable basis.

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APPENDIX 1: TASK FORCE MEMBERS

S.NO.	NAME	ORGANISATION	ROLE	EMAIL ADRESS
SOUTH EASTERN KENYA UNIVERSITY:				
1. 1.	Dr. Johnson U. Kitheka	South Eastern Kenya University, School of Water Resources Science and Technology	Project co-ordination and management; Hydrological survey of proposed dam sites	Jkitheka@seku.ac.ke; Kolbio_kolbio@yahoo.com
2. 2.	Dr. Simon Nguluu	South Eastern Kenya University, School of Agriculture and Veterinary Science	Survey of proposed sand dam sites for irrigation	nguluu@yahoo.com snguluu@seku.ac.ke
3. 3.	Dr. Patrick Kariuki	South Eastern Kenya University, Department of Geological Sciences.	Installation of GIS and production of GIS maps	pkariuki@seku.ac.ke
4. 4.	Dr. Amos Mutua 5.	South Eastern Kenya University, School of Water Resources Science and Technology	Survey of proposed sand dam sites for fish farming	akyalom@yahoo.com amutua@seku.ac.ke
5. 6. 7.	Mr. Festus Mutiso	South Eastern Kenya University, School of Water Resources Science and Technology	Survey of environmental conditions	mutifestox@yahoo.com
6. 8.	Mr. Samuel Kamau	South Eastern Kenya University, Department of Geological Sciences.	Installation of GIS and production of GIS maps	Skamau@yahoo.com
KITUI COUNTY GOVERNMENT:				
1. 9.	Mr. Kennedy Mutati 10.	Kitui County- Ministry of Agriculture, Water and Irrigation	Support project coordination and management	kennedy.mutati@kitui.go.ke
2.	Mr. Dominic Mumbu	Kitui County-Ministry Environment	Survey of environmental conditions	dominicmumbu@gmail.com
3.	Mr. Paul Kaleve 11.	Kitui County- Ministry of Agriculture, Water and Irrigation	Survey of irrigation potential at the proposed sand dam sites	mukaleve@yahoo.com
4.	Mr. Julius Muindi 12.	Kitui County- Ministry of Agriculture, Water and Irrigation	Survey of hydrological conditions at proposed sand dam sites	muindi.julius@gmail.com
5. 13.	Mr. Kyuu Kang'e 14.	Kitui County- Ministry of Agriculture, Water and Irrigation	Survey of proposed sand dam sites	kyuu.kange@yahoo.com
6. 15.	Mr. Titus Saidi 16.	Kitui County- Ministry of Agriculture, Water and Irrigation	Survey of engineering aspects	Kilonzo.josphine@gmail.com

APPENDIX 2: Sand Storage Dams Questionnaire:

	Site 1	Site 2	Site 3
Serial No.			
Basin/Stream Name			
GPS Co-ordinates(E/N)			
Elevation(M)			
Site Name			
Location(Village)			
1. Technical Criteria:			
a) Stream Width (M)			
b) Fetch Distance (M)			
c) Distance to Access Road(KM)			
d) Banks Depth(M)			
e) Nature of the Sediments on the River Bed			
f) Sand Accumulation Rate			
g) Bedrock Exposed? (Yes/No)			
h) Soil Type/Color on the Banks			
2. Socio-Economic Criteria:			
a) Population Size to Be Served(H.H)			
b) No. of Livestock			
c) Water Demand			
d) Existing/Similar Initiatives			
e) Alternative Water Source			
f) Status of the Alternative Water Source			
g) Distance to Alternative Water Source(KM)			
h) Land Use			
i) Land Cover			
j) Overall Suitability			

APPENDIX 3: Sand Storage Dams Attribute Data Table (Guide)

	Attributes	Descriptions
1	**Longitude- [E]**	This is the coordinate value for the Longitude at the site. Referred to as Easting, **E**. For example; **0379375**
2	**Latitude - [N]**	This is the coordinate value for the Latitude at the site. Referred to as Northing, **N**. For example; **9806980**
3	**Elevation (m)**	The height above sea level. Given in metres (m)
4	**S/No.**	The site number. Listed in hard copy
5	**Stream**	The name of the stream where the sand dam is located or proposed. List provided in hard copy
6	**Village**	The village that will be served. List provided in hard copy
7	**Ward**	The Ward within Kitui County where the proposed site is located
8	**stream-width (m)**	The maximum width across the river channel. Given in metres.
9	**Bank-depth (m)**	The estimated depth of the river channel.
10	**Gradient**	Computed as the ratio between the estimated river bank depth and fetch distance. [g=bank depth/fetch distance]. Formula provided in Excel Sheet: [KITUI COUNTY_SSD Database Template]. Given as a dimensionless value
11	**Fetch-Distance (m)**	Estimated horizontal distance at the maximum capacity of the sand dam; measured Upstream. Given in meters
12	**Storage-Capacity (m^3)**	Computed from the estimated sand dam dimensions. The formula is provided in the Excel Sheet-[KITUI COUNTY_SSD Database Template].
13	**Distance-to-access-road (km)**	The estimated distance to access road. Given in Kilometers (km).
14	**Land-Use**	Describe the land use at the area close to the proposed site for the sand dam; for example; cultivation, grazing, settlements etc.
15	**Land Cover**	Describe the nature of nature of vegetation in the area close to the proposed site [for example: Bare land, Crop Land, Bush Land, Forest, Grassland]
16	**Soil-type/color**	Describe whether the soils on the river banks are [Loamy, Clay, or Sandy]. You can also give the color of the soil as; [Red, light-grey, Grey, black]
17	**Bedrock-Exposed**	In this column, Put YES if the bedrock is exposed or NO if the bedrock is not exposed on the river bed
18	**Sand-Accumulation-Rate**	Give the rate in a scale of; [Very High, High, Moderate, Low, or Very Low]
19	**Nature of Channel sediments**	Indicate the nature of sediments in the river channel e.g. sand, clay, mixture of sand & clay etc.
20	**Alternative-water-Source**	Give the specific alternative source of water; [for example a Borehole, Shallow well, River-water, Sand dam etc]
21	**Distance-to-alternative source (km)**	This is the distance to the specified alternative source of water. Given in Kilometers (Km)
22	**Status-of-alternative-source**	Specify whether it is [Very Reliable, Reliable or Not Reliable]
23	**Population-Size (H.H)**	Given in the estimated number of households to be served
24	**Number-of-livestock**	Estimated number of the livestock to be served
25	**Similar-Initiative**	Give the alternative method of water conservation being applied in the same area if any e.g. sand dam 200m upstream.
26	**Overall Suitability**	Specify the suitability of the site. for example excellent site, good site, fair site etc

APPENDIX 4: Questionnaire for Sand Storage Dam Project Stakeholders

SOUTH EASTERN KENYA UNIVERSITY
SCHOOL OF WATER RESOURCES SCIENCE AND TECHNOLOGY

THE COUNTY GOVERNMENT OF KITUI
MINISTRY OF AGRICULTURE, WATER AND IRRIGATION

QUESTIONNAIRE FOR THE ASSESSMENT OF OTHER SAND /SUB SURFACE DAM PROJECT INITIATIVES IN KITUI COUNTY

LESSONS AND CHALLENGES IN THE IMPLEMENTATION OF SAND DAM AND/OR SUBSURFACE DAM PROJECTS IN KITUI COUNTY

To: .....

.....

Questionnaire for Project stakeholders;

The Kitui County Government through the Ministry of Agriculture, Water and Irrigation is proposing to construct sand dams and subsurface dams in several seasonal rivers in the County/ Sub-Counties. It's a jointly undertaking, identification of 2400 sand/surface dams in the entire county with a vicar of implementing the same.

To facilitate successful implementation of the project, we are gathering information on the successes and challenges in the implementation of previous sand dams and subsurface dams in Kitui County. As a key stakeholder, we request for your comments on the successes and challenges experienced in the implementation of your similar project.

1. Name of the Project:……

2. The date of commencement of the project:……..

3. The source of funds for the project:……

4. The estimate cost of constructing the sand dam:……..

5. State whether the project is a community-based initiatives:……

6. Number of members of the project if it is a community-based project:

   ……..

7. Estimated number of beneficiaries:

   ……

8. Estimated number of people drawing water from the sand dam:……..

9. Estimated number of livestock drinking water from the sand dam:……..

10. Estimated number of farmers using water from the dam for small-scale irrigation:……

11. Estimated total size of farms using water from the sand dam for irrigation:……

12. State the types of crops that are irrigated with water from the sand dam:……..

13. State whether the crops are for either subsistence or commercial purposes:……

14. Estimate of incomes derived from sale of crops:……..

15. What major challenges have you experienced in the project?

    ……

    ……..

    ……..

    ……..

16. What measures did you undertake to address the above listed challenges?

……

……

17. What positive impacts have you noticed following implementation of the project?

……

……

18. What negative impacts have you noticed following implementation of the project?

……

……

……

……

We value your input.

Please fill and drop the same at;

The office of Deputy Director
Water resources development and services
P.O Box 412-90200
KITUI

In case of difficulties please contact; 1. Director (Water) - **0723585781**, 2. Dr. Kitheka (SEKU) - **0714645694.**