Towards Ensuring a Supply of Sufficient and Quality Water in the Lagam Escarpment and the Kerio Valley in Marakwet District, Kenya

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Abstract

This paper is based on a study that sought to determine the quality of surface water in use and the means of attaining sufficient water in the Lagam Escarpment and the Kerio valley, located Marakwet District, Kenya. This followed the realization that rivers have been drying up while springs have dwindled in the region leading to limited water supply and subsequent conflicts in water use, among the residents. Remote sensing was used to study both surface and ground water, though it was supplemented by various research methods such as the use of questionnaires, interviews, observation, sampling, experimentation and mensuration. Remote sensing, thus, was used to study surface water resources (their extent, depth, purity, density and types) besides identifying areas where ground water can be found-using various environmental leads, such as vegetation mapping, sedimentary rock identification and mapping of grey tone areas. An overlay of two Landsat satellite images of the area (1985 and 2000) was also done to give a picture of change in water cover over the years, according to GIS techniques. From the study findings a, it emerged that the quality of water was not uniform, just as some ground water in some parts of the area was far beyond the reach of man in terms of accessibility. Generally, deforestation and water pollution may be the leading causes of water shortage in the study area, besides water losses resulting from excessive water percolation (infiltration) into the Earth's crust and water mismanagement. The research study is of benefit both to future researchers in the area of study and the Marakwet community, especially if the research recommendations are implemented, such as those pertaining to community involvement in the quest for water provision and sufficiency, projects for water sourcing, water catchment protection and water management procedures.

Keywords: Ensuring, Supply, Sufficient, Quality Water, Lagam Escarpment, Kerio Valley, Marakwet District, Kenya

1. Introduction

Various people, especially at the international and national level, have done elaborate studies on water, though majority of these works do not give a hint on the applications of remote sensing to assess water availability. The general works on water include the works of such people as Reichard *et al*. (*Ground water contamination*, 1990). This book discusses ground water as a resource that is of significant social value. Castelino and Khamala (*Sources of water and water provision*, 1977) argue that the provision of just a few cupfuls of water a day can highly contribute to the life of an ASAL inhabitant. Similarly, Raghunath, in *Hydrology; Principles, Analysis and Design* (1991), discusses a variety of aspects that pertain to water – including precipitation as a source of water. The oldest studies that have been done in the area of study are mainly geological and date back to the early part of the 19th century. They include the works of such people as Gibson (*Geological Sketch of Central East Africa*, 1893), Champion (*Physiography of the Region to the West and South West of L. Rudolf*, 1937), Gregory (*The Rift Valley and the Geology of the E. Africa*, 1921), Fuschs (*The Geological History of the L. Rudolf Basin, Kenya Colony*, 1939) and works of geologists like Mason and Gibson, who carried out a geological study of the Kolossia-Tiati area (1957). According to Mason and Gibson (ibid.), the Lagam-Kerio Valley rocks comprise lavas, tuffs and volcanic ash that may have been formed during the Rift Valley formation. As for Champion (ibid.), the Kerio Valley is filled with alluvium while the Elgeiyo Escarpment (Lagam) "has its base in gneissic rocks having irregular caps of phonolite" (Champion, 1937, p. 97). Gregory (ibid.) notes that the Western fault of the Rift Valley in Kenya bifurcates North of Nakuru so that the plateau of Kamasia (Baringo block) stands in between the two branches of the Great Rift Valley (Gregory, 1921, p. 215). This means that the Kerio Valley is a western arm of the Great Rift Valley, the Eastern arm being the Suguta-Baringo valley, which has Lake Bogoria and Lake Baringo in it. According to Fuschs (ibid.), the Kerio Valley may have been formed during the Pliocene period since the "Kerio river was probably initiated in the miocene period and its course was modified by the Pliocene movements" (Fuschs, 1939, p. 223). These may be the movements that may have placed river Kerio within a fault line.

Mason and Gibson (1957), in their geological study of the Kolossia-Tiati area, state that the Escarpment Rivers form the Western tributaries of River Kerio and they are "diverted and used for irrigation purposes on the slopes of the escarpment" (p. 8). Recently, following the arrival of such organizations as the Kerio Valley Development Authority (KVDA), Semi Arid and Rural Development Programme (SARDEP) and Water Assessment and Planning Project (WRAP), more studies, especially as relating to water, have carried out in the area of study. SARDEP, for instance, has carried out a study on participatory land use in Marakwet District and discovered that people in the District "have to walk everyday to springs and rivers where they can only find contaminated water" (SARDEP, 2002, p. 11). Water pollution, according to the same report, is a product of natural processes as well as human activities such as urbanization, poor farming methods and soil erosion owing to deforestation. In fact, Kapsowar town is said to be "killing the surrounding natural habitat" (SARDEP, 2002, p. 13), showing that urbanisation can be a cause of water shortage through pollution. Besides water pollution, the report also owns up deforestation as a cause of water shortage, especially on the Lagam Escarpment where shifting cultivation and poor road construction are named as the culprits of increased soil erosion.

WRAP (1984) carried out a regional assessment on the quality and quantity of water resources in the Kerio Valley and the escarpment of the Keiyo-Marakwet Districts. In its report, WRAP notes that ground water and surface water in the area of study is not evenly distributed (WRAP report, 1984, p. 8). It also notes that rivers and springs are the dominant sources of water in the study area where artificial ground water harvesting is limited. Related water studies have also been carried out in the neighbouring districts, such as in West Pokot. Van Klinken, in a paper submitted for the African Water Technology conference in 1987, gives an elaborate explanation on the design and functioning of the Pokot furrow system as far as irrigation is concerned (The Pokot Traditional Furrow Irrigation, 1986).

As for remote sensing application in assessing water availability, the main works have been integrated in Remote Sensing books, for instance, Drury (*A guide to Remote Sensing, Interpreting Images of the Earth*, 1990), explains how remote sensing can be used to study water quality, while Sabins (*Remote Sensing Principles and Interpretation*, 1986) explains the significance of using lineaments to locate ground water resources. Separately, Lillesand and Kiefer (*Remote Sensing And Image Interpretation*, 1999) explain how water pollution can be detected using normal colour and ultraviolet aerial photography. Barret and Curtis (1992), in *Introduction to Environmental Remote Sensing*, state that the satisfactory monitoring of environmental water is one of the most difficult yet pressing problems confronting remote sensing as a distinctive discipline today. Engman and Gurney (*Remote Sensing in Hydrology*, 1991) also discuss varied aspects of water that can be studied using remote sensing, for instance, application of remote sensing to investigate ground water resources.

The Economical and Social Commission for Western Asia (ESCWA), United Nations Environmental Programme (UNEP) and Islamic Development Bank (IDB) have funded a study on the use of remote sensing and GIS techniques to assess water resources in the ESCWA region (*Water Resource Assessment in the ESCWA Region Using Remote Sensing And GIS Techniques-A Final Report*, 1996). From the study, water resources, both surface and ground, were mapped out in Egypt, Iraq, Jordan, Lebanon, Syria, and Arabian countries, using aerial photography and satellite imagery. In other distant lands, remote sensing and Geographic Information Systems (GIS) have also been ostensibly applied to study water resources.

Such studies include those carried out by Jeyram, Mohabey, and Adiga (2004), who applied GIS to assess ground water potential in Uma-Kalhar watershed, Chandraphur District of India. In Malaysia, Matjafri, Abdullah, and Lim (2004) have used satellite images to map the quality of water around the Penag Island. The Malaysian scholars noted that the traditional water mapping and monitoring techniques have already become too expensive and a solution is found in remote sensing surveillance (*Malaysian Tiungsat-1 Imagery for Water Quality Mapping*, 2004).

In Kenya, remote sensing and geophysics have been used in the exploration of ground water in Nyanza Province by Van Lissa, Van Maanen and Odera (1987). These researchers note that faults and fractures in an area's rock may be an important cue to the existence of ground water. In a similar research, Krol (*Application of Remote Sensing for Ground Water Survey in Kenya*, 1986) applied remote sensing in the study of water resources in Kenya, especially in the Kerio Valley, L. Baringo area, Mathews Range and East Samburu. For the Kerio Valley, the researcher identified alluvial sediments along the Kerio River, coarse flood sediments in the valley alongside weathered and fractured zones in the area rock **-** as potential aquifers.

Krol's work may actually be considered the pioneer remote sensing work on water, as far as the area of study is concerned. .

1.1. Statement of the Problem

In the recent years, it has come to be realized that water supply is on the decline in Marakwet District, especially in the drier areas of the District such as the extensive Lagam Escarpment and the Kerio Valley, yet water is the livelihood of the people in ASALs. The limited water is causing conflict and competition in its usage, amongst humans and between humans and animals.

Water shortage is at its extreme levels during the dry season in the ASALs of Marakwet District, such as between July and March. The situation is even harder for those who farm at the extreme ends of the Kerio Valley, near river Kerio (*Kew*). During the dry season, these people will either make do with stagnant water that is found in pools along drying up rivers, or face health problems arising from thirst. The problem is that the stagnant water (*Tangiyiy*) is shared with animals, both wild and domestic, so that its safety as far as health is concerned, becomes doubtful. This is because the animals do not only turbidize the water, but also excrete in it or leave remnants of their feed in the water. Worms then may not be absent in such water, besides bacteria and algae that thrive well due to eutrophication. For this reason, stagnant water that is found in pools in the Kerio Valley, during the dry season, is always greenish, as it grows green algae amid a horde of other micro-organisms, including the dangerous Cynobacteria – all of which will be harmful to man if ingested.

Visible water shortage, such as less water in rivers or drying up of streams, as in above, make one problem, the other being water shortage resulting from unavailability of safe drinking water. During the wet season, for instance, water may flow in abundance but the water is of poor quality. This is supported by ground knowledge that the people living on the Lagam escarpment and the Kerio Valley often suffer from Typhoid and other water borne diseases. The research, on which this paper is based, therefore investigated water quality and suggested ways of attaining sufficient water **-** besides ways of mitigating water pollution problems.

1.2 The Study Area

The study was conducted in the Lagam escarpment and Kerio Valley in Marakwet District, Kenya. Generally, the Marakwet District has been divided into three main topographical regions, which run parallel to each other in a N-S direction. These are the Highland Plateau, the Marakwet Escarpment (Lagam Escarpment) and the Kerio Valley. In terms of climate, the Escarpment and the Kerio Valley receive less amounts of rain ranging from 750mm to about 1000mm per year. Rainfall is trimodal with first rains occurring in March, second rains in July/August and third rains in October/November, though the rainfall varies from place to place and is generally unreliable. Evaporation is also high in the area of study being about 2400mm per year (Mason & Gibson, 1957). Thus, a larger part of the Marakwet District may be described as Arid and Semi Arid Lands (ASALs). In fact, irrigation cultivation is predominant in the Lagam Escarpment and the Kerio Valley.

Winds are moderate, at most in the area, with a few storms during the wet season (C*hepkiriri*, as they are called in the local language).

Whirlwinds are also experienced during the dry months; but they may not be described as dust storms. As for humidity, it may be said to be low during the months of May, June, September and December, but quite high during the wet months, owing to the region's high temperatures. The other forms of precipitation that are less accounted for in the area's climate are frost, fog and dew, which are common in the highland plateau. In respect to geology, Precambrian basement rocks are the oldest rocks in the area of study. These comprise of metamorphosed sedimentary rocks (formed by regional metamorphism during the rift valley formation) such as gneiss, schist, quartzite and marble. They are found as rock outcrops along the base of the escarpment, while their fragments litter the escarpment itself forming lithosolic soils. On the Kerio Valley floor, the basement rocks have been buried by tonnes of sediments and volcanics.

Old tertiary rocks are also present in the area of study and are represented by conglomerates, sandstones and siltstones, which are limited in extent. Similarly, volcanic rocks are also quite common in this area and they may be dated back to the mid Miocene to mid Paleocene periods (25-70 million years ago). They include basic lavas (basalts) and intermediate lavas such as phonolite and trachyte. Basalts are commonly found around the river Kerio area, besides phonolite that has build the many hills punctuating the lowland terrain of the Kerio Valley. Trachyte rock is more recent and is found on the Eastern bank of river Kerio towards Baringo East, at the foot of Mt. Tiati. Alongside the rocks, the area has alluvial fans and landslide mounds that are found along the foot of the escarpment. These stand out as rock vaults, grit or clay hills.

Noticeably, the Lagam Escarpment and the Kerio Valley are endowed with minerals that are lodged in Gneiss rocks. They include green, red and pink Garnets (at Rorok hill, Kamworna and Katilit), Hematite, Chalk (at Ng'achar), Marble (at Kowow and Koitillial, around Arror) and alluvial Gold at the banks of river Embobut. Faulting on the Escarpment is evident in many places, though many of the faults have been buried by alluvium. To the North Western part of Tot, for instance, there are faults that are marked by hills build of brecciated and silicated tertiary superficial deposits. These are the same faults that have been colonised by vegetation lines.
The vegetation on the escarpment is mainly sparse, sometimes lacking in certain places. The vegetation here is predominantly shrub and woodland type, where most trees are drought resistant. Fruit bearing trees are numerous in this vegetation and they include *Murkullyon, Tokometwo, Tiling'wo, Tillomwo, Tuyunwo, Tongururwo-* (as they are locally known), most of which are important sources of food. Thorny trees are also not uncommon in this area. They consist of a number of acacia species and some of the fruit bearing trees, while the non-thorny woods include *Tobong'wo* (Parasol Tree), *Ililwo* (E.A Yellowood), *Kerelwo* (Croton), *Rotyon* (Sausage Tree), *Kurion* (Teclea), *Sigowo* (African Satin Wood) and *Oron* (Tamarind), just to mention a few that are also found in the Kerio Valley. The escarpment woodland graduates into a forest on the highland plateau, where deforestation threatens it. On the valley floor, though, natural vegetation comprises tall grass and a variety of thorny bushes, acacia being on the lead. The acacia forest is particularly denser, with taller trees towards the Kerio River, just as there is more grass in the swampy portions of the valley.

In both the Escarpment and the Valley, planted vegetation is quite prevalent. It includes the many Mango forests, cassava crops and banana plots-amid a host of other crops. Riverine vegetation is also uniquely dense and healthy in both the Lagam Escarpment and the Kerio Valley. This consists of fig trees such as *Sitet* (The Bark Cloth Fig), *Boryotwo* (Cape Fig) *Mokong'wo* (Sycamore Fig) and *Simotwo* (the Strangler Fig) among other trees.

In 1989, the total population of the Marakwet District lay at a figure of about 108,250 people with the highland plateau and the Lagam Escarpment having more people. The Escarpment is even more densely populated than the other regions because of its warm temperatures, enhanced safety from cattle rustlers and absence of mosquitoes. During the recent years, though, the population of Marakwet District has been decreasing, owing to family planning and emigration of people from the district to the neighbouring districts of Trans Nzoia and Uasin Gishu, especially as a result of cattle rustling. In itself, cattle's rustling is a backward practice that is bend to ruin development in the area of study, though a ripe topic for another study. As for the population's structure, it can be said that there are more women than men in the District because men are the ones who move out to towns and high potential areas in search of employment, besides succumbing to the wounds of the cattle rustlers' guns. In the year 2001, for instance, cattle rustlers killed about 100 men and 40 women in the area of study (Chief's account, Endo Location).

Children aged 0-14 years make up about 48.8% of the population, while old people of 80 years and above contribute a marginal 1.1% of the total population (*Marakwet District Development Plan*, 1997-2000).

This means that the population has a high Dependency Ratio, especially from the children's quarters. Consequently, food production should be enhanced in the area of study and it can only be done with sufficient water.

The area's drainage forms a part of the Lake Turkana drainage basin, through the river Kerio drainage system. The main sources of water in the area of study (the Lagam Escarpment and the Kerio Valley) are rivers, furrows, springs, swamps and rainfall. The rivers originate from the forested areas of the highland plateau, and they include Embobut, Embosumer, Embomoon, Embochesegon and EmboArror – noting that 'Embo' is a Marakwet term that is synonymous to the English word river. Most of these rivers are perennial, though their flow has become seasonal so that some of them no longer reach river Kerio, where they should be draining their waters. Springs are mostly found at the foot of the Lagam Escarpment, and they are all products of sub-surface water flow, probably right from the highland plateau. Their examples include the Kipkoito Springs, Kiptegan springs, Kabetwa Springs and the Chesongoch springs, among others. Today, the water coming out of these springs has also dwindled quite a lot. Swampy regions in the area of study are mainly found on the floor of the Kerio Valley and may be described as extended springs, or areas of water collection during rainy seasons. They form good grazing areas for livestock during the dry season, besides providing water for animals in grazing.

Rainfall remains the overall provider of water in the area of study, though rainwater harvesting is not very well developed. The rainwater that is harvested is only by natural means so that what is stored by the Earth is what will benefit the people most. Unfortunately, deforestation in the highland plateau seems to have destroyed this natural process of ground water recharge.

2. Materials and Methods

Both structured and unstructured questions were used in interviewing the people in the study area. The author held interviews anytime, whenever and wherever respondents were found, such as at home, in their farms, at water points and even along the road. Questionnaires were administered to various people and in a case where a respondent could not read nor write, the questionnaire bearer gave aid. Questionnaires were also administered randomly, for instance whenever and wherever a respondent was found. Samples of water were collected from two rivers and two springs. The rivers are Aaror and Embobut while the springs are Chebenow and Kiptegan springs. The various secondary data sources that were studied, as relating to the area of study and the question at hand, included Topomaps of the region, aerial photographs, books and satellite images. Ground based photographs were also used to collect data on faulted areas where water may be found, wet spots in dry areas and dry rivers fossilised by rock boulders-among other features. In the study, both participant and non-participant observation were also engaged to collect data. Observation was used to collect data on water use, stream flow, spring flow and cases of water pollution.

2.1. Remote Sensing

Remote sensing is a growing field of science that involves the measurement of electromagnetic energy that can be used to characterize the landscape – or infer properties of it. For its definition, remote sensing may be said to be reconnaissance from a distance, or the collection of information from an object without being in touch with the object. It has also been defined as the science of deriving information about the Earth's land and water areas from images acquired at a distance (Campbell, 1987). In this field of science, different sensors are used to provide unique information about the properties of the Earth's surface or shallow layers of the Earth. Examples of such sensors are, for instance, the Thermal sensors that measure surface temperatures and Microwave sensors that measure the dielectric properties of the soil (Engman & Gurney, 1991). The work of the remote sensing specialist is to interpret these remotely sensed properties of the Earth; in a way that viable information is generated.

There are four basic components of remote sensing that primly influence (limit or control) what one can measure about the Earth's surface from remotely sensed images. These are: Radiation source (which may be natural or artificial), transmission path, nature of the target and the kind of sensor that is used. Some sensors, for instance, can penetrate clouds to image what is on the Earth's surface (such as radar sensors) while others cannot image well when atmospheric conditions are unstable, as in the case of aerial cameras.

Depending on the interaction of these components, various photographs and satellite images are usually produced by remote sensing. Some of these are the ones that have been studied and analysed to provide information pertaining to water availability in the area of study, since remote sensing can be applied successfully to investigate both surface and sub-surface or groundwater resources.

Although remotely sensed images seldom replace the usual sources of information concerning water resources, they can provide valuable supplements to the field data, by revealing broad scale patterns not recognizable at the surface. Remote sensing records changes that take place over time and provides information (data) for inaccessible regions and water bodies.
For surface water resources, remote sensing - both aerial photography and satellite imagery, provides information on:

i) The extent of water bodies and the changes that take place in the size of a water body over time
ii) The depth of a water body
iii) Water purity
iv) Drainage patterns or stream network features
v) Surface runoff characteristics
vi) Density of water bodies
vii) Type of surface water
viii) Presence or absence of a surface water feature

Remote sensing also plays a major role in the investigation of ground water, which is an important source of water in ASALs. This is done through soil moisture mapping. Soil moisture may be defined as the temporary storage of precipitation within a shallow layer of the Earth that is generally limited to the aeration zone or the root zone. This is the moisture that forms the bulk of evapotrasnpiration water, if it does not percolate to the phreatic (saturated) zone as ground water recharge. The origin of soil moisture may be precipitation, or underground water that attempts to escape as evaporation, through capillary forces, to the surface of the soil. Whenever a soil displays wetness, presence of ground water may be inferred.

Data analysis involved analysis of GIS layered data, use of satellite images and topographical maps, presentation of ground photographs, drawing of tables and quantitative analysis (where questionnaires are concerned). Mention was also made on water demand and distribution in the area of study, water quality and ground water potential.

3. *Results and Discussion*

3.1. Surface Water purity and Quality

Water quality today has attracted a great deal of attention from environmental scientists (CPLO, 1986). For its definition, water quality refers not only to the chemical but also physical (appearance) and biological characteristics of water in an area. Turbidity, which has been mentioned earlier, signifies physical impurity of water, which may also be standing for chemical as well as biological water impurity - if investigated further. Water that is not harmful because its physical, chemical and biological characteristics are not dangerous to its users may be considered to be of good quality (pure or potable water). The reverse of this is polluted or impure water that is of poor quality. Water is considered polluted when the presence of impurities in it is sufficient to limit its use for a given domestic and\or industrial purpose (Lillesand & Kiefer, 1999). Notably, not all pollutants are as a result of human activity.

There are natural sources of water pollution such as minerals leached by rainwater into a water body and rotting vegetable matter along a river course or around a water body. On the other hand, the various pollutants that result from human activity are many and diverse. They include:

- Domestic sewage (from pit latrines)
- Animal droppings, especially from animal sheds (*Kano* and *Katich*)
- Pesticides, especially from the spraying of citrus fruits
- Fertilizers, which may be in limited use in the area of study, with an exception of the highland plateau
- Detergents
- Sediments, owing to excessive water runoff
- Leacheate from graveyards

From water samples that were collected from two rivers (Embobut and Arror) and two springs (Kiptegan and Chebenow), the following information was deduced as pertaining to surface water quality.

Table 1: Some of the Pollutants Found in River Water (Measurements are in mg\l)

River	Date of Sampling	PH	NO_4	Fe	PO_4	F	SO_4	TDS
Embobut	14.04.05		0.2	0.22	0.1	0.06	1.0	
Arror	14.04.05		0.6	0.22	0.19	0.03	6.0	

<u>KEY</u>
PH- A test of water acidity, i.e 1-6 is acidic while 8-14 is alkaline.7 is neutral
NO_4 - Nitrate
Fe-Iron
PO_4 - Phosphate
F - Fluoride
SO_4 - Sulphate
TDS -Total Dissolved Solids

The above information can be compared to one that was recorded by Wrap in 1983, which is as shown below.

Table 2: Data adapted from Wrap Report

River	Date of Sampling	PH	NO_4	Fe	PO_4	F	SO_4	TDS
Embobut	10.03.83	7.2	_	_	_	0.06	1	37
Arror	10.03.83	7.8	_	_	_	0.2	Not recorded	62

Source: Wrap Report, 1984, Annex 4-6, p. 4-5

The spring water was also sampled and the table below was the result.

Table 3: Some of the Pollutants Found in Spring Water

Spring	Date of Sampling	PH	NO_4	Fe	PO_4	F	SO_4	TDS
Kiptegan	14.04.05		0.7	0.07	0.17	0.7	25.0	
Chebenow	14.04.05		0.5	0.09	0.17	0.75	2.0	

For the two springs whose waters were sampled, previous data was not available

Though the total amount of dissolved solids (TDS) in the two studied rivers does not exceed 100mg\1, it is still quite high especially for river Arror where TDS levels can rise up to 126mg\1 during the wet season (WRAP, 1984). As for the other chemical components mentioned above, there seems to have been a rise over time, for instance fluoride that has risen from 0.2 mg\l in 1983 to 0.3mg\l in 2004. It should be noted that a normal colour aerial photograph should be used to give information on the purity of water in an area just as mentioned in chapter three of this paper. Again, high resolution false colour Landsat images can give the same information.

3.2. Drainage Patterns

Rivers in the area display a dentritic as well as a parallel kind of drainage pattern, especially on their way down the escarpment to the Kerio River. On joining River Kerio, the rivers assume a trellis kind of drainage pattern since the rivers join the Kerio River at more or less right angles. These drainage patterns are clearly seen on the satellite images used in the study.

3.2. Ground Water\Sub-Surface Water

Ground water resources, as mentioned earlier, have not been fully utilized in the Lagam Escarpment and the Kerio Valley yet ground water has lots of advantages over surface water, for instance, ground water is not readily affected by adverse weather neither is it susceptible to catastrophic events such as volcanicity, war and landslides.

Ground water is not also easily polluted compared to surface water, besides being cheaper to supply because it does not often require an elaborate piping system. Consequently, the ground water that the people use in the area of study is the one that has come out of the earth as springs. This shows that there is still a lot of ground water in the study area that has not been utilized by the people and it is this same water that remote sensing strives to identify for future use. The following factors of ground water were assessed by the study.

3.2.1. Ground Water Quality

Ground water in the area of study is hampered by a problem of saltiness. According to the 1984 Wrap report, the water is either of sodium bicarbonate or magnesium bicarbonate type, when it was sampled from drilled boreholes (WRAP, 1984, p. 7). High TDS levels and high fluoride concentrations also limit the portability of ground water in some parts of the study area, especially in areas where fluoride concentrations exceed the WHO limit of 1.5mg\1, for instance along the Kerio Valley.

3.2.2. Ground Water Accessibility

Ground water in the area of study is not also evenly distributed neither is it uniform in its depth. In some areas, like the Lagam Escarpment, the water table can be as deep as 500m (or more) below the surface while on the valley floor, the water table can be estimated to lie at about 50 to 150m below the surface. According to the 1984 WRAP report, the depth of a borehole that was dug at Tot area lay at 96m below the Earth's surface (WRAP, 1984, p. 3- As for its occurrence, Ground water is associated with:

- Weathered or fractured zones in metamorphic and volcanic rocks
- Sediments interbedded between volcanic rocks
- Flood plains (such as along River Kerio)
- Torrent wash deposits (screen fans along the Lagam escarpment)

3.2.3. Sub-Surface Water Mapping

Ground water mapping can be done through various photography and imaging techniques. In all the remote sensing techniques that were used in the study, three factors were sought due to their association with groundwater. These are:

- Healthy vegetation islands or lines
- Geological lineaments
- Sedimentary rocks

The following are examples of some of the remote sensing techniques that were used to map out ground water in the area of study.

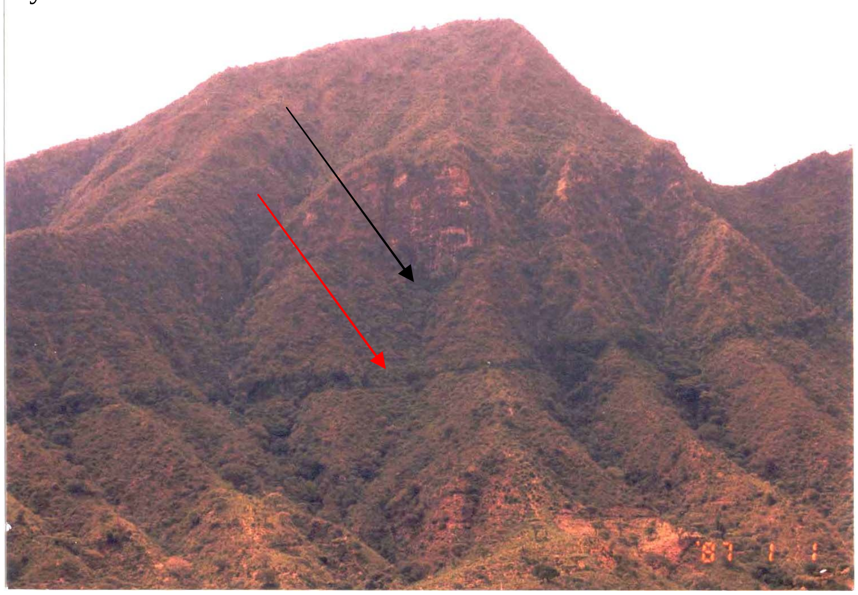

Plate 1: A ground photograph showing healthy vegetation islands on Wewe Hill to the northwest of Tot centre

The area pointed by the black arrow on the hill represents a wet spot where the people can tap ground water for use. The area pointed by the red arrow, though is a water furrow (Kowow furrow), which is one of the oldest water furrows cutting across the escarpment from river Embobut. There are many others of the kind, which are unfortunately experiencing a low water flow due to the high water demand in the area against the decreasing water in the Embobut River. The reduction in the flow of water furrows is also as a result of excessive water loss accruing from damaged furrow walls due to soil erosion and crab (*Chemoter*) attack.

Plate 2: Ground photograph showing healthy vegetation lines (areas of fractured rock) on the escarpment above Tot health centre (also North Western part of Tot)

The areas pointed by the black arrows in Plate 2 above represent areas of healthy vegetation lines, which are synonymous to fractured rock zones where underground water may be in existence. There are other remote sensing techniques, other than the above, that can also be used to map out ground water. These are for instance, the use of Radar imaging and Thermal Scanners. While thermal scanners can identify cool areas on the ground, due to moisture, Radar images diffuse the scattering of electromagnetic energy so that sand furrows and plains can stand out as dark signatures on the Earth. Naturally, and noting that sand are depositional materials, the dark areas on a radar image can be investigated for ground water just as the cool areas of a Thermal Scanner image.
Generally, though, it should be noted that the remote sensing images and ground photographs that have been used in this paper do give a myriad of information about water resources in the area of study. One image, consequently, may be interpreted to give more than one piece of information as pertaining to water.

3.3. Water Demand and Supply

Information was also collected through questionnaires on water demand and supply in the area of study. The following figures were then picked out:

- The average amount of water required per an individual per day is 35 to 45 litres
- The amount of water required by an individual's livestock per day is 200 to 300 litres
- The amount of water needed by an individual for irrigation of land is around 1728 million litres (A filled sample of the questionnaire used is attached to this paper)

According to the Wrap report of 1984, the amount of water that was needed by an individual per day in 1979 was 25 litres while livestock units required about 75 litres each per day (WRAP report, 1984, p. 6-5). The report does not give information on irrigation water requirements. Noticeably, water demand per an individual in the area of study seems to have escalated over the years, for instance from 25 litres to 300 litres.

As regards water supply, it can be said that most parts of the area of study are served by surface water, mainly rivers, furrows and springs. The problem here is that most of this surface water is not potable neither is it sufficient. Over the escarpment, for instance, furrow water is immensely polluted by organic waste so that it is not safe for drinking. Again, the furrow water is over diverted, through mini furrows, into people's farms and homesteads so that the water seldom reaches the valley. The water shortage that ensues, then, causes war between the Valley and the Lagam residents, bringing out tragic results.

From the data analysis, it becomes evident that there are areas with so much water, for instance around River Kerio, but the population of the people utilizing the water is quite low. There are also areas with many people but less water, such as the Lagam Escarpment. Similarly, there are areas with lots of water which is not potable due to pollution, for instance Chebenow springs, just as there are areas with lots of water which is not accessible, for instance ground water in the Lagam Escarpment.

3.4. Conclusion and Recommendations

It is true that the area of study is facing water scarcity and there is need for adequate supply of potable water. This then means that we have to join hands, all those who have an interest in the area of study, to seek a means of aiding sufficient water supply, noting that the provision of just a few cupfuls of water a day can highly contribute to the well being of an ASAL inhabitant (Castelino & Khamala, 1977). To achieve such a provision, the following must be attempted in the study area:

3.4.1. Community Involvement

The community should be highly involved in all the attempts that will lead to sufficient water supply in the area of study. The community should thus be engaged in such projects as:

- Borehole digging
- Furrow management
- A forestation
- Construction of ground water reservoirs in the Lagam Escarpment
- Construction of water tanks (concrete) to tap rain water in homes
- Management of water projects

3.4.2. Projects suitable for Non-Governmental Organizations

Since the region is Semi Arid and economically unstable due to cattle rustling, majority of the people may not manage to financially support the various projects that will eventually lead to water provision. NGOs funding may thus be directed towards such projects as:

- Borehole drilling
- Construction of Earth reservoirs
- Furrow construction
- Poking of aquifers (and all wet spots that will be remotely sensed) both on the escarpment and in the valley
- Construction of pit latrines, especially in the escarpment

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