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Farming methods, crop water use and conservation technologies

By

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WATER USERS ASSOCIATION SUPPORT INITIATIVE REPORT

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Introduction

This document aims to address the theme 'to contribute to improved water resources management through the development of appropriate water management tools, leading to informed decision making in water resource management and conflict resolution' of the Mpala project and respond to water information needs and resolutions raised by stakeholders and basin inhabitants during the participatory workshop on *Partnerships And Information Needs For Improved Water Use, Allocation And Conflict Resolution* held in August 2002, which recommended promotion and adoption of 'Technologies For Suitable Water Management'.

The workshop identified water problems as water scarcity, high variability of water availability in space and time and inadequate access during low flows. The problems cited by basin inhabitants through participatory appraisals and reiterated in the workshop are due to catchment degradation, dependency on river water, inefficient irrigation practices and increased human and animal population that has increased demand. Water scarcity situation has also been stamped by the central provincial water engineer Mr. Tom Ogalo saying that "a water shortage has hit the Mt. Kenya area following a drop in river levels' and that " the rivers supplying the semi-arid Laikipia District were the most affected' (DN, Friday, August 23, 2002). Such water scarcity scenarios are common in the basin during the dry seasons.

The workshop resolved that technologies for suitable water management should be put in place to solve the water problems. These technologies, in pursuit of 'efficient and beneficial use of water in the public interest' and 'applicable catchment management strategies' as outlined in the current water bill (the water bill, 2002), hinge on:

1) Rain water Harvesting technologies
2) Promotion of better irrigation methods for efficient water use and,
3) Promotion of sustainability of our catchment areas that are already destroyed.

Water management problems in the basin are usually associated with the history of settlements, land use, vegetation distribution, and climatic characteristics and constraints.

Settlements, land use and Vegetation distribution

- **Settlements**

After Kenya's independence in 1963 followed government's initiative to resettle landless Africans. This involved subdivision of white owned farms and establishment of settlement schemes. This involved land-buying companies that bought and subdivided land amongst its shareholders. Early settlements on the Ewaso Ng'iro north river basin established through such mean include Naro-Moru, Kalalu, Ngusishi Kithithina, Ex-lewa, Nyandarua and West Laikipia settlements. About 70% of the farms have sizes between 1 and 5 acres. The first settlements focused on the few areas with high agricultural potential before shifting the focus to scramble for land even in areas of low agricultural potentials. Agricultural productions are unable to bridge the gap between food demand due to increased population and supply. Due to lack of appropriate farming technologies in the area, production has remained low and highly variable while scramble for irrigation water has generated conflicts.

- **Land use distribution**

Land use varies from forest reserve on the upper mountain slopes to large and small scale farming on the lower mountains slopes and foot slopes to public and private ranches on the dry lowlands. Landuse is however changing rapidly especially on the lower mountain slope and foot slopes where large scale irrigated flower and vegetable production is taking root. Figure 1 shows the ecosystem situation in the basin.

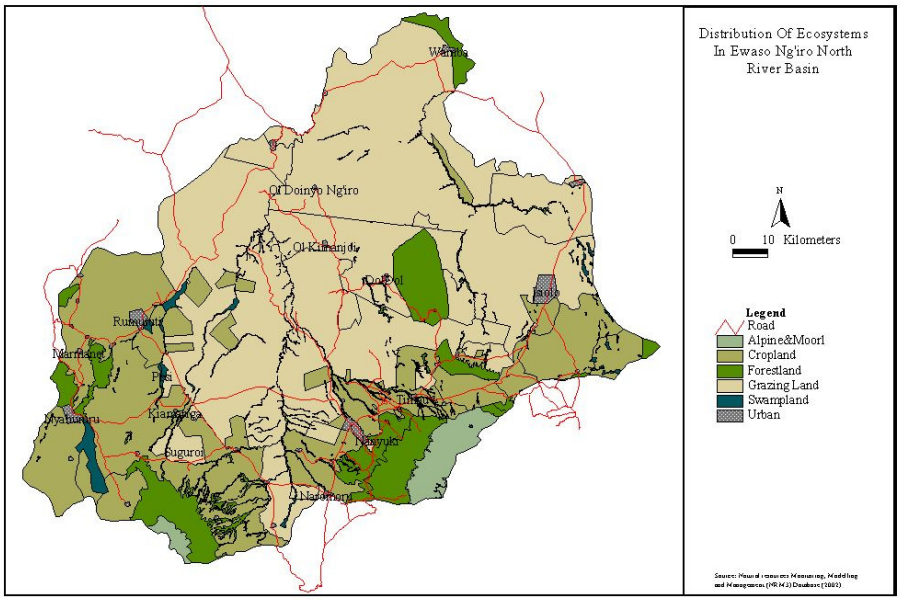


Figure 1: **Ecosystem Distribution in the basin**

Grazing land, comprising of livestock and wildlife grazing areas under private, communal and reserve management, is the most widespread (Table 1). This area is not suitable for crop production and is inhabited by sedentary and nomadic pastoralists.

Table 1: Area Under Different Ecosystems

Ecosystem	***% of Basin area***
Grazing land	55
Cropland	32
Forest land	10
Alpine Moorland	2
Swamps	1

- **Vegetation distribution**

Vegetation in the basin is comprised of shrub-bush grassland, grassland, woodland/bush land and forests. Forests are mainly dry land forests, river line forests and wet forests occupying the mountain areas. These occupy only 11% of the whole basin with the rest occupied by short shrubs and open grasslands.

Climatic characteristics and constraints

The Ewaso Ng'iro River Basin is characterized by a rapid highland to lowland climatic change with vast parts lying within semi-arid and arid environment. Climatic variations are mainly determined by altitude and aspect due to the close proximity to Mt. Kenya. The variations also affect vegetation and crop production through rainfall, evaporation and temperatures.

- ***Rainfall and rainfall distribution***

Annual Rainfall received within Ewaso Ng'iro river basin varies between 1200mm recorded within the Mt. Kenya and the Aberdares and less than 500 recorded in the lowland plains as shown in figure 2.

The rainfall received is distributed within 3 main seasons Vis a Vis long rains, short rains and continental rains. The long rains occur during the months of March to May while the short rains are from October to November. The continental rains experienced on the foot zones of the Aberdare ranges occurs during the months of July-August. The importance and distribution of the rain seasons varies in space. In the western part of the Laikipa plateau, the long and continental rains dominate. In the central plateau, the long rains dominate. In the southern part of the plateau and on the North- eastern slopes of Mount Kenya, both long and short rains dominate (see Figure 3).

Within cropland area, the rainfall, mostly bimodal, varies in amount from 600mm in the semi arid lower parts to 1000mm on the slopes. More than 60% of the rainfall comes in form of storms with very high intensities and lasting for only a short duration. Rainfall distribution and onset of rainy seasons varies greatly from one region to the other. Besides, only a percentage of the rainfall is received within the crops' growing season. The high variability and unreliability of rainfall and the inability to forecast availability in the future was noted during the August 2002 water workshop as leading to high crop production risk to inhabitant.

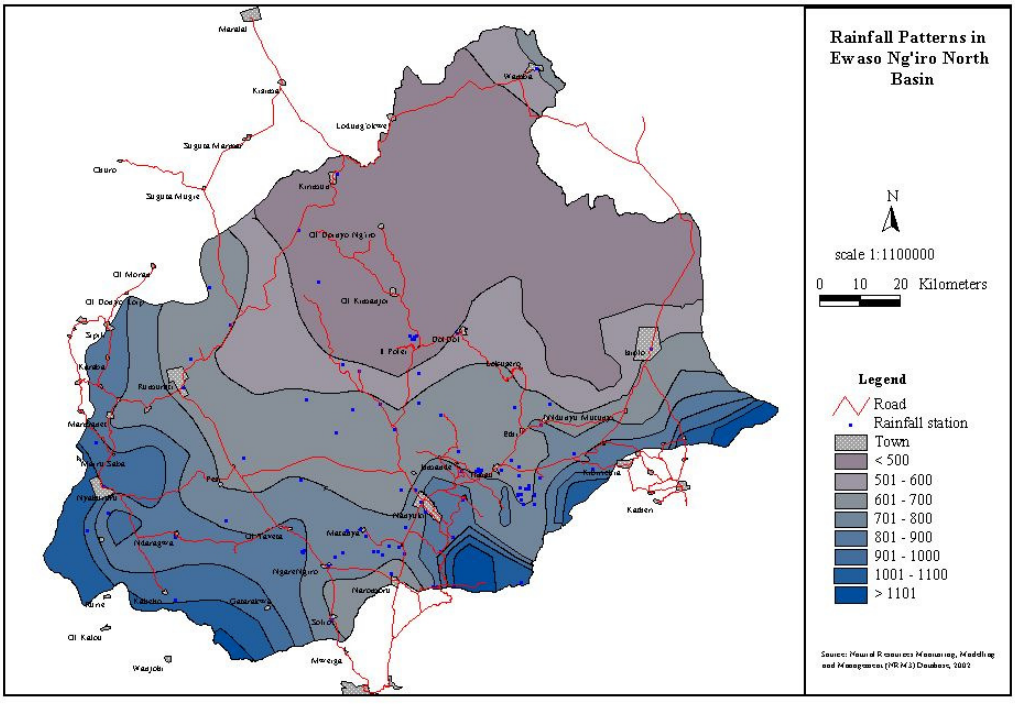


Figure 2: RAINFALL DISTRIBUTION IN THE EWASO NG'IRO BASIN

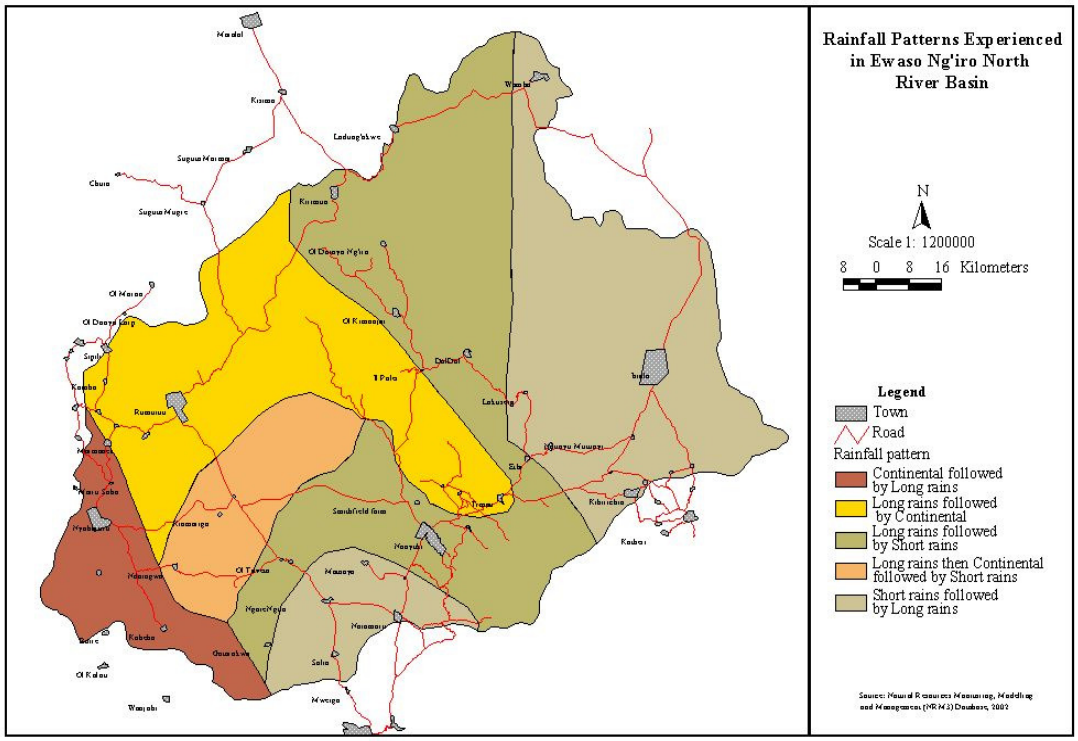


Figure 3: RAINFALL PATTERNS IN THE EWASO NG'IRO BASIN

- ***Evaporation***

Evaporation varies between 1000 mm per annum in the mountain areas and 2500mm per annum in the lowland plains. This contrasts with rainfall leading to water deficit in much of the basin. Monthly evaporation recorded in 2 NRM3 stations, representing agro climatic zones IV and V are shown in Figure 4 below. Since crop growth is possible with rainfall recorded being more than half of evaporation, there are only a few months when growth can be recorded.

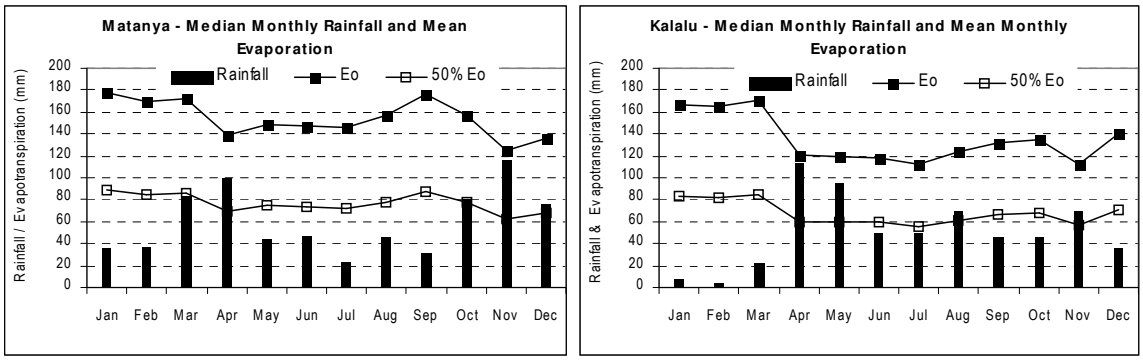


Figure 4: MONTHLY RAINFALL/ EVAPORATION GRAPHS

- ***Temperatures***

Due to high variations in altitude within the Ewaso Ng'iro basin, temperatures vary from 0^{o}c within mount Kenya to as high as 38^{o}c at Archers Post. On average, temperatures range between 10 in the upper areas and 25^{o}C in the lower areas. Daily temperatures in

some places such as Matanya in the foot zones however record values as low as 0^{o}c and this often leads to frost-crop damage.

- ***Agro-climate***

There are six agro climatic zones as shown in the figure 5 below. The agro zones, which are influenced by the rainfall pattern, dictate the distribution of cropland. The small-scale mixed farming for example, is found in agro ecological zones III and IV between altitudes of 1700 to 2200 m.a.s.l. Agro-ecological zones I and II occupy the forest and moorland zones while zones V and VI are unsuitable for crop production due to low water availability.

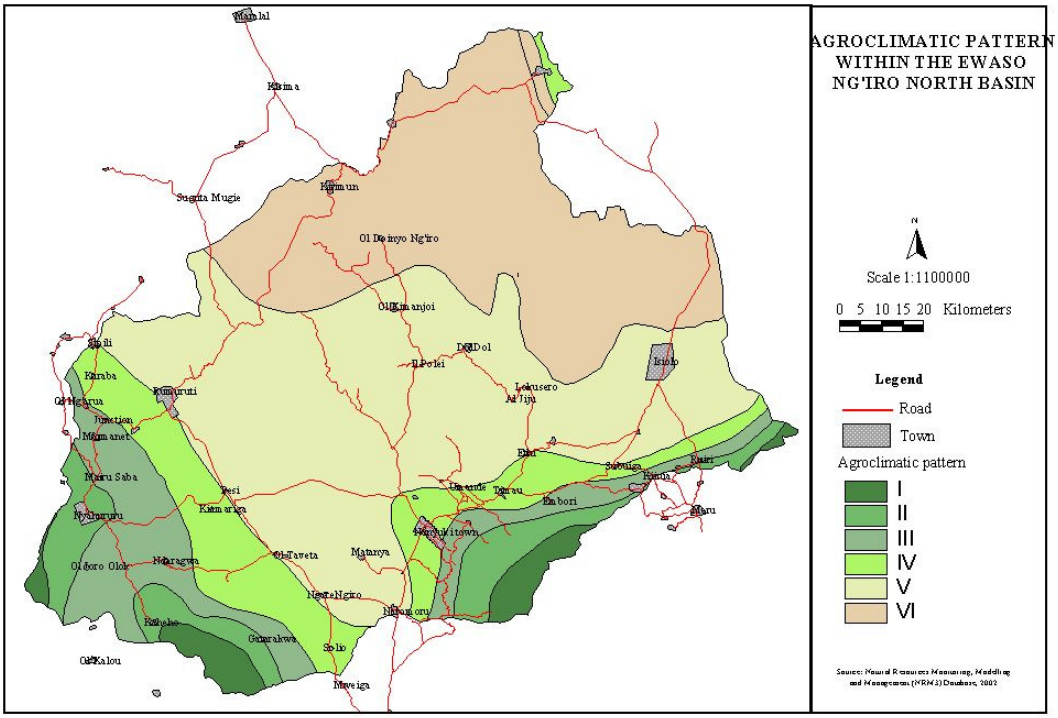


Figure 5: **AGRO CLIMATIC ZONES WITHIN THE EWASO NGI'RO BASIN**

Soil types and distribution (require basin soil map)

Studies from two experiment sites (Matanya and Kalalu) have shown that the soils are deep and have a high water storage capacity of as much as 250 mm within a 160cm profile. Heavy soil losses have been reported in Kalalu and Embori area,

The limitations offered by climatic characteristics, river water and soils determine crops grown in different parts of the basin as well as influence the economic activities. The inhabitants have not adopted well the water conservation and other survival and livelihood strategies. Besides, crop production (mainly maize and beans) is low and failures are frequent.

Geographic distribution of Crops

Cropland system in the Ewaso Ng'iro North river basin, occupies a total of 5073.4m2. Production areas are mainly along the slopes of the mountain areas bordering the forests. The main crops are maize, potatoes, beans, wheat and barley (See map). Maize is the most extensive crop occupying 84% of the total cropped area and 28% of the whole Ewaso Ng'iro North river basin. Beans are widely produced in the basin but are predominant in the Southeastern tip of the basin in Meru district and cover a total area of 398.9 km2. Wheat and barley production sub systems are located in Embori-Kisima area in the foot slopes of Mount Kenya. The production zone covers an area of 158.9km2 and is mainly large-scale production. Potatoes in the basin are dominant in two areas namely Karuri (at slopes of Mount Kenya) and Shamata (Arberdare mountains near Lake Ol bollosat) with a total of 232.7 km2.

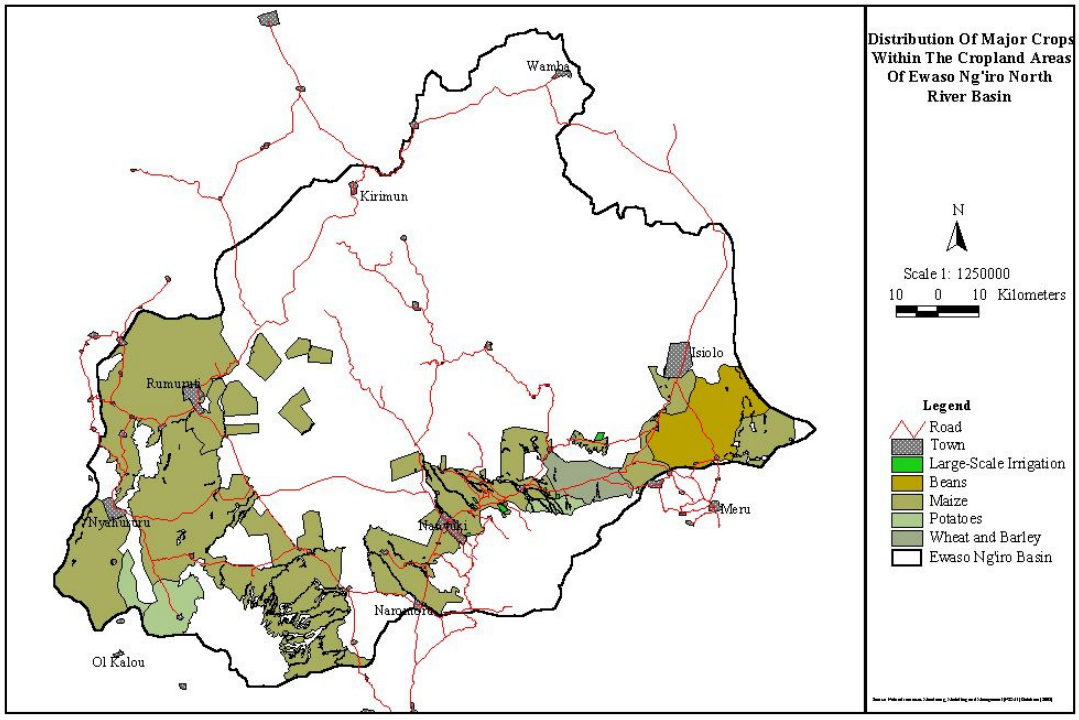


FIGURE 6: DISTRIBUTION OF MAJOR CROPS WITHIN THE BASIN

Commercial large-scale irrigations in the basin are located within Nanyuki-Timau belt among other areas. They occupy an area of only 14.9 km^2.

Current farming practices

Farming systems consist of both rain-fed and irrigated production. Rain-fed production includes both high input large-scale wheat and barley production and low input small-scale maize, wheat, bean, potato and pea production. Maize crop that covers most the farming area (84%) is normally intercropped with beans. The Stovers are burned up or in some cases gathered and stored for livestock feed during the dry season. The removal of stovers and other farm trash expose the soil to high evaporation losses, increase runoff

and generally lower fertility of the soil. Crop residuals are known to improve soil structure and texture and water holding capacity.

According to FAO, crop water requirements during the growing season are shown in the Table 2 below

TABLE 2 THE BIOPHYSICAL REQUIREMENTS OF MAIN CROPS IN THE BASIN

Crop	Growing Period (GP) (days)	Sensitivity to salinity	Water Requirement (mm/GP)	Water availability (mm/GP)	Sensitivity to water supply Ky factor	Water utilization efficiency(kg/m3) Ey Factor
Maize	100-140+	Moderate	500 - 800	340-500	High (1.25)	0.8 - 1.6
Wheat	100-130	Moderate	450-650	310-360	Medium-high (1.0)	0.8 - 1.0
Sorghum	100-140+	Moderate	450-650	320-380	Medium-low (0.9)	0.6 - 1.0
Bean	90-120	Sensitive	300-500	280-340	Medium-high (1.15)	0.3 - 0.6
Peas	85-120	Sensitive	350-500	280-340	Medium-high (1.15)	0.5-0.2
Irish Potato	100-150	Moderate	500-700	340-500	Medium-high (1.1)	4.0 - 7.0
Cabbage	100-150+	Moderate	380-500	340-500	Medium-low (0.95)	12-20
Tomato	90-140	Moderate	400-600	320-380	Medium-high (1.05)	10-12

Source: Adopted from ***FAO Irrigation and Drainage Paper 33, Yield response to water, 1979***

Water is identified as the major limiting factor to crop production. As shown in the Table above, water available from rainfall does not match crop water requirement for good productivity. Farmers also lack appropriate knowledge on dry land farming techniques and hence crop failures are frequent. In efforts to improve production, some farmers have attempted various irrigation methods.

Irrigation farming is both small-scale practiced by local farmers and large-scale irrigation practiced by the newly established flower and vegetable horticultural companies. Irrigation farming, though covering only 14.9 km^2 is important in the basin due to the large amount of water it consumes. Irrigation practices are mainly flood and sprinkler irrigation, both of which take up over 90% of the irrigated area. Besides, most of the small-scale irrigators use flood and sprinkler irrigation methods. These rapid and broad methods of irrigation waste water through runoff, evaporation and deep percolation, especially with inflexible irrigation water supplies. These methods were found to be inefficient during the water Workshop with the members proposing ‘that better irrigation methods should be promoted for efficient and suitable water use’.

Table 3: Irrigated land and percentage under different methods of irrigation

Item	*Nanyuki*	*Burguret*	*Ngushishi*
Land Under Irrigation (Ha)	33	573	210
% Predominantly Under Drip Irrigation	0.02	4.5	1
% Predominantly Under Sprinkler	54.6	86.4	88
% Predominantly Under Flood	45.38	9.1	11

Crops under irrigation farming include maize, snow peas, flowers, potatoes and cabbages and kales.

River water availability

Rivers in Ewaso Ngiro comprise of ephemeral streams and a few perennial rivers as shown in (Figure 7). Ephemeral streams, which are dry for most of the year recording flows only during the rainy season, are the most widespread. Their significance to water provision is little apart from where the water is harvested in river-line dams. On the other hand, perennial streams have faced declining water availability over the years as shown in the figure below. Declining water resources has generated concern in the recent past across all users and stakeholders. Water experts have especially been concerned with the Naromoru River that is rated as the worst affected by irrigating farmers living upstream. The effects are felt by residents of semi-arid Laikipia district and may reach as far down as Isiolo district.

River water is currently under heavy pressure due to increasing human and livestock population as well as rapid horticultural development leading to increasing abstractions to meet irrigation demand. The pressure on water resource is "aggravated by the farmers who use portable pumps" (Central Provincial Water Engineer, DN August 23, 2002). Increasing scarcity, high variability in time and space and the inadequate access of river water during low flows have been cited as current water problems in Ewaso Ng'iro river basin.

Water resources management studies such as the flood utilization study carried out in this area indicate that there is no further potential for using river water for irrigation unless water storage facilities are developed. Developing small storage structures such as water pans would increase potential of water harvesting and would supplement rain fed crop production. From the foregoing, it is important that water conservation technologies are adopted and used by small-scale farmers. This would reduce water stress and hence ensure some level of stability within the small-scale production system.

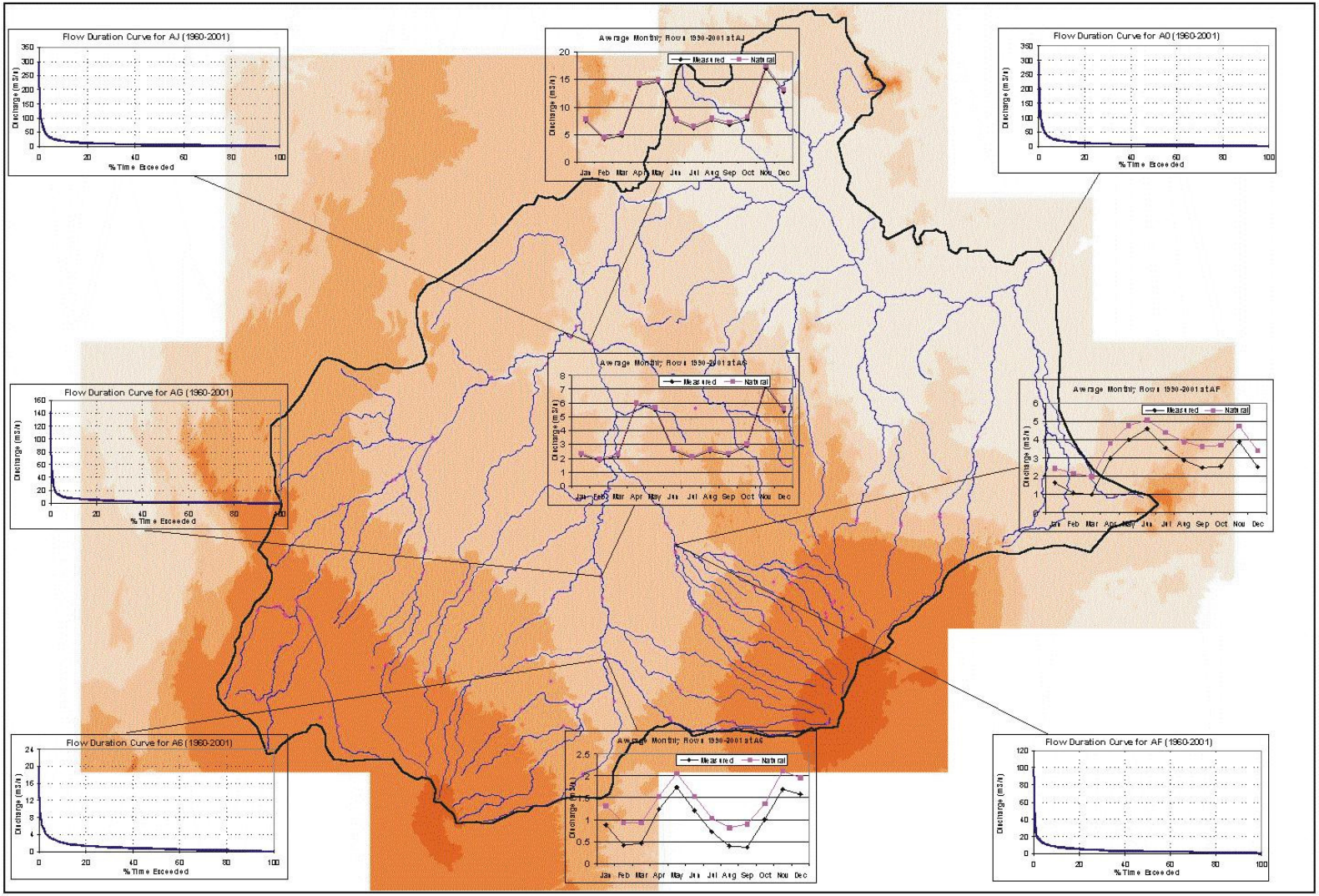


FIGURE 7: MAIN RIVERS AND LONG-TERM FLOWS AND DURATION CURVES SHOWING WATER AVAILABILITY IN EWASO NG'IRO NORTH RIVER BASIN

Options for increasing efficiency/productivity

Since water is so scarce during the long dry seasons, it is important that every drop be used in the most efficient way possible. To achieve efficiency and productivity in water use, water management and conservation practices should aim at the following tenets;

- Minimizing runoff and maximizing infiltration of rain and irrigation water to the garden soil by improving soil structure
- Minimizing evaporation and excess transpiration in the garden
- Minimizing loss of water below the root zone

Water conservation methods to achieve these aims include; mulching and agro forestry techniques, harvesting floodwater through pans and shallow garden wells, covering and shading surfaces of reservoirs, tanks, pots, or other storage structures, lining irrigation conveyance systems and use of efficient irrigation methods.

1. Agro forestry and Mulch for water conservation

Within a semi arid environment, a substantial amount of the seasonal rainfall is lost through surface runoff and soil evaporation. Researches carried out within semi arid environment have shown that water loss can be minimized through agroforestry and mulching. Some of the advantage of agro forestry and mulch includes reduce soil evaporation through wind breaking and soil surface cover and reduced runoff loss through soil surface cover and roughness.

Since 1986, NRM3 has carried out on station and on farm experiments to evaluate the potential of agro forestry and mulch for water conservation. Some of the parameters monitored include surface runoff, soil water condition and resulting crop yield. The agro-forestry and mulch system is compared to a local further situation without any water conservation strategy.

Figure 8 shows run-off and soil moisture under the agro-forestry and mulch system as compared to a typical farmer system without any water conservation. With agro forestry and mulch, water loss is completely reduced. Without water conservation, between 10 and 136 mm of water can be lost as surface runoff from the production system. This represents between 5 and 25% of the seasonal rainfall. Water conservation leads to higher available soil moisture throughout the growing season. The water conservation is higher during the rain season and decreases during the growing season as crops use the stored moisture. Water conservation also leads to higher crop yield. The yield is increased by between 1 and 11 bags per acre at Kalalu and 0.2 and 9 bags per acre at Matanya. This could raise self-sufficiency from a one-acre plot for a 10-member family from 30% to over 90%. It has been observed that without conservation yields as low as (< 0.5t/ha) in years with bad rainfall distribution are recorded.

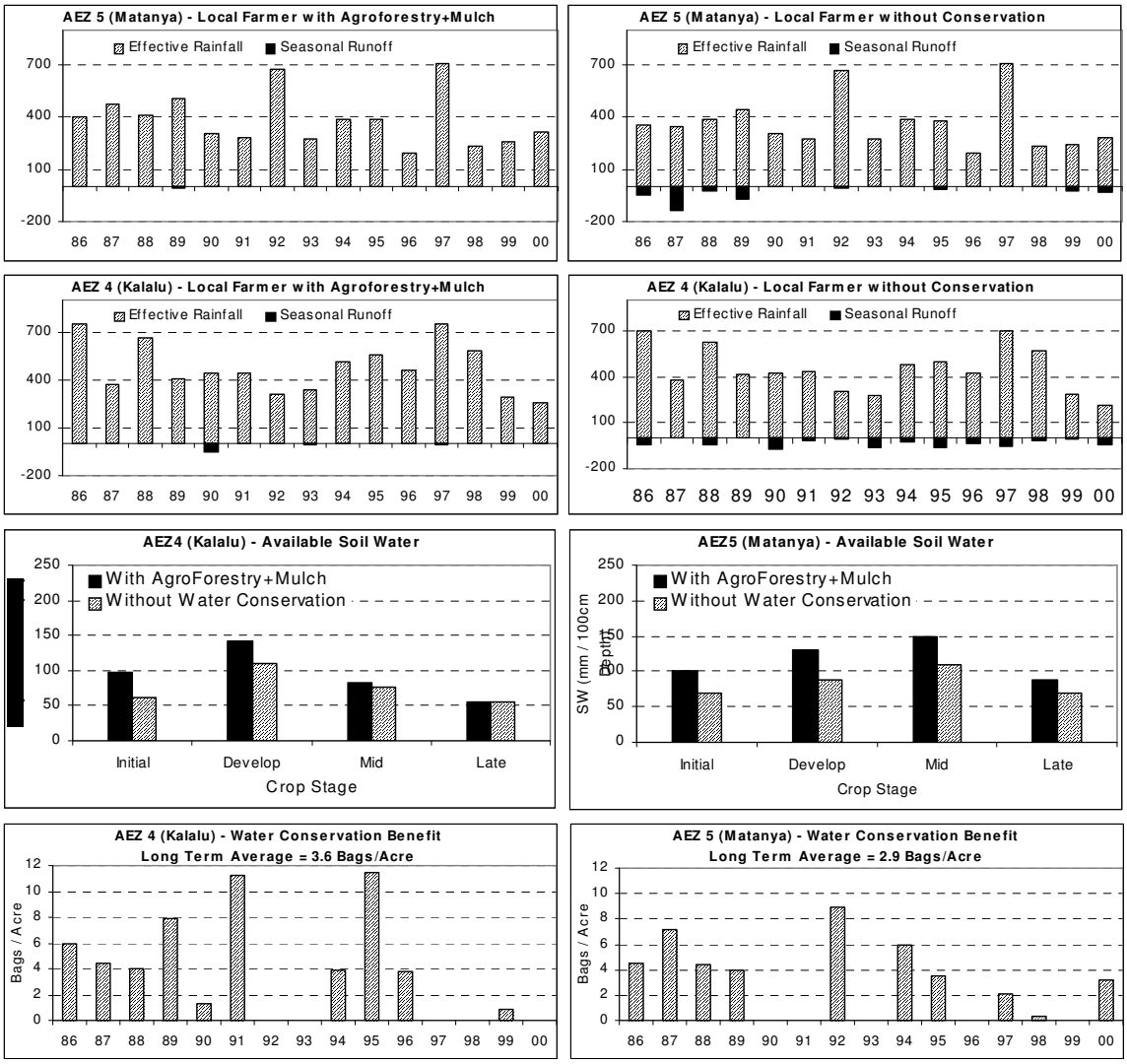


FIGURE 8:SOIL MOISTURE AND YIELD IMPROVEMENT THROUGH MULCH AND AGROFORESTRY

High value trees for agroforestry have already been evaluated. These are good trees that have little competition with farm crops, take less space, yield more, provide animal fodder, protect soil, enrich soil with nutrients and improve soil structure. Such trees could be fodder species, medicinal plants, fruit trees or other trees. Examples that have been doing well within Ewaso Ng'iro North river basin are *Morus alba* (Ndare), *Grivellea robusta* (Mukima), e.t.c.

Various agroforestry techniques that may be employed by farmers include; boundary planting, establishment of woodlots, hedgerow intercropping and alley planting.

2. Improved Irrigation Methods

The Workshop on Partnerships And Information Needs For Improved Water Use, Allocation And Conflict Resolution of August 2002 noted that current irrigation methods such as overhead irrigation are wasteful (efficiency in water use is between 20 and 50% i.e. as much as 80% of the water used is wasted) and that more efficient irrigation systems for small and medium irrigations that are highly specialized –giving the plant

only what it needs and not more, and use of low pressures sprinklers should be encouraged. The need for efficient method of irrigation has been expressed by a survey of the main irrigation projects in the upper Ewaso Ngiro North basin (Nanyuki, Timau and Naro Moru rivers) that showed most of abstraction is done using furrows (Table 4).

Table 4: Conveyance system

Category	% Of total
Bucket	0.5
Furrow	80
Pipe	19.5

Drip irrigation system is one of the new efficient irrigation methods. A drip irrigation system delivers water at slow application rates directly to the rooting zone of a plant thus maintaining near optimal soil moisture conditions at all times. Use of drip irrigation kits could significantly improve the quality of life of the people and contribute positively to poverty alleviation. Drip irrigation kits can contribute to sustainable development through efficient utilization of scarce water, soil nutrient and land resources and reducing production risk.

In order to promote small-scale drip irrigation in some parts of the Basin, NRM3 has set up drip experiments in Matanya and Kalalu stations. Smallholder-scale farmers were also provided with drip kits for trial trails on their farms and the results were quite encouraging. NRM3 has also gone a step ahead in trying to use locally available and affordable materials to fabricate drip lines (kits). Four low-cost drip systems are now available.

1. *Bucket Kits* are Low-cost, simple systems affordable by low-income families. They consist of a simple household bucket attached to a pole at shoulder height, which supplies a drip line with 26 micro tubes, each of which waters four plants. Using the bucket drip kit, for example, application of only 10 gallons of water daily grow enough vegetables to feed a typical family.
2. *The Drum Kit* uses a 200-liter drum instead of a bucket, and uses five lateral lines to irrigate a 125 square meter plot. This would cost about $25.
3. *Shiftable Drip Systems. The shiftable drip system reduces capital cost by using* increased labor. This is done by making lateral lines shiftable, so that each line is capable of irrigating ten rows of plants instead of one. Water drips out of baffled holes or curled micro-tubes instead of more expensive emitters.
4. *Larger Low-cost Drip Systems* for 1000 to 10,000 square meters cost $625 a hectare for crops like cotton. One lateral line can irrigate four rows by using micro tubes. This does not include the cost of a pressure pump.

Adoption and use of drip irrigation method is limited by:

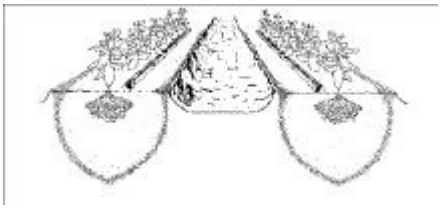
- Limited supply of water during the dry months of January and February. In some areas farmers are forced to buy water even for domestic use.
- Inability to tap rainwater through roof harvest.
- Cost of drip kits. Although the cost of Ksh 1000 for the 20 liters drip kit seems small, this is expensive for many farmers. However, farmers in some areas have purchased the drip kit through group contributions hence making it possible to acquire the kits.

- Use of kitchen wastewater that result in blockage of the drip lines in some cases.

A locally fabricated 3*15m lateral bucket kit drip system for 150 vegetable plants is considered best for smallholder farmers. The assembly and maintenance simplicity as well as the costs can make the kit more adoptable amongst the low-income farmers.
Using the bucket kit principles, bigger containers can be fabricated cheaply e.g. the 50ltrs kit and 200ltrs kit (drum kit) for 300 plants and 500-1000 plants respectively. In the development and promotion of the drip kit an integrated approach is required where the farmer is also trained on pest and soil fertility management.

Drip tape

Drip tape is generally the most cost- effective technology and is widely used on single-season and long-term row crops. It is a thin wall hose with emitters molded into the wall of the tube. Drip tape is available in wall thickness ranging from 0.12 mm to 0.40 mm and emitter spacing from 10 cm to 60 cm. A variety of flow rates are available to meet the needs of specific crops and growing conditions.



3. Other improved farming methods

Optimizing crop density for water conservation

With good production resources, the harvested yield increases with crop density. However, under poor rainfall season, reducing crop density can conserve water resources. The farmer can therefore avoid crop failure as well as reduce the amount of money invested. Using APSIM model, the optimal maize density for different seasonal rainfall condition is evaluated (Figure 9). The figure shows the predicted maize yield for different rainfall condition and plant density. In good rainfall season, i.e. 1988 the higher the plant density, the higher the crops yield. There is no difference between the local farmer situation and a water conservation situation where surface mulch is applied. Lack of difference between water conservation and non-water conservation farming under good rainfall season has also been observed in the field experiments. In a poor rainfall seasons, i.e., 1995 crop yield drastically decreases under high crop density. It has been noted for example that increasing crop density from 4 to 6 plants per Meter Square during a low rainfall season reduces crop yield from 6 t/ha to 2 t/h with water conservation and to 0.5t/ha with no water conservation.

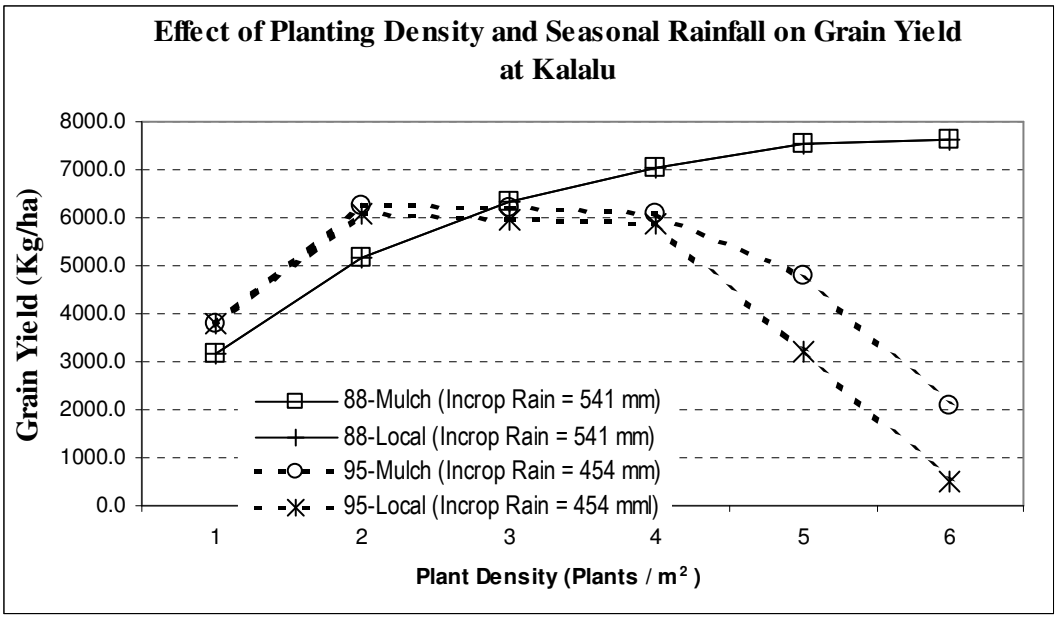


FIGURE 9:EFFECT OF PLANTING DENSITY AND SEASONAL RAINFALL ON GRAIN YEILD

Drought Escaping Crops (DECs)

The introduction of drought Escaping Crops (DECS) aimed at enhancing household food security by making Improvements to the established maize/potatoes/beans system. Late blight resistant potatoes varieties (Tigoni Asante and Furaha) were introduced by ASAL. Further in collaboration with KARI, Katumani, early maturing bean varieties, chickpeas, cassava, oil crops (Sunflower, safflower) sweet potatoes, dolichos lab, pigeon peas, millet and sorghum were introduced. While the performance of this innovations was mixed, the on farm multiplication of the blight resistant varieties and early maturing beans through informal, farmer-led seed enterprises was particularly successful (Ng'ethe 2000).

Multi-storeyed bags

This is also a promotion of kitchen gardening where plants are grown on bags filled with soils. These bags are supposed to be kept under the shade in order to control the rate of evaporation. They are also superior to planting plants directly on the ground since there is no chance of loosing the irrigation water to soils further from the root zone.

Double dug plots

The main aim of double digging plots is to increase the rate of infiltration such that as the rain falls most of the water is absorbed by the soils instead of being lost as runoff. The roots of crops are also able to penetrate deeper into the soils. The soils are also enriched with manure. Follow-up by NRM3 has shown that double digging practiced in conjunction with drip irrigation is a great success.

4. Rainwater and runoff harvesting

Water harvesting for crop production involves collecting or diverting rainfall and runoff water from rainstorms and concentrating it into the field where crops are grown. The purpose is to increase the amount of available water in the soil by supplementing normal rainfall thereby enabling crops to be grown in areas with insufficient rainfall. The potential for rainwater and runoff harvesting is high in the basin but only a small fraction has been tapped. The technologies for tapping this resource have not fully trickled to the

local farmer. Besides, the development of roof catchment and storage facilities being expensive, most inhabitants are newly settled and have not adjusted themselves to the survival techniques within this harsh environment. Nevertheless, there are appropriate water harvesting methods both for rainwater and runoff that have worked well in the basin. These are both infield systems with predetermined size basically involving a farm section devoted for water collection and external field catchment systems where runoff water is collected from hillsides, cropped area and roadsides. The system in use depends on the terrain of the farm area.

Underground water tanks and pans

Underground storages have been promoted through initiatives of SARDEP, NCCK, CPK and other NGOs and aimed at improving the livelihood of small-scale farmers by promoting kitchen gardening and providing water for livestock. Pilot projects by SARDEP for example, were started in West Laikipia – Ng'arua and Rumuruti where underground tanks of $100m^3$ were made to trap runoff. Some farmers have gone further and dug trenches which are fed directly by roadside runoff. These trenches are planted with Bananas, pineapples and citrus fruits. Elsewhere, some farmers such as in Mwireri, Kalalu, Matanya and Sweetwaters have harvested surface runoff in pans during the rainy seasons for use in irrigation and kitchen gardening during the dry season. The water also meets domestic and livestock needs. The tanks are specially constructed to eliminate seepage and evaporation. However, the water pans have high rate of water losses through evaporation (40-60% of rainfall received) and ground seepage.

The cost of constructing the water tanks and pans has been a challenge to many of the inhabitants. Alternative sources of funding are not common. Previously, ASAL/ SARDEP, Ministry of Agriculture and Women Groups have played an important role in facilitating and contributing towards construction of water pans and tanks to harvest roof and runoff water. In view of low external sources of funding, local groups and individuals can pull their resources together to achieve a common water purpose.

Roof water harvesting

The potential for roof water harvesting is high. In this area, majority of households store less than 2000 liters of the rainwater. A few farmers have storages of between 2000 and 10,000 liters while very few farmers have greater than 10,000 liters. Considering the rainfall received, thousands of liters of water resource can be harvested during the rain season if storage capacities are enlarged. With adequate storage, for example, a typical roof of $60m^2$ would harvest enough water to meet the annual domestic and livestock water supply as well as the drip and kitchen garden water requirements.

Catchment protection, conservation and restoration

Catchments serve important roles in ensuring continued river flows and ground water recharge. Their protection is therefore vital. Conservation policies of riparian reserve are however conflicting. For example, water policy to protect river line riparian reserve and catchment areas conflict with agricultural policies promoting its development.

Riparian and conservation areas are designed to protect water catchments. Within Ewaso Ng'iro Basin, problems facing conservation areas include; loss of habitat due to encroachment by human settlement, cultivation, fires, uncontrolled grazing, high water abstractions and charcoal burning and clearing of forest cover and destruction by wildlife. The most threatened areas are forests, wetland and river lines.

Wetlands and Flood plains are known to regulate and buffer the flow of water within basin(s) and act as reservoirs when drainage capacity is reduced and are also home to aquatic and semi-aquatic wildlife. Within the Upper Ewaso Ngiro Basin wetlands/ swamps that cover a total area of 56Km^2 are important dry season grazing areas. Within Ewaso ng'iro river basin swamps such as Marura, Pesi and Narok and Lake Olbollosat as well as small river line swamps considered to have minimal ecological and social use have been taken over for cultivation. The rate of reclamation is very high and threatens future ground water recharge. Since the early 70's, extensive use of swamps has resulted from the increasing demand for cultivation land. In a semi-arid environment, the wetlands are drained to provide arable land with adequate water for crop production. The drained water is also used for irrigating adjacent semi-arid land.

Wetlands are destroyed through pollution and cultivation due to "lack of comprehensive policy on wetland management in Kenya"(Workshop proceedings, August 2002). Under the new water bill, section 25 sub section 1 (b) stipulates that a permit shall be required for 'the drainage of any swamp or other land'.

Protection of catchment areas will involve improvement of farming methods, rehabilitation of degraded or eroded areas, reduction of livestock numbers to match with carrying capacity of ecosystems and restriction on tampering with catchment forests. It will also require increased public awareness on the impact of human activities in such areas, change and improvement of farming/production systems, introduction of conservation education programs in schools and ensuring land tenure system that enable people own land and feel responsible for it for the benefit of themselves and of their future generations "(Workshop proceedings, August 2002).

Pollution control

The problem of water scarcity is compounded by pollution of the existing sources in some areas. River pollution cases have been reported in Burguret, Likii, Kongoni and Sirimon. Kongoni inhabitants for example have complained of heavy pollution problems of their river to the point where the water is unfit for drinking by both humans and livestock. The water is said to be smelly, dirty, feacal and chemical contaminated. Further, a local self help group (Nkando) was stopped from installing an abstraction opposite Likii village after feasibility study by MOWD and Ministry of Agriculture revealed heavy pollution from the village that included chang'a wastes, domestic waste water and dead animals (cats and dogs).

Other pollution problems are due to heavy amounts of dissolved solids from runoff. Presently, on-going farming activities in riparian areas are exposing the water to heat and riverbank erosion that has increased dissolved oxygen demand. For example, while10 mg

DOD is allowed in the river, rivers around Timau area have 12. Other dissolved solids have also increased in the rivers.

Pollution control and prevention require concerted efforts by small-scale farmers, Government departments and other stakeholders. These will involve adoption of individual prudent measures for water and land use, community policing and reporting, quality monitoring by the Water Department and general catchment protection.

Optimizing returns on water use

Appropriate decisions at farm level are required in efforts to optimize on water use. Consideration and choice of crops to grow under an irrigation system should be based on the economic returns that are achieved. Such considerations mean that water will be used for the best opportunity cost.

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