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Full Length Research Paper

Difficulties of Food Production and water resource management in areas with unstable climate in Kenya

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The Tropics depend upon rain as the main source of water supply for agriculture. Concerns of food security and water scarcity in the wake of climate change are global and real particularly in the sub-Saharan Africa. As communities struggle to adapt to the challenges of food insecurity caused by climate change, they are also sensitive to the diminishing and management problems of water resources. Kenya with an estimated population of 36 million people of whom 10 million are faced with starvation is highly vulnerable to climate change effects. There is evidence from Food and Agricultural Organisation (FAO) that 850 million people in the world are affected by food insecurity, of whom 820 million live in the developing countries. To come up with climate change associated challenges on food security and water resource management in Kenya, the study carried out climate and food related researches on agriculture in Arid and semi-arid parts of Kenya (ASAL), irrigation and fishing activities in the ASAL districts, evaluated climate and socio- economic data from Drought Monitoring Centre Nairobi (DMCN). It also evaluated and collected data from selected industrial towns in the country. It was established that Kenya faces severe food insecurity problem caused by climate change and mismanagement of water resources. Many seasonal rivers dry up due to poor management of irrigation processes, a lot of fish die due to release of industrial effluent to rivers, there is drying up of seasonal rivers, lakes and boreholes due to prolonged droughts, there is persistent crop failure and animal death and increased environmental migration from the ASAL due to increasing aridity. Proper management of water resources therefore, calls for the implementation of such measures as Environmental Impact Assessment (EIA) for industrial operations, Assessment of sustained yields for rivers before abstraction is allowed, re-afforestation and forest protection for sustained river yields and increased rainfall for increased food production.

Key words: Food production, water resources, eutrophication, abstraction, water pollution, industrial effluent, sustained yields, droughts.

INTRODUCTION

The first Millennium Development Goal (MDG 1) is to eradicate extreme poverty and hunger; this goal is the backbone for achieving the other seven MDGs (Mabesa, 2008). Today, there is a global outcry over food insecurity. The situation is severe in sub-Saharan Africa, with Kenya included. Climate change manifested in frequent droughts, floods and drying up of water resources has made Kenyans very vulnerable to food insecurity. Hunger, starvation and malnutrition related diseases are affecting the ASAL rural population severely. Although one way of addressing food insecurity is through irrigation, the challenge facing Kenya is scarcity of water as evidenced in little and erratic rainfall, frequent droughts and many seasonal rivers.

Agriculture provides food supply to only 60% of the population, the remaining 40% of whom majority stay in the ASAL suffer from constant food scarcity, famines, starvation and malnutrition related diseases such as kwashiorkor and marasmas

Developing Countries Kenya included, already face social, economic and environmental stresses and constraints, which limit their ability to adapt to climate change problems. It is anticipated that African countries in particular will endure some of the worst effects of climate change by 2080 causing stress on water resources and food production (CCAA, 2006). Many parts of Africa, Kenya included already experience high variability in rainfall as evidenced in frequent occurrences of droughts and

floods, drying of surface water resources. This variability threatens the livelihoods of many people who depend on rain fed agriculture for food production to the extend that, scientists are today advising countries in Africa to develop copying strategies such as the introduction of controversial biotech farming or Genetically Modified foods (GMOs) to deal with climate variability food related problems such as prolonged frequent droughts which are normally accompanied by severe famines.

Water in all forms is a vital resource to all living organisms for domestic, industrial and especially agriculture for countries within the tropics. The scarcity of water affects all aspects of life in Kenya, and threats to water quality are as dangerous as scarcity of it. As demand for water continues to rise rapidly and new sources of supply become scarcer, food production becomes increasingly scarce in the country. Competition among water users affects irrigated agriculture in many arid and semi- arid areas. These pressures become more severe as water supplies are more utilized.

On the global scene, agriculture accounts for 70% of water consumption, while industry accounts for 25% and households, 5%. In developing countries such as Kenya, agriculture accounts for 80% of water consumption. Worldwide, the demand for water is growing rapidly, and in many countries, the cost of developing new supplies of water is becoming prohibitive. Increased water pollution is worsening the imbalances between water supply and demand (Nkemdirim, 2003). Water resource management and irrigation are therefore, of critical importance in any efforts to improve food security and sustainable agricultural production in developing countries, in particular Kenya (Ngaira, 1999).

Main sources of water in Kenya include: surface water found in oceans, lakes and rivers, ground water in wells and Aquifers and rainfall ranging between 200 mm in the arid and semi-arid (ASAL) parts to 2500 mm in the Kenya highlands (DMCN, 2001).

In Kenya, quantity and flow patterns of surface water resources particularly rivers depend on: basin shape, vegetation cover in the basin, rainfall intensity and seasonality plus human settlement and land use patterns. Water quality on the other hand is compromised by: mineral composition of the eroded material, industrial pollutants such as sulphur and nitrogen dioxides, agrochemicals such as fertilizers, pesticides and herbicides from commercial farming areas, domestic pollutants like human and animal wastes from open sewers. Water quantity is highly depended on the location of the region in question in relation to the factors influencing rainfall, such as windward or leeward location, equatorial, tropical or Desert (Arid and Semi- Arid) climatic system. Frequent droughts, industrialisation and Urbanisation are blamed for compromising water quantity and quality, which in turn leads to severe food scarcity.

Kenya with an estimated population of 36 million people covers an area of 477,000 sq km, of which 80% is arid and semi-arid. This is home to 5.8 million people, and only 20% is classified as having high agricultural potential (ISDR, 2003).

Rainfall in Kenya depicts very complex patterns, which are related to the equally complex physical features. Large variations occur in time and space. Low, erratic and unpredictable rainfall characterise the region. Annual rainfall varies from as low as 200 mm in the arid areas lying on the floor of the rift valley (Turkana, mandera, Moyale) to as high as 2500 mm in the highlands (DMCN, 2001). The region is experiencing climate change as depicted in the melting of snow on mt Kenya and the frequent occurrences of prolonged droughts lasting between 2-3 consecutive years, for example, the 1990-1992, 1998-2001, 2004-2006 droughts (Ngaira, 2005). Low rainfall together with high temperatures coupled with high evapo-transpiration rates result in negative water balance, which is inadequate for food crop growing and pasture for livestock production in the semi-arid parts. A study done in East Africa to establish the quantity of water used by rural African households for domestic and irrigation of horticultural crops suggest that, water uses in rural areas is limited to 10 litres per person per day and that a large percentage (about 75%) of rural population in Kenya do not have access to enough water to meet their demands (Table 1).

The figures above are a measure of the magnitude of water scarcity in East Africa.

Sources of food in Kenya

The most common food sources in Kenya are: (a) cereals and pulses, which include maize, wheat, rice, sorghum and millet, (b) legumes and oils which include groundnuts, simsim, cowpeas, beans, green grams and soya beans, (c) roots and tubers which include cassava, sweet potatoes, Irish potatoes, bananas and yams, (d) vegetables, (e) livestock (cattle, sheep, goats and pigs), (f) fish, both pelagic and dermasal. The main determinant of all the stated food production in Kenya is water found in different stated sources such as ground, surface and precipitation that are all climate depended for their recharge. In Kenya, the effects of climate change are adversely manifested in (a) frequent droughts, (b) increasing aridity, (c) flash floods (d) decreasing rainfall amounts. The arid and semi-arid districts are vulnerable to both water scarcity and food insecurity caused by climate change. The selected ASAL study districts were: Mandera, Wajir, Turkana, Moyale, and Marsabit which are designated as very arid; Baringo, Kitui and Machakos as semi-arid.

METHODOLOGY

Data for the study was collected from the following areas in Kenya:

i) The Drought Monitoring Centre Nairobi (DMCN)- rainfall characterristics.
ii) Ministry of Agriculture and Livestock-types of crops grown and

Table 1. Water Resource access for rural and urban household in East Africa.

Country name	Year of data collection	Population with access	% of rural population with access	% Urban population with access
Kenya	1993	8,059,048	43	74
Uganda	1988	1,637,101	12	45
Tanzania	1993	9,677,232	45	65

livestock kept.
iii) The Ministry of water and Irrigation- irrigation projects and water management techniques used.
iv) Webuye, Naivasha Kericho and Kisumu industrial towns-sewage plants and effluent disposal.
v) Selected ASAL districts for rainfall characteristics, irrigation, fishing projects and other socio-economic activities,

Methods of data collection and analysis

(i) Structured questionnaires, focused group discussions and Participatory Research Appraisals were administered to farmers, fishermen, factory workers at Pan paper Mills in Webuye.
(ii) Documentary data on rainfall amounts and seasons were collected from DMCN

Data collected were analysed quantitatively and qualitatively; they were presented in the form of discussions, tables, charts and percentages.

RESULTS AND DISCUSSIONS

Water management and food production

Irrigation and diversions

Irrigation is the artificial application of water to dry lands to encourage plant growth. The use of irrigation for increased agricultural yields is an ancient practice, which is traced to the early Egyptians in the year 500 B.C. Irrigation can transform arid regions into agriculturally productive ones, but rivers from which water is diverted or abstracted will inevitably be reduced and may even-tually dry up (Ngaira, 2002) (Table 2)

Irrigation farming in Kenya is mainly practised in semi-arid regions where annual rainfall is less than 750 mm (Ngaira, 2002) . Table 2 shows irrigation projects and foods grown in selected semi-arid districts in Kenya.

Challenges of irrigation

Whereas irrigation increases food production in semi-arid areas which are moisture constrained, there are challenges found in the management of the rivers from which irrigation water is abstracted. Irrigation water sometimes contains salts, which are left behind when water is transpired by plants and evaporated from yields. If the salts are allowed to accumulate in the soil, the salts retard plant growth and may eventually kill the food crop thereby interfering with the ecosystem. Salinity has resulted in the abandonment of irrigation of millions of hectares of land and reduced yields on millions more. For example, in the Aral basin of the former Soviet Union, high salt levels reduced crop yields on about 50% of the 7.6 million hectares irrigated in the basin (Kenneth, 1990). In Kenya, seasonal rivers such as Chemeron, wesegese, Endao and Nyoro in Baringo district have dried up due to abstraction. Dams constructed across rivers for irrigation purposes invariably trap silt, cause reservoir sediment-tation and accelerate downstream erosion. They affect meander patterns, delta characteristics and stream biodi-versity (vegetation); they cause disappearance of fish from some hydrologic systems. Irrigation schemes pro-vide breeding grounds for such disease as malaria and Bilharzia which have increased especially around the Lake Victoria Basin in Kenya. A reservoir creates a new environment which may favour some species at the expense of others (ecosystem interference); it also re-places the natural recreational benefit of free flowing stream with those of a lake, case of Ahero rice irrigation scheme in Nyando District (Ngaira, 1999).

Ngaira (1999) carried a research on the effect of water abstraction for irrigation in semi-arid Baringo District and established that: Irrigation projects in the semi-arid lands of Kenya have had negative impacts on the surface water resources and the aquatic life. Lake Baringo is the largest fresh surface water resource located on the floor of the Rift Valley. It accumulates its water from the sur-face run-off, seasonal streams such as Endao, cheme-ron, Wesegese and Perennial Rivers such as Molo and Perkerr. Human and livestock population depend on the lake for their livelihoods in terms of drinking and domestic water, fishing and livestock watering. The severe drought of 1984 which caused total crop failure and killed 69% of the livestock forced the population to start self -help irrigation farming by abstracting water along both sea-sonal and perennial rivers as a strategy for copying with droughts. Table 3 shows river abstraction in Baringo Dis-trict.

The impacts of water abstraction for irrigation were established as follows:

(i) Abstraction of rivers flowing into Lake Baringo caused a reduction in the lakes surface area from 144 km^2 in 1980 to 112 km^2 in 1995 while the depth reduced from 2.2 m in 1985 to 1.7 m in 1995 (District Hydrologist 1996).
(ii) Fish production reduced from 280 metric tonnes in

Table 2. Irrigation and food production in semi-arid districts in Kenya.

Project Name	District	Water Source	Total area in hectors	Crop grown
Mwea	Kirinyaga	River Thiba	10,000	Rice
Perkerra	Baringo	River Perkerra	415	Onions, chillies, pawpaws
Hola	Tana River	River Tana	872	Groundnuts, Maize, Sorghum
Ahero	Nyando	River Nyando	850	Rice
Bunyala	Siaya	River Nzoia	380	Rice

Source: Waters and Odero, 1986.

Table 3. Water Abstraction for irrigation on rivers flowing into Lake Baringo.

River Name	Dam Name	Irrigation Project	Year Established
Chemeron	Chemeron	K. V. D. A.	1984
		Losekem	1985
		Lamalok	1986
Endao	Endao	Salabani	1988
		Endao	1989
Wesegese	Sandai	Sandai	1988
Molo	Loboi	Kapkuikui	1985
		Kamaskoi	1988
		Eldume	1988
		Nyoro	1989

Source: Adopted from Ngaira 1999.

1989 to 37 metric tonnes, in 1994 due to lake recession, over fishing and drying of fish lings due to exposure (Fisheries Department; Baringo, 1996). This affected the economic livelihoods of the Njemps community who are fishermen.

iii) The damming of waters of River Molo in the 1980's led to the migration of many crocodiles from the river to Lake Baringo, thus affecting the river's aquatic life.

The Intergovernmental Panel on climate change (IPCC, 2006) warns that rain fed lakes such as Baringo and Turkana in Kenya could dry up, affecting some of the most populated parts of East Africa due to drought and river diversions. For example, Turkana District in the arid Kenya, which borders Ethiopia, has only two sources of fresh water: the Turkwel and Omo Rivers. River Turkwel has been dammed to generate electricity (The Turkwel Hydro Power Project) reducing its flow downstream to Lake Turkana, while river Omo which originates from Ethiopian highlands is being diverted for irrigation purposes, therefore very little water is reaching Lake Turkana. The diversions of the two rivers coupled with prolonged droughts in the district have caused the level of Lake Turkana to drop 60 m over the last 10 years and fish production has been reduced by 40%.

Management of Irrigation projects

Diversions and dam construction along rivers for irrigation purposes have been the causes of shrinking lake levels (Baringo, Turkana and Naivasha), drying of rivers (Molo, Omo, Turkwel) and dying of aquatic life. To protect these water resources for sustained food production, the following needs to be done.

(i) There is need for a meaningful study of sustained yield on a given hydrological system before any water abstraction is carried out, Random abstraction for irrigation purposes leads to both water scarcity as in drying of some rivers and reduction of volume of water in lakes which are served by the abstracted rivers. A case in point is Lake Baringo.

(ii) Decisions for issuing permits for water abstraction should be made by local experts (hydrologists) after an assessment of the sustained yield of a particular hydrological system (Ngaira, 1999).

(iii) Provision of proper knowledge of the water balance of lakes and numerical simulations of lake levels which assesses the likely effects of lake water abstraction should be provided by hydrologists on the ground and not from the central Government (Songrea, 1981).

Droughts and food production

About 183 million people in Sub Saharan Africa alone could die of diseases mainly malnutrition related directly attributed to climate change particularly droughts by end of the 21st century (CCAA, 2006). Rainfall plays a key role in providing water for agricultural activities. Rainfall

anomalies are occurrence of above normal which may result in floods or below normal which may result in either meteorological drought, hydrological drought or agricultural drought. Such anomalies impact negatively on agriculture.

Widespread droughts occurring particularly, after the 1960s in the sahelian Africa and Eastern Africa have sparked speculation as to whether or not Africa is experiencing a pronounced climate change episode. Certainly, climate variability is a dominant feature of the climate of Africa and droughts are a common occurrence. The most recent 1968 – 1973, Sahelian drought suggest that the droughts are entirely natural and climatologists assert that human interference with the environment may prolong dry periods and poor land management practices may damage ecosystem balances which greatly influence the availability of water resources and food production in the tropics (Nkemdrim, 2003).

Whenever droughts occur, they have devastating effects particularly on water availability and quality, agricultural activities, food security and human health, bovine and aquatic health, which in turn may lead to loss of both human and bovine lives, mass migration and environmental refugees (Parry et al., 1988). Evidence of drier weather in sub tropical Africa is confirmed by the loss of wetlands and diminishing water levels in rivers and lakes and severe crop failure and devastating famines. For example, the Sahelian drought of 1968- -74 reduced the size of Lake Chad from 25,000 km^2 in 1967 to 1000 km^2 in 1974. In Ethiopia, the same drought caused severe famine, which was one of the causes of the civil war that led to the overthrow of Emperor Haile Selassie (Nicholson, 1983).

The 1980-1984 drought in Kenya led to (i) reduced rice production on Mwea Irrigation Scheme by 2000 Metric tonnes (ii) In Semi arid districts of the Rift Valley, famine was so severe that the locals in Baringo District nicknamed it the “Rubetab Sibinsi” meaning hunger of yellow maize. The government distributed yellow maize from USA as copying strategy to food shortage.

The 1990-1992 drought led to (i) shrinking of the size of Lake Baringo from 144 km^2 in 1988 to 112 km^2 in 1992 (ii) Fish catch in the lake dropped from 380 metric tonnes in 1990 to 37 metric tonnes in 1992. (iii) The Tugens from Baringo District moved with their livestock to Marakwet and Laikipia Districts in search of pasture and fed their animals on some palatable trees locally known as *Koloswo, lokoywo and kilimbil.* This led to ecosystem disturbance and overstretched carrying capacity for pasture resources (iV) 70% of the pastoralists in Mandera, Wajir and West Pokot had all their livestock wiped out by the drought causing serious livelihood sustainability, particularly food insecurity.

1998- 2001 La Nina drought

The period was characterized as one of the longest and severest droughts in many parts of East Africa. The most notable impact included: (i) Drying up of rivers Karanga, Weruweru and Kikafau in Tanzania and Rivers Nginyang, Endao and Chemeron in Kenya’s Baringo District.(ii) Reduced water levels of rivers Tana in Kenya, Pangani in Tanzania and Kagera in Uganda led to reduced Hydropower generation, reduced industrial output, redundancies and unemployment due to low water supply (iii) Closure of some industries due to insufficient hydropower (iv) Widespread crop failure, food insecurity, famine and high livestock mortality and introduction of artificial powdered milk in the Kenyan markets in 2001 (DMCN, 2002).

The 2005-2006 drought led to 80% livestock loss due to lack of water and pasture in the semi-arid districts of Turkana, Wajir, Mandera and Karamoja. It also caused;
(i) Drying of water resources in the ASAL, (ii) Drying up of pasture (iii) Total crop failure in Mandera (iv) Death of both human and animals and migration of environmental refugees which caused conflicts and death around the watering points in Mandera and Wajir Districts.

Management of water and challenges of climate

Rainfall anomalies in Kenya are a common occurrence. Droughts have devastating and long-term impacts on food security, human and animal lives. To protect the livelihoods in the affected areas, the following needs to be done.
The government should provide water to the people and animals through digging of boreholes in the:

(i) Arid and semi-arid areas to ensure livestock sustainability.
ii) Since droughts are a common occurrence and get the governments unprepared, leading to loss of both human and animals lives due to famines, there is need for timely, precise and reliable climate information and prediction systems in order to facilitate responses to disaster preparedness, mitigation and management by the government. In this regard, the Drought Monitoring Centre Nairobi (DMCN) world Meteorological Organization (WMO) and the International Research Institute for climate prediction (IRI) which are mandated to provide climate information and prediction services for Kenya, need to go a step further and predict long term rainfall anomalies apart from the normal decadal (ten day) predictions.
iii) Water harvesting and storage during floods for use during droughts.

Floods and food production

Arid and semi-arid lands are characterized by erratic rainfall, which normally is above normal. This type of rainfall causes floods and flash floods that lead to run-off, causing soil erosion, drowning of farms, animals, destruction of infrastructure and pollution of existing water resources. The heavy rains caused by the 1997/1998 El Nino event

Table 4. Livestock population in 000's Marigat Division.

Year	Goats	Cattle
1979	74	21
1986	98	25
1990	120	30
1992	150	37

Source – Livestock office, Marigat 1993.

disrupted the following ecosystems and livelihoods: (i) Livestock died due to drowning, lightning and mudslides in the highlands e.g. Kiambu in Kenya. (ii) Damage to food crops such as maize, beans and bananas by hailstones, winds and frost in commercial tea estates of Kericho, Kenya. (iii) Outbreak of waterborne diseases such as malaria, typhoid, cholera in humans and Bovine Pleuropneumonia, Rift Valley fever and East Coast fever in livestock. (iv) Massive mudslides and soil erosion. (v) Damaged infrastructure (roads, bridges, and rail lines) which hindered delivery of both raw food crops and processed product to and from industries. (vi) Pollution of surface water due to soil erosion and surface run off (DMCN, 2003). The October-November 2008 floods caused flooding, flash floods, mud-slides, drowning of people and animals in Wajir, kiambu, Tharaka and Budalang'l regions.

Management of floods and food production

(i) Rain water can be harvested from roofs, ground surfaces and intermittent water courses, instead of leaving run off to cause erosion. (ii) Water harvesting on croplands may be achieved through micro-catchments systems or macro-catchments systems or through floodwater farming. (iii) In the semi-arid and drought-prone areas water harvesting enhances yields and reliability of food production while also conserving the soil. (iv) Rainwater harvesting provides a source of water for household use, for irrigating vegetable gardens and small-scale fish farming projects. (v) Rainwater harvesting provides for agriculture where it provides full or supplemental irrigation, environmental conservation and prevention of flood damage (WMO, 1999).

Pastoral activities and droughts

Pastoralism is the dominant socio-economic activity in the arid and semi arid region with milk and meat forming the main sources of food. Types of animals kept are the local breeds are namely: the Red Maasai sheep, the East African goat, Zebu cattle and camels. The livestock carrying capacity is far beyond the number of animals kept. For example, in Marigat division of Baringo District in Kenya, the livestock carrying capacity was established to be 60,000 goats or 10,000 cattle during a wet year, but livestock numbers increased steadily from year to year regardless of droughts or rainfall. This was a strategy for food security during droughts. Table 4 shows that the steady livestock increases between 1979 and 1992.

In adequate livestock management such as overstocking by pastoralists causes soil sealing and trampling, destruction of vegetation leaving the ground bare and exposed to high evaporation which lead to heavy loss of soil moisture causing soil desiccation which is unsuitable for crop farming.

Management of livestock activities

Livestock officers who were born and bred in these dry regions should be deployed back home to study and understand the traditional risk avoidance strategies of livestock farmers so that attempts are made along this line to introduce broader knowledge of improved technologies to reduce numbers of animals without grossly interfering with the culture of the pastoralists who believe that large herd numbers are a sign of wealth, social security and a strategy against famines caused by climate change.

Water pollution and fish production

Industrial emissions

Industrial developments, for example the textile factories, paper mills, steel mills, power stations, burning of fossil fuel and vehicle exhausts produce high concentrations of atmospheric pollutants such as sulphur and nitrogen oxides which have obnoxious odours. Once in the atmosphere, the sulphur and nitrogen oxides combine with moisture to produce sulphuric and nitric acids which fall as acid/black/corrosive rain. Any form of atmospheric water such as rain dew or snow with a pH of less than 5.6 is termed as acid precipitation. When the concentration of sulphur dioxide reaches 0.2 ppm, acid precipitation is formed. Aquatic ecosystems are more affected by acid precipitation than plants. Acid rain is harmful to both plant and animals and it is responsible for the destruction of vegetation near industrial areas in towns such as Nairobi, Thika, Mombasa and the Pan Paper factory in Webuye.

Industrial effluent

Human activities such as accelerated run-off from fertilized and manured agricultural land such as Kericho tea farms, Ahero rice scheme and Mumias sugar farms discharge of raw domestic sewage and industrial release (effluent) lead to eutrophication of lakes. Eutrophication is the enrichment of water resources by nutrients such as phosphorous and nitrogen which are very important because they regulate the growth of aquatic plants (plankton). This anthropogenically-accelerated eutrophication

has led to:

(i) Excessive growth of algae which is widely blamed for the presence of water hyacinth in Lake Victoria.
(ii) Depletion of dissolved oxygen as algae decays after death leading to death of some fish species such as the tilapia-(Nilotica barongonesis) from Lake Victoria.
(iii) Some algae blooms are so toxic that consumers of the seafood which have been exposed to them can suffer from diarrhoea.

Examples of water sources in Kenya suffering from eutrophication due to industrial and agricultural pollution are: (i) Lake Victoria which suffers pollution from agricultural areas such as Kericho and Nandi tea farms, Chemelil and Muhoroni Sugar farms, Ahero rice scheme, industrial waste water effluents from Kisumu, Kericho, Homabay, Webuye and Busia towns. The pollution of Lake Victoria often leads to outbreak of water borne diseases such as cholera, diarrhoea, dysentery and typhoid in the Lake Victoria Basin. (ii) Lake Naivasha suffers pollution from agro – chemical from the horticultural farms and damping of raw sewage from Naivasha town. The two have led to decline in fish species, eutrophication shrinking of the lake levels and reduced number of Flamingo birds. (iii) In Lake Magadi, the main pollution threats to the lake include deposit of raw effluent and domestic waste from the Magadi Soda Company deposited into the lagoons. The pollution has endangered the Cichlid fish, which if non-protected from industrial effluent will soon be extinct.

Conclusion

Threats to water resources management and food production due to climate change pose a major challenge to the government. The Government of Kenya has demonstrated its commitment to sustainable use of the water resources by initialising and implementing some important statutes and policy framework that directly govern the management of lakes and wetlands for sustainable food production, for example, the 2005 water Act. The government initiated and financed the digging of 800 boreholes in the ASAL between 2005 and 2008. The government through the Ministry of Agriculture developed drought resistant food crops such as mwezi moja beans, katumani maize, cassava and green grams which are today grown in the ASAL.

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