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Climate Variability and Water Resources Degradation in Kenya

Improving Water Resources Development and Management

Hezron Mogaka
Samuel Gichere
Richard Davis
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Foreword

This report—a flagship product of the Africa Water Resources Management Initiative (AWRMI) prepared with the support of the Kenya Country Team, Mainstreaming Fund for the Environment, the Bank Netherlands Water Partnership Program, World Bank Institute and Environment Department, and Sida—is a critical step in the World Bank's policy dialogue on water resources management reforms and investment planning being promoted by the Government of Kenya through the Ministry of Water and Irrigation (formerly the Ministry of Water Resources Management and Development).

It represents a pioneering attempt by the AWRMI to focus on the economic implications of water resource management in Kenya (and indeed in Africa), looking specifically at two of the most important water-related issues that make the economy and people of Kenya highly vulnerable—the effects of climate variability and the steady degradation of the nation's water resources.

In both areas, the report finds significant economic impacts. The El Niño-La Niña episode that occurred from 1997 to 2000 cost the country Ksh 290 billion, about 14 percent of GDP during the three year period. Given their regularity, over the long term, floods and droughts are estimated to cost the economy about Ksh 16 billion per annum (2.4 percent of GDP). This is a very serious drag on the country's economic performance. Water resources degradation costs the country at least Ksh 3.3 billion (0.5 percent GDP) annually. *The long term annual impact of nearly 2.9 percent of GDP from these two factors has been estimated conservatively; the true cost is likely to be much greater.*

While it is not economically efficient to avoid all costs, many of them can be minimized by increased investment in water resource management and infrastructure and more efficient, accountable, and participatory management and operation of the water resource sector.

The report thus provides a clear economic rationale for investing in improved water resources development and management in Kenya.

The findings of this report have already had considerable impact inside and outside of Kenya. They were central to shaping the analyses and recommendations of the World Bank's recently completed Economic and Sector Work published as a grey cover report—*Water Resources Sector Memorandum: Towards a Water Secure Kenya*—which forms the basis for preparing a long term investment program on water resources management and development and is informing the policy dialogue in Kenya. The report also introduces a complex analytical methodology that has been modelled for broader application elsewhere—for example, in nations such as Ethiopia, Mozambique, and Mali.

James Warren Evans
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Environment Department

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The preparation of this report was funded and supported by a partnership among the World Bank's Africa Water Resources Management Initiative, Kenya Country Team, Mainstreaming Fund for the Environment (MFE), the Bank Netherlands Water Partnership Program (BNWPP), World Bank Institute (WBI), and the Environment Department, as well as the Swedish International Development Agency (Sida) and the Government of Kenya.

The report is a product of a collaborative effort supported by many water resources stakeholders, who are listed in Appendix A. We sincerely thank officials of the MWI, the Forestry Department of the Ministry of Environment and Natural Resources, Kenyan Marine and Fisheries Research Institute, Permanent Presidential Commission on Soil Conservation and Afforestation, the Ministry of Energy, and the Ministry of Agriculture and Rural Development. We also thank the members of the Kenyan Inter-Ministerial Steering Committee on the Integrated Water Resources Management Strategy.

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Abbreviations and Acronyms

AfDB	African Development Bank
AEEF	African Environment Education Foundation
AFD	Agence Française de Dévelopment
ALRMP	Arid Lands Resource Management Project
ASAL	Arid and Semi-Arid Lands
AWRMI	Africa Water Resources Management Initiative
BNWPP	Bank Netherlands Water Partnership Programme
CAAC	Catchment Area Advisory Committee
CAS	Country Assistance Strategy
CDA	Coast Development Authority
CEM	Country Economic Memorandum
DANIDA	Danish International Development Agency
DFID	Department for International Development (UK)
EAC	East African Community
ENEP	El Niño Emergency Project
ENNDA	Ewasso N'giro North Development Authority
ERSWEC	Economic Recovery Strategy for Wealth and Employment Creation
EWDAF	Water and Sanitation Program: Africa
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Fund
GWh	Gigawatt Hour
GOK	Government of Kenya
GNP	Gross National Product
GTZ	German Technical Assistance
IDA	International Development Association
IFAD	International Fund for Agricultural Development
IGAD-DMC	Inter-governmental Authority on Development—Drought Monitoring Center
IMSC	Inter-ministerial Steering Committee
JICA	Japan International Cooperation Agency
KENGEN	Kenya Electricity Generating Company Limited
KEWI	Kenya Water Institute
KfW	Kreditanstalt für Wiederaufbau
KMFRI	Kenya Marine and Fisheries Research Institute
Ksh	Kenyan Shillings
KVDA	Kerio Valley Development Authority
KWS	Kenya Wildlife Service
LBDA	Lake Basin Development Authority
LNGG	Lake Naivasha Growers Group
LNRA	Lake Naivasha Riparian Association
LVDP	Lake Victoria Development Program
LVEMP	Lake Victoria Environmental Management Project

MENR	Ministry of Environment and Natural Resources
MOARD	Ministry of Agriculture and Rural Development
MOF	Ministry of Finance
MOL&FD	Ministry of Livestock and Fisheries Development
Mm^3	Million cubic meters
MW	Megawatt
MWI	Ministry for Water and Irrigation
NAWRD	National Water Resources Assessment Database
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Strategic Action Plan
NEMA	National Environment Management Agency
NGO(s)	Nongovernmental Organization(s)
NIB	National Irrigation Board
NWCPC	National Water Conservation and Pipeline Corporation
NWRMS	National Water Resources Management Strategy
O&M	Operations and Maintenance
PRSP	Poverty Reduction Strategy Paper
RDA	Regional Development Authority
RBDA	River Basin Development Authority
RWUA	River Water Users Association
Sida	Swedish International Development Agency
STP	Sewage Treatment Plant
TARDA	Tana and Athi River Development Authority
TAC	Technical Advisory Committee
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations Children's Education Fund
WHO	World Health Organization
WRM	Water Resources Management
WRSM	Water Resources Sector Memorandum
WRMA	Water Resources Management Authority
WSB	Water Supply Board
WSRB	Water Supply Regulatory Board
WSS	Water Supply and Sanitation
WUA	Water Users Association
WWF	World Wildlife Fund

Notes: All dollars are U.S. dollars; all tons are metric tons.

Executive Summary

> "(Kenya's) storage capacity is gradually being reduced by siltation and destructive natural calamities, such as the heavy floods of the El Niño rains, as well as inadequate application of conservation measures. Considering all the factors governing the availability and accessibility of water resources, it is clear that improvement in the management of water resources is a top priority in our country."
>
> —*Daniel Arap Moi, President of Kenya, Integrated Water Resources Management Conference, Nairobi, March 2002.*

Although several studies have been conducted in recent years on Kenyan water resources development and management, none has specifically focused on the economic implications of water resource management or mismanagement. This report attempts to fill that gap for two of the most important water-related issues facing the country—the effects of climate variability and the steady degradation of the nation's water resources.

The study reported here concluded that the El Niño-La Niña episode from 1997–2000 cost the country Ksh 290 billion (about 14 percent of GDP during that period). During El Niño-induced floods, this cost primarily arises from destruction of infrastructure such as roads, water supply infrastructure, and pipe networks. The largest costs incurred during the La Niña droughts (1998–2000) were from loss of industrial production and other costs arising from reduced hydropower generation, as well as from crop and livestock losses. These costs are felt throughout Kenyan society.

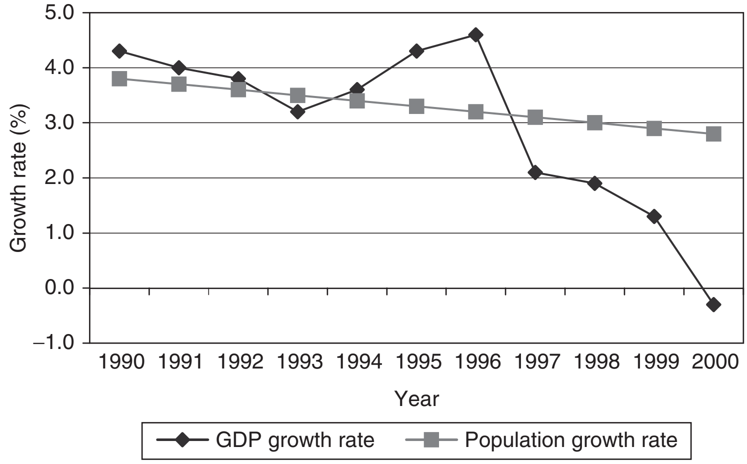
Based on the limited data available, water resources degradation costs the country at least Ksh 3.3 billion (0.5 percent GDP) annually. This estimate has been developed conservatively; the true cost is likely to be much greater. All sectors of the economy are dependent on water resources, including agriculture, energy, urban, rural, livestock, tourism, industry, and fisheries. While it is not economically efficient to avoid all of these costs, many of them can be avoided (or minimized) by increased investment in water resource infrastructure and more efficient, accountable, and participatory operation of the water resource sector. In most cases, this is a regular cost that the country now faces as a result of the degradation of water catchments, siltation of water storage facilities, pollution of surface and groundwater, eutrophication of lakes and other water systems, and unauthorized abstractions. Some degradation costs are rising steadily, such as pumping costs for groundwater to Nairobi as the water table falls.

Kenya's Economic Performance

Kenya's economy is largely rural-based and heavily dependent on its natural resource base, a resource base with intricate interlinkages. Water plays a key role in the economy as a resource for urban and rural consumption, for energy generation, for agricultural development, for industrial growth, livestock and tourism development.

Since 1997, the economic growth rate has consistently been lower than the population growth rate (Figure 1). Around the same period, the number of people living below the

Figure 1. Trend of GDP and Population Growth Rates (1990–2000)



Source: Republic of Kenya 2001e.

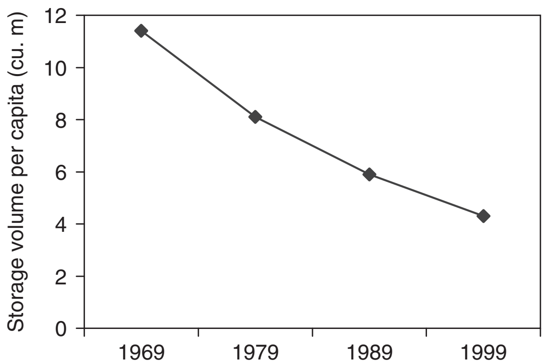
poverty line and who subsist predominantly on natural resources has increased from 48 percent in 1994 to 52 percent in 2000, and to about 56 percent by 2001 (Godana 2002). This coincides with a period when investments in water resources development and management have shrunk significantly. In the absence of major changes in the use of natural resource inputs, the disparities in these rates will continue to exert pressure on environmental goods and services, including water resources. Existing resources will have to be used more efficiently to even maintain the same standard of living, let alone meet the country's development goals.

A number of government reports (Republic of Kenya 2001b; UNEP/GOK 2000) have pointed out that poor governance of natural resources has increased the vulnerability of the country to extreme environmental events, such as droughts and floods, which have had a strong influence on Kenya's economic performance. They also show that recovery from extreme events is costly and extends several years after the events. As this report shows, poor water resource management also has a significant impact on the economy even in the absence of floods and droughts.

Poor Management of a Limited Water Resource Base

Kenya is classified by the U.N. as a chronically water-scarce country (Republic of Kenya 1992). The country's natural endowment of freshwater is highly limited, with an annual renewable freshwater supply of about 647 cubic meters per capita, significantly below the 1,000 m^3 per capita set as the marker for water scarcity. The current level of development of water resources in Kenya is very low. Only 15 percent of the safe yield of renewable freshwater resources has

Figure 2. Decreasing Storage for Domestic Water Supply in Kenya (1969–1999)



Source: Ministry of Environment and Natural Resources, Kenya.

been developed currently.[1] This low level of development means that water supply storage per capita has declined dramatically from 11.4 m^3 in 1969 to about 4.3 m^3 in 1999—simply because of population growth (Figure 2).

However, the country possesses sufficient water resources to meet demand. A recent study[2] has estimated that, based on current water use efficiencies, the predicted aggregate demand will rise to 5,552 Mm^3 per year in 2020. This would still be within the country's safe yield (8,447 Mm^3/yr), although the cost of supplying each additional increment of water is likely to rise steeply as readily accessible sources are progressively tapped.[3]

As the decline in water storage infrastructure implies, there has been a declining budgetary allocation for water resources management in Kenya. Expenditure on water supplies and related services declined from Ksh 4,249 million in 1994 to Ksh 1,765 million in 2001.[4] The proportion of total funds allocated to water development and water management activities are skewed, with the budget allocation for recurrent costs consuming about 92 percent of the total budget.[5] Consequently, there have been insufficient funds to properly allocate water, police illegal water extractions, control discharge of wastes into lakes and rivers, protect catchments, and help prevent excessive erosion in headwaters. Water users have taken advantage of these conditions to use water illegally to the detriment of those further downstream.

1. Republic of Kenya (1992) refers to the qualitative improvement of the water quality, availability, supplies and accessibility to and for different user needs.
2. "Kenya's Water Resources Infrastructure Gap." Background Paper No 2.
3. The projections are based on expected growth of the irrigation sector in 1992. This growth rate has not been fully realized. These projections should be revised in light of recent data.
4. Republic of Kenya (2003). Figures are based on constant 1982 prices. The water resources development components include, water development, rural and self-help water supplies, water conservation and pipeline cooperation, county council and urban water supplies, training, and miscellaneous water supplies.
5. Includes the expenditure by the National Water and Pipeline Corporation.

The Costs of Climate Variability

The combination of a limited endowment of water and high temporal variability in its delivery—coupled with an economy that is very dependent on water, an absolute decline in investment in capital infrastructure and maintenance of existing infrastructure, and the increasing degradation of catchments, lakes, and aquifers—means that Kenya now has very low water security. In other words, the country is highly vulnerable to climate variability, both droughts and floods.

The 1997/98 El Niño floods are estimated to have destroyed and damaged infrastructure with a replacement cost of approximately Ksh 64 billion ($820 million). Only Ksh 8 billion ($100 million) of that was actually replaced, implying a major long-term cost to the country. The prolonged La Niña drought that followed was even more expensive, costing at least Kshs 220 billion ($2.8 billion). The loss of industrial production arising from inadequate water storage for hydropower generation was estimated at Ksh 110 billion ($1.4 billion), and agricultural losses are estimated at about Ksh 30 billion ($370 million). Urban-based industries were forced to relocate both within the country and to neighboring countries (for example, steel rolling mills mostly relocated to Uganda), leading to long-term loss of important industrial capacity. Over the long term, floods and droughts are estimated to cost the economy about Ksh 16 billion per annum (2.4 percent of GDP). This is a very serious drag on the country's economic performance.

Although the occurrence of such extreme climatic events is outside of a country's control, it is possible to minimize their impacts through proper planning and investment. The onset of El Niño events can often be predicted 8–10 months in advance, and consequently, it is possible to institute short-term measures to minimize their effects.[6] In the long term, construction of adequate storage and distribution infrastructure will limit the losses from these drought events. It is more difficult to control floods. Nevertheless, acting on predictions of La Niña—and maintaining infrastructure such as bridges and roads—will reduce costs.

The Costs of Poor Water Resource Management

Kenya has had a poor record of water resource management in recent years.

Water allocation decisions are made on the basis of inadequate hydrological information, and outright theft of water is common in some parts of the country. Questionably granted water permits are also common. In water-stressed areas, the consequences of poor water allocation are significant. The annual minimum discharge at Archer's Post on the Ewaso Nyiro North River, for example, has decreased steadily since 1961 in proportion to the increase of water abstraction in the upper catchment of the basin. The maximum mean annual flow recorded was 82.36 m^3 per second in 1961. In 1984, 1986, 1991, 1994, and 2000 the river dried up over a stretch of about 60 km upstream of Archer's Post, clearly showing the limitations for further development of surface water (Republic of Kenya 2001f).

Groundwater resources have also been exploited beyond their sustainable yield in intensively settled parts of the country. Thus, seawater is contaminating some coastal aquifers causing hoteliers to spend about Ksh 600 million ($7 million) per annum on

6. Glantz (2001) studied the response of 16 countries, including Kenya.

desalinization, and the steady lowering of the groundwater table under Nairobi is estimated to add Ksh 870 million ($11 million) per annum in pumping costs alone.

Water quality has also deteriorated through both uncontrolled discharges of urban and industrial wastes. This is estimated to impose an additional Ksh 850 million ($11 million) per annum in water treatment costs alone. Pollution of rivers and lakes with sediments, nutrients and agro-chemicals from catchment sources imposes additional costs. Economically and ecologically important lakes, such as Lake Victoria, suffer from eutrophication because of excessive nutrient inputs from both atmospheric and riverine sources. The loss of potential exports to Kenya of Nile perch alone is estimated to be worth Ksh 680 million per annum ($9 million)—without including losses to other fisheries and to other uses of the lake.

Although these costs are not as great as those arising from extreme climate events, they occur every year and exert a considerable drag on the Kenyan economy. Even these partial estimates of water resource degradation costs amount to 0.5 percent of GDP, and the full amount is many times higher. These costs can be avoided in many cases by proper enforcement of existing regulations and laws. In other cases, such as reduction in exports of sediments and attached pollutants, it will take the implementation of an integrated plan involving transfers of responsibility, provision of knowledge and techniques, enforcement of regulations and provision of funding.

Seizing the Initiative

A recent paper from the World Bank (Grey and Sadoff 2002) proposes that continued water resources degradation, pollution, and the lack of preparation for climate variability are increasing poverty and undermining economic growth—not just in Kenya but across the African continent. It is clear from the literature, as well as the experience of other countries, that the long-term benefits from prudent protection, development, and management of water resources far outweigh the costs of cleaning up. The findings of this study are consistent with this experience: poor management of water resources, water resources degradation, and rainfall variability are reflected in Kenya's macroeconomic performance.

The government is committed to reversing this trend. The 1999 National Policy on Water Resources Management and Development articulates principles of sound water resources management. The Water Act, passed in late 2002, authorized the establishment of the Water Resources Management Authority (WRMA) to focus on overall regulation of the country's water resources. The Water Act legislates for the decentralization of water management decisionmaking to the catchment/river basin level, and broadens the participation of water user groups and communities in water management institutions. It also calls for treating water as a scarce resource with an economic value. Under the Act, access to that resource can be regulated through water user charges. These water user charges are closely linked to the devolution of responsibility and formation of mechanisms for water users to participate in decisions. Operations and Management (O&M) is to be funded from water user charges and these charges are only likely to be collected if those paying the charge have a say in the expenditure of the monies.

The Country Strategy on Integrated Water Resource Management under preparation by the government will provide the foundation for the proposed Authority and other institutional reforms. The draft strategy calls for increasing investments in new water storage and sustainable water supply, as well as strengthening the water resource management system. It also provides the basis for identifying water management as an important national priority and for harmonizing the various sectoral and national development initiatives such as the National Development Plan, Kenya Rural Development Strategy, Energy Policy, Land Use Policy, Industrialization Strategy, and the Poverty Reduction Strategy (as contained in the Poverty Reduction Strategy Paper and Action Plan). The strategy also calls for a National Water Campaign, developing financing mechanisms for funding water resources management, re-establishing monitoring networks and programs, promoting catchment management, strengthening regulation and enforcement of the Water Act, and supporting investments in pilot catchments and river basins among others.

Through these reforms, Kenya will achieve not only increased storage of water to provide greater security against shortages during droughts, but will also improve the management of its water resources. The decentralization of decisionmaking will speed up issuing of permits; the proposed local retention of income from permits will provide operating funds for enforcement; the separation of the policy functions from water resource management in the WRMA will improve operational efficiency and avoid conflicts of interest; and the public awareness campaign will help build grass roots support for better water resource management

CHAPTER 1

Introduction

A wide range of government policy documents, including the 1999 National Policy on Water Management and Development, have recognized effective water resource management as key to both basic human needs and sustainable economic development. However, there has been little quantitative analysis on the linkages between good management of the country's water resources and economic performance. This report establishes and discusses the costs to the economy due to low investment in water resources development and poor management of existing water assets. It demonstrates the importance of finalizing the Country Strategy on Integrated Water Resources Management and provides guidance on the issues to be addressed by the Water Resources Management Authority.

Background and Aims of the Study

Water in National Development

Kenya's development policy is intended to raise the level of economic development and improve the population's standard of living. Efforts to develop the water sector have been based on water being both a basic human need and a catalyst to accelerate social and economic development. This objective has been articulated in various development policy documents starting with Sessional Paper No. 10 of 1965 (Republic of Kenya 1965), which emphasized the need for the provision of major basic social services, including water.

Other policy documents that contain references to the importance of sustainable water resources development and management include the National Development Plans (Republic of Kenya 1974, 1994a, 1997, and 2002c); the Sessional Paper No. 1 of 1986, entitled *Economic Management for Renewed Growth*; the 1992 policy on the development of Arid and Semi-Arid Lands; the National Poverty Eradication Plan (1999–2015); Sessional

Paper No. 2 of 1996 on Industrial Transformation to the year 2020; the 1992 National Water Master Plan; the National Environment Action Plan (NEAP); and the Country Strategy on Integrated Water Resources Management (IWRM).

The importance of water resources in national development has been reaffirmed in recent policy documents, including the Sessional Paper No. 1 of 1999 on the National Policy on Water Management and Development. The current National Development Plan (2002–2008) also places great emphasis on the value of water toward attainment of the country's development objectives. Key political and policy pronouncements made during the National Conference on Water Resources in March 2002 emphasize the importance of water resources management to the country's economic development.

The vision for the Kenya Water Sector is that of achieving sustainable development and management of the country's water resource as a basis for poverty reduction and promotion of socioeconomic development (Republic of Kenya 1999). Key national water policy objectives are to:

- Conserve and protect available water resources,
- Apportion water resources in a sustainable, rational, and economical way,
- Supply adequate and quality water to meet various needs,
- Ensure safe disposal of wastewater to safeguard ecological and environmental processes,
- Establish an efficient and effective institutional, policy, and legal framework to achieve systematic development and management of water resources, and
- Develop a sound and sustainable financing mechanism for effective water resources management, supply, and sanitation systems.

The country's economy and political stability are critically dependent on maintaining those aspects of the country's ecological integrity that have a direct bearing on the status of water resources. Agriculture and industry, two of the largest sectors of the economy, are both directly dependent on sound management of environmental goods and services. Similarly, Kenyan cultural and political structures are closely tied to the natural resource base, linking erosion of ecological systems to the erosion of social and political systems as well (Mugabe 1997).

Development Policies

In recent years, the Government of Kenya has been developing a water supply and sanitation sector strategy and an integrated water resources management strategy as part of the overall country's efforts to support economic growth and reforms in the water sector. The 1992 National Water Master Plan, which called for major investments in infrastructure and administrative capacity, was accepted in principle by the government and regarded as an important guide to the country's water resource development and management. The 1999 National Policy on Water Management and Development is now being implemented through both legislative changes and the development of a comprehensive Country Strategy on Integrated Water Resources Management.

The Regional Development Authorities also have developed their regional development strategies, which recognize the importance of water resources in supporting regional economic activities.[7] All these documents recognize the need for adequate water resources to meet both domestic and industrial water needs. In both the Eighth and Ninth National Development Plans (1997–2001; 2002–08), the government acknowledges the scale of water resource threats. It cites the degradation of water catchment areas as one of the main challenges confronting sustainable water resource management efforts (Republic of Kenya 1997). Other relevant and recent initiatives that underscore the inadequacy of water resources development, as well as critical constraints to development and the importance of sound water management in the national economy, include the 9th National Development Plan, Kenya Rural Development Strategy Paper, the National Health Sector Strategic Plan 1999–2004, the Sessional Paper on Environment and Development,[8] and the Poverty Reduction Strategy Paper.

Kenya has signed and ratified a number of international and regional conventions, treaties, and agreements with significant components on sustainable water resources conservation, development, and management. The government has, for example, ratified the Convention on Biological Diversity (CBD), whose key objectives include sustainable conservation of biodiversity (including important water catchment areas), as well as the United Nations Convention to Combat Desertification (UNCCD).[9] Achieving the objectives of the latter involves long-term integrated strategies that focus on improved productivity of land and water resources.

Purpose of the Study

Despite the acknowledged role of water resources in socioeconomic development and growth, there is little quantitative information on the extent to which water resource degradation impacts Kenya's economy. Similarly, there is little empirical data on both the micro- and macroeconomic impact of rainfall variability and water resource degradation and its applicability to development policy formulation and decisionmaking.

The overall goal of this study, therefore, is to assess the macroeconomic impacts of both extreme climate events and water resources degradation. Specifically, we collect, collate, and document data and information describing the linkages between Kenya's economy and natural resource base, and use these to estimate the macroeconomic cost of the

7. For example, Lake Basin Development Authority's Integrated Regional Development Master Plan (Water Resources Sector), and Ewaso Nyiro North Catchment Conservation and Water Resources Management Study.

8. The principal components of the Rural Development Strategy are: increase agricultural productivity, expand farm and non-farm income earnings and food, reduce disease and ignorance, and achieve sustainable natural resource management. To realize these components, prudent water resources management is a necessary condition. The Poverty Reduction Strategy Paper underscores the role of water resources in reducing poverty. The Health Sector Strategic Plan calls for strong links to be developed between the Ministry of Environment and Natural Resources and the Ministry of Health in order to combat water borne diseases in rural and urban areas. The Sessional Paper on Environment and Development spells out the need to ensure adequate, accessible and high water quality for rural and urban supplies.

9. UNEP (1992). The main objective of this convention is to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, with a view to achieve sustainable development.

Box 1.1: Country Strategy on Integrated Water Resources Management: Key Issues

The Country Strategy on Integrated Water Resources Management acknowledges the need to manage water resources for sustainable development and poverty reduction. The strategy's key principles include:

a. The separation of water resources management from water supply and sanitation.
b. The separation of policy, regulatory, and implementation functions.
c. The devolution of regulatory responsibilities from the director of water development to national water resources management authorities and catchment boards.
d. Establishment of a pricing policy that addresses equity issues ("polluter pays" principles) and economic, financial, and environment values, thus internalizing costs of water management.
e. Human resources development/re-deployment, leading to more effective institutional frameworks.
f. Increased public spending and budget allocation to the sector.

Source: Republic of Kenya, 2002b.

country's vulnerability to droughts, floods, and water resources degradation. These sets of data and information form the basis on which more efficient water resource development and management plans and strategies can be developed.

The study provides an economic rationale for strengthening water resources management in Kenya, thus supporting the ongoing reforms in the water sector. The draft Country Strategy on Integrated Water Resources Management (Box 1.1) provides a foundation for the establishment of the Water Resources Management Authority (WRMA) as mandated by the Water Act. The strategy recognizes and treats water as a scarce commodity with impacts on social, economic, and political developments.

The study does not estimate the benefits and costs arising from improved water resources management. These will be defined on the basis of detailed analysis to be carried out by the MWI as part of the IWRMS process.

Data and information on the contribution of water resources to Kenya's economy are scarce and scattered. The manifestations of water resources degradation are long-term; this complicates efforts to determine the economic implications. Water affects all sectors of the economy in an intricate way, and, hence, delineation of the economic costs associated with water resource degradation is relatively complicated. Consequently, the authors have had to make assumptions in many places. These assumptions are conservative, so the results understate the overall economic impacts. In addition, not all the costs of climate variability and water resources degradation have been calculated in the report. Some of these costs are not easily quantifiable and/or have impacts spread over several years. For both these reasons, the full costs of climate variability and water resources degradation to Kenya's economy are significantly greater than calculated here.[10]

10. For logical comparison, throughout the document, quantified data is expressed in 1996 US $ despite the year to which they refer, unless otherwise stated.

Structure of the Report

The remaining sections of this report describe the state of development of Kenya's water resources and the role of water in the various sectors of the Kenyan economy (Chapter 2); an analysis of the effects of rainfall variability on economic activities (Chapter 3); and an analysis of the effects of water resource degradation—including abstractions, pollution, catchment degradation, and eutrophication problems—on various sectors of the economy (Chapter 4). The economic impacts of rainfall variability and water resource degradation will be noted where they are available in this literature. In Chapter 5, we bring together the information from the preceding chapters to present an analysis of the costs to the Kenyan economy based on current water resources management regimes. Taken into consideration are the impacts of rainfall variability and water resources degradation. The impacts are converted into monetary measures as far as possible. Finally, in Chapter 6, we make some specific recommendations for improved development and management of water resources, as well as mechanisms for coping with the country's characteristic rainfall variability.

CHAPTER 2

Kenya's Economy and Water Resources

The UN rates Kenya as having one of the lowest natural water replenishment rates in world. Even so, it has currently developed only 15 percent of its available safe water resources. Consequently, there is now only 4.3 m^3 of water per person in storage for domestic water supply. In addition, the country's water resources are poorly managed, with the water sector budget declining by 20 percent during the 1990s. The country's water largely comes from the five Water Towers, which are under threat from excision and clearance. All sectors of the economy will need increased access to water because of population growth and the country's development goals, particularly irrigated agriculture and the power sectors. However, the poor state of development and management means that all sectors are very vulnerable to interruptions in water supply. For example, hydropower output dropped by 40 percent during the 1999/2000 drought.

Overview of Kenya's Water Resources

Limited Water Resources

Kenya is classified as a chronically water-scarce country. The country's natural endowment of freshwater is limited by an annual renewable freshwater supply of only 647 cubic meters per capita. Globally, a country is categorized as "water-stressed" if its annual renewable freshwater supplies are between 1,000 and 1,700 cubic meters per capita and "water-scarce" if its renewable freshwater supplies are less than 1,000 cubic meters per capita (World Bank 2000). Only 8.3 percent of the countries in the world are classified as water-scarce, while 9.8 percent of the countries are considered water-stressed. By comparison, Kenya's neighbors, Uganda and Tanzania have annual per capita renewable freshwater supplies of 2,940 and 2,696 cubic meters per capita per year respectively.

The availability of water is often a key factor in determining the patterns of human settlement and the value of land for agricultural and livestock production. Within arid and semi-arid lands (ASALs), the food security of pastoral and farm households improves considerably during the wet years. Improved grazing fundamentals in several pastoral areas has resulted in favorable livestock body conditions, increased calving rates, and improved milk output—together bringing market improvements in pastoralist food security.[11] However, the limited endowment of water resources places an added financial burden on the population of Kenya compared to other countries. This burden is even greater because of the country's vulnerability to rainfall variability. In these circumstances, water ought to be treated and managed as a scarce resource with real economic, social, ecological, and political values.

Available Yields

Kenya uses both surface and groundwater resources to meet the current demand. The magnitudes of annual renewable water from surface and groundwater resources differ. The volume of annual renewable surface water is on the order of 19.7 billion cubic meters per year (m^3/yr) while the volume of renewable groundwater is on the order of 2.1 billion m^3/yr (Tuinhof 2001). Renewable groundwater is therefore approximately one-tenth as large as renewable surface water.

Only a certain proportion of renewable water can be used (known as the safe yield), while the remainder is either technically inaccessible or required to safeguard environmental and ecological processes. Even though all water up to the safe yield can be tapped, it can only be accessed at a steeply increasing cost. The safe yield for surface water is estimated to be on the order of 7.4 billion m^3/yr, while the estimated safe yield from groundwater is on the order of 1.0 billion m^3/yr (Table 2.1). The current actual withdrawal from both surface and groundwater resources is much smaller than the potential safe yield. The current withdrawal of surface water is on the order of 1.1 billion m^3/yr (3 million m^3 per *day*), whereas the current withdrawal from groundwater resources is estimated on the order of 180 million m^3/yr (493,000 m^3 per *day*) from both shallow wells and boreholes.[12] Thus, approximately six times more water can be safely abstracted from surface water resources, and approximately five times more water can be safely abstracted from groundwater resources.

There is no contradiction in the country being simultaneously water-scarce and able to safely exploit many times the current water usage. It simply means that not only does Kenya receive one of the world's lowest per capita water replenishment rates each year, but that it has also not developed the limited amount of water available. This, together with the long-term degradation of the existing water resources, makes the country very vulnerable to perturbations in water supply, particularly from climate variability.

11. See FEWS NET Site.

12. Tuinhof (2001). A recent demand estimate ("Kenya Water Resources Infrastructure Gap" Background Paper No 2) has put the total estimated water demand in Yr 2000 at 3.15×106 m^3/day—less than the figures published in the 1992 Water Master Plan.

Table 2.1. Safe Yield from Water Resources by Major Drainage Basins in Kenya

	Safe yield in '000 cubic meters per day					
Basin	**Surface Water**	**%**	**Groundwater**	**%**	**Total**	**%**
Lake Basin	11,993	59.2	539	18.7	12,532	54.1
Rift Valley	211	1.0	586	20.3	797	3.4
Athi River	582	2.9	405	14.0	987	4.3
Tana River	6,789	33.5	685	23.8	7,474	32.3
Ewaso Ng'iro	674	3.3	663	23.0	1,337	5.8
Totals	**20,249**	**100**	**2,878**	**100**	**23,127**	**100**

Source: Surface water data from Republic of Kenya 1992; Groundwater data from Tuinhof 2001.

Geographic Distribution

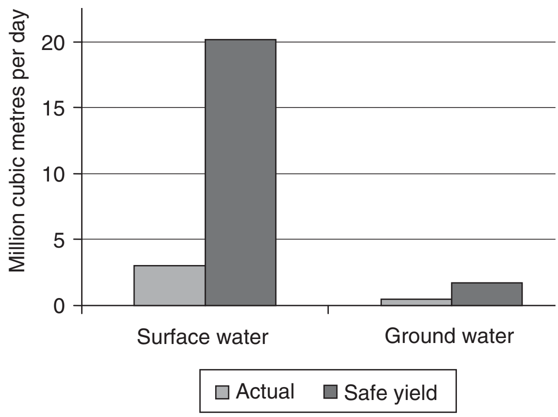
Kenya's surface water resources are distributed within five drainage basins—the Tana, Athi, Ewaso Nyiro, Rift Valley, and the Lake Basin (Table 2.1). With the exception of Lake Victoria and two small lakes along the Kenya-Tanzania border (Lakes Jipe and Chala), all the major Kenyan lakes are located within the Rift Valley Basin. These lakes are saline, except Lakes Naivasha and Baringo, which are freshwater lakes. Lake Naivasha water, together with local groundwater abstractions, supports a multimillion-dollar horticulture and floriculture industry.

Groundwater has considerable potential for boosting water supplies. The country's geology and hydrogeology favor economic exploitation of groundwater resources, with an estimated annual safe yield of 1.0 billion m^3 per year (Figure 2.1). These resources are spread over five hydrological areas: (1) the volcanic rocks area in the Rift Valley; (2) the volcanic rocks area outside of the Rift Valley; (3) the metamorphic basement rocks area; (4) the eastern quaternary sedimentary rocks area; and (5) the western quaternary sedimentary rocks area.

Water Catchments

Catchments in five main ecosystems—Mt. Kenya, Aberdares, Mau Complex, Mt. Elgon, and Cherangani—provide most of the water for the major rivers in the country. They are commonly referred to as "Kenya's Water Towers" (see endplate). By extension, these water towers support all the major sectors of the economy. The Mau Forest Complex is the source of Rivers Mara and Sondu. The Mara River is key to the survival of wildlife in Masai Mara Game Reserve in Kenya and the Serengeti National Park in Tanzania. The Sondu River has the Sondu Miriu Hydropower complex, which is currently under construction and is expected to contribute about 60 MW to the national grid. The Njoro River, which rises in the Mau Forest Complex, provides water to Lake Nakuru. The Mt. Kenya ecosystem is the source of Tana River, which is the foundation of hydropower generation in Kenya. It also supports agricultural development along the Tana Basin. The numerous streams and springs that support commercial and subsistence farming on the lower slopes of Mt. Kenya owe their flow to the Mount Kenya catchment area. Finally, the Nzoia River, which drains into Lake Victoria, originates on Mt. Elgon.

Figure 2.1. Actual Withdrawal and Safe Yield of Water



Activities that affect the quantity, timing, and quality of water emerging from these water towers—such as the proposed excisions of forests, poor land use practices, and encroachment into recharge areas—have the potential to adversely affect the performance of major sectors of the economy.

Future Demand

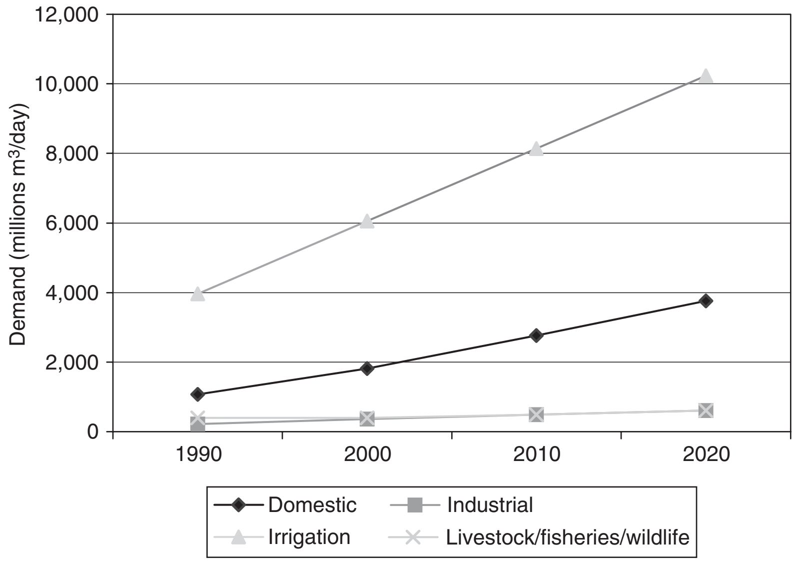
The 1992 National Water Master Plan (NWMP) estimates the future demand for water in the year 2000 and 2010 (Figure 2.2). The estimates have recently been revised as part of the background papers for the World Bank's Kenya Water Resources Sector Memorandum; the revised figures are used in the remainder of this report. Data on actual water use in 2000 are not available to check the accuracy of these predictions.

Irrigated agriculture is the largest water-using sector. Demand is predicted to rise from 3,965 million m^3/day in 1990 to 8,138 million m^3/day in 2010—double the level in 1990. These estimates are based on current water use efficiencies. Actual demand could be significantly less if efficiency incentives are introduced along the lines of those demonstrated by the Kibwezi Pilot Irrigation Scheme and other projects in the horticultural industry.

Livestock demand for water is not expected to increase as rapidly as irrigation demand. It is estimated to increase from 335 to 491 million m^3/day over the 20-year period from 1990 to 2010. This estimate is lower than that contained in the NWMP, partly because it incorporates livestock losses during the 1999–2000 drought.

From 1990 to 2010, urban water demand is predicted to increase by 309 percent and rural demand by 203 percent. Except in the late 1990s, Kenya's industrial sector had grown steadily since independence. Indeed, Kenya plans to become a newly-industrialized country by the year 2020. Water demand from this sector is estimated to increase by 223 percent to 491 million m^3/day. Hydropower growth was not calculated as part of these revised demand projections, but the 1992 NWMP estimated that it will grow by 86 percent

Figure 2.2. Estimated Water Demand



Source: Republic of Kenya 1992.

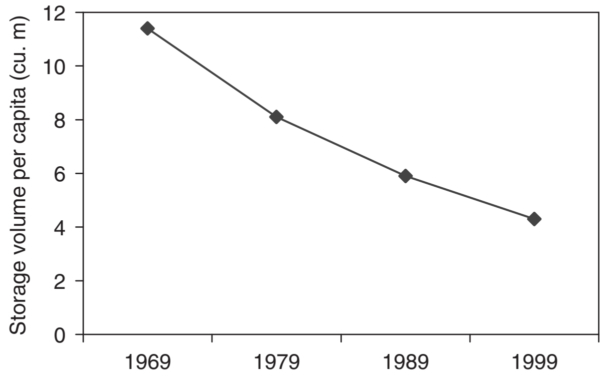
from 4,230 GWh currently to 7,900 GWh by 2010/11. This will require a peak capacity of approximately 1400 MW by 2010 compared to the 750 MW currently available (Okemo 2002).

Overall, demand for water is estimated to rise from 2,067 million m^3/yr in 1990 to 3,150 million m^3/yr in 2000 and 4,343 million m^3/yr in 2010. While these are likely to be overestimates because of assumptions about water use efficiency, there is no doubt that substantially more water resource infrastructure will be needed to augment that available in 1990 because of both population increases and increasing demand to meet the country's national development goals. The projections used here should be revised to take account of better management of water resources under the country's water reforms as well as a more realistic estimate of irrigated agricultural development.

Underdevelopment of Water Resources

Although Kenya has one of the lowest water endowments in the world, it still possesses adequate total stocks of surface and groundwater, although these resources do not always coincide geographically with demand. However, the country has failed to invest adequately in the water storage capacity needed to exploit these stocks, as called for by the 1992 National Water Master Plan and the subsequent AfterCare Study Report of 1998. In fact, even the 1992 infrastructure has not been properly maintained in the face of damage from the 1997/98 El Niño floods, siltation of storage facilities, and general depreciation.

Figure 2.3. Decreasing Storage for Domestic Water Supply in Kenya (1969–1999)



Source: Ministry of Environment and Natural Resources, Kenya.

The consequence is that, given both population growth and the depreciating asset base, the maximum per capita storage of surface water for water supply has declined from 11.4 m^3 in 1969 to only 4.3 m^3 by 1999 (Figure 2.3). This very low level of per capita storage reduces the reliability of supply and increases the vulnerability of supply to minor variations in rainfall.

The uses of surface and groundwater resources differ. Development of groundwater resources is preferable in areas where no or very little surface water is available, such as the arid and semi-arid lands (ASALs). In these regions, groundwater is almost the only resource available for dryland agriculture and grazing during long periods of the year, and so is the cornerstone for socioeconomic development.[13] In other regions, such as Nairobi and other cities and towns, development of surface water resources is preferable because of the volumes required and the limited recharge rates of groundwater.

Development of surface water resources requires construction of storage areas to capture both storm flows and regular river base flows. Development of groundwater calls for resource assessments, determination of the safe yield levels, monitoring of resource quality, and investment in appropriate water extraction technologies (Box 2.1).

Although, in principle, water storage volume has increased somewhat since 1992 with the construction of Ndakaini and Turkwel dams, the water storage per capita for non-hydropower purposes has not kept pace with increasing demand from population growth, as shown in Figure 2.3. In fact, because of sedimentation, the effective volume of stored water may have declined.

The AfterCare Study of 1998 (Republic of Kenya 1998a) estimated that the total cost of building infrastructure for the water sector (excluding hydroelectricity production) to

13. Note that a number of irrigation areas are located in the ASALs and are dependent on river flows in these regions.

Box 2.1: Major Programs for Groundwater Development

- The Kwale Water Supply and Sanitation Programme (1980–1994)
- Kajiado-Narok Ground Water Development Programme (1985–1989)
- South Nyanza Ground Water Development Programme (1989–1996)
- Tharaka-Nithi Water Supply and Sanitation Programme (1990–1999)
- Kenya/Netherlands Rural Water Supply and Sanitation Programme (1989–1998)
- Kenya/Egypt Technical Cooperation Phase I (1996–2001)
- Kenya/Egypt Technical Cooperation Phase II (2002–2003)
- Laikipia/Samburu/Baringo/Koibatek Rural Ground Water Project (1999–2000)
- Kenya/China Water Supply Programme Phase II (2001–2002)
- Drought Intervention Programme (2001–2002)

Constraints on groundwater exploitation:

- Low levels of funding for groundwater resources assessment
- Uncoordinated efforts on groundwater development
- Inadequate human resources capacity in monitoring, evaluation and enforcement of Water Act

2010, assuming no additional deforestation and catchment degradation, is on the order of Ksh 208 billion ($2.6 billion, see Table 2.2). This would require approximately 2.8 percent of the country's GDP over that period, an investment that is urgently needed to sustain current production and provide the current and future water supply needs of the nation.

Deteriorating Management of Water Resources

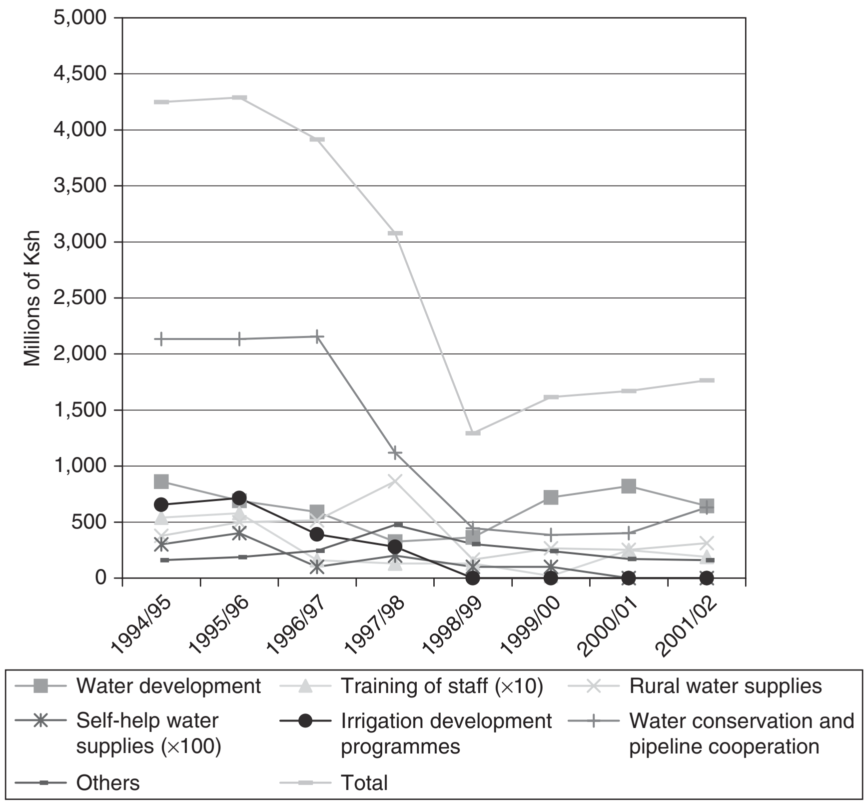
Largely as a result of declining government budget allocations and decreases in donor funding, overall investment in water resources development and management declined

Table 2.2. Infrastructure Cost Estimates for Water Sector

	Amount (thousands of US$)		
Project	**Urban**	**Rural**	**Total**
Rehabilitation	44,500	95,100	139,600
Ongoing	7,400	67,700	75,100
Planned/Designed	27,500	8,700	36,200
Newly proposed	1,243,000	159,800	1,402,800
Sub-total	1,322,400	331,300	1,653,700
Sanitation	477,084	93,230	571,314
Livestock	—	349,760	349,760
Total	**1,799,484**	**775,290**	**2,574,774**

Source: Republic of Kenya 1998a.

Figure 2.4. Development Expenditure on Water Supplies and Related Services, 1994/5–2001/2 (millions of Ksh)



Source: Adapted from Republic of Kenya 2003.

during the 1990s; by 2001–02, total investment was only 42 percent of that in 1994–95 (Figure 2.4). This decline was felt in most components of water resources management, including training, irrigation development, and rural water supplies. The only exception was in water development, where investment increased significantly following the 1999/2000 drought due to donor funding inflows.

Government investment dominates surface water development and management. However, the private sector (for example, the hotel industry) invested heavily in groundwater development during the 1999/2000 drought. Given the decline in government investment and limited funds available, there are opportunities for more private sector investment in water resources development and management.

Decline in Funding of Water Resources Assessment

Nearly 90 percent of the Department of Water's budget is allocated to salaries, leaving limited funds for running costs and development activities. The consequences are apparent,

Table 2.3. Condition of Gauges for Measuring Flow into Lake Nakuru

Gauging Station	Description	Existing Conditions
Njoro River	Automatic flow recorder (installed in 1995)	In working condition; needs frequent calibration to obtain reliable data
Makalia River	Automatic flow recorder. (installed in 1997)	Located on a curved river path. Riverbed is eroded and the gauge is above the bed; needs to be relocated at an appropriate location
Nderit River	Staff gauge with facility to equip with automatic recorder.	Flow recorder missing. Riverbed is eroded and the gauge is above the bed. Requires to be reinstalled with appropriate design
Town Drainage Channel	Staff gauge	Gauge is above the flow most of the time; needs to be reinstalled. Culvert where the gauge is installed needs to be repaired
Baharini	Staff gauge; water depth is monitored.	Not suitable for flow measurement. Channel need to be stabilized and made suitable for flow measurement.

Source: Republic of Kenya 1998.

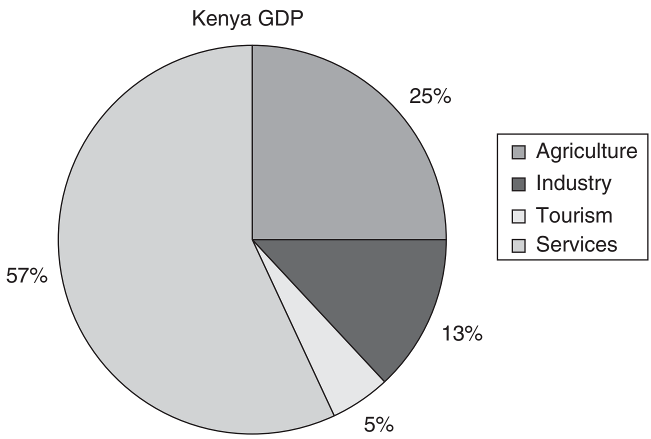
for example, in the water resources assessment area.[14] Flow gauging is vital for sustainable and equitable management, but has been chronically underfunded, with equipment falling into disrepair and flows not always being recorded even when monitoring stations are operational. It was pointed out in the 1992 National Water Master Plan that many of the then-900 water-monitoring stations were not working. The situation has only worsened since then. Table 2.3 gives the results of a recent investigation of the condition of flow gauges for Lake Nakuru, which is a Ramsar-listed site. This situation is common throughout Kenya and fundamentally undermines the very basis for instituting sound governance of water resources.

It is not only the river gauging stations that are debilitated. There is a general neglect of the entire hydrometeorological data network, making it impossible to carry out meaningful water resources planning and operations. Consequently, water allocation and abstraction decisions are based on inadequate data, opening opportunities for water permits to be granted without following proper procedures or to appease vested interests.

There are also inadequate funds for the enforcement of decisions and to follow up water permit requirements. Such regimes have exacerbated conflicts over water use and access, particularly in ASAL areas such as Turkana, Laikipia, and the Tana River districts. In some cases, water use conflicts are very significant and have resulted in violence, extensive damage to property and, at times, loss of human life.

14. Republic of Kenya (1999) recognizes that the database and information management and flow in the water sector is characterized by significant data gaps.

Figure 2.5. Principal Economic Sectors



Source: Republic of Kenya 2002a.

Water Resources and Sectoral Development: The Nexus

Kenya has a Ksh 672 billion ($8.4 billion) economy. Agriculture produces approximately 25 percent of the Gross Domestic Product (GDP), industry produces about 13 percent, tourism produces nearly 5 percent, and services produce 57 percent (Figure 2.5). All these sectors are highly dependent on an adequate supply of water.

Agriculture uses 76 percent of the total water consumption, with industry using about 4 percent and wildlife and inland fisheries 1 percent (Table 2.4). This indicates that 81 percent of the water use in the country has a direct bearing on economic production. Urban and

Table 2.4. Estimated Water Demand, 1990–2010 (thousands of m³/day)

Demand by Category	1990	2000	2010
Domestic water			
Urban	573	1,169	1,906
Rural	532	749	1,162
Industrial	219	378	494
Irrigation	3,965	7,810	11,655
Livestock	326	427	621
Inland fisheries	44	61	78
Wildlife	21	21	21
Total/Day	**5,680**	**10,615**	**15,937**
Total m³/Year (Millions)	**2,073**	**3,874**	**5,817**

Source: Republic of Kenya 1992.

Box 2.2: Declining Per Capita Commercial Energy Consumption

"Petroleum imports cost Kenya about Ksh 53.7 billion in 2000, about 49 percent of the country's foreign exchange earnings. Despite this heavy expenditure of our meager foreign exchange earnings, per capita consumption of commercial energy, basically petroleum and including hydro and geothermal energy, was 94 kilograms of oil equivalent (KOE), having dropped from 101 KOE in 1996 and from 120 KOE in 1980. These per capita consumption figures are below the average for sub-Saharan Africa, which in 1994 stood at 272 KOE for low-income economies. The decreased consumption is attributed to reduced growth of the economy and the associated rise in poverty over the time."

Source: Presentation by Hon. Eng. R A Odinga, Conference on Integrated Water Resources Management Strategy, Nairobi, March 2002.

rural domestic water supply use most of the remainder; this consumption has a direct impact on public health. Hydroelectric power provides 72 percent of the country's electricity production, but the amount lost through evaporation from hydroelectric storage areas is not known and is therefore not shown in the table.

The Energy Sector

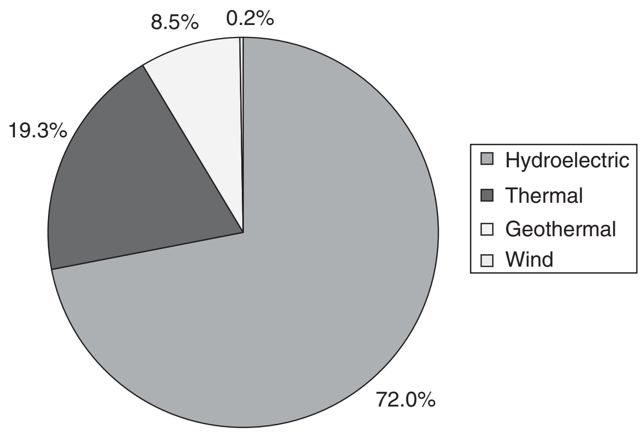
Kenya's energy sector can be divided into "commercial" and "traditional" components. The former relies on imported oil or electricity (jointly meeting 72 percent of commercial energy needs) and domestically generated electricity (28 percent of commercial energy needs). Traditional energy is generated mainly from charcoal. The "commercial" sector uses 37 percent, and "traditional" components 63 percent, of the total energy consumed (Box 2.2).

Domestically generated electricity, although only 9 percent of total energy used in Kenya, plays an important role in satisfying the commercial energy needs of cities and other urban centers as well as some parts of rural areas. In 2002, hydroelectric power provided 72 percent of the domestically generated electricity (Figure 2.6). Thus, water is central to domestic electricity production. This dependency became a reality during the 1999/2000 drought—the worst since that of 1947–51—when the contribution of hydroelectric energy to the national grid was reduced by 41 percent, from 3,062.5 GWh in 1999 to 1,793.8 GWh in 2000 (Figure 2.7).

There is only limited substitutability between the traditional and commercial components of energy. When the domestic electricity supply is reduced, some rural electricity users turn to traditional energy sources. However, industrial enterprises cannot utilize these sources and must either obtain electricity from other sources (oil or imported electricity) at a higher price or reduce electricity consumption and even, in extreme cases, cease production. This was clearly demonstrated during the 1999/2000 La Niña event, when the country turned to imports of electricity and the installation of short-term generating capacity,[15] while some industrial operations were substantially reduced during the period at considerable cost to the economy.

15. The government installed about 100 MW of emergency diesel-fired plants for about 8 months. In addition, another 46 MW of permanent and semi-permanent plants were installed (Okemo 2002).

Figure 2.6. Sources of Electric Power Used in Kenya

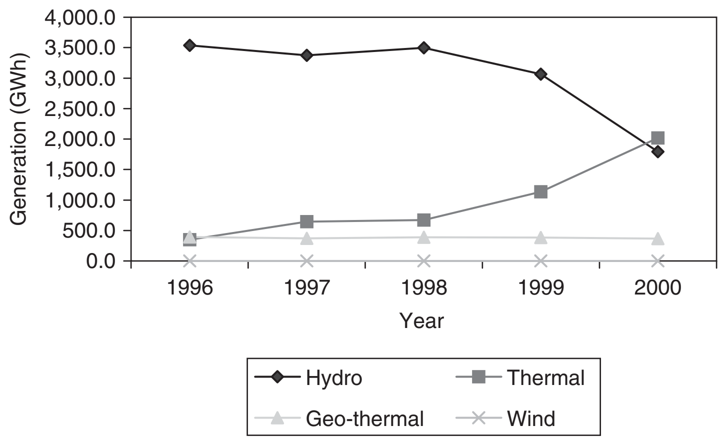


Source: Republic of Kenya, 2002a.

The country's hydropower potential has been minimally developed. There is a capacity for 2,263 MW from hydropower plants of 30 MW and above, while a further 3,000 MW can be generated from small plants. However, only 707 MW has been developed and connected to the national grid to date (Okemo 2002).

There are also links between the traditional component of the energy sector and water resource development and management. Traditional users rely mainly on charcoal and fuelwood as their main sources of energy. There has been a dramatic shift in the sources of fuel-

Figure 2.7. Sources of Electricity Generation, 1996–2000



Source: Republic of Kenya 2001b.

Table 2.5. Estimates of Livestock Populations in Kenya (millions)[16]

Herd Type	ASALs	Rest of Country	Total National Herd
Dairy cattle	Negligible	3	3
Other cattle	4	5	9
Goats	6	6	12
Hair Sheep	4	3	7
Wool Sheep	Negligible	1	1
Camels	1	Negligible	1
Total	**15**	**18**	**33**

Source: Adopted from Aklilu and Wekesa 2001.

wood in the last 20 years from forests to farm-based production; 47 percent was from natural forest estates in the 1980s, compared to only 8 percent in 2000 (Okemo 2002). When the demand for these traditional energy sources increases, it results in increased felling of wood in forests because of the immediate availability of forest wood and its low cost to poachers. In particular, in the ASALs, the increasing demand for fuelwood due to rapid population increase (for example, from refugees) is currently causing a shift in tree harvesting to more ecologically fragile eco-zones, impacting negatively on soil and water resources.

Agriculture and Livestock Development

Only 20 percent of Kenya's land surface is suitable for rainfed agriculture. Most of the cash crops and food crops are grown in these areas. These areas cover most of the coastal, central, and western regions of Kenya and carry about 80 percent of the population. ASALs occur in the other 80 percent of Kenya, covering parts of the Rift Valley and some northern and eastern areas. These areas are suitable for livestock farming and account for about 45.5 percent of the country's livestock population (Table 2.5).

Kenya's development has continued to rely on the agricultural sector as the base for employment creation, and generates over 60 percent of foreign exchange earnings (Republic of Kenya 1997). The foreign exchange earnings are mainly from coffee, tea, and horticulture. It accounts for over 70 percent of total employment and contributes about 25 percent directly to the GDP and a further 27 percent through linkages with other sectors (Godana 2002). In addition, the sector contributes most of the national food requirements, provides over 70 percent of agro-industrial raw materials, and 45 percent of total government revenue.

16. Livestock in this context is measured in its contribution to the national economy and not just a measure of wealth to Kenyan pastoral communities.

Table 2.6. Major Crop Production in 1990 and Projected Production in 2010

	1990			2010		
Crop	Production ('000 tons)	Yield (tons/ha)	Cultivated Area ('000 ha)	Production ('000 tons)	Yield (tons/ha)	Cultivated Area ('000 ha)
Maize	2700	1.8	1,500	4,701	2.8	1,679
Wheat	294	2.1	140	588	3.4	173
Sorghum/ millet	216	0.8	270	546	1.5	364
Rice	43.5	2.9	15	204	3.0	68
Total			**1,925**			**2,284**

Source: Republic of Kenya 1992.

Some of the poorest segments of the population are found in rural areas. To meet growing national food requirements, there is an increasing emphasis on intensification and expansion of irrigated agriculture. The majority of irrigation occurs through small-holder schemes (57,000 ha) and commercial operations, especially for private floriculture (40,000 ha). Much of this irrigation occurs in the ASALs, where high evaporation rates mean that the growth in irrigated agriculture will mean significant increases in water extractions unless conservation measures are taken. The National Water Master Plan, for example, projected that the acreage under rice would increase from 15,000 hectares to 68,000 hectares in order to boost its production from 43,000 tons to 204,000 tons between 1990 and 2010 respectively (Table 2.6). However, the current water usage rates are excessive because inefficient behavior is encouraged through the low level of water fees. Consequently, high-water-using crops, such as rice, are grown at the expense of more water-efficient crops.

Water influences the productivity of horticulture and floriculture. For example, within the Lake Naivasha region, the floriculture industry uses approximately 33.2 million cubic meters of water annually to support 1,566 hectares of flowers. The annual returns from cut flower production around the lake are estimated at $45.1 million.

The demand for water to meet agricultural and livestock requirements is expected to continue to grow significantly as shown in the recent water demand estimates following the recovery in stock numbers after the 1999–2000 drought (Figure 2.2). Livestock rearing in the ASALs has been growing at a rate of about 2.2 percent over the last five years. Livestock production is geared to meeting the domestic demand. This subsector contributes more than 50 percent of small-scale farmers' cash income. Future livestock development prospects within the ASALs will depend mainly on the availability of water.

Rainfall variability has an important bearing on livestock production. Areas affected most include those within the ASALs. During the 1999–2000 drought, the country lost about 26 percent of its livestock. A survey carried out by a consortium of donors at the onset of the drought and after the drought estimated the value of these losses at Ksh 5.8 billion ($77 million, see Table 2.7). At the onset of the drought, 11 million head of livestock were at risk.

Table 2.7. Estimated Economic Loss from Livestock Deaths Due to 1999–2000 Drought Stress

Attribute	Small Stock	Cattle	Camels
Northern Kenya rangelands	43% of total	35.2% of total	18% of total
Southern Kenya rangelands	16% of total	25% of total	Negligible
% average mortality	29.5% of total	30.1% of total	18% of total
Total animals at risk	8 million	3 million	80,000
Likely no. lost	2,360,000	903,000	14,400
Average price per animal during drought (Ksh)	500	5,000	6,500
Total loss (Ksh)	1.18 billion	4.52 billion	93.6 million
Total loss ($)	15.73 million	60.2 million	1.25 million
Grand total loss (Ksh)		**5.8 billion**	
Grand total loss ($)		**77.3 million**	

Source: Adopted from Aklilu and Wekesa 2001.

Tourism Development and Wildlife Management

Kenya is rich in wildlife resources, with over 25,000 known animal species. The country has 59 wildlife parks covering about 8 percent of the total land area. Wildlife management is the principal responsibility of the Kenya Wildlife Service (KWS). In almost all the wildlife parks, there are either natural river flows or boreholes, wells, and dams that provide water for the wildlife.

However, over 70 percent of terrestrial wildlife are found outside the protected area network, with wide-ranging implications for human-wildlife conflicts. The rising degree of poverty levels within the ASALs is partly attributed to wildlife-human conflicts emanating mainly from competition over scarce water resources. Studies conducted on the Arabuko-Sokoke forest, a coastal forest, demonstrate that wildlife-human conflict is most intense during the dry season (Mogaka 1992 and 1993). This is the time when communities living adjacent to the forest depend most heavily on natural forest water ponds.

Wildlife occurrence and concentration are partially determined by the availability of water resources. The spectacular scenery and abundant wildlife along the Mara River within the Masai Mara Game Reserve, for example, is attributed to the perennial flow of the river. Springs discharging into the Ewaso Nyiro North River near Archers Post (Buffalo and Shaba Springs) are an important source of dry-season flow for wildlife and pastoralists.

The country's wildlife contributes an average of $450 million per year to the tourist industry with considerable prospects for growth. It is estimated that 70 percent of gross tourism earnings in Kenya and 5 percent of total GDP can be attributed to wildlife (Emerton, Ndugire, and Bokea 1997). The sector also contributes over half of the earnings in the trade, restaurant, and hotel sectors. In 1996, 38,000 direct jobs and 360,000 indirect jobs (or 13 percent of all informal sector employment) could be attributed to wildlife-related activities.

Wildlife tourism is currently the highest value use of marginal rangeland, yielding profits of $4.40 to $32.50 per hectare annually in 1996/7 (excluding earnings from other tourism-related activities such as curio shops). This is four times the per hectare income from livestock. Tourism earnings in 1989 were $200 million, while in 1996 the country earned about $890 million from the tourism trade.

To support this important industry, water must be clean and safe with minimal chances of causing waterborne diseases. Water supplies must also be adequate in order to avoid serious conflicts between wildlife and humans. However, the tourism industry is under real threat due to water resources degradation. Illegal water abstractions by upstream users and encroachment on catchment areas threaten the ecological stability and proper functioning of national parks such as the Tana River Primate Reserve and Masai Mara Game Reserve, and important wetlands such as the Lorian Swamp, Tana Delta Wetlands, and Lakes Baringo, Naivasha, and Nakuru.

Fisheries Development and Management

The fisheries sector provides food for about 11.2 million Kenyans. Fish provides an important source of protein and therefore plays an essential role in public health and contributes directly toward poverty eradication. Kenya's fishery sector is also a major employer and foreign exchange earner. Inland fisheries comprise about 90 percent of total landed fish in Kenya. The total estimated Kenyan revenue from fish exports in the year 2000 was Ksh 3 billion ($37 million) with freshwater fish accounting for 95 percent. In 1999, the sector contributed 0.45 percent of total GDP and 2.4 percent of total export earnings. The fisheries industry employs over 15,000 artisanal fishermen and engages about 450,000 persons directly or indirectly in fish processing and trade.

Lake Victoria accounts for about 98 percent of total inland fish production and 93 percent of the total fish landed in 1999 in Kenya (Table 2.8). In 2001, 201,152 tons of fish were landed in Kenya from Lake Victoria; the extent of the Nile perch fishery is unknown in that year. In 2000, the Kenyan catch of Nile perch was estimated at 60,000 tons with a value at landing of $4 million per year.[17] In addition, fish sales around Lake Victoria provide about Ksh 150,000 ($1,900) annually for small-scale wholesalers, and about Ksh 4.1 million ($51,000) for large-scale wholesalers (Abila, Mbatia, and Odhiambo 1997). Kenya earned Ksh 2,700 million ($34 million) for the year 2000 from sales of Nile perch to international markets.

Adequate water of high quality will continue to be a key consideration in inland fisheries development. However, expansion of cultivation in the highlands, coupled with increased levels of urbanization, has led to higher levels of water pollution. The introduction of exotic fish species and invasion of introduced weeds in the inland lakes have threatened the livelihoods of the poorer fishing communities, although the introduction of Nile perch to Lake Victoria has also produced a major export industry for the country. Pollution from poorly controlled development around the shores of the inland fisheries is a threat to the industry, particularly that part of the industry that is dependent on export to countries with strict food safety standards. Thus, the high concentration of lead and zinc in some parts

17. Communication with Dr Kazungu, KMFRI, 2002.

Table 2.8. Quantity and Value of Fish Landed, 1995–2001

Quantities (tons)	1995	1996	1997	1998	1999	2000	2001
Freshwater fish:							
Lake Victoria	181,888	166,460	164,174	158,876	155,084	196,714	201,152
Lake Turkana	2,332	4,799	4,866	4,268	4,002	5,305	3,544
Lake Naivasha	84	54	69	50	48	14	6
Lake Baringo	126	72	99	141	175	392	219
Lake Jipe	150	109	130	97	91	103	61
Fish farming	1,083	1,089	1,086	994	986	899	999
Other areas	2,231	2,488	2,360	3,421	1,409	1,003	1,336
Total	**187,894**	**175,071**	**172,784**	**167,847**	**161,795**	**204,430**	**207,347**
Marine fish	4,665	4,915	4,790	3966	4,633	4,261	3,878
Crustaceans	455	461	458	800	951	927	1,511
Other marine products	874	887	881	232	222	298	212
Grand Total	**193,888**	**181,334**	**178,913**	**172,845**	**167,601**	**209,916**	**212,948**
Value (thousands of current Ksh)							
Freshwater fish	4,855,440	5,429,920	6,480,620	6,446,840	7,401,512	7,310,855	7,833,580
Marine fish	211,400	244,340	133,780	185,660	201,359	233,639	188,420
Crustaceans	62,400	65,280	99,060	132,020	96,533	101,274	237,380
Other marine	74,960	76,120	85,040	14,240	14,721	16,223	18,200
Total	**5,204,200**	**5,805,660**	**6,798,500**	**6,778,760**	**7,714,128**	**7,661,991**	**8,277,580**

Source: Adopted from Republic of Kenya 2000 and 2002a.

of Lake Victoria from Kisumu Harbor and the adjacent "*jua kali*" sites—that is, sites where self-employed workers operate small-scale enterprises such as metal working and furniture making—pose a threat to the fishery industry (Mwamburi and Oloo 1997).

The coastline and the 200-mile Exclusive Economic Zone are highly productive but remain relatively unexploited, mainly due to lack of appropriate technology and inadequate funding. It accounted for about 3.5 percent of the total fish catch in the country in 1999 and 2.6 percent in 2002. Future development of the EEZ will be partly dependent on the quality of water draining from major catchments into the sea.

Manufacturing and Industrial Development

Water is an important input in both manufacturing and industrial processes. In addition to ensuring adequate supplies of water for manufacturing and industrial processes, it is essential that industrial and manufacturing effluent does not pollute the country's water resources, thereby imposing costs on downstream water users.

As the country pursues its industrialization policy, it is expected that there will be increased demand for water to meet production requirements (Biwott 2002). The recent water demand estimates show that industrial water demand is expected to grow from 220,000 cubic meters per day in 1990 to 366,000 m^3 per day by 2000 and 491,000 m^3 per day by 2010. Increased storage capacity, together with adequate water transmission infrastructure and facilities for industrial wastewater treatment, will need to be provided throughout the country.

Industrial effluents need to be treated to a nationally accepted standard before being discharged into surface or groundwater bodies. Industrial water pollution control in Kenya is ineffective. Currently, most industrial and manufacturing plants near major cities and towns discharge their wastes—often partially treated or non-treated—into open water bodies. The Pan African Paper Mills, the defunct Kenya Meat Commission (KMC), Thika-based tanneries, and the textile industry not only require large volumes of water, but also discharge their effluents into the Nzoia, Athi and Chania rivers. The Kenyan government (1996) has spelled out its commitment to efficient systems for handling industrial waste discharge into water bodies.

Urban Development

Only 30 percent of the 142 gazetted urban areas in Kenya have sewerage systems. Only 28 percent of these urban areas are connected to properly maintained sewerage systems. It is also estimated that only 74 percent of the urban population has access to safe drinking water. These figures have serious environmental and health implications. The problem is compounded by the constant breakage or leakage of the sewerage systems, inadequate capacity to handle peak sewage loads and the discharge of effluents to water bodies. Most water supply and sanitation systems do not raise enough revenue to cover their development, operational, and maintenance costs (Box 2.3).

In addition, the high urbanization growth rate (7 percent) means that floodplains are being converted to squatter settlements. The Mathare and Korogocho informal settlements in Nairobi are examples of this trend (Katana 2002). Solid and liquid wastes readily enter rivers from these settlements and the settlements themselves are susceptible to flooding.

Box 2.3: Consequences of Underpricing Water Supply

"The provision of water as a basic social service has been either free or highly subsidised. This is because water has been and still is considered to be a non-economic good, hence what the consumers have been paying for are treatment and delivery services only. Consequently, the sector has not been able to meet its obligations on conservation, monitoring, protection, and exploration of water resources, an obstacle that has constrained integrated water resource management policy. Establishing this policy has been an elusive goal and not easy to attain, and the majority of Kenyans have continued to suffer from lack of access to clean water. Poor management of existing water works and non-existent or poor sewerage systems has compounded the problem further. The diverse nature of players and providers of the commodity has led to uncontrolled utilization of the commodity and to disjointed efforts in management of the resource."

Source: Presentation by Hon. Chris Obure, Minister for Finance, Conference on Integrated Water Resource Management.

Water supplies are currently under the management of more than one agency. The Water Department manages over 600 rural water supplies, out of which 200 schemes are gazetted for revenue collection. In addition, the National Water Conservation and Pipeline Corporation (NWCPC) runs over 40 projects, communities run more than 300 schemes, and local authorities run 9 schemes (Republic of Kenya 2001a). The institutional mandates defining roles and responsibilities are often not clear, especially in urban water supply, operations, maintenance, and development. Harmonization of these overlapping instructional roles and responsibilities would contribute to efficient and effective management of water resources.

Forests and Water Resource Management

Forests cover 2.9 percent of Kenya's land area, consisting of 1.24 million hectares of indigenous forests, 165,000 hectares of plantations, and 200,000 hectares of private forest (Republic of Kenya 1995). Kenya's ASALs account for 70 percent of tree resources and 30 percent of woody biomass. Mangrove forests account for 1 percent and wetlands 2 percent of Kenya's landmass.

Forests generate revenue and employment and provide a wide range of ecological services. Through the provision of charcoal and fuelwood, they provide 95 percent of the rural energy, and generate value-added products amounting to an average of Ksh 16 billion ($200 million) annually (2.4 percent of GDP). In 2000, some 489,000 tons of wood were used by the pulp and paper industries. Over 100,000 people are employed in wood-based enterprises. Forests are also habitat to about 40 percent of Kenya's terrestrial animal species, 30 percent of bird species, and 35 percent of butterfly species.

Unlike other sectors where water is a vital input, water is an output from the forest sector. Consequently, activities in this sector directly affect the quantity, timing, and quality of the available water resources. At the local level, forest cover significantly affects soil temperatures and soil moisture conditions, as well as wind speed and humidity patterns. Forests moderate the intensity of small-to-medium flood flows by slowing runoff during storm events, thereby reducing the height of the flood peak. They also protect water quality by trapping sediments and attached nutrients before they reach streams, and provide habitat for biological activities that remove pollutants from runoff. These relationships are examined in more detail in Chapter 4 and Appendix B.

CHAPTER 3

The Physical Impacts of Rainfall Variability: Floods and Droughts

Kenya is affected by both local droughts and floods as well as by periodic, widespread El Niño/La Niña events. The country is especially vulnerable to El Niño/La Niña events because of the high dependence of its economy on water resources, the low natural water replenishment rates, past underdevelopment of its water resources, and poor management of its existing resources. The 1997/98 El Niño floods seriously damaged water supply infrastructure and transportation networks as well as exacerbating water-borne health diseases. The Ksh 8.7 billion rehabilitation program addressed only some of these costs. The 1999/2000 La Niña drought reduced the output of every major sector of the economy. The loss from livestock deaths was Ksh 11 billion, hydropower generation was reduced by over 40 percent, and Kenyan industry lost Ksh 110 billion in production.

Kenya's Climatic Conditions

Kenya lies across the equator. Despite its equatorial location, the country experiences wide variations in climate due to its wide variety of landforms. A relatively wet, narrow tropical belt lies along the Indian Ocean Coast, with large areas of semi-arid lands behind the coastline. Thereafter, the land rises steeply to the temperate highland plateau through which the Rift Valley runs. All the mountain ranges in the area have high rainfall, although dry areas are found in the valleys and basins. Western Kenya, east of the Rift valley, is also wet.

Generally, the seasonal northward and southward movements of the Inter-Tropical Convergence Zone (ITCZ) have considerable influence on the country's climate. As a result, most parts of the country are characterized by two rainy seasons, March to May

Table 3.1. Distribution of Rainfall in Kenya

Mean Annual Rainfall (mm)	Land Area km²	% of Land Total
>1,000	64,070	11.2
800–1,000	32,960	5.8
700–800	24,260	4.3
500–700	73,140	12.8
300–500	270,410	47.4
<300	105,730	18.4
Total	**570,570**	**100**

Source: UNEP/GoK 2000.

(long rains) and October to November (short rains). The country has a mean annual average rainfall of about 500 mm, which varies between 250 mm in the ASALs to 2,000 mm in the high mountain ecosystems. About 66 percent of the country receives less than 500 mm of rainfall annually (Table 3.1). However, the rainfall is highly variable, especially in the ASALs, and unreliable for rainfed agriculture and livestock production (Mwango 2000). The country experiences moderate droughts and floods, in many cases on a regional basis, every three to four years.

Kenya experienced major floods in 1961 and 1997/98 (Republic of Kenya 2001d). Major drought[18] periods have been recorded about every 10 years (Table 3.2). Droughts are a pervasive phenomenon affecting basic needs such as food, water, and livelihoods, and creating knock-on effects throughout the local and national economies. They have become endemic in some parts of Kenya; in some areas, return periods have become shorter. The arid and semi-arid areas, the poorest regions of the country, are the areas most affected by drought.

A specific pattern of droughts and floods in Kenya can be identified in association with El Niño and La Niña years (UNEP/GOK 2000). El Niño and La Niña describe the appearance and then disappearance of a large pool of warm water in the western equatorial Pacific. This phenomenon alters major Pacific currents and affects global weather patterns, including the southern Pacific and Indian oceans. The return period for this phenomenon is about three times every decade. El Niño/La Niña events in Kenya are characterized by severe flooding followed by a period of drought. In Kenya, the flooding typically affects coastal settlements, urban areas, river valleys, and the fringes of Lake Victoria. Landslides triggered by heavy rainfall undermining unstable soils constitute a secondary hazard associated with El Niño events. The La Niña droughts usually affect the whole country. The most recent El Niño (1997/98) and La Niña (1999/2000) were the most severe in 50 years.

18. Drought is categorized as a moderate to severe threat in Kenya, which affects some 80 percent of the land defined as arid or semi-arid, 20 percent of the population of Kenya, and 50 percent of its livestock.

Table 3.2. Drought Incidence in Kenya, 1883–2001

Date	Region	Remarks
1883	Coast	Worst famine in 30 years
1889–1890	Coast	1 year of drought and famine
1894–1895	Coast	—
1896–1900	Countrywide	Failure of three consecutive rainy seasons; human deaths
1907–1911	Lake Victoria, Machakos, Kitui and Coastal	Minor food shortages
1913–1919	Eastern and Coast Provinces	Impacts exacerbated by warfare
1921	Coastal areas	Record dry year at the coast
1925	Rift Valley, Central, and Coast Provinces	Local food shortages, crop and livestock losses (about 50% in Baringo)
1938–1939	Northern Rift Valley and Central Provinces	Heavy loss of livestock; Lorian Swamp dried up; deaths reported
1942–1944	Countrywide	Food shortages; about 200 deaths
1947–1950	Central and Coast Provinces	Very severe drought in Coast Province
1952–1955	Eastern, Central, Coast, Nyanza, Western, and Rift Valley Provinces	Mombasa reported driest; water shortages in Nairobi
1960 –1961	Eastern, South/North Rift Valley	Droughts followed by floods, cattle mortality about 70–80% in Masailand
1972	Widespread	Rains about 50% long-term mean; Nairobi hit by water shortage; wildlife deaths in Nairobi National Park
1973–1974	Most of Kenya	Human and livestock deaths in the Northern Districts
1974–1976	Eastern, Central and Northern Provinces	Maasai cattle losses of about 80%
1980	Central, Eastern, Western and Coast Provinces	Crop production paralyzed; water shortages in towns
1981	Eastern Province	Famine in Eastern Province
1983	Countrywide	Water shortages; migration of people and livestock
1984	Central, Rift Valley, Eastern and North Eastern	Large food deficits
1987	Eastern and Central Provinces	Severe food shortages in Eastern Province, less in Central Province
1992–1994	Northern, Central, Eastern Provinces	Moderate to severe in Eastern Province; relief food imported
1999–2000	Countrywide except west and coastal belt	4.7 million dependent on food relief; power and water rationing.

Source: Adopted from UNEP/Government of Kenya, 2000.

Extent of Kenya's Vulnerability to Floods and Droughts

Kenya's water vulnerability arises from a combination of the country's very limited natural endowment of water, the high variability with which annual rainfall occurs, the heavy dependence of the economy on water resources, and inadequate preparedness for regularly recurring climate shocks to the economy. The agriculture sector—which accounts for about 25 percent of GDP, 60 percent of foreign exchange earnings, and 70 percent of total employment—is particularly sensitive to climate changes. In 1999, for example, the country realized only 69 percent of the expected maize harvest (a total of 2.25 million tons were harvested) mainly because of the failure of the rains, particularly in the Eastern, Central, and Northern Provinces (UNEP/GOK 2000). There was a further 12 percent decline in the maize harvest (to 2 million bags) in 2000, resulting in the importation of 409,000 tons of maize valued at Ksh 4,700 million ($59 million) for relief and commercial purposes (Republic of Kenya 2001b).

As described in Chapter 2, the failure to develop surface and groundwater resources has exacerbated the country's vulnerability. Consequently, there is very little stored water per capita, so when severe droughts occur water storage areas are rapidly drawn down. Those dependent on surface water resources very quickly experience water shortages.

The country's vulnerability is exacerbated by the extensive degradation of the nation's water resources and weak water resource management. In the last decade, the country has severely reduced its expenditure on water resources operations and maintenance. It is widely accepted that good catchment and aquifer management influences the quality and reliability of water resources (UNEP/GOK 2000). Thus, heavy rains cause erosion from the cleared forests and poorly-maintained agricultural lands, leading to accelerated siltation and loss of storage capacity in the country's water storage dams and pans. Noticeable population increases have occurred in the ASALs as a result of migration. This has affected the ecosystems of these regions, making them more vulnerable to disasters such as drought and environmental degradation (Glantz 2001). Many dams and reservoirs silt up years before their design life. Of the estimated 3,200 dams and pans nationwide, between 80 percent and 90 percent have lost at least 50 percent of their expected economic life from siltation. This depletion in volumetric capacity arises from both siltation and lack of investment in new infrastructure. A variety of strategies can be used to optimize water resources and reduce vulnerability, including the protection of groundwater recharge areas, siting and operation of boreholes, protection against groundwater pollution, and the conjunctive use of surface and groundwater.

The combination of high vulnerability and a poor record of investment in the infrastructure and O&M needed to manage that vulnerability means that Kenya has low overall water security.

Table 3.3 shows the shortage in water infrastructure in the ASALs during the 1999/2000 drought. The shortage was partly due to poor maintenance of existing infrastructure and partly due to inadequate investment in new dams and boreholes to keep up with population increases.

The problem is further exacerbated by excessive and uncontrolled abstraction, mostly illegal but unpoliced, of water from rivers. These water allocation problems are magnified during droughts, partly because of the inadequate storage available and partly because of the poor allocation and enforcement mechanisms. The UNEP/Government of Kenya report (2000) on the 1999–2000 drought shows a steady decline in the flows of the Maragua River

Table 3.3. Existing Water Dams/Pans and Boreholes and Deficit in Most-Affected Districts

		Dams/Water pans				Boreholes			
Province/ Districts	Water deficit (m^3/d)	Existing	Capacity (m^3)	Rehab	New	Existing	Yield (m^3/d)	Rehab	New
Northern Province									
Mandera	23,022	40	540,000	10	5	100	0	0	20
Wajir	29,769	24	890,000	10	5	145	3,297	8	20
Garissa	25,529	50	850,000	10	5	127	3,886	14	20
Ijara	7,700			10	5	0	9,619	18	20
Eastern Province									
Moyale	4,860	0	0	10	5	30	900	17	20
Machakos	85,581	66	1,654,000	10	5	408	19,055	10	20
Mbeere	17,076	23	450,440	10	5	5	374	10	20
Isiolo	7,793	22	869,500	10	5	135	3,846	8	20
Kitui	49,495	150	760,000	10	5	129	3,675	6	20
Mwingi	29,955	82	1,522,000	10	5	20	575	5	20
Marsabit	9,897	37	440,000	10	5	138	3,838	8	20
Makueni	71,173	43	152,200	10	5	244	9,212	9	20
Tharaka	5,686			10	5	322	7,357	6	20
Coast									
Tana River	17,916	5	140,000	10	5	25	640	5	20
Taita Taveta	21,943	153	325,730	10	5	92	4,762	9	20
Kwale	36,382	58	241,235	10	5	649	22,196	10	20
Rift Valley									
Samburu	12,710	41	1,326,200	10	5	92	2,483	18	20
Turkana	35,816			10	5	520	14,806	18	20
Kajiado	23,096	84	1,163,540	10	5	520	29,006	12	20
Baringo	24,103	131	6,218,100	10	5	76	3,995	10	20
Koibatek	12,552	143	778,000	10	5	38	2,079	10	20
West Pokot	29,105	53	4,252,970	10	5	95	2,992	10	20
Laikipia	24,690	209	3,464,300	10	5	281	12,683	6	20
Narok	35,474	40	821,060	10	5	58	1,376	7	20
Central Province									
Nyeri	63,200	77	1,079,500	10	5	80	3,833	6	20
Totals	**704,523**	**1,531**	**27,938,775**	**250**	**125**	**4,329**	**166,485**	**240**	**500**

Source: Adopted from UNEP/Government of Kenya 2000.

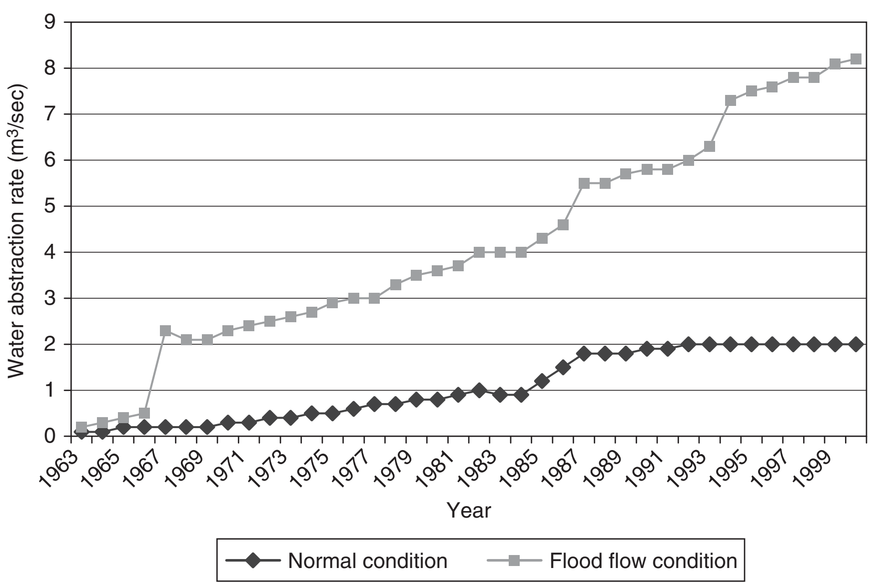
Note: The "Existing" column refers to functioning dams and pans, or boreholes. The "Rehab" column refers to the number of previously constructed dams and pans or boreholes that need rehabilitation; some may no longer be functioning. The "New" column refers to new dams and pans, or boreholes.

upstream of the Masinga Dam and the Molo River in the Rift Valley that exacerbated the effects of the drought. The mean annual discharge of the Maragua River declined by 13 percent over 38 years and the Molo River declined by 26 percent over 27 years. While there were probably a number of factors involved, excessive abstractions almost certainly played a major role. In another well known example, the median decadal flow of the Ewaso Nyiro North at Archer's Post during the month of February has dropped from 9 m^3/sec in the 1960s to about 4.5 m^3/sec in the 1970s, 1.2 m^3/sec in the 1980s, and 0.9 m^3/sec in the 1990s (Gichuki and others 1998). In 1984, 1986, 1991, 1994, 1997, and 2000, the river dried up completely for a 60 kilometer stretch upstream just above Buffalo Springs, an event that the communities along the river and recent studies both note to be unusual (Republic of Kenya 2001f).

Similarly, there is an evident increase of water abstraction from the river during both flood and drought periods (Figure 3.1). The Ewaso Nyiro basin cuts through Archer's Post, Chanler's Falls, Malko Bulfayo, Merti, Sericho, and Habaswein. The river flow reached Habaswein (which is 250 km from Archer's Post) during the early 1900s. Between the 1950s and 1970s, the river flow reached Sericho (200 km from Archer's Post) even during the driest period, but dried up between Sericho and Habaswein. In the 1980s and 1990s, the river frequently dried up between Archer's Post and Merti, which is 123 km from Archer's Post. More than 65 percent of water abstractions on this river are considered unauthorized. The effect of illegal abstractions on downstream water users is discussed further in Chapter 4.

Although this report concentrates on the impacts and costs arising from droughts and floods, periods of excess rainfall also bring long-term benefits by recharging aquifers and filling storages. The natural recharge of aquifers can be augmented during floods by either

Figure 3.1. Water Abstraction Rate in Upper Ewaso Nyiro North River



injecting floodwaters into the aquifer or holding the floodwaters into areas for long periods to allow extended natural recharge to occur. These techniques, called Aquifer Storage and Recovery (ASR), are being tested and implemented around the world. However, in spite of its wet-dry cycles, Kenya does not have any trials of ASR techniques under way.

Despite the established pattern of droughts and floods in Kenya, there is no clear policy and strategy that specifically addresses drought and water resources management. First, there is no coordinated national early warning system for climate variability, in spite of the country having ready access to one of the Drought Monitoring Centres—Kasarani—in Nairobi. An early warning system is being developed by the Arid Lands Resource Management Project. Second, while a coordinated response has been developed to water and sanitation issues during droughts,[19] there are no coordinated institutional structures and arrangements to mitigate the negative impacts of climate variability or to take advantage of the positive elements of climate variability—for example, recharging groundwater reserves during El Niño events. Third, inadequate human and financial resources limit the country's responsiveness to rainfall variability. Although the Water Policy of 1999 addresses major aspects of water resources, there is no explicit reference to droughts or floods. The country is in the process of preparing a National Disaster Management Strategy that "recalls and learns from past events, in order to anticipate and reduce the impact of disasters" (Republic of Kenya 2001d). This process was initiated in the early 1990s but reinvigorated following the recent El Niño and La Niña experience.

The approval and adoption by Parliament of the Sessional Paper No. 1 of 1999—the National Policy on Water Resources Management and Development—is an indicator of the government's efforts to address water resources development and management. Other recent efforts include the new Water Act, the formation of the Ministry of Water and Irrigation, and the Water Resources Management Authority. Some regional development authorities (for example, Ewaso Nyiro North Development Authority, and Lake Basin Development Authority) have put in place strategies for effective water resources development and management, including catchment conservation. However, the government budget is inadequate to support effective implementation of the NWP, the Water Act, and the RDA's plans and strategies.

Sectoral Impacts of Floods

Kenya experiences both large, devastating floods with a national impact—typified by El Niño events—as well as local, annual floods. The economic impacts of these floods

19. WESCOORD, the water and sanitation sector coordination mechanism, is based in the Office of the President and is supported by UNICEF. WESCOORD brings together the many agencies active in responding to the water and sanitation needs of people and districts affected by emergencies. It aims to achieve a more coordinated and integrated approach in implementing emergency interventions. WESCOORD is a water and sanitation sectoral specialist group of the Kenya Food Security Steering Group (KFSSG), itself a technical arm of Kenya Food Security Meeting (KFSM), which oversees the Emergency Operation Programme (EMOP). The process has helped achieve a number of initiatives, including resource mobilization, standardization, mapping, response preparedness, and coordination, among others. Establishment of WESCOORD came as a result of the La Niña-related drought of 2000/2001 (information provided by UNICEF).

Table 3.4. Major Rehabilitation Projects in Response to El Niño Floods in Most-affected Areas

	Number of projects					Works contract prices (millions of Ksh)				
Province	Water	Rural Roads	Urban Roads	Health	Total	Water	Rural Roads	Urban Roads	Health	Total
Nyanza	6	6		5	17	132	241		29	402
Rift Valley	4	6		6	16	201	417		33	651
North	6	3		8	17	79	112		3	194
Eastern	10	5		8	23	144	443		42	629
Coast	7	7		16	30	116	257		66	437
Western	5	7		2	14	181	192		9	382
Nairobi/ Nyanza Coast			8		7			2108		2108
All Districts	4				4	45				45
Total	**42**	**34**	**8**	**45**	**129**	**896**	**1,662**	**2,108**	**182**	**4,848**

Source: Adapted from Republic of Kenya 2000a.

cut across key sectors of the economy, including agricultural production, industrial processing, manufacturing, tourism, infrastructure, and public health. The physical effects of these floods are summarized in Table 3.6.

As an indication of the cost of large episodic floods, the government initiated a rehabilitation program estimated at Ksh 8.7 billion ($108 million) following the 1997/98 El Niño floods. Contributions came from the Kenyan Government, the World Bank, the African Development Bank (ADB), and Agence Francaise de Development (AFD). Table 3.4, although covering only a small proportion of the areas affected by the El Niño event, shows both the sectoral impacts of the floods and their geographic spread.[20]

During the 1997/98 El Niño floods, many water supply structures were either destroyed or severely damaged. Table 3.5 shows the estimated damage to dams, pans, and some pipelines for 22 districts and part of the NWCPC jurisdiction (based on reconstruction costs). Given that the estimated cost of Ksh 1.2 billion covers only 22 districts, it is clear that the damage in this sector is considerably greater than the expenditure of Ksh 896 million in the rehabilitation program. Table 3.5 and Box 3.1 also illustrate the geographic spread and diversity of damage, ranging from loss of dams and pans for stock and human use in ASALs, to damage to pipelines and distribution networks.

In addition, the floods damaged irrigation infrastructure such as intake structures, canals, and drains. The Perkerra River changed its course, depriving the Perkerra Irrigation

20. However, this figure does not account only for the damage attributed to the floods, but also includes rehabilitation of infrastructure that was run down prior to the floods. We assume that the bulk of the budget was directed at the infrastructure affected by the floods.

Table 3.5. Flood Damage Costs to the Water Sector (to two significant figures)

District	Type of Service Affected	Cost (millions of Ksh)
Wajir	Dams pans silted up	95
Garissa	Dams and pans silted up	144
Mandera	Dams and pans silted up	63
Lamu	Dams and pans silted up, water pipeline destroyed	48
Malindi	Dams and pans silted up, water pipeline destroyed	16
Taita Taveta	Dams/pans silted up	9
Kilifi	Dams/pans silted up, some destroyed	26
Tana River	Dams and pans damaged	63
Kwale	Dams/pans silted up, water pipelines damaged	58
Kisumu	Dams/pans silted up or damaged, water pipelines damaged	11
Suba	Dams/pans silted up or damaged, water pipelines damaged	19
Rachuonyo	Dams/pans silted up or damaged, water pipelines damaged	9
Busia	Dams/pans silted up or damaged, water pipelines damaged	63
Isiolo	Earth dams/pans destroyed	42
Makueni	Earth dams/pans destroyed	34
Mwingi	Earth dams/pans destroyed	11
Moyale	Dams and pans silted up, some destroyed	29
Marsabit	Earth dams/pans destroyed	29
Baringo	Dams/pans silted up, water distribution network damaged	134
Keiyo	Earth dams/pans destroyed	16
Marakwet	Dams and pans silted up	11
Samburu	Dams and pans silted up	26
National Water Conservation and Pipeline Corporation		
	Kwale	28
	Kilifi	220
Total (22 districts and some NWCPC)		**1,200**

Source: Republic of Kenya 1998.

Scheme of water for some years. This destruction had a major impact on the livelihoods of those dependent on irrigated agriculture.

Storm damage due to El Niño affected food distribution in areas where roads were flooded, damaged, or washed away (notably the Tana River and Lamu Districts). There were major crop losses from the El Niño floods, as well as livestock losses. The food

Box 3.1: The Impact of Floods

The damage due to the 1997/8 El Niño event was severe in Nyanza, Western, Coast, Eastern and North Eastern Provinces. For example:

- Over 300,000 people were displaced by floods and turned into internal refugees.
- Environmental diseases such as typhoid, amoeba, cholera, and bilharzias normally associated with contaminated water and poor sanitation reached epidemic levels in areas where water and sanitation facilities were destroyed.
- Socioeconomic activities, including agricultural production and schooling, were severely disrupted because women and children had to trek longer distances in search of cleaner water.
- Damage to health facilities disrupted the delivery of quality health care services at a time when there were epidemics of both water-borne and vector-borne diseases.
- Road communication was disrupted or completely cut off; services such as relief food supplies required expensive airlifting; and the marketing of agricultural produce and supply of farm inputs was impossible in rural areas, which depend on motorized transport.

Source: Republic of Kenya 2001g.

shortage had a major effect on the health of children less than five years old, as shown by the prevalence of delayed malnutrition disorders such as kwashiorkor and marasmus. In some districts—for example, Tana River, Garisa, and Lamu—cases of marasmus soared for several months after the El Niño floods.

Public health was also affected. During and immediately after El Niño, damage to potable water supplies forced communities to obtain water from unsafe water sources (unprotected wells, rivers, ponds, lakes, and sometimes rainwater), thus exposing them to waterborne infections such as typhoid, cholera, amoebic dysentery, and bilharzias. Morbidity patterns reveal that over 60 percent of the top 10 diseases in Kenya are waterborne or sanitation-related; malaria accounts for about 32.2 percent, and diarrhoea and intestinal worms account for 17 percent (Ongeri 2002). Consequently, there was an upsurge in these diseases following the floods.

Annual flooding events cause less damage. Nevertheless, they are locally severe. For example, farming communities in the Kano Plains, the lower Tana River Basin, and Budalangi areas are displaced every year, and agricultural production in the Budalangi area is reduced by over 50 percent about once in every three years.

The El Niño floods affected the tourism industry too, not just from destruction of infrastructure but from damage to the ecology on which much of the tourism industry depends. Thus, sediment plumes from the Rivers Tana and Galana traveled far offshore during the El Niño floods. There was a significant reduction in light penetration around the discharge points of the rivers, and the waters became eutrophied and deoxygenated. Coral reefs were damaged from sediment deposition, and the lack of light inhibited coral productivity. More than 50 percent of the coral reefs in the Malindi area were killed from these large runoff events.[21]

21. Communication with KWS Staff—Coastal Region.

Sectoral Effects of Droughts

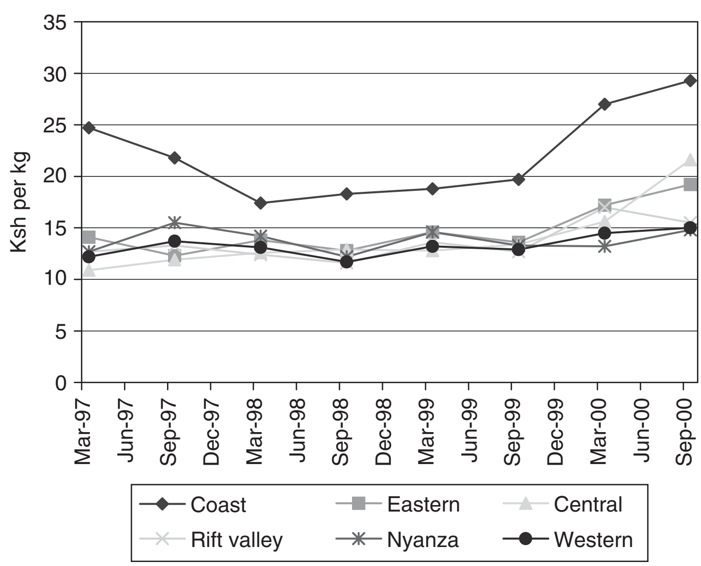
Like floods, droughts affect nearly all sectors of the economy. These effects are summarized in Table 3.6. The recent La Niña-related drought particularly affected the agriculture, livestock, energy, industrial production, and tourism sectors. In addition, drought leads to intense competition over remaining grazing land, even across borders.

The production of most rainfed agricultural crops is affected by drought (Republic of Kenya 2001b). In the year 2000, national maize production declined to 2 million tons from 2.3 million tons in 1999. In districts where the drought was severe, the declines were dramatic. For example, in Kirinyaga District maize production dropped from 15,000 tons to 2,400 tons and beans dropped from 4,839 tons to 1,080 tons. In Nyeri District, maize production fell from 1.8 tons/ha to 0.2 tons/ha, and beans dropped from 1.4 tons/ha to less than 0.2 tons/ha (UNEP/GOK 2000). Maize production dropped by about 1 million tons, and centrally marketed maize declined from 223,500 tons in 1999 to 201,200 tons in 2000. To help reduce the deficit, Kenya imported 409,000 tons of maize valued at Ksh 4,700 million. Wheat production was low in 1999 and 2000, registering 55,400 tons and 73,800 tons respectively, compared with the record 177,000 tons produced in 1998. These declines were attributed largely to the 1999/2000 drought (Republic of Kenya 2001b).

The effect of the drought is also reflected in the prices paid for crops in rural markets. Figure 3.2 shows that maize prices rose in all provinces in 2000. The greatest increases occurred in the Coast, Eastern, and Central Provinces, where the drought was most severe.

Most agro-based industries reported losses of 30 to 40 percent in production due to insufficient supplies of raw materials.

Figure 3.2. Changes in the Price of Maize in Kenyan Regions



Source: Republic of Kenya 2001b.

Livestock production makes a significant contribution to the national economy, contributing approximately 13 percent of the agricultural sector's GDP over the last decade. Within the ASALs, livestock production forms the major economic activity, with the value of the asset estimated to be about Ksh 70 billion ($875 million) during non-drought periods. Livestock deaths from drought in 1999/2000 are shown in Table 2.7. The value of these livestock is estimated to be Ksh 5.8 billion ($73 million) during this period.[22] A considerable proportion of this loss is attributed to drought. The UNEP/Government of Kenya report estimates the loss due to livestock deaths at Ksh 12 billion over the two-year drought period, greater than the loss estimated in the survey above.

In addition to these private sector losses, government expenditures to address the drought-related stress and diseases amounted to Ksh 190 million ($2.4 million) per annum. These government interventions included de-stocking, supplementary livestock feeds, restocking, emergency veterinary program, subsidized transport, and conflict management/cross-border initiatives.

Fish production is influenced by drought. Many people displaced from their regular jobs in farming, industry, and tourism turn to fishing for subsistence and limited commercial purposes. Coastal fishing activities increased by more than ten-fold during the 1999/2000 droughts (UNEP/GOK 2000). Overfishing is common during these periods because new entrants into the industry tend to have no commitment to the sustainability of the industry, and tend to use inappropriate fishing technologies, such as undersize nets, poison, and other water-polluting agents.

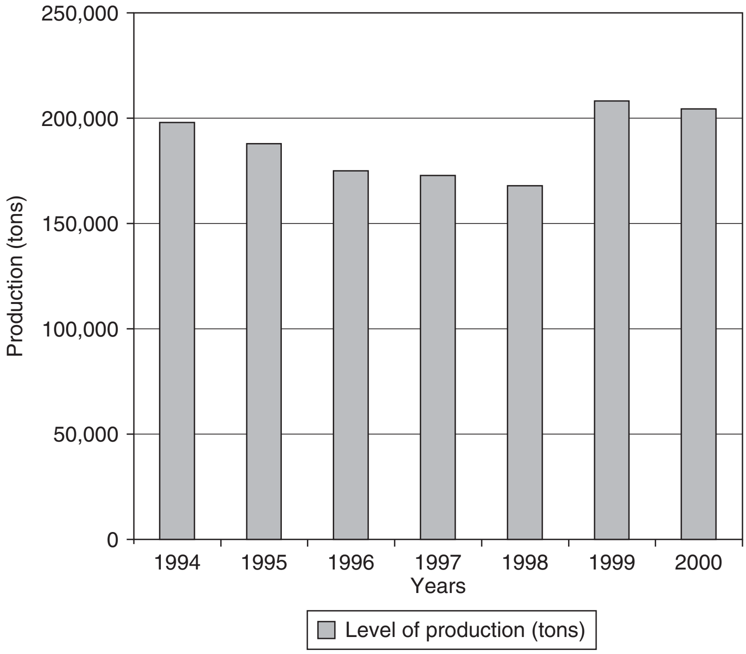
Fish production from natural waterbodies within high potential areas is also affected by drought. Figure 3.3 indicates that during the drought years (1994, 1999/2000) fish production is higher than during normal years (1995, 1996, 1997, and 1998). This production is dominated by the fish catch from Lake Victoria, where many species, including the economically important Nile perch, are known to be overfished.[23] There are a number of reasons for the inter-annual variability in the fish catch, but the drought adds to the pressure on these fisheries. It also affects fish farming. The drop in production from fish farms may be attributed to reduced water flow during the drought. Production declined from 1,089 tons in 1996 to 887 tons in 1999, largely because of a lack of suitable water for rearing fish.

The forest subsector experiences increased deforestation during droughts due to increased charcoal production, forest clearing for agricultural expansion, increased logging, frequent fires, intensified forest grazing, and increased incidence of forest diseases. Forest fires cost the government an estimated Ksh 25.8 million and 28.6 million in suppression and damage losses respectively during the 1999 drought. Similarly, herding in forest areas increases considerably during the drought periods. The illegal felling of timber for charcoal burning during drought is attributed to the increased numbers of persons turning to the business as a result of the collapse of farming and livestock activities. During these periods, household income is usually eroded and most people cannot afford the high cost of electricity, gas, and kerosene, thus leading to an increased demand for charcoal and fuelwood.

22. Livestock mortality per stock type and estimated values: small stock (2,360,000) estimated at a value of Ksh 1.18 billion; cattle (903,000) estimated at Ksh 4.52 billion, and camels (14,400) estimated at 93.6 million (for details see Aklilu and Wekesa 2001).

23. Gill net mesh has been reduced so that the majority of the Nile perch catch is now aged before maturity (van der Knaap 2001).

Figure 3.3. Freshwater Natural Fish Production, 1994–2000



Source: Adopted from Republic of Kenya 2001.

In the recent La Niña drought, power rationing—necessitated by reduced water flows and storage levels—caused job and production losses, including social interruptions. In the power sector, reduced storage resulted in a drop in hydropower generation of about 41 percent from 3,500 GWh in 1998 to about 1,800 GWh in 2000 (Okemo 2002). The monthly cost to the hydropower industry due to lost generation from this reduction in hydropower generation is estimated at $68 million.[24] This imposed a very high cost on the country because of the need to import electricity from Uganda and make increased investments in thermal generation, as well as from the lost revenue and lost jobs in industries where replacement energy could not be arranged. It is estimated that KPLC lost Ksh 1.6 billion and, partly due to that, the company has been considering laying off 1,700 employees out of a workforce in 1999 of 9,283 (Republic of Kenya 2001e). The restricted access to, and high cost of, water was instrumental in causing some industrial enterprises in Mombasa to relocate to Nairobi and even neighboring countries.

The tourism sector was also affected by the drought. Tourists are more sensitive to inadequate water supplies than most residents, so hotels along the coast that relied on groundwater had to invest heavily in desalination plants because of saltwater intrusion into

24. Also "The Assessment of the effect of drought to the manufacturing sector" (August 2000) states that there was an electricity supply shortfall of 45 percent daytime and 19 percent night-time total installed capacity during the year 2000.

heavily used aquifers. Water sources diminished and, in some areas, dried up entirely in the Rift Valley, reducing the wildlife available for tourism purposes as animals migrated in search of water. It is difficult to disentangle the effect of the drought from other factors that influence tourist numbers, but it is likely that the decreased opportunity to view game affected the industry. Inflows to Lake Nakuru ceased during this period and the lake dried up. Flamingos, which are the flagship attraction in this national park, moved to other waterbodies.[25]

During the 1999/2000 drought, urban water supplies were restricted and prices rose dramatically. The price of a 20-liter container from water vendors in Nairobi increased from Ksh 5 to Ksh 20 during the 1999/2000 drought. With the number of vendors reduced because of the difficulty of collecting water, residents—particularly women and children—spent valuable time every day (varying from three to five hours) queuing for water. In rural areas (for example, Machakos), some residents spent up to eight hours trekking for water. New boreholes were drilled in the Nairobi Conservation Area and old ones were deepened in response to the water shortages. The water table, which had been declining prior to the drought due to overpumping, was lowered even further. Not only does this increase the cost of pumping, but it limits the future options for this valuable water resource.

Summary

Table 3.6 presents a summary of the physical impacts of floods and droughts.

25. The factors controlling the presence of flamingos in the Rift Valley lakes are not fully understood. Clearly, the depth of water and availability of specific food sources is very important, but other factors seem to play a role as well.

Table 3.6. The Physical Impacts of Floods and Droughts

Extreme Event	Sector	Physical Impact
Floods	Water supply and sanitation	*Extensive damage to water supply and sanitation infrastructure, including pipelines and pumping stations*
	Transportation	*Roads and railways damaged from flooding*
	Agriculture	Silting or destruction of small dams and pans, especially in ASALs
		Losses of crops and stock from heavy rains and floods
	Health	Food shortages from crop losses affected children's health
		Increased incidence of water-borne diseases following flooding
		Some damage to health facilities from heavy rains
	Education	Schooling of children disrupted by destroyed roads, as well as demands for children to trek for clean water
	Tourism	Destruction of infrastructure used by tourism industry (especially roads)
		Damage to ecosystems on which tourism depends (e.g. coral reefs)
Droughts	Agriculture	*Reduced crop harvest*
		Loss of livestock, especially in ASALs
		Additional costs of livestock maintenance, veterinary costs, supplemental feeding, etc
	Fisheries	Increased production of fish, adding to overfishing
		Reduction in fish production from aquaculture
	Forestry	Increased tree loss from illegal felling, fires, grazing, diseases
	Energy	*Reduced hydropower production from low water levels*
		Cost of importing higher-cost power from neighbors and provision of replacement generators
	Industry	*Loss of income from industries that reduced production because of power shortages*
		Permanent loss of employment from industries that relocated to other countries
	Tourism	Cost of desalinating groundwater in coastal areas, where seawater has intruded into aquifers
		Reduction in wildlife viewing opportunities in the Rift Valley
	Water Supply	*Increase in the cost of vendor-supplied water in urban areas; more time spent queuing*
		Increased time spent searching for water in rural areas
		Increased pumping of groundwater in urban areas

Note: Impacts that are quantified in economic terms in Chapter 5 are noted in italics.

CHAPTER 4

The Physical Impacts of Water Resource Degradation

Operating funds for managing the country's water resources have been falling, with serious consequences for water allocation decisions, enforcement, and water quality management. The country's water resources are now seriously degraded. A high percentage of water abstractions are unauthorized. Some rivers have dried up during low-flow periods, and conflicts have broken out between groups of water users. Forest excisions and clearance lead to greater upstream use of water during dry periods, more variable flows, and higher sediment loads. Dams and pans silt up and coastal industries are affected. Groundwater is also being exploited unsustainably beneath Nairobi and possibly other urban areas. Urban sewage is discharged directly into water bodies because many sewage treatment plants are either not working or only partly working, and most industrial effluent is not treated before it is discharged. Agricultural chemicals (including banned pesticides) continue to reach rivers and lakes. Nutrient pollution of Lake Victoria from the atmosphere and rivers is now so advanced that about 20 percent of the Lake's volume is uninhabitable by most fish species.

Key Water Resource Degradation Issues

In contrast to the episodic nature of rainfall variability described in the last chapter, degradation of the water resource base of the country causes chronic, long-term problems. The effects of water resource degradation are not always as apparent as are those from rainfall variability, partly because of their incremental nature and partly because the effects are often felt at a distance, both in time and space, from the source of the degradation.

The principal causes of water resource degradation in Kenya are:

- Excess abstractions of surface and groundwater,
- Soil erosion causing turbidity and siltation,
- High nutrient levels causing eutrophication of lakes and pans,
- Toxic chemicals, including agricultural pesticides, and heavy metals, which are toxic to water-dependent biota.

Water resource degradation also exacerbates the costs arising from rainfall variability. Poorly managed catchments shed their runoff quickly into rivers and streams, thereby increasing the size of flood peaks during moderate to large storms. Forests and agricultural catchments with good ground cover slow down the runoff and reduce the size of the flood peak.[26]

Investment in Water Resource Development and Management

Historically, the government has assumed the lead role as a water resources developer and manager, although other stakeholders (NGOs, the communities, self-help organizations) have contributed. The private sector has only been involved in groundwater development.

Despite an increase in investment in the water sector between 1994–97, overall investment in water resources development and management declined during the 1990s by about 42 percent, largely due to declining government budget allocations and decreased donor funding (Figure 2.4). Although private sector investment in water resources infrastructure is small in Kenya, private enterprises—such as the hotel industry—invested heavily in groundwater development to ensure secure supplies during the drought.

Inadequate Operational Funding

Flow monitoring: Nearly 90 percent of the water sector budget is allocated to salaries, leaving few funds for running costs and development activities. The consequences are apparent in, for example, the water resources assessment area,[27] as described in Chapter 2.

Water quality monitoring: Water quality monitoring has also been affected. For example, analytical services at the Central Water Testing Laboratory in Nairobi, after growing strongly during the 1975–85 period, declined by over 75 percent during the 1988–1996 period (Figure 4.1). Some of this decline has been taken up by analyses carried out by universities and private laboratories. Overall, however, there has been a reduction in water quality monitoring. Consequently, there is little ability to determine the extent of pollution problems, identify the sources of pollution, and enforce permit procedures.

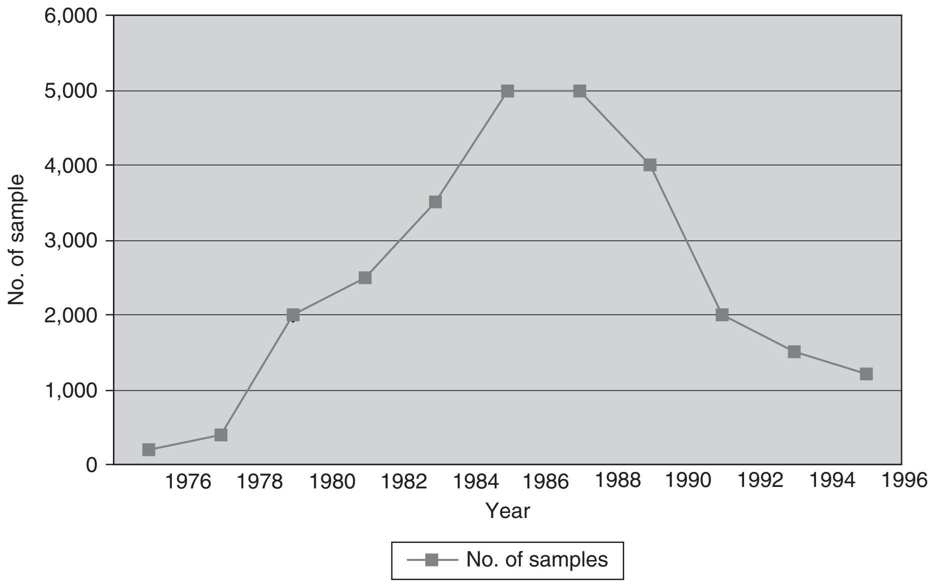
Water Allocation and Abstraction: Social Implications

Water Allocation: Water is allocated in Kenya through permits. The responsibility for issuing these permits is vested with the Water Apportionment Board (WAB), based on

26. Very large storms produce so much runoff that the size of the flood peak is the same from both well-vegetated and poorly managed catchments. However, the erosion and loss of productive soil is much greater in poorly managed catchments.

27. Republic of Kenya (1999) recognizes that the database and information management and flow in the water sector is characterized by significant data gaps.

Figure 4.1. Trends in Analytical Services at Central Water Testing Laboratory, Nairobi



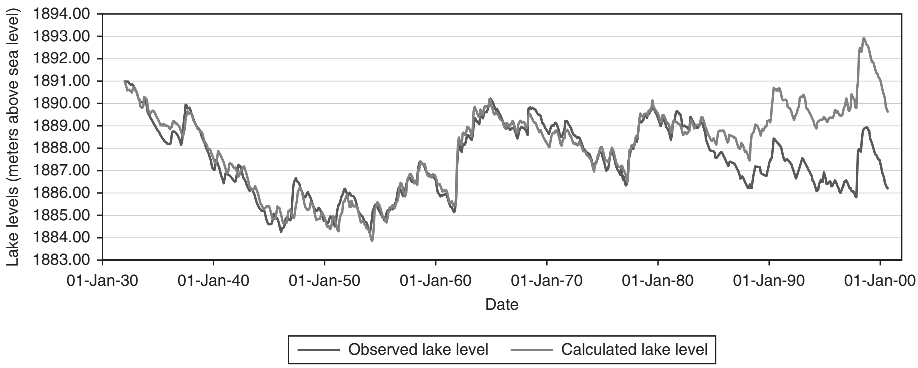
Source: Mwango 2000.

advice from District Water Boards, Water Catchment Boards, and technical advice from the Director of Water Development. The procedures for the application and processing of water abstraction permits are lengthy and involved. Although there are clearly defined legislative procedures for water allocation, effective enforcement has been affected by lack of sufficient and timely data, inadequate cooperation among water users and managers, and corrupt practices. These practices have led to delays in issuing water abstraction permits and inequitable distribution of water resources among users. In several cases, delays in issuing permits have led to illegal abstractions and further inequalities in sharing water resources.[28] This, in turn, has led to conflicts (Kiteme 2002).

Even when water is being abstracted legally, it can place a heavy burden on the available resource. Thus, the horticulture industry around Lake Naivasha is reliant on large volumes of lake water. The level of the lake fluctuates naturally because of changes in inflows and evaporation losses. Even so, over a 14-year period beginning in the mid-1980s, modeling results show a steady reduction in the lake's storage capacity of about 800 million m^3. This loss is coincident with the abstractions from the lake and its associated aquifers (Figure 4.2; Oyieko 2002).

28. Under the new Water Act 2002, authority for issuing permits has been decentralized to catchment level. It is planned that the proposed Water Resource Management Authority will issue permits locally, thus significantly reducing the delays.

Figure 4.2. Observed and Modeled Levels of Lake Naivasha Showing a Steady Decline in the Potential Water Level after 1984



Source: Data from Professor R Becht, ITC, Netherlands.

In certain Kenyan districts there has been excessive abstraction of water from rivers. The consequences are very apparent in the Baringo, Laikipia and Nyandarua districts, where downstream water users are denied essential water, important lakes and wetlands are severely threatened, and aquatic biota on which the poorer population depends, such as fish, are in decline. During the four-year period from 1990 to 1993, there was a 300-percent increase in water use in Laikipia District;[29] the increase was mainly due to increased human settlement and an expansion of irrigated agriculture (Table 4.1). The increased water use has led to severe social, environmental, and economic problems.

Groundwater exploitation has also increased over the years. The number of boreholes drilled in the Ewaso Nyiro North Basin, for example, has risen from near zero in the 1930s to about 900 in 2002 (Figure 4.3).

Illegal Abstractions: A large percentage of these abstractions are unauthorized (Table 4.2). An earlier study (Republic of Kenya 2001f) in the Ewaso Nyiro North catchment upstream

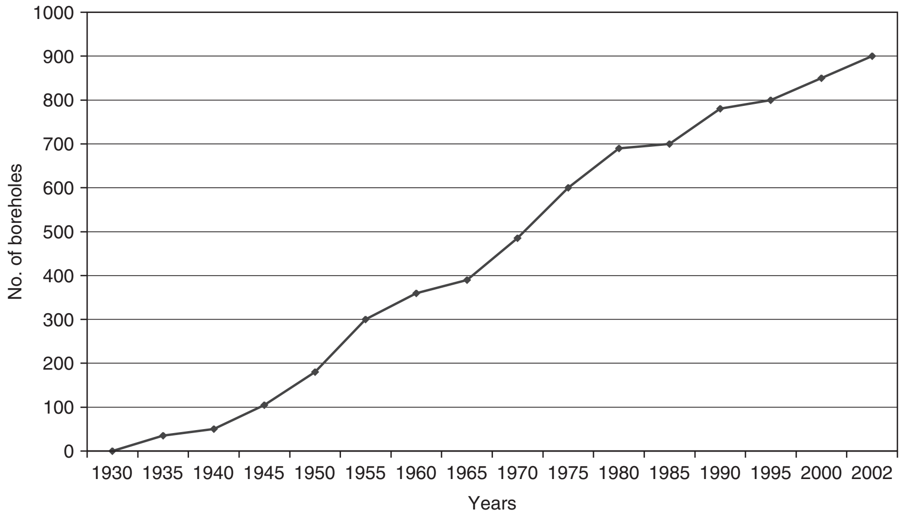
Table 4.1. Growth in Absolute Number of Abstraction Points in Three Rivers, Ewaso Nyiro North Basin, 1997–2002

	Number of Abstractions		
River	1997	2002	% Increase
Nanyuki	32	89	278
Barguret	43	113	263
Ngusishi	26	80	307

Source: Kiteme 2002.

29. Information provided by Laikipia Research Programme.

Figure 4.3. Trends in Borehole Drilling in Ewaso Nyiro North Basin, 1930–2003



of Archer's Post found that only 67 out of 901 water permits were valid. The remainder had expired or were illegal.

The decline in the depth of Lake Baringo can be partially attributed to illegal abstractions. Although subject to fluctuations due to rainfall variability, the lake's depth has declined steadily from over 15m in 1921 to about 1.8 m in 2001 (Table 4.3; Davis 2001). Although partly due to erosion in the surrounding catchments and export of eroded material into the lake, this dramatic decline is also partly attributable to illegal water abstractions from the inflowing rivers.

These unauthorized or illegal abstractions place the legal abstractions under threat and result in social and economic conflicts among the various water users groups—domestic,

Table 4.2. Percentage of Unauthorized Abstractions for River Basins in the Northern Ewaso Nyiro Catchment, 1994–95

River Basin	January–March	April–June	July–September	October–December
Naro Moru	69.6	32.1	59.0	36.8
Barguret	70.9	56.4	60.3	47.6
Nanyuki	62.4	45.3	56.5	38.3
Likii	58.3	38.1	57.2	43.8
Ontulii	72.5	52.8	70.4	49.9
Sirimon	78.2	47.7	59.5	48.6
Timau	65.8	55.4	61.6	51.6

Source: Ministries of Finances and Health Insurance Funds 2003.

agriculture, industrial, livestock, wildlife, and hydropower generation (Table 4.4 and Box 4.1). These conflicts sometimes occur between individuals wishing to use water for the same purpose—for example, among upstream and downstream farmers over access to irrigation water—and sometimes between different user groups—such as urban water supply or hydropower generation or rural land users. Newspaper reports show that about 90 people have died since January 2001 in an eruption of violence between ethnic groups in the Tana River District over land and water rights. In another example, water scarcity within the Ewaso Nyiro North Basin, particularly during dry periods, has led to serious conflicts. These low flows are attributed to overabstraction of water in the upper zones, and changes in river flow regime induced by land use and management changes.

Table 4.3. Depth of Lake Baringo

	Depth (m)
<1921	>15
1929	7.5
1930–1	7.5
1968–77	3
1977–79	8
1993	3.5
1994	3.0
1995	3.0
1996	3.0
1997	3.1
1998	4.5
1999	3.7
2000	2.7
2001	1.8

Source: Gichuru, KMFRI, Baringo.

Catchment Degradation

Investment in development expenditure in the forestry sector (funded by both donors and the Government of Kenya) has declined from Ksh 780 million in 1995–6 to Ksh 14 million

Box 4.1: Social Implications of Water Scarcity

In February 2000, residents of Kariminu village in Nyeri District barricaded the Nyeri-Nyahururu highway, causing serious transport disruption. They were protesting against the diversion of the Kariminu River by a group of large-scale irrigators. As a result, five protesters were seriously injured and several vehicles damaged. The residents claimed that their village had gone without water for several weeks due to overabstraction by upstream irrigators, resulting in increased incidence of typhoid. The District Water Officer had failed to take any action to stop the illegal overabstraction.

In 2000–2001, the pastoralists who depend on water from the Nanyuki River sought court orders to restrict the overabstraction of water for flower growing by upstream horticultural farmers. In the same year, a Nanyuki farmer lost 30,000 trout following the diversion of the Likii River for upstream irrigation. The loss was estimated at Ksh 4 million ($53,000).

In March 2000, two residents of Takaba Trading Centre, Mandela District, were killed and ten seriously injured by monkeys in a 2-hour struggle over water delivered by a charitable organization. The conflict started when monkeys attacked Takaba villagers while they were drawing water from three water delivery tankers. Clawing and biting, the monkeys sent the villagers fleeing. They then started to drink the water to quench their thirst. The villagers regrouped and counter-attacked, killing 8 monkeys.

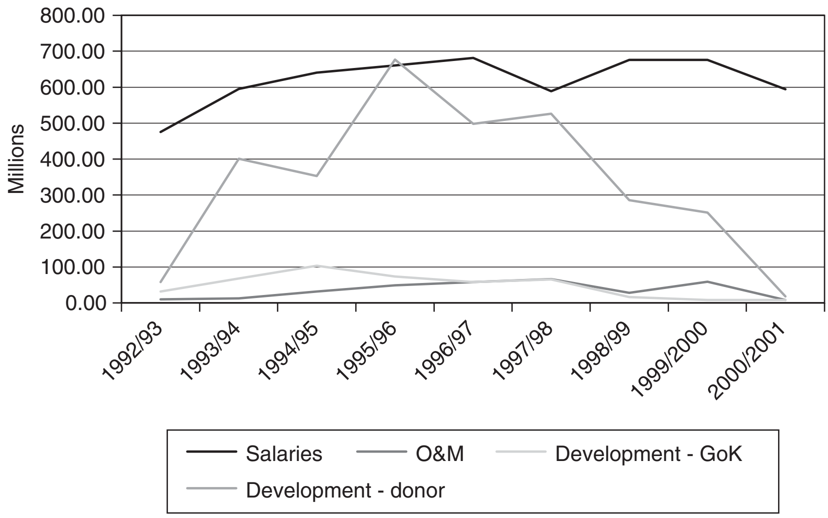
Source: Kiteme 2002.

Table 4.4. Economic Opportunities Lost Due to Water Overabstraction, 1999–2000

River Basin	Estimated No. of Households Directly Affected	Key Economic Activity Denied	Opportunity Lost
Naro Moru	34	Agriculture (small horticulture)	Based on average landholding of 5 acres, about 2 acres for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre.
Barguret	75	Agriculture (small-scale farming, domestic water supply)	Based on average landholding of 5 acres, about 2 acres for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre. Increased time spent on accessing water for domestic needs
Nanyuki	120	Agriculture (small-scale farming, domestic water supply)	Based on average landholding of 5 acres, about 2 acres for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre. Increased time spent on accessing water for domestic needs by an average of 2 hours per household per day for about 3 months.
Likii	5	Fishing	60 tons of trout fish killed
Ontulili	35	Agriculture (small-scale farming, domestic water supply)	Based on average landholding of 10 acres, about 1 acre for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre. Increased time spent on accessing water for domestic needs by an average of 3 hours per household per day for about 3 months.
Sirimon	25	Agriculture (small-scale farming, domestic water supply)	Based on average landholding of 3 acres, about 0.5 acres for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre. Increased time spent on accessing water for domestic needs by an average of 2.5 hours per household per day for about 3 months.
Timau	30	Agriculture (small-scale farming, domestic water supply) and fishing	Based on average landholding of 20 acres, about 2 acres for each household is dependent on irrigation. Lost crop production opportunity of about 10,000 cabbages per acre. Increased time spent on accessing water for domestic needs by an average of 1.5 hours per household per day for about 3 months.
Ewaso Nyiro North	95	Livestock	123,500 livestock were severely affected and most died due to water diversion for other uses.

Sources: Interviews with government officials in Laikipia District, 2002.

Figure 4.4. Expenditure in Forest Sector, Kenya (Ksh)



in 2000–01 (Figure 4.4). The precipitous drop was largely a result of a withdrawal of donors from this sector and a reduction in government funds. The salary budget shows the effect of two rounds of staff redundancies in 1997–98 and 2000–01. The O&M budget declined almost 90 percent—from Ksh 65.8 million in 1997–98 to Ksh 7.8 million in 2000–01—because operating funds were treated as supplementary after salaries had been accounted for. As a result, overall funds available to manage the forests sustainably from both O&M and development budgets have dropped very significantly since the mid-1990s.

Forest Conversion

Most of Kenya's main forests are located in the headwaters of catchments that provide vital water sources. The annual protection value[30] of these catchments has been estimated at Ksh 2,104 million. This figure is based on studies carried out on the effect of clearing major forest areas in Kenya, including the Mau Complex and the resulting losses arising from soil erosion and wildlife damage (Republic of Kenya 1995).

Despite their economic and environmental importance, forests in Kenya continue to be under threat from clearance. Figure 4.5 (see endplate) shows the dramatic extent of forest removal in the Lake Nakuru catchment. The excisions carried out in 2003—of Eastern Mau Forest Complex (35,301.01 ha), Molo forest (901.62 ha), and Nakuru scrubland (270.5 ha)—has exacerbated the situation.

An aerial survey conducted in 1999 by the Kenya Wildlife Service (1999) indicated that over 2,400 charcoal kilns were placed in the Mt. Kenya Forest Reserves—including the

30. The protection value includes the benefits provided to off-site land and water users through maintenance of good catchment condition.

main Mt. Kenya Forest, Lower and Upper Imenti Forest, and Ngare Ndare Forest. The cutting of wood for these kilns is causing serious damage to the surrounding forests. About three mature, indigenous trees need to be felled each week to maintain one kiln, implying that over 7,000 trees are cut per week for this purpose. Similarly, woodlands and bush lands are estimated to decline by 55,000 ha per year because of conversion to other land uses and timber removal for fuelwood.[31]

The Impact on Hydrology

Forest Clearance: Deforestation almost always leads to increased runoff and increased sediment loss (described later). Runoff increases because, under most circumstances, evapotranspiration is a much larger pathway for water loss from forests than surface runoff or groundwater recharge. When this pathway is reduced by tree clearing, more rainfall is available for streamflows (see Appendix B for a review of the literature, including experiments conducted in Kenya and Tanzania). Thus, replacing forest with annual crops that have relatively low evapo-transpiration characteristics will lead to a long-term increase in both mean annual flows and base flows, as long as other pathways are unaltered. If the tree clearance is accompanied by other changes, such as major abstractions of groundwater and surface water flows, then streamflows may not increase.

Cloud forests[32] can be an exception because these forests intercept mist directly from the atmosphere. Thus, there is an actual loss of incident rainfall when these forests are cleared. This process of condensation on leaf and trunk surfaces has been found to add as much as 15 to 20 percent to total effective rainfall in Central American countries (Bruijnzeel 1995; Reynolds and Thompson 1988). Persistent cloud bands occur in the forests between 7,000 and 11,000 feet (2,100 to 3,600 meters) in the Abaredare and Mau Ranges of Kenya for about three or four months of the year. There are no data available on the extent of direct water harvesting by the forests at these times. However, assuming that they are as efficient as the Central/South American forests at water harvesting, it is reasonable to estimate that about 5 percent of the precipitation occurs from the direct harvesting effect. Thus, clearance of these areas may lead to a reduction in effective precipitation of about 5 percent, and this would consequently reduce runoff and river flows.

Combining Clearance and Settlement: There is ample evidence that dry season flows have decreased significantly in a number of Kenyan rivers after clearance and settlement of large parts of their catchments. Much of the cleared area is replanted with annual crops, such as maize, although trees are also established for shelter and fuelwood purposes. The evapo-transpiration from the replacement vegetation is less than that from

31. Republic of Kenya (1994b). The main forms of land use change include conversion from natural forests to plantations; from forests to agriculture; and from bushland to grazing. These changes have important implications on water resources.

32. Cloud forests, as the term is used here, are ones where there is a near continuous supply of moisture from mist and that moisture is constantly replenished. These conditions are encountered in Central and South America and parts of Asia where there are high mountains near coasts with on-shore breezes and fogs.

the cleared forest. Thus, the observed decreases in river flow are more likely to arise from the increased abstraction of surface and groundwater to support the settlement than by the change in vegetation. If extensive abstraction is allowed to occur, then flows can decrease by (in the case of the Ewaso Nyiro North catchment) a factor of 10 in dry months.

The clearance of forest and settlement in the main river basins has increased the volume and flashiness of medium-sized storm flows and, when there is extensive water abstraction, decreased base flows. This will not only exacerbate flooding but will also require greater storage volumes to capture the same quantity of flow for water supply, irrigation, and hydropower purposes.

Unless carefully managed, forest clearance generally results in greater investment in infrastructure to achieve the same degree of water storage reliability. However, the size of this effect is difficult to estimate from the very limited data available. The 1992 National Water Master Plan, which recommended that the level of water storage needs to be increased dramatically, did not take account of this effect. As recommended earlier, the suggested storage increase by a factor of 30 needs to be revised in light of a better understanding of water demand. The effect of increased flow variability on storage security should be included in those revisions.

Some regions—such as the Nyando River and Kano and the Budalangi plains in the Lake Victoria basin—experience annual flooding that causes serious and costly health problems. Although it is impossible to determine the extent of flooding prior to catchment clearance from the hydrologic records, it is likely that more than 50 percent of the flooding is attributable to the clearance in the headwaters of the Nyando River since the 1920s. Although the top parts of the catchment, used for tea plantations, are relatively stable, the slopes consist of shallow, highly permeable soils that quickly saturate and produce quick overland flow during storm events. Residents of the Kano Plains are dependent on shallow wells for their drinking water. Pit latrines and other wastes contaminate the water table and there are outbreaks of cholera and amoebic dysentery when the residents return after the floods recede.

Increased Sediment Delivery

Land Use: There is strong evidence from controlled experiments throughout the world that deforestation leads to increased erosion and sedimentation. Bruijnzeel (1992) says: "In contrast to the misconceptions regarding the influence of forests on rainfall, water yield and major floods—the popular view of trees as checkers of soil erosion by and large is supported by the evidence." The widespread empirical evidence in Kenya of increases in soil loss following deforestation is consistent with these international findings (Katana 2002). However, soil loss need not inevitably follow forest clearance. If good ground cover is maintained on the cleared land (for example, by retaining mulch on the soil surface), then the ability of the rain drops and runoff to detach soil particles is greatly reduced. Erosion control depends on good land management.

Apart from forest clearing, poor agricultural land management practices also contribute to high stream sediment loads. Cultivation of unsuitable areas, such as stream banks and steep slopes, has caused considerable loss of soils. In some parts of the country, very steep slopes are under cultivation, without appropriate soil conservation measures. Roads and tracks that run straight down slopes to rivers for water access provide direct conduits for the eroded material.

Deposition in Storages: The majority of eroded material is usually deposited en route, with only a small fraction reaching downstream storages. Consequently, the abundant literature on erosion and sediment loss from plot-scale studies cannot be used to estimate a measure of sedimentation unless coupled with studies in the water storage itself. In spite of the low sediment delivery ratio, there is usually still an appreciable increase in sedimentation of water reservoirs after clearance of headwater catchments.

The deposition of sediment in reservoirs reduces their economic life, reduces the hydraulic capacity of the conveyance facilities and disrupts water supply operations. The suspended sediment load also causes mechanical damage to power production infrastructure. Turbine blades and canal linings can be damaged (Okemo 2002).

The Kamburu Dam on the Tana River was threatened by excessive rates of sediment deposition before the construction of Masinga Dam in 1980. The latter dam was designed on the basis of a siltation rate of 3 million tons per year. However, by 1988, the siltation rate had increased by 3.5 times to 10 million tons per annum because of upstream catchment degradation. The water storage of the reservoir had been reduced by 6 percent over the eight years. A recent survey established that the original estimate of the dam's volume was in error, making it impossible to directly measure the volume of sediment deposited since 1982. However, erosion in the catchment is estimated to be causing about 1,500 tons of sediment per km^2 per year to enter the reservoir. Although the reduction in volume is unknown, it is clear that the reservoir is silting up considerably more rapidly than envisaged when designed (Annandale 2002).

The dramatic reduction in the depth of Lake Baringo (Table 4.3) is partly due to the reduced inflows and partly to the increased sediment load from the surrounding catchments. The tourism industry at this site depends on the presence of a large variety of water-dependent birds. Once the lake turns into an ephemeral wetland, many of these species will no longer be present.

Apart from the loss of storage volume in larger reservoirs, sedimentation has also affected numerous small dams and pans in the ASALs. In the 25 most drought-affected districts, there are 1,531 water dams and pans with a capacity of 27.9 million cubic meters and 4,329 boreholes yielding 166,486 cubic meters daily (UNEP/GOK 2000). Additional storage capacity is required in order to secure reliable water supplies. This can be partly achieved through rehabilitating old storages that have fallen into disrepair through lack of investment, as well as by removal of sediment from pans and dams.

Coastal Impacts: The load of sediment being delivered down the Athi River into the Indian Ocean has risen from 50,000 tons a year during the 1950s to 8.4 million tons a year by 1992. Although this increase may be partly due to better monitoring of storm flows, much of it represents a real increase in loads resulting from changes to the vegetation cover in the upper catchment since the 1950s. The high suspended sediment load in this river has caused serious problems to the water supply intake at Baricho for Mombasa,

Box 4.2: Effects of Increased Sedimentation on the Sabaki River

The load of sediment delivered by rivers in Kenya has almost certainly increased in recent years, but insufficient measurements make it difficult to quantify this increase. In the case of the Sabaki River, the results of the increased sediment load are noticeable in several ways, including:

- The Sabaki Water Treatment Works had to be designed for high sediment load and there were subsequent operational problems associated with the raw water pumping plant.
- The Malindi North Beach area was transformed from one of scour and removal to one of discolored deposition during the north-east monsoon (Kaskazi winds).
- The discoloration to a deep red of the water and beaches in the Mambrui area and to the north during the south-east monsoon (Kusi winds).
- The rapid siltation of Malindi Harbor so that it can only be accessed or exited at high tide and even then only by boats with a shallow draft.
- The rapid siltation around the Malindi jetty such that it will have to be extended if it is to be used by even the smaller cargo ships and other ocean-going vessels.

While these affects are apparent, it is difficult to estimate their cost. In the case of the Sabaki Waterworks constructed in the late 1970s, the treatment works required the inclusion of extensive primary settling basins before the conventional sedimentation clarifiers. This cost over $1 million.

The sediment load caused a marked reduction in the amount of water that could be abstracted during periods of high flow at the raw water intake-pumping station, which had cost implications on bulk water supply and revenue. In addition, the working life of the raw water pumping plant was reduced from the expected 10–12 years to no more than 5–6 years. This meant that the six pump sets required replacement twice as frequently (at a cost of about $1.5 million) as normal. In addition, the band-screens that should have had a similar life failed within less than four years, largely due to abrasion of moving parts caused by the sand carried in the water.

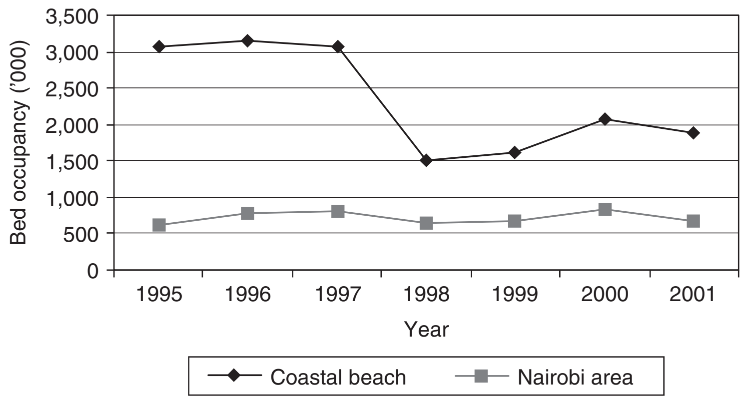
Source: Personal communication, David Baker, Gauff Engineers.

resulting in the eventual abandonment of the International Development Assistance (IDA)-funded Mombasa Water Supply Project. The Sabaki Waterworks constructed in the late 1970s required the inclusion of extensive primary settling basins before the conventional sedimentation clarifiers. This had investment cost implications of over $1 million (Box 4.2).

The high sediment loads in coastal rivers, even during "normal" years (see Chapter 3 for effects during El Niño floods), have also degraded inland, coastal, and marine resources. Wetlands become saturated with sediments and the morphology of the rivers and estuaries is altered, leading to changes in the physical habitat for aquatic life. Over the last 20 years, the beach at the exit of the Sabaki River has extended seaward by more than 950 meters and the jetty and the beach in the vicinity of the river mouth have been rendered unusable (Box 4.2).

The hotel industry along the Kenyan coast, compared to that in central Kenya, has suffered a major loss of income since 1992 (Figure 4.6). Politically instigated tribal clashes in 1992 and 1997 and breakdown of basic infrastructure as well as the deterioration of the coastal beach, (particularly at river discharge points) have all contributed to the reduction in occupancy rates.

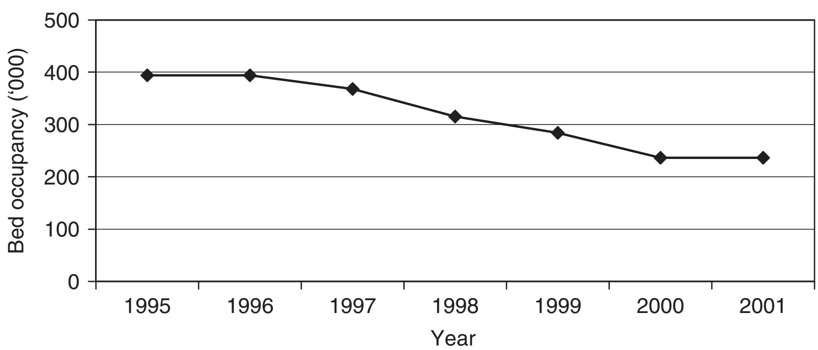
Figure 4.6. Trends in Bed Occupancy in Coastal Beaches and Nairobi Area



Source: Interviews conducted with Hotel owners, 2002.

The hotel industry along the Malindi beach has suffered particularly. Surveys of the 15 hotels along Malindi beach indicate that 50 percent of the declining number of occupied beds is directly related to the deteriorating state of Malindi beach due to sediment deposition from the Galana River. Seven of the hotels have closed down since 1999, while the other eight have suffered declines of over 40 percent in bed occupancy over the last five years (Figure 4.7).[33]

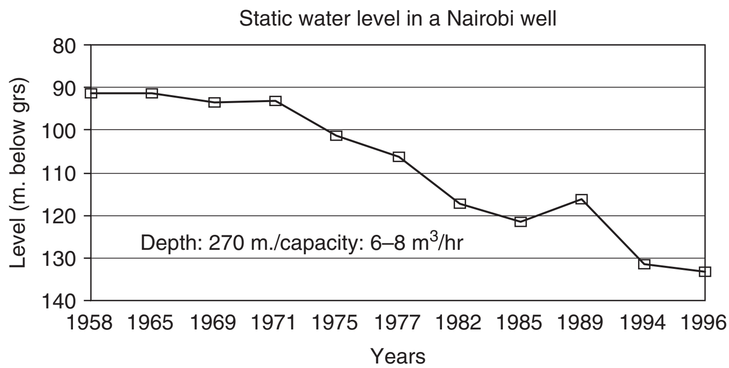
Figure 4.7. Bed Occupancy for Eight Hotels along Malindi Beach



Source: Interview with hotel owners, 2002.

33. The loss of revenue due to the closure of seven hotels and declining bed occupancy for eight other hotels is considered to be a loss to the local economy. However, some of the tourist trade may have shifted from Malindi hotels to other areas within the coastal region—notably Watamu—and so will not be lost to the national economy.

Figure 4.8. Drawdown of Water Table in a Private Well in Nairobi Area



Groundwater Management Regimes

Groundwater, although only a small component of the national water resource, is the main source of water in the ASALs as well as being an important source of urban drinking water in, for example, Nairobi and Nakuru. Although the exploitation of groundwater resources is well regulated in principle, in practice the regulations are largely ineffective. Permits are not issued on the basis an assessment of sustainable yields, and the oversight of permits is seriously underfunded. Many boreholes have been drilled with little regard to the proper procedures, largely because the procedures are so cumbersome or because of abuses by well-connected individuals.

Drawdown under Urban Areas

The costs from overpumping groundwater can be seen in the Greater Nairobi Area. The aquifer complex reaches some 400 meters underneath Nairobi City and is underlain by impermeable basement rocks. Groundwater abstraction started in the early 1950s and had increased to 1350 boreholes by 2002, totaling about 60,000 to 70,000 m^3/day at present (Republic of Kenya 1998a; Tuinhof 2001). This represents about 21 percent of the water supply to the Nairobi area.

Groundwater depletion was already recognized in Ruaraka in the early 1950s. A groundwater observation network was established in the mid-1950s and was operational until 1975. Little groundwater level data are available after 1975. However, various surveys in 1964 (Gevaerts 1964), 1971, 1984, 1988, and 1998 showed consistent declines of between 0.1 and 0.9 m/yr in groundwater level.[34] In one example of an intensively used portion of this aquifer, biannual water level measurements in a 275-meter deep borehole in the period 1958–1996 show a decline in groundwater level starting about 1970, which had reached 40 meters in 1996 (Figure 4.8).[35] These declines represent addition costs to water users because

34. M Lane, private communication, March 2002.

35. Note that this depression in the water table is likely to be localized to this intensively used part of the aquifer.

of increased pumping costs as well as reduced options for future use of this high quality water resource.

Both drilling and pumping costs have also increased over the years. Ordinarily, a 60-meter borehole in the Nairobi area is sufficient to supply water for domestic use (particularly for the hotel industry). However, due to overextraction, the average well depth has increased to 84 meters. Although no data are available for drilling these deeper wells, the average cost of drilling 60- and 70-meter wells is estimated at about $10,430 and $11,430 respectively (Anon. 1998).

The water table in the vicinity of Nakuru has also been dropping. Abstractions from the Njoro River and connected aquifers, as well as inappropriate agricultural water use following clearing and replacement of indigenous vegetation with high water using trees such as *Pinus* and *Eucalyptus,* have all reduced the infiltration of water into the aquifers and greatly lowered the water table in the area. At the Njoro campus of Egerton University, for example, only 8 out of the original 14 boreholes are functional. Pumping of water from boreholes within the campus is stopped overnight to enable replenishment (Shivoga 2002).

Inoperative Equipment

Poor maintenance of equipment owned by the (then) Ministry of Environment and Natural Resources has impacted on the provision of water services. For example, 24 of the 28 drilling rigs owned by the Water Development Department were reported to require rehabilitation in 2000. Proper management of the valuable groundwater resource requires considerable investment in monitoring, data interpretation, and modeling, as well as enforcement of permits to ensure its exploitation on a sustainable basis. For example, rehabilitation of the drilling rigs and five test pump units would cost about Ksh 750 million. With these repairs, 525 boreholes could be rehabilitated, providing an additional 26,250 cubic meters of water per day (Mwango 2000).

However, funding by itself will not protect this important source of high-quality water. A well-managed permitting system with regular monitoring and enforcement is also required to ensure its protection.

Water Pollution

Water resources in Kenya are increasingly becoming polluted from both point and non-point sources. Pollution imposes a high cost on the economy through detrimental health effects (particularly on the poor and the vulnerable), increased treatment costs for drinking water, reduction in future use options for the water (particularly groundwater), loss of economically significant fauna and flora, and degradation of environmentally important areas.

Key sources of water pollution are:

- Discharge of untreated or semi-treated urban sewage and storm-water,
- Industrial effluents and urban solid wastes,
- Sea water intrusion into water aquifers,

- Surface erosion/run-off of sediments and nutrients,
- Atmospheric deposition of nutrients (especially in the case of Lake Victoria), and
- Agro-chemicals.

Weak enforcement of regulations controlling polluting activities simply transfers costs caused by private enterprises to the public sector or future generations. Polluters need to be confronted with the full cost of their activities in line with the government's "polluter pays approach" (Republic of Kenya 1996). Monitoring needs to be improved, staff members need to be trained, and public interest groups need to be increasingly involved so that polluting activities are seen to be socially unacceptable.

Point Sources: Municipal and Industrial Sources

Sewage Treatment Plants: A number of urban centers in Kenya have installed modern sewage treatment plants (STPs) that are developed and maintained by the local authorities. They discharge on average about 300,000 cubic meters a day of sewage effluents. Many of these sewage works operate at an efficiency of less than 50 percent due to poor operations and maintenance and inadequate designs, inadequate connections, and overloading. Some, such as Naivasha STP, do not function at all. Food grown with water contaminated with untreated sewage imposes health costs on those consuming it and, in the case of some irrigation areas, costs arising from the rejection of crops in export markets.

Industrial Effluent: The industrial sector in Kenya experienced rapid growth in the early and late 1960s with an annual growth rate of about 6 percent. Most of the industries are based within or near major urban centers. Such industries include tanneries, textile mills, breweries, creameries, paper production and recycling plants, chemical processing industries, and slaughter houses, which discharge effluents into the existing sewers and thus exert more pressure on the existing sewerage infrastructure. Water pollution arising from urban-based industries is evident in Nairobi (chemical processing, paper recycling, and slaughter houses), Webuye (paper production), Thika (tanneries, textile industries, and chemical processing), Athi River (slaughter house and tannery), Nakuru (chemical and textile industries), Kisumu (fishing, chemical processing, and agro-processing), and Mombasa (fishing industry, chemical industries, oil industry, and agro-processing). In a recent incident, householders in Mombasa turned on their taps to find that the water had traces of oil in it. The contamination came from the leakage of an underground diesel storage tank into the drinking water supply (Odinga 2002). Agricultural produce from irrigated areas has been rejected from export markets because of contamination by heavy metals from industrial wastes.

A number of agro-processing industries are located within rural areas. Such industries include coffee pulping and fermenting industries, tea processing, sisal fibre processing, sugar processing, and canneries. The discharges from these industries are mainly organic with high BOD loads. For example, sugar milling consumes large quantities of water and the discharge has a BOD range of 3,000 to 5,000 mg/l (Mwango 2000). The quality of the final effluent is invariably poor and depresses the oxygen levels of the receiving waters.

Lake Nakuru: Nakuru city typifies many of the problems. The city has grown rapidly, causing a considerable annual increase in domestic and industrial waste with insufficient investment in waste handling and treatment facilities. A recent study (JBIC 2001) indicates that, although one sewage treatment plant is discharging effluent close to standards and the other is not discharging effluent at all, few of the large number of industrial establishments and only about 15 percent of the households have been connected to the STPs (even the establishments that are connected do not always provide influent of the required standard; JBIC 2001; KWS 2001). Consequently, stormwater contains high levels of untreated household and industrial waste, which is discharged directly into Lake Nakuru.

The old town landfill at Nakuru was sited on the shores of Lake Nakuru and was not properly sealed when it was abandoned. Heavy metals are leaching into the lake, and waterbuck that graze the site have symptoms of lead poisoning. In addition, the water quality testing station and an education center have been constructed on the old dump. Clearly, these are inappropriate land uses for this contaminated area. This example illustrates one of the difficulties with managing landfill sites. In spite of these clear problems, it is difficult to identify a specific economic loss being suffered from this contamination because of the long time constants sometimes involved, the presence of confounding factors, and the lack of good monitoring data. This problem happens at a number of sites throughout Kenya. As stated recently by the Minister of Public Health, "…discharges or seepages from these dump sites find their way to the surface or groundwater. Some of these discharges may contain heavy metals such as fluoride, arsenic, lead, mercury, cadmium, etc., which could cause damage to the nervous system as well as cancer" (Ongeri 2002).

Toxic cyanobacterial blooms have been observed in Lake Nakuru and there is evidence that toxins released by the cyanobacteria have caused the deaths of flamingos. The origins of these blooms are unknown; they may have arisen or been promoted by the untreated stormwater. The lake attracts about 165,000 tourists a year and generates revenue estimated at Ksh 264 million annually ($3.3 million) through gate fees alone.[36] The flamingos are the central attraction for most of these visitors. A 1991 study (Mungatana 1992) estimated that the annual recreational use value of flamingo viewing is between $2.3 million and $6.4 million depending on which method of estimation is used. The non-use value of the flamingos could be even higher, but was not estimated in that study. Although there is insufficient evidence to be certain that these untreated discharges are affecting this important industry, it is risky to allow the situation to continue.

Nonpoint Sources: Agriculture and Urban Runoff

Agricultural Chemicals: Agricultural fertilizers and pesticides, which are the most important nonpoint source pollutants, are in widespread use throughout Kenya. The

36. Data supplied by KWS Nakuru Area Warden.

volume of agro-chemicals used has increased over the years in response to increasing population and decreasing land fertility because of topsoil erosion and heavy cropping. In some areas, such as the Rift Valley, pesticide breakdown products are routinely detected in lake sediments and sometimes in the water (JBIC 2001). Although the death of flamingos in Lake Nakuru has been blamed on heavy metals and pesticides, it is more likely that other causes, such as cyanobacterial toxins, were responsible. Nevertheless, it is clearly risky allowing these chemicals—many of which have been banned because of their toxicity—to be used in the catchment.

Matteson and Meltzer (1995) estimate that 7 percent of workers in Kenya's agricultural sector are severely poisoned by agri-chemicals every year and that the percentage rises to 25 percent in the horticultural sector. Although no figures are given for hospital admissions or time lost, these figures imply considerable economic losses apart from the obvious social distress. In addition, the cut flower trade is being threatened with loss of access to the European market because of high pesticide residue concentrations.

Nutrients such as phosphorus and nitrogen from excessive fertilizer applications and untreated sewage are carried into rivers and streams during storm events. Much of the phosphorus is attached to eroded soil particles. These nutrients contribute to eutrophication of downstream waterbodies and the occurrence of algal blooms and aquatic weeds. However, the extent of nutrient losses from agriculture has not been quantified, and it is difficult to attribute the costs arising from algal blooms to these nutrients.

Sediment Pollution: Sediment losses have been dealt with previously. However, agricultural sediments usually have high concentrations of nutrients, particularly phosphorus, attached to them. These nutrients can fuel algal blooms and nuisance weed growth, such as water hyacinth (*Eichhornia crassipes*), many miles distant from their sources. These blooms, when they decay, deplete oxygen in the water of lakes and storages, making them uninhabitable for fish and many other animals. Fish kills from this cause have been seen in the Nyanza Gulf and other parts of Lake Victoria.

Eutrophication of Lake Victoria: Lake Victoria receives atmospheric nutrient inputs that are greater than its riverine nutrient inputs (Hecky 2003; Okungu and Opango 2001). High nutrient levels lead to excess growth of nuisance weeds (such as water hyacinth) and algae, which impede transport, block water intakes to treatment plants, impede water collection and fishing, and deplete oxygen levels when they die and decompose. Eutrophication has now restricted the deeper parts of this large lake to many fish species (Davis 2001). Thus Nile perch, the most commercially valuable and heavily-fished species, cannot tolerate the low oxygen levels found in the bottom 30 meters of the lake over much of the year, although some of its prey species can. Other commercial fish species (Nile tilapia and *Rastrineobola argentea*) are more tolerant of low oxygen levels and are believed to be less affected.

Certain cyanobacterial species can release highly toxic poisons. These toxins include neurotoxins, hepatotoxins, cancer promoters, and skin irritants. Since the early 1990s, Lake Victoria has hosted a permanent population of potentially toxic *Anabaena circinalis*. However, it is difficult to attribute human illness to these poisons because the symptoms can arise from many other common illnesses.[37] Nevertheless, there does not appear to be a toxin-monitoring program in place to protect those reliant on the lake waters for drinking and other household purposes.

Currently, fish production levels in Lake Victoria are considered unsustainable, and the Nile perch fishery in particular is threatened from overfishing (van der Knaap 2001). Gill net mesh sizes have been reduced from 7" to 5" (illegal nets with smaller meshes were found in a recent survey by Makene, 2001), and now the majority of Nile perch caught are juveniles.

Invasive Weeds: Economic Implications

Infestations of various waterweeds—notably water hyacinth, ferns, and lettuce—are a further source of surface water degradation. In the best known example, water hyacinth (*Eichhornia crassipes*) infested the waters of Lake Victoria during the late 1990s. At its peak, the weed occupied about 90 percent of the lake's shoreline (Ong'ang'a, Othieno, and Munyirwa 2001).

There were significant negative economic and social impacts from the water hyacinth during the peak of the infestation. The impacts included impaired water transport, reduced fishing activities, higher cost water supply and lower quality, and promotion of diseases and vermin. Fish landings declined by 15 percent between 1995 and 1999 for a number of reasons, including overfishing and eutrophication. The presence of water hyacinth probably also contributed to the decline, particularly for artisanal fishing close to shore because of the difficulty of movement (Ong'ang'a, Othieno, and Munyirwa 2001), obstruction of beaches, and the increased shelter for fish. Sheltered bays experienced nutrient reduction, which interfered with breeding and nursery grounds for some key commercial fish, particularly tilapia. The weed clogged important waterways and landings and commercial transportation as well as movement by small fishing boats was obstructed. Docking by large steamers was regularly delayed.

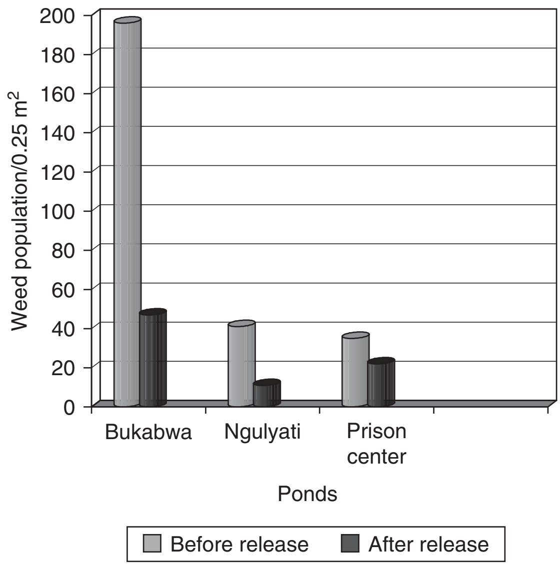
The weed interfered with families' and communities' access to the lake for water supply and increased the cost of urban water treatment because of higher concentrations of suspended and decaying organic matter. The weed mat provided an environment for the proliferation of mosquitoes and the *Biomphalaria* snail, which hosts *Schistosomiasis* (bilharzia).

The water hyacinth is currently under control via a bio-agent, the *Neochetina* weevil. In some recent studies (Aloyce and others 2001; Ndunguru and others 2001), the area infested has been found to be reduced by over 75 percent (Figure 4.9). The remaining areas, predominantly at river mouths and other locations that were favorable to plant growth, had only low concentrations of water hyacinth where the weevils were present in the weeds.

However, like the invasion of Nile perch some years earlier, the invasion of the water hyacinth also provided economic opportunities, including the manufacture of fancy

37. Even so there is evidence that cyanobacterial toxins have caused widespread chronic ill-health amongst populations in China who are dependent on cyanobacterial contaminated drinking water.

Figure 4.9. Reduction in Water Hyacinth Density after Release of Bio-agent at Three Sites in Tanzanian Part of Lake Victoria



Source: Ndunguru and others 2001.

chairs, and the production of paper and pulp, dry fuel fodder and silage, and yarn and rope (Table 4.5).

Water hyacinth and other invasive weeds also occur in many other water bodies in the country. However, the severity and extent of the problems arising from them is not known.

Summary

Table 4.6 presents a summary of physical impacts of water resources degradation.

Table 4.5. Main Economic Uses of the Water Hyacinth

Economic Use	Organization
Furniture making	Kisumu Innovation Centre—Kenya
Organic fertilizer	Industrial Technology and Engineering Trust
Rope making	Kisumu Innovation Centre—Kenya
Soil conditioner	Industrial Technology and Engineering Trust
Pulp and paper	Kisumu Innovation Centre—Kenya, Kenya Matches

Table 4.6. Summary of Physical Impacts of Water Resources Degradation

Issue	Physical Impact
Overabstraction of water	Illegal abstraction of water reduces production from irrigators holding permits. Illegal abstractions have led to conflicts resulting in social disruption, injury, and deaths. Illegal abstractions and overabstraction reduce beneficial functioning of wetlands, lakes, and waterbodies. *Overabstraction of groundwater for urban use and irrigation increases the cost of extraction and reduces future water use options.* *Overabstraction in coastal areas leads to sea-water intrusion and need for desalination.*
Forest clearance	Increased erosion with high sediment loads being delivered to *dams, pans*, wetlands, lakes, *estuaries, and coastal regions*. *Increased erosion leading to loss of urban water supply facilities.* *Increased flows, including flashier flood peaks, when clearance is followed with low vegetation cover land uses, leading to increases in flooding with crop losses and waterborne diseases.* Decreased flows when forest clearance is followed with intensive settlement.
Poor soil management	Increases in riverine sediment and nutrient loads, leading to *siltation of dams, pans,* wetlands, lakes, *estuaries, and coastal regions*. *Increases in dust and attached pollutants such as nutrients, leading to eutrophication of waterbodies.* *Increases in soot and nutrients from stubble and grassland burning, leading to eutrophication of waterbodies.*
Discharge of human wastes	*Poor operation of sewage treatment plants results in microbial contamination, de-oxygenation, and eutrophication of receiving waterbodies.* Crops grown with contaminated water cause health effects and may lead to rejection of export crops.
Discharge of industrial wastes	BOD loading and heavy metal contamination of receiving waters. Crops grown with contaminated water cause health effects and may lead to rejection of export crops.
Poor management of agricultural chemicals	Leaching of agri-chemicals can threaten aquatic life, including fish and birds. The health of agricultural workers is affected by poor handling of chemicals.
Occurrence of invasive weeds	*Weeds choke harbors and landing sites, harbor pests, reduce fishing accessibility, clog water offtakes, and affect navigation.*

Note: Those impacts that are quantified as economic impacts in the next chapter are in italics.

CHAPTER 5

Economic Impacts of Rainfall Variability and Water Resources Degradation

Because of lack of data, it is difficult to develop a comprehensive cost to the national economy from rainfall variability and water resource degradation. Nevertheless, the 1997/98 El Niño event is estimated to have cost, at a minimum, Ksh 70 billion, and the following La Niña drought cost at least Ksh 220 billion. These figures represent about 11 percent of GDP in 1998/9 and 16 percent of the GDP in each of the two drought years. Water resource degradation costs the economy annually at least Ksh 3.3 billion; about 0.5 percent of GDP. These estimates are conservative since they are based on only those impacts described in the preceding chapters that could be quantified. The costs are borne by many sectors of the economy, including agriculture, water supply and sanitation, health, and power generation.

Overview

In this chapter, we use the information collated in the preceding two chapters to assess the economic costs arising from rainfall variability and water resource degradation. Even though a wide variety of impacts from both rainfall variability and water resource degradation are described in those chapters (Tables 3.6 and 4.6), only some of these impacts could be costed because of the limited data and information available on both biophysical and socioeconomic aspects.

Methodology

Different methods are used in this section to monetize the costs from rainfall variability and water resource degradation. These methods are described in Appendix C.

Direct Costs: In some cases, the costs can be obtained directly and are clearly distinguishable from other influences. For example, estimates of replacement costs for infrastructure damaged or destroyed by the 1997/98 El Niño floods are available from other studies. When the direct cost is not available, we can sometimes use the income forgone from production of a commodity as an estimate of the cost of water resource degradation or climate variability. The costs arising from reductions in the production of some crops following the La Niña drought—and the fisheries income forgone as a result of eutrophication of Lake Victoria—fall into this category. Where the value of an actual commodity is not available, we use the value of time at a typical labor rate as a surrogate for the profit foregone. Thus, the extra time taken to collect household water, assuming that the time would have otherwise been spent on income-earning activities, provides an estimate of the cost of scarce water supplies during the La Niña drought.

Table 5.1 to 5.3 show the component costs that have been calculated for each of the 1997/98 El Niño floods, the 1999/2000 La Niña drought, and ongoing water resource degradation. Because different methods of calculation carry different assumptions, the component costs are not always comparable. The details of each calculation are included in footnotes.

The costs have been developed taking into account duplications and interactions between the sectors. Thus, the loss of income to the power industry from reduced hydroelectric generation during the La Niña drought could also appear as a loss of production in industries reliant upon electricity. To some extent, the shortfall in electricity generation in Kenya was compensated by imports from Uganda, which limited the reduction in final output in the Kenyan economy. The cost item accounted for is then the incremental cost of importing electricity. However, to some extent, alternative power was not available in a timely and sufficient manner, which hurt industrial production. In such cases, we have defined the cost as the loss in final output.

Indirect Costs: Other costs, although real, were incurred indirectly and are therefore more difficult to estimate. These include:

- Loss of future employment opportunities (for example, permanent relocation of firms outside of the Kenyan economy because of unreliable hydroelectricity supply),
- Uncertainties for legal water licensees because of insecure water supplies,
- Cost of replacing water supply intakes and pipes,
- Non-compliance with international agreements (for example, the silting up of the Ramsar-listed Lake Baringo),
- Increased incidences of social disruption (for example, conflicts over water access and usage), and
- The reduced resilience and proper functioning of ecological systems as a result of water resource degradation.

None of these indirect costs have been included in the calculations in this chapter. In particular, amenity costs have not been included. These include loss in pleasure (for example, visual amenity from a clean, running river), loss of spiritual values, convenience, and so forth. Even though these benefits from well-managed water resources may sound ethereal, they represent potentially large losses.[38]

In developing these cost estimates, we have used only the economic costs, i.e. those where a true loss was incurred by some sector of the Kenyan economy. In cases where financial costs were borne by an individual or enterprise but equivalent benefits were received by another within the Kenyan economy, the costs are noted but not included. Thus, the restocking costs borne by the Government of Kenya for cattle lost during the La Niña drought were not included because these cattle were purchased from other pastoralists and so represent a transfer within the Kenyan economy.

Finally, we have used conservative estimates for the costs wherever possible. Not only have we used lower estimates of variables used in the calculations but, in most cases, we have based the calculations on individual locations or regions where data are available, rather than estimating costs across the whole country. Crop and livestock losses and urban water treatment costs are some of the few cases where national data were used.

Costs of 1997/98 El Niño Floods

The floods resulting from the El Niño rains occurred during a period of four months—October 1997 to February 1998—although the costs arising from this event were incurred for many months thereafter, and even years in the case of destroyed infrastructure. We report the costs here for the event—that is, we do not annualize them, although a comparison is made to the GDP over the duration of the events. These impacts, while devastating, were not as great as the impact of previous events such as the floods of the early 1960s. Thus, they represent a specific flood event and not a "typical" rainfall extreme event.

Costs from the floods already calculated in reports reviewed in Chapter 3 are included here; otherwise, the calculations are based on the size of the physical impacts described in Chapter 3 using the methods described in footnotes.

Not all these costs can be avoided when a major flood occurs. Insofar as this report contributes to the argument for better preparation for extreme events and better management of water resources, it would be helpful to estimate the fraction of these costs that can be avoided through early warning, prior preparation, and decisive responses. However, this is very difficult to do. For example, the physical extent of flooding is unlikely to be greatly influenced by human interventions (although levees can protect some critical assets), but better management of roads and bridges and better use of land use planning

38. A study in Germany (Nicolaisen, Dean, and Hoeller 1991) found that inclusion of amenity losses increased the costs of water resource degradation by nearly an order of magnitude. While the loss of amenity is likely to be valued less in a developing country, there are no studies that show what the multiplier would be for a country like Kenya.

Table 5.1. Costs Arising from El Niño-induced Floods (Rounded to two significant figures)

			Estimated Cost ('000,000)	
Attribute	**Effects**	**Associated Costs**	**Ksh**	**$US**
Floods	Damage to infrastructure	Water systems[a]	3,600	45
		Road network, communication, and buildings[b]	62,000	777
	Public health hazard	Treatment costs[c]	4,500	56
	Loss of crops	Crop loss/reduced productiond	33	
Total			**70,000**	**870**

Notes:

a. Quoted from Republic of Kenya, 1998.

b. Quoted from Republic of Kenya, 1998 with 50 percent depreciation assumed.

c. Number of water-borne disease instances (diarrhoea, typhoid and malaria) obtained by subtracting the average incidence in year preceding and year following El Nino event from the incidences in 1997/8 as recorded by Republic of Kenya (2001g). Costs obtained by using average treatment costs for each disease separately. Lost productivity and deaths not included in cost estimates.

d. Losses obtained using "change in production" method. Volumes marketed in 1997/8 were subtracted from the average marketed volumes in three "normal" years (1995,1996,1998) for maize, wheat, coffee, and tea. Costs calculated by multiplying the lost production by the average price for these commodities during the normal years.

to prevent settlement on floodplains can reduce the extent of damage.[39] Consequently, we will only report the costs arising from the floods here.

The experience of Peru during this same El Niño event provides an indication of the benefit of good preparation (Glantz 2001). In that country, the government took the six months of advance warning to construct levees, acquire pumps, plant rice and other water-tolerant crops, and strengthen bridges. Not all these preparations were successful, and the floods still affected the economy. Nevertheless, the impacts were less than would have been the case with no preparation.

The component costs are shown in Table 5.1. The major cost arises from damage to infrastructure, based on the replacement cost for the destroyed and damaged assets—that is, it represents the cost that the country bore (after removing the contribution from international donors) following the floods. The source used for these data (Republic of Kenya 1998) does not provide a detailed breakdown of the types of infrastructure damaged and destroyed during the floods, so it is not clear whether damage to irrigation infrastructure is included or not. However, these assets were often old and had depreciated in value, and

39. The Ministry of Lands and Settlements is empowered to prepare physical regional and local (urban) development plans that can identify areas at risk from floods, important groundwater and surface water source areas, and buffer areas such as wetlands.

it is arguable that the contribution of the floods *per se* to these replacement costs was significantly less than the full replacement cost. Because we were unable to obtain information on the depreciated value of the assets, we have assumed that all were halfway through their expected lifespans.

In fact, only $101 million worth of these assets were replaced in the reconstruction program that occurred immediately after the floods, and much has still not been replaced. The non-replacement will impose a long-term cost on the economy through increased transportation costs, reduced production capacity from damaged buildings and equipment, and reduced communications efficiency.

The health costs reflect the additional costs of hospitalization and treatment arising from waterborne diseases. They do not include the large costs arising from deaths and injury or from the loss of productivity of those affected by the floods. Nor do they include the additional costs for emergency water treatment as a result of destroyed and damaged water treatment plants, since this expenditure is presumed to have prevented some of the incidence of waterborne diseases.

The agricultural losses have been obtained from government records of marketed produce, and so do not include the real costs arising from loss of important non-marketed produce such as maize. This figure reflects the cost associated with the El Niño floods.

Costs of 1999/2000 La Niña Drought

The drought caused by the La Niña event lasted from October 1998 to May 2000, encompassing four consecutive rainy seasons (UNEP/GOK 2000). However, the effects of the drought were felt for a longer period, particularly via the power rationing, which lasted to December 2000. We report the costs here (Table 5.2) for the full two-year event (we do not annualize them).

Similarly, the livestock losses do not include transfer payments within the Kenyan economy or costs that were borne by countries (international donors) outside the economy. Both crop and livestock losses are for the ASALs only, and so underestimate the full agricultural losses across the country.

The costs from reduced fish production occurred where farmers had kept fish in farm ponds. In many districts these ponds dried out, either killing the fish or denying the farmers the use of this source of food.

The large loss from increased cost of power generation arises from the reduced head of water in the reservoirs feeding the hydropower plants. Although the losses arising from reduced sales of electricity are available, they have not been included here because they represent a financial cost. The economic cost is the loss in welfare among households consuming electricity, and lost production by industry. These losses are approximated by industrial production losses. The full losses in industrial production have been included here since they represent either a loss of export revenue, an increase in import cost to replace the production lost, or the foregone consumption of goods.

The cost from lost productivity because of increased walking time to collect water in rural areas is an indication of the hardship experienced by those with subsistence lifestyles in drought-affected areas. This lost time has serious implications for other economic

Table 5.2. Costs Arising from 1998–2000 La Niña Drought (Rounded to two significant figures)

Attribute	Effects	Associated Costs	Estimated Cost ('000,000) Ksh	$
Drought	Loss of crops	(a) Crop loss[a]	19,000	241
	Loss of livestock[b]	(a) Livestock deaths[c]	5,800	73
		(b) Veterinary costs	93	1
		(c) Reduced livestock production[d]	5,100	64
		(d) Conflict management[e]	6	
	Forest fires	(a) Forest destruction and damage[f]	29	
	Damage to fisheries	(a) Reduced aquaculture production[g]	19	
	Reduced hydro-power generation[h]	(a) Increased cost of generation[i]	51,000	632
		(b) Increased import substitutes[j]	806	10
	Reduced industrial production[k]	(a) Loss of production[l]	110,000	1,400
	Water supply			
		(a) Increased water collection time—ASALs[m]	5,100	64
		(b) Increased water collection time—Nairobi[n]	4,400	55
		(c) Time loss due conflict management meetings[o]	3	
		(d) Cost of vendor water in Nairobi[p]	22,000	270.
Total			**220,000**	**2,800**

Notes:

a. Cost calculated using the "change in production" method. Lost production obtained by subtracting volumes of maize, potatoes, beans and sorghum grown in 1999 and 2000 from the average for normal years (1995, 1996 and 1998) using district production figures from Economic Survey 2001 (see Table 3.6). The drought was the dominant reason for these major reductions in crop production. Unit prices were taken to be Ksh 1,450, 3,150, and 1,000 per bag for maize, beans and sorghum and Ksh 15,000 per tonne for potatoes.

b. Costs do not include restocking (Ksh 8.8 million) since these represent transfers within the economy. Destocking costs (Ksh 78.2 million) also excluded because these costs were funded from the international donors and so were not borne within the economy.

c. Actual livestock deaths and associated costs obtained from Aklilu and Wekesa, 2001 for small stock, cattle and camels. These figures derived from surveys in the most drought affected districts, particularly within ASALs, and so are an under-estimate of the national stock deaths.

d. Loss in production obtained from Aklilu and Wekesa (2001) for small stock, cattle and camels. These figures derived from surveys in the most drought affected districts, particularly within ASALs, and so are an under-estimate of the national stock deaths.

e. Actual expenditure on negotiations and compensation mainly to Uganda for cross-border livestock grazing, obtained from Aklilu and Wekesa (2001).

activities where women play a central role. Such induced costs are not captured by this report, but other sources indicate the figure to be about Ksh 24.6 million. The increased costs for urban people arise from the additional queuing time for water, as well as the dramatic increase in the cost of water from vendors serving the slum areas of Nairobi. Presumably slum dwellers in other urban areas faced similar costs, but no data were available. Both the rural and the urban water collection costs were borne primarily by women in low-income households, illustrating the impact of the drought on low-income families.

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f. Based on data from UNEP/Government of Kenya (2000). Supervisors were not paid for the additional time worked. We have assumed that they would have spent that time on productive activities with a value equivalent to their normal wage.

g. Based on loss of 10,000 fish in ponds in Nyeri District. Assumed average fish weight of 0.5 Kg and value of Ksh 150 per kg and 25 districts affected. Other fish losses, reported in UNEP/Government of Kenya (2000, p. 49), have not been included because of uncertainties in numbers and values. Note that there is evidence that capture fish production increases in drought years through overfishing and illegal methods, putting pressure on the breeding stock. This cost is not included here because it is not clear how much of this increase in capture is due to farmers displaced by drought.

h. Job losses from power reduction estimated to cost Kshs 306 million but not included because already incorporated in loss of income to KENGEN.

i. Figure is the actual cost of rental of emergency generation equipment during the drought. Value provided by KENGEN.

j. Obtained using the proxy or substitute method. Cost of purchasing electricity from Uganda calculated by subtracting electricity imports in "normal" years (1996-1998) from import costs in 1999-2000. Data from Republic of Kenya (2001b).

k. Kshs 288 million losses from lost industry jobs, already incorporated in production losses.

l. Calculated using the "change in production" method. The actual value of industrial production in 2000 (Kshs 661,200 million) was subtracted from estimated value (Kshs 772,500 million) based on linear projection of growth in production over the previous four years.

m. Based on UNEP/Government of Kenya (2000) report that walking time for water increased from 6 hours to 21 hours per day per household in ASALs. 50 percent of the 0.5 million households in ASALs were affected. Opportunity cost of this lost time was calculated using a rate of Kshs 30 per hour—the value of rural labor.

n. Cost calculated using the opportunity cost of extra time spent queuing. Based on four extra hours queuing for water vendors per day. Estimated 100,000 slum households (slum population of approximately 1 million and 10 people per household) dependent on water vendors in Nairobi and the value of time lost is Ksh 30 per hour—the rate for manual labor. Data from interviews with slum dwellers.

o. Based on data from Laikipia District where there were a total of 18 meetings held during the 1999/2000 drought and attended by 1,410 persons for an average of 0.5 days. These data were obtained from interviews conducted for this study. The opportunity cost of time was taken as Ksh 30 per hour. It was assumed that such meetings to address conflicts over water resources were held in the 23 most-affected districts in the country.

p. Calculated using the direct change in the market price in response to the drought. The market is very competitive with hundreds of water vendors obtaining water from numerous sources. Consequently, the increase in price arises from the increasing scarcity of water rather than opportunistic profit taking. Value based on 100,000 slum households in Nairobi dependent on vendor water. Assume each household uses the basic amount of 40 liter per day. During the drought the price rose from Ksh 5 to Ksh 10 per 20 liter container.

Long-term Costs

The costs in Tables 5.1 and 5.2 arose from a specific drought and flood. While comparable economic data are not available for other floods and droughts, it is still possible to estimate the long-term costs to the economy.[40] Figure 6.1 shows that a drought of at least a two-year duration has occurred four times in the last 22 years (about once every 5 years) and annual rainfall greater than 120 percent above the average has occurred three times in that period (about once every 7 years). While the 1997/8 flood and 1999/2000 drought were exceptionally severe, it is reasonable to assume that 1-in-5-year droughts and 1-in-7-year floods are typically about 50 percent as severe. That is, on average, the country experiences a flood that costs it about 5.5 percent of GDP (Ksh 37 billion) every seven years, and a drought that costs it about 8 percent of GDP (Ksh 53 billion) every five years. This translates to a direct long-term fiscal liability of about 2.4 percent GDP (Ksh 16 billion) per annum.

The annualized cost of Ksh 5.3 billion from floods largely arises from capital losses (bridges, roads, and so forth). This indicates that the country is facing steady degradation of its infrastructure because of climate extremes. The annualized cost of 1.6 percent GDP (Ksh 10.7 billion) from droughts largely appears as losses of annual production rather than losses to the country's infrastructure. This loss, coupled with the minimum annual loss of 0.5 percent GDP from water resource degradation (below), is about 50 percent of the annual GDP growth in the early 1990s.

Water Resource Degradation Costs

The costs of water resource degradation are more difficult to estimate than those from rainfall variability because they are incurred over a long period, often at sites distant from the source of the degradation. Consequently, the influence of water resource degradation is usually confounded with many other influences. While the difficulty of separating out the specific influence of the water resource issue from other influences is true in all countries, it is particularly true in Kenya because of the poor quality of monitoring data and the lack of scientific understanding of the processes that link sources of degradation and the sites of impact. Consequently, only a small number of the effects of water resource degradation, described in Chapter 4, could be costed here. Many of these costs can only be calculated for specific sites, even when the problem is known to be widespread.

Unlike the costs from rainfall variability, the costs in Table 5.3 are ongoing (with the exception of those arising from water hyacinth) and so can be regarded as annual costs. However, the costs of pumping groundwater for Nairobi are an exception; in this case the costs are expected to increase annually as the groundwater table continues to drop. Where the costs are incurred regularly, we have used a simple annual cost; where they arise from the shortened life of an asset, we annualize the costs using a 10 percent discount rate.

Many large dams for irrigation, water supply and electricity are known to have received more than their design loads of sediments because of poor land management practices in their catchments. However, the actual loss of storage volume is not known, either because

40. The authors are grateful to Tony Garvie of the World Bank for suggesting this method of extrapolation.

Table 5.3. Costs from Water Resource Degradation (Rounded to two significant figures)

Attribute	Effects	Associated Costs	Estimated Annual Cost (millions) Ksh	$US
Water reservoirs	Siltation	Increased maintenance cost for minor dams/pans[a]	6	
		Reduced life of pumps (Mombasa) leading to abandonment of water supply[b]	3	
		Extension cost of Malindi jetty[c]	8	
Water quantity	Increased flooding downstream	Health effects in Kano Plains[d]	4	
	Crop production	Reduction in crop production in Budalangi area[e]	170	
	Lowered water table	Increased pumping costs for Nairobi[f]	870	11
Water quality	Water treatment	(a) Cost of urban water treatment[g] (b) Desalination[h] (c) Water hyacinth in Lake Victoria[i]	850 600 50	11 7
	Transportation	Water hyacinth impediments[j]	2	
	Fisheries	Water hyacinth impediments[k]	79	1
		Reduced fish production from eutrophication[l]	680	9
Relocation of water intakes	Replacement cost of shifting water intake points	(a) Upper catchment[m] (b) Lower catchment[n]	1 11	
Total (excluding water hyacinth costs)			**3300**	**41**

Notes:

a. There are 3,200 water pans in Kenya (Republic of Kenya 1992) of which 80 percent are at least half silted up (UNEP/GOK 2000). Based on the LUMO Community Wildlife Sanctuary experience of desilting 5 pans for a cost of Ksh 1.3 million, the cost of desilting 2560 pans is Ksh 679 million. This cost has been annualized over 50 years at a discount rate of 10 percent.

b. Based on replacement cost of six pumpsets. The present cost of replacement is estimated at Ksh 20 million based on data supplied by Gulf Engineers, Nairobi. The annual cost is calculated on the basis of an economic lifespan of the pumps of 10 years and a discount rate of 10 percent.

c. The abandoned Malindi jetty needs to be extended by 50 m into the sea to make it operational. The cost is based on an estimate of Ksh 1.5 million per meter (data supplied by Edon Consultants, Nairobi—consultants for the task). The cost is annualized over 50 years at a discount rate of 10 percent.

d. The annual flooding of this area is estimated to be 50 percent caused by catchment clearance (communication with Prof David Mungai, University of Nairobi). The "background" incidence of water-borne disease in the health dispensary records for Kisumu district was subtracted from the reported and treated cases after the floods. Data were obtained from Nyanza Provincial Hospital. Costs were estimated using the average treatment cost for the diseases; other costs from loss of earnings or from those not admitted to hospital were not included.

e. The Budalangi irrigation area lies at the end of the Yala River whose headwaters have now been totally cleared. The area has severe land degradation as a result. Conservatively, about 50 percent of the annual flooding can be attributed to the higher peaks from the cleared catchment areas. The cultivated area is estimated at 333,000 ha and 10 percent of this area is flooded annually (District Reports).

Annual maize yield is 1.8 tons per ha at a value of Ksh 5,555 per ton. Thus, the crop loss attributable to land degradation is Ksh 165 million.

f. 65,000 m^3 of groundwater are pumped each day in Nairobi (Republic of Kenya 1998a). This water has to be raised an additional 0.5 m on average each year because of the declining water table. Electricity costs Ksh 7.3 per Kwh, adding up to Ksh 866 million per year in additional pumping costs because of the declining water table.

g. Water treatment costs Ksh 4 per m^3 (data provided by Gulf Engineers, Nairobi), largely to remove sediment and pollutants originating from catchment degradation and waste discharges. The year 2000 urban water demand is estimated at 426 million m^3 per year (Republic of Kenya 1992). Although the data from the Water Master Plan is inaccurate, there are no data on current actual urban water consumption. Can conservatively assume that 50 percent of this cost would be avoided if proper catchment management was implemented along with control of pollution.

h. In 1999, 1.7 million bed-nights were spent in coastal hotels (Republic of Kenya 2000a). Assumes 600 liters of water required per person per day (Republic of Kenya 1992, T-78, Vol I) giving total coastal hotel water requirement of 102,000 m^3 per day. Approximately 10 percent of this water needs to be desalinated at an estimated cost of Ksh 160 per m^3 (information obtained from interviews at coastal hotels, 2002), giving a cost of Ksh 595 million per year.

i. Approximately 72,400 households use reticulated water in Kisumu. Each household uses about 400 liters a day, giving a total urban water consumption of 10,600 million liters per year. Water costs Ksh 0.014 per liter of which about 25 percent arises from treatment costs. Unit treatment costs are reported (Atera 2001) to have risen by 42 percent during the water hyacinth outbreak, although consumption fell by 36 percent because of the clogging of intakes and so forth. Thus, aggregate treatment costs are estimated to have fallen by Ksh 3.4 million during the hyacinth outbreak, because of the significantly lower volume of water consumed. However, the amenity of water consumers fell by at least Ksh 53.6 million based on the households previously expressed willingness to pay for this volume of "lost" water.

j. The waiting time for the large ships providing transport across Lake Victoria was estimated to be about 2 hrs longer at Kisumu in 1997–8 than in the weed free times (Data obtained from interview with Kisumu Harbor staff, 2002). Fuel consumption is 150 liters of diesel per hour and an average of three ships dock at Kisumu per week. At a cost of Ksh 50 per liter this amounts to Ksh 2.3 million per year. This does not include other costs such as idle time for staff. This cost was only borne during the time that water hyacinth invaded Kisumu harbor and is not an ongoing cost.

k. It is estimated that about 235 small fishing boats were grounded at the peak of the weed invasion in 1997 (data obtained from interviews with Kisumu Harbor staff and staff of OSIENALA, a local NGO). The income generation from each boat per week is approximately Ksh 6,500 and so about Ksh 79.4 million of income was lost per year whilst the water hyacinth was obstructing movement. This cost is not borne every year.

l. Cost arising from eutrophication of Lake Victoria. Approximately 20 percent of lake volume unavailable to Nile perch reducing the potential catch by 20 percent (communication with Dr. Kazungu, KMFRI). Assuming that, in the long run, overfishing is controlled and Nile perch catch is limited by food availability, this reduction represents a loss of 25 percent of current export earnings, worth Kshs 678 million (US $8.5 million) per annum.

m. The upper catchment refers to the portion of the catchment located within the forested part of Mt Kenya. It is estimated that over the last five years, eight intakes were shifted further upstream along the Ontulili River because of siltation (present intakes are located in the Mt. Kenya forest—right at the source of the river) and another three along the Sirimon River. The cost of relocating such small-scale intakes is estimated at Ksh 200,000 per scheme (Data from interviews with staff of Laikipia Research Station). Average economic lifespan of the schemes is 50 years. The cost estimated here is annualized over 50 years at a discount rate of 10 percent. The key assumption is that water catchment degradation is the source of the problem. Other minor sources include variability in rainfall patterns and quantity.

n. The lower catchment refers to the settled portion of Mt Kenya, below the forested area. Within the lower catchment sunk investment include the EEC irrigation project at Garfasa where after completion of the Ksh 90 million project in 1996 it did not become operational as the river had changed its morphology which is associated with catchment degradation. A further investment of Ksh 9 million by the French Government did not solve the problem. A total of about seven main water intake points have been shifted within the lower catchment over the last five years at estimated cost of Ksh 2 million each.

of inadequate original surveys (as at Masinga Dam) or because of lack of funds for current bathymetric surveys, and so these costs are not included here. However, the costs of siltation of small dams and pans, together with the observed large loads of sediment entering the large dams, makes it clear that siltation is a much more expensive problem than is shown by the costs estimated here.

Sedimentation is heavy in most of the minor dams and pans throughout the country; many now cannot be used. There have been few new small dams constructed in recent years to provide an estimate of replacement costs. We have estimated the annualized costs of rehabilitating these minor dams based on a trial desilting that was carried out in Taita-Taveta District (LUMO Community Wildlife Sanctuary Project).

The Mombasa water supply had to be abandoned because of continual damage to the pumps from high-suspended sediment loads and silting of the weir supplying the water. The cost of the replacement pumps is fully attributed to water resource degradation and is depreciated over 10 years.

Catchment clearance is a major factor in flooding of the plains around the Nyanza Gulf. On the Kano Plains the annual health costs from waterborne diseases are conservatively estimated to be about Ksh 3.4 million per annum. These costs are based on treatment and admission costs and do not include those arising from deaths or loss of agricultural production in this area. However, loss of production for the cropping area at Budalangi is estimated at Ksh 165 million annually. This loss arises from flooding that is exacerbated by the clearance of the catchment (Nandi Hills and Mt. Elgon Forests), leading to both greater peak flows and greater volumes of floodwaters.

The costs from the drawdown of the water table below Nairobi are represented by the additional electricity costs borne each year to raise the water an additional 0.5 meter. This result is conservative in that it does not include other elements of O&M, does not account for the cumulative nature of these pumping costs (that is, each year the water has to be raised an additional 0.5 meter), and assumes 100 percent electrical efficiency. Other towns using groundwater—such as Nakuru, Mombasa, and Malindi—also face costs from over-pumping, but these are not included here.

The additional increase in urban water supply treatment costs because of the need to flocculate sediments arising from catchment degradation and disinfect the water because of industrial and agricultural pollution is estimated to be Ksh 853 million nationally. This figure is based on the conservative assumption that only half the treatment costs arise from these sources. In coastal areas, there is an additional treatment cost because of the intrusion of seawater into aquifers and a consequent increase in salinity. These coastal aquifers are primarily used by tourist hotels, so the costs are calculated on tourist numbers.

The water hyacinth problem in Lake Victoria lasted for a number of years in the late 1990s. We have costed three of the impacts—impediments to lake transport, local fisheries, and water treatment for Kisumu. Although the delays to lake transport gave rise to a number of costs, we have only included the additional diesel fuel costs here. Consequently, the Ksh 2 million is a significant underestimate, given the delays to schedules, loss of productive labor time, and other factors. The disruption to local fishing, although a relatively small cost compared to other water degradation costs, fell directly on poor families and had a disproportionate effect on their livelihoods. The water treatment costs for Kisumu water supplies include both the increases in treatment costs to remove organic matter and the reduction in service because of the clogging of water intakes and pumping equipment. These costs have not been included in the totals in Table 5.3 because they only arose during the height of the water hyacinth outbreak and have not been regular costs imposed on water users.

The eutrophication of Lake Victoria causes deoxygenation of the bottom half of the lake, reducing the volume available to Nile perch and their prey. At present, the Nile perch is overfished and production is probably not limited by food availability. However, the overfishing is being corrected by enforcement of regulations and involvement of the fishing community in management, and the long-term production of Nile perch is likely to be limited by the availability of prey species. Nile perch cannot tolerate oxygen concentrations below about 6 mg/l, thus excluding them from the bottom part of the lake for most of the year, even though their principle prey species can tolerate oxygen levels down to 3 mg/l. Assuming that, in the long run, Nile perch production is limited by food availability, it is the loss of lake habitat to the prey species that will determine the economic loss. On average, about 20 percent of the lake volume experiences oxygen levels below this level, although oxygen levels vary considerably within the lake and seasonally. Thus, we can assume that the Nile perch fishery could be 25 percent larger if the lake were fully oxygenated, as occurred prior to the 1960s. Conservatively, this translates as a loss of Ksh 680 million per annum from lost production of Nile perch and a lesser amount from other commercially valuable species. This is a particularly important loss for Kenya because the Nile perch is one of the country's main export products and the industry is a large employer. Note that although Kenya contributes to the eutrophication of the lake, through both riverine and atmospheric nutrient inputs, this is a regional problem involving at least countries that are riparian to the lake and possibly more distant.

CHAPTER 6

Conclusions and Recommendations

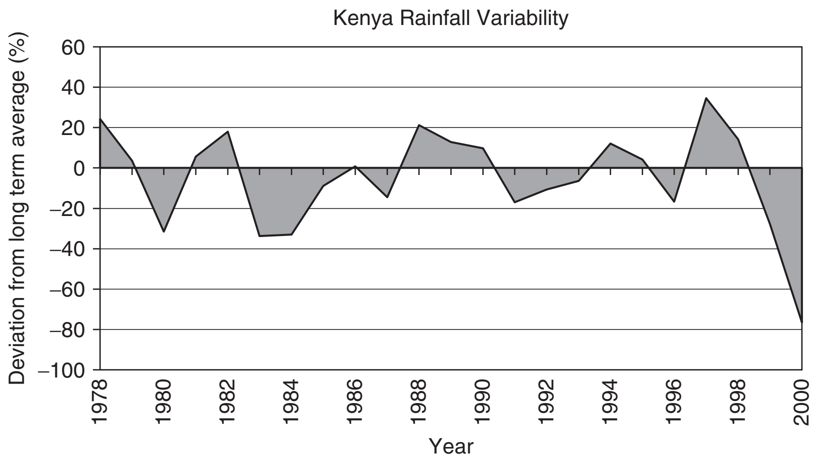
The 1997/98 El Niño floods and 1999–2000 La Niña drought cost on average at least 14 percent of Kenya's GDP for each of the three years in which they occurred. Water resource degradation costs the economy annually at least Ksh 3.3 billion, or about 0.5 percent of GDP. The current water sector reforms have the potential to reduce water resource degradation costs substantially by initiating better management of the resource and leading to investment in badly needed infrastructure. Increased water storage infrastructure, together with more notice of early warning of El Niño/La Niña, will reduce the costs arising from these episodic events.

Conclusions

The costs from episodic rainfall events of the magnitude of the recent El Niño and La Niña events are conservatively estimated to be Kshs 290 billion spread over the three years of flood and drought. Although events of this size are estimated to occur only every 40 years (the last major floods in 1961 caused even more damage), Kenya experiences many smaller, but still very destructive, floods and droughts (Figure 6.1). Consequently, there is an irregular, but very large, drain on the national economy from these episodic events. We estimate that the costs from floods and droughts, over the long term, to be equivalent to about 2.4 percent GDP.

The costs of water resource degradation are much harder to estimate. However, the results in Chapter 5 show that these costs amount to at least Ksh 3.3 billion annually. Many known impacts of water resource degradation, described in Chapter 4, have not been included in these costs because of a lack of data. Consequently, this estimate is very conservative and the true impact is likely to be much higher. The diversity of impacts costed here, from loss of fisheries production to health costs to water supply treatment,

Figure 6.1. Percentage Change from Long-term Mean Rainfall Illustrating a Sequence of Floods and Droughts



illustrate the pervasive influence of water resources degradation across most sectors of the economy.

Aggregated, the costs arising from water resources degradation represent at least about 0.5 percent of the Nation's GDP[41] and probably much more than that (see Box 6.1 for the costs of environmental degradation in other countries). This is a severe burden for the nation to carry. The costs of rainfall variability are more difficult to compare to the size of the economy, since floods and droughts occur episodically and with varying intensities. Nevertheless, the costs of the 1997/98 floods and the 1999/2000 drought amounted to an average of at least 14 percent of the country's GDP for each of the three consecutive years over which they occurred.

Although we have not carried out a quantitative analysis of the benefits and costs from investment in better management of natural resources, it is clear from the discussion that the lack of investment in water resources in preceding years has been a contributory factor in these high costs. For example, the drought would not have impacted so many people as severely if there had been better access to water supply through more surface water storages and more groundwater development in the ASALs. Similarly, the reduction in the useful life of major and minor water storages could have been partly avoided if there had been pre-emptive management of erosion in catchments and/or regular desilting of dams, or sustainable management of reservoirs.

The water sector reforms being undertaken by the government have the potential to change this situation. The formation of a separate Water Supply Services Regulatory Board and a Water Resources Management Authority (WRMA), together with strengthening of stakeholder involvement and simpler administrative procedures, will go a long way to improving matters. However, these reforms must also be backed up by a government-wide

41. Based on a Year 2000 GDP of Ksh 672 billion.

Box 6.1: International Costs of Water Resource Degradation and Climate Variability

A 1996 study estimated the cost of environmental pollution and degradation in China was equivalent to 5.5 to 9.5 percent of China's GDP in 1990. These estimates ignore many important effects, and the author suggests that 10 to 15 percent of GDP is a more realistic estimate. Out of these costs, the water-related issues include loss of fisheries production, waterborne diseases, industrial and agricultural production losses, the need to treat groundwater, siltation of canals and reservoirs, crop losses during flooding, and agricultural and industrial losses due to water shortages. These water-related costs amount to between 1.2 percent and 1.9 percent of China's GDP.

Earlier OECD reports put the macroeconomic cost of water pollution in Germany (1983–5) and the Netherlands (1986) at 0.55 percent and 0.4–0.66 percent of GDP respectively. In the case of Germany, the large majority of this cost arises from damage to groundwater systems; with the exception of damage to freshwater fisheries, other pollution costs are not calculated. Neither estimate includes water resource degradation costs.

Using a different approach, a study in the United States found that $26.5 billion in damage was avoided in 1978 through the application of environmental policies. Of this total, $4.8 billion accrued to water users. Thus, the cost of water pollution was at least 0.22 percent of the country's GNP. Again, other components of water resource degradation were not included.

The World Bank's Water Resources Sector Strategy quotes examples of the impact of climate variability on economic performance. The drought in Zimbabwe in the early 1990s was associated with an 11 percent decline in GDP; the 1999 floods in Mozambique led to a 23 percent reduction in GDP; and a drought in Brazil in 2000 halved projected economic growth.

Source: Smil, 1996 (China); Schulz, 1986 (Germany); Opschoor, 1986 (Netherlands); Freeman, 1982 (US).

commitment to water resources management and the necessary budgetary allocations that allow these new institutional structures to operate effectively. Once these changes are implemented, the high costs shown here can be reduced through active management of the nation's water resources.

Recommendations

The underlying lesson to emerge from the previous analysis is that the magnitude of the cost to the national economy from episodic floods and droughts is extremely large. The impact of climate variability extends to key sectors of the economy—including agriculture, energy, livestock, manufacturing, and transport. The impact of water resources degradation on the economy also is significant and affects many sectors. The government and people of Kenya probably do not appreciate the extent of the water resources challenges faced by the country or recognize the social, economic, and political risks associated with poor water resource management, and so do not treat and manage water as a strategic resource with important social and economic values. The specific recommendations below focus on the themes of building political commitment, increasing water storage capacity; improving water management through decentralization, greater transparency and increased community participation, and increasing the knowledge base for management.

As a matter of priority, the MWI needs to seek political support—in the form of a Cabinet Memorandum—for elevating WRM reforms to an important national and multisectoral priority with an appropriate budget allocation in the Economic Recovery Strategy for Wealth and Employment Creation. Cabinet support would provide the basis for the subsectoral policy and institutional realignment that will be essential to address the economy-wide implications that relate to the various water-using sectors and other water-related sectors.

Development of Adequate Water Storage

The amount of water in storage is seriously inadequate for the population of a country that is growing rapidly and exposed to considerable rainfall variability. The recommendations of the 1992 Water Master Plan and the 1998 Aftercare Report on the development of new and additional storage facilities should be acted upon urgently in order to mitigate the effects of periods of both droughts and floods. However, the recommendations should first be reassessed to make sure that the estimates of additional water storage are well-founded. The process should avoid "white elephants" or undertakings such as the Turkwell Dam and Biron irrigation scheme, which have yielded very limited benefits and major negative environmental impacts, particularly for downstream dwellers. The Water Master Plan was developed based on water use rates for irrigation and urban water supply (the largest water using sectors) that were current in 1992. Conjunctive use of surface water and groundwater banking, water reuse, and water demand management are all mechanisms for improving the efficiency of water use, and should be considered along with investment in new sources of water. The lessons of Masinga Dam and elsewhere are that good catchment management must accompany any developments if these assets are to be fully utilized.

Groundwater is an especially important resource for large portions of Kenya. Key areas of improvement here include understanding of the geology and hydrology of specific areas with high potential prior to drilling; regular monitoring and evaluation of water levels, water discharge, and water quality; establishment and enforcement of standards; and development of groundwater programs that are based on known recharge rates.

Raising Awareness of Water Resources Management Challenges

The MWI's efforts to develop and launch a National Water Campaign must be supported to highlight the problems facing the country, to elevate water resources management as a key national priority, and to raise awareness about individual and collective responsibilities as stewards of the nation's water resources.

As noted above, an immediate goal of the National Water Campaign is to broaden and strengthen political support at the highest level in order to make the WRMA operationally effective. This new Authority will be built around the policy and legal frameworks that are in place or are in the process of being legislated. Firm political will, support, and commitment, as well as bold and innovative actions, will be required to adequately address the water crisis. A demonstration of high-level support will, on the one hand, mobilize Kenya's high-caliber professional expertise and, on the other hand, harness the desire and ability of communities and organizations to help themselves.

A longer-term goal of the National Water Campaign will be to initiate actions to share experiences and knowledge and inform water users about practical solutions, and promote water-wise behaviors. The campaign should be targeted to water users such as farmers, industrial companies, and urban residents, and should seek to include the private sector and NGOs in supporting the reforms. The younger members of society could be sensitized to the importance of preserving the nation's scarce water resources by building on existing programs such as the UNICEF water and sanitation "WASH" program in schools.

As part of raising awareness, the Integrated Water Resources Management Strategy being developed by the MWI should be disseminated widely for comment to help build support for the Ministry's leadership in water resources management.

Institutional Reforms

Operating under the new Water Act, the WRMA will bring about three major shifts in water management in Kenya.

Decentralization: At the catchment level, the WRMA will oversee the decentralization of water resources management functions such as assessment, allocation, and enforcement at the catchment level. Decentralization will provide opportunities for sharing power and responsibilities of governance over water development and allocation, and provide water users with a more effective input to decisions. This process will dramatically affect the traditional top-down approach to management and will fundamentally change the planning process. Decentralization, however, must be matched by capacity building efforts to ensure that the local levels can cope with increasing responsibilities and unequal power structures.

Decentralization will also speed up decisionmaking for permits, reducing the incentive for illegal abstractions. Provided that water user charges can be (at least partially) quarantined for local use, it will also provide a source of revenue for local enforcement activities such as policing of waste discharges and enforcing licenses for abstractions.

Participation: The second major shift will be from centralized, technical water resources planning and management to the inclusion of all stakeholders in planning and management decisionmaking, implementation, and operations of water management through Catchment Area Advisory Committees and Water User Associations. Achieving sustainable water use in the basin or catchment will require commitment to and ownership by all stakeholders of both the goals of sustainable water resources and the means to achieve them. Informed and substantive participation of stakeholders in decisionmaking is closely linked to revenue raising and maintenance of infrastructure. That is, the user fees needed to maintain and operate water resources infrastructure are only likely to be raised if water users feel that they have a say in the use of those funds and see a return from them in the form of operational water systems.

Sustainability: A third shift will be to recognize that investments in water resources management and use are too important and too costly to be managed for the short term. Many of the resources invested in the water sector are used inefficiently; provisions for operations and maintenance are not sufficient to maintain the condition of vital assets; and catchment degradation is impacting the economic life of storage structures, resulting in under-use and deteriorating performance. Under the new Water Act, it will be possible to better coordinate policies across sectors that affect water and land management. NEMA, the new National Environmental Management Authority, will further strengthen this coordination. The implications of unsustainable land and water use practices (such as excessive water abstractions, single purpose use, destructive land management practices, polluted water discharges, and so on) are significant, and in some instances even threaten the water resource base. Such practices not only cause irreversible degradation of the resource base and alter the hydrology (and therefore the available water supply), they also undermine sunk investments in water supply, irrigation, and hydropower infrastructure.

Financing Water Resources Management

If water resources management reforms are to be successful, it will be essential that water is treated as a social and an economic good and financial practices are realigned accordingly. Sound and fair financial management, with a goal of cost-recovery and financial sustainability, is needed to improve the efficiency of services, provide additional resources for reinvestment, encourage demand management, promote catchment management, and pollution prevention and control. The new Water Act includes provisions for water user charges, catchment levies, and licenses to pollute. These charges, levies, and fees should be established following a systematic study. The Water Act also provides for establishing a fair mechanism for financing water resources management while protecting the needs of the poorest citizens.

Catchment Management

Catchment degradation is one of the most serious water resources threats facing Kenya. It is a lose-lose situation for all concerned. Not only does soil erosion and excessive use of agro-chemicals represent a loss for the landowner, but it also causes large costs to downstream water users. There is good evidence from Kenya, as well as the rest of the world, that most landowners want to manage their properties sustainably if they can generate an adequate income and have access to the technologies and knowledge required. Catchment management groups consisting of upstream and downstream stakeholders, assisted by government agency staff, are envisaged in the new legislation and form a fundamental plank to managing many of the causes of degradation reported here. A number of pilot projects, such as the IFAD-funded Mt Kenya East project, can be used to develop and demonstrate good catchment management practices.

The new Water Act allows the Minister for Water Resources to gazette priority catchments and recharge areas in order to protect important water sources. Given the powers held by other Ministers under their legislation, the gazettement of these priority areas should be coordinated with both the Ministry of Lands and Settlement and the Ministry of Environment and Natural Resources.

Good catchment management is so central to many of the issues reported here—including siltation of dams, nutrient pollution of Lake Victoria through both river-borne and atmospheric pathways, and potential loss of high-quality water supply from cleared forests—that it represents one of the highest priority actions for the government. However, other reforms, such as in land tenure, may also be needed to ensure that responsibility is clear for land management decisions.

Enforcement of Regulations

In many cases the appropriate legislation and regulations are in place, but water resources degradation occurs because of a lack of enforcement. This is partly because of a lack of funding (for example, it is difficult for regional staff to travel to check for compliance with regulations), partly because of a lack of information and data, and partly because of a perceived lack of institutional and political will to enforce the existing regulations. Stakeholders have little incentive to comply with the regulations when the procedures for granting permits and licenses are slow, cumbersome and even tainted. More effective control of abstractions and pollution will safeguard water quality and sustainability.

Perhaps the most serious example is the large number of illegal water abstractions on the arid/semi-arid zone rivers, which have led to severe conflicts between upstream and downstream water users. Lack of enforcement has now created a situation in some places where the normal expectation of stakeholders is that the regulations are to be ignored, or that it is cheaper to pay the penalties than to comply with the regulations. The perception that groundwater permits can be obtained illegally at a price considerably below the actual cost of the permit by "well-connected" individuals contributes to the low expectations of ordinary stakeholders.

Enforcement will be most effective where there is transparency in administration, granting, and enforcement of procedures, and where there is good community participation in decisionmaking and acceptance of the equity and need for the regulations. Thus, proper enforcement requires not just adequate funding, but also strong support from high levels of the government and from a wide variety of interest groups at the catchment level. The water reforms being implemented by the government at present will establish these necessary underpinnings of enforcement.

Development of an Early Warning System

It is widely accepted that Kenya was unprepared for the impacts of both the recent El Niño and La Niña events (UNEP/GOK 2000; Glantz 2001). However, there is good institutional capacity in the country to anticipate and respond to these extreme events. The Meteorological Department and the regional Drought Monitoring Centre provide seasonal weather forecasts, and the Arid Lands Resource Management Project uses these forecasts in an early warning system. However, farmers are skeptical of these forecasts because they are often non-specific and hard to understand (UNEP/GOK 2000). More can be done to make these forecasts accessible and believable at the local level. When warnings are received, typically six months in advance, the government can make preparations for the floods and droughts to minimize their impacts. Unfortunately, Kenya responded to the 1997/98 El Niño only after the event had happened (Van Aalst and others 2000). Lessons can be learned from the preparations of other countries during the 1997/98 El Niño event (Glantz 2001).

Studies in the developed world show that benefits from ENSO forecasts can range up to $2.60 per ha (Hill and others 1998). Even though there is good evidence that these benefits cannot be realized without infrastructure and knowledge that is seldom available in the developing world, there is also evidence that large numbers of lives and wholesale destruction of property can be prevented in the developing world with good warning (Van Aalst and others 2000). In addition, the actions of government agencies can be better coordinated during both floods and droughts so that the impacts, particularly from droughts, can be anticipated and dealt with across the different sectors of government. Flood management strategies and plans can help reduce the dangers to people living in floodplains and identify risks associated with infrastructure in floodplains. Flood risks can also be reduced with a functioning flood forecasting and warning system and watershed management programs. Proper management of water resources—from provision of more water storage to better planning and enforcement of water allocations, demand management, and rationing—would limit the impact of droughts.

Re-establishment of a Monitoring System

The importance of reinvesting in water resources assessment, particularly monitoring the extent and quality of the nation's water resources, has been apparent throughout this report. Without an adequate knowledge of climate, water use, and sources of pollution, it is impossible to make wise decisions on water allocation, enforce pollution controls, plan and design water resources infrastructure, and target investments in better catchment management. Monitoring also provides the means to detect water quality and flow problems at an early stage, thereby allowing management interventions to occur before the problems grow to the size of some of those documented here.

Water resource assessment involves not just the physical infrastructure for rainfall and riverflow gauging and sampling and groundwater level monitoring, the laboratory analysis of the samples taken, and the recording of the results in a widely accessible computer database. It also should involve investment into studies that link and establish rainfall-runoff relationships and the physical, chemical, and ecological processes linking the cause of degradation or pollution and the effects. At present, we have to base these cause-effect linkages on general scientific principles and evidence from elsewhere, rather than on knowledge that is validated for Kenya. For example, investment in improved catchment management could be precisely targeted at optimal expenditure if there was knowledge about the width of riparian buffer strips that were effective in trapping sediment under Kenyan environmental conditions.

The monitoring data could be input to the district level water resource planning systems being developed by the Arid Lands Resource Management Project. This project has established GIS-based planning system in three districts to date—Wajir, Marsabit, and Mandera.

A well-designed hydrological and water quality monitoring network and systematic water resources assessment has been instituted through earlier, externally funded efforts. However, few of the monitoring stations were maintained once project funds had been expended. Many have now fallen into disrepair and require replacement, while others need to be rehabilitated. A comprehensive hydro-meteorological system is essential for making and enforcing water allocation decisions at the catchment level and could be funded, at least partially, through water user charges.

Building Capacity for Effective Water Resources Management

Knowledge and information alone is not enough to bring about changes. Enabling and empowering individuals to use that knowledge will require training and capacity building. Institutions involved in water resources management will have to emphasize interdisciplinary approaches to water resources management, and generate and disseminate knowledge on good practices. Training in water law, conflict resolution and mediation, water resources economics, environmental planning and management, and financial administration may be required for the staff of the new WRMA. Similarly, the community and water users grouped envisaged under the Water Act will need to be trained to make sure that they possess the skills and knowledge to be confident and effective in their roles.

Pilot Catchment or Basin Management Projects

The implementation of the Country Strategy on IWRM should be supported through the development of specific pilot projects to support the strengthening of the catchment boards to address specific water resources management challenges such as flood management in the LV Basin, water apportionment, catchment degradation in the Mt. Kenya region, or groundwater management in the ASAL areas. The pilot projects should be selected to address priority issues. They may be identified either on the basis of ongoing projects or new priority areas. The pilots can be used to draw lessons that will be learned and replicated in other catchments.

APPENDIX A

List of People Consulted

Name	Designation	Contact Address
Dr. Kazungu	Managing Director	Kenyan Marine and Fisheries Research Organisation
Dr. Andrew Othina	Researcher	Kenya Marine and Fisheries Research Institute
Dr. Bernard Kigomo	Deputy Director, Research and Development	Kenya Forestry Research Institute (KEFRI)
Dr. Fanuel Schechambo	Regional Co-ordinator, Biodiversity Economics Programme	The World Conservation Union (IUCN)
Dr. Francis K. Lelo	Senior Lecturer/Chairman PRA Department	Egerton University Department of Natural Resources
Dr. John Waithaka	Programme Manager	Biodiversity Conservation Programme
Dr. Nathans Gichuki	Project Manager	Rift Valley Lakes GEF Project National Museums of Kenya
Dr. Paul Ongugo	Programme Co-ordinator Natural Forests Programme	Kenya Forestry Research Institute (KEFRI)
Dr. S. N. Amayi	Deputy Managing Director	Lake Basin Development Authority (LBDA)
Dr. Wilson Wasike	Researcher	Kenya Institute of Public Policy Research and Analysis (KIPPRA)
Eng. Abdulrazaq A. Ali	Managing Director	Ewaso Nyiro North River Basin Development Authority (ENNDA)
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Mr. Andrew Asila	Researcher	Kenya Marine and Fisheries Research Institute
Mr. C. Lambrechts	Programme and Policy Officer	Division of Early Warning and Assessment UNEP
Mr. Anderson Koyo	Wetlands Officer	Kenya Wildlife Service (KWS)
Mr. Boniface Kiteme	Programme Advisor	Laikipia Research Program
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Mr. D.K. Mbugua	Deputy Chief Conservator	Forest Department
Mr. D.M. Maina	Economist	External Resources Department Ministry of Finance and Planning
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(*Continued*)

Name	Designation	Contact Address
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Mr. Henry Muhindi	Deputy Warden	Laikipia District
Mr. Isaac Mburu	Billing Clerk	Naivasha Municipal Council
Mr. John Gichuki	Researcher	Kenya Marine and Fisheries Research Institute
Mr. John Wainaina	District Water Officer	Laikipia District
Mr. Joseph Ndungu	Programme Manager	Natural Resources Management, Monitoring and Modelling, Laikipia
Mr. Joseph O. Ayieko	Senior Lecturer – Resource Ecologist	Egerton University Department of Natural Resources
Mr. Kimutai A. Terer	Senior Assistant Hydrologist	Kerio Valley Development Authority (KVDA)
Mr. M.O. Ogola	Economist	Drought and Relief Monitoring Unit, Office of the President
Mr. M'twarimi	Agronomist	Tana and Athi Rivers Development Authority
Mr. Mathews K. Murgor	Environmental Planner	KenGen
Mr. Musuva	Economist	Ministry of Environment and Natural Resources
Mr. Mutune Masai	Researcher	Kenya Marine and Fisheries Research Institute
Mr. Njiru Muruithi	Researcher	Kenya Marine and Fisheries Research Institute
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APPENDIX B

Hydrologic Effects of Forest Clearance

There is an extensive literature on the effects of deforestation and, to a lesser extent, reafforestation on runoff and river flows (Bruijnzeel 1992). Deforestation has a number of hydrological effects, including decreased canopy interception of rainfall, (usually) decreased transpiration from the replacement vegetation, (usually) increased evaporation from the exposed soil surface, decreased soil infiltration because of changes in soil structure, and increased velocity of runoff after removal of surface litter and roughness. In addition, in cloud forests the trees intercept mist and this source of moisture is lost after logging. The "mist harvesting" effect amounts to between 5 and 20 percent of total precipitation (Bruijnzeel and Proctor 1995). There is also evidence that convective currents that increase local precipitation are eliminated when extensive areas of forest cover are removed. However, this does not seem to occur for removal of smaller areas, and the size of this effect is difficult to establish.

Some of the effects of removing forest cover increase runoff and some decrease runoff. There is very strong evidence from well-conducted, paired-catchment studies[42] that the net effect is for mean annual runoff to increase after deforestation, although the size of the increase depends on factors such as the annual rainfall, soil characteristics, and type of replacement vegetation (Zhang, Dawes, and Walker 2001). Streamflows following moderate-to-large storms also increase in size and flashiness because of the quicker runoff when the forest is replaced with crops and grasses. However, removal of tree cover has very little effect on runoff from very large storms. Large enough storms simply overwhelm whatever cover (trees, crops, grasses) is present, either because the ground rapidly becomes saturated or the precipitation is so intense that it cannot infiltrate into the ground quickly enough and runs off.

42. A paired catchment study is where two catchments with similar hydrological properties and experiencing the same climatic conditions are compared; one is left with its original forest cover and the other is cleared.

The effect of deforestation on flows during non-rain periods, base flows, is less clear cut. It depends on factors such as the vegetation cover that replaces the trees, the quality of the land management, and the aquifer structure. In most cases, the loss of evapo-transpiration from the removal of trees outweighs any evapo-transpiration from the replacement vegetation. This is particularly true when annual crops (such as maize) and grasses replace the forest. Thus, more water accumulates in the soil and base flows increase after deforestation. There are exceptions to this generalization, such as when the "mist harvesting" effect is lost in cloud-forests, when the infiltration is severely reduced and evaporation from a bare soil surface increases, and when deep-rooted perennial plants (for example, mature tea plantations) replace the trees. In these cases, there is experimental evidence that base flows can remain similar to those that occurred under forests. However, cases where base flows increase after forest removal are considerably more common than cases where base flows remain the same or even decrease after deforestation. Note that these results from controlled experiments measure the effect of replacing forest cover with other vegetation, but do not include any other disturbances to the catchment.

The only three controlled studies to be carried out in east Africa all conform to these international findings. There was an overall reduction in vegetation water use following clearing of forest for a tea plantation at Kericho, Kenya, with increases in stream flow (Blackie 1979a). Once the tea bushes were established, the water yield returned to values similar to the yield under forest mainly because the tea bushes had similar evapo-transpiration (ET) values to trees and the ground still had good infiltration capacity. Replacement of a bamboo forest at Kimakia, Kenya, with pine trees and vegetables led to a large increase in stream-flow because of the loss of ET and higher groundwater levels (Blackie 1979b). Once the pines reached canopy closure (eight years), water yield returned to about pre-clearance values, again because the ET values of pines and bamboo are similar and the soil surface was not greatly disturbed under pine trees. The third example at Mbeya, Tanzania, is the only one involving the establishment of *shambas* (Edwards 1979). When the evergreen forest was cleared there was a very large increase in stream-flow, largely because of a doubling of base flows. The volcanic soils retained a high infiltration capacity in this catchment. The vegetation in the *shambas* had only about 60 percent of the ET of the forest, so the increase in flow (about 410 mm per yr) persisted for as long as measurements were continued. Other experiments in tropical areas around the world show increases in flows, including base flows, after clearance, although the long-term hydrologic effects depend on the type of farming system that replaced the trees (Bruijnzeel 1999).

It is a truism in hydrology that the scale of measurement affects the size of the response. Thus, the sediment loss measured in erosion plots at paddock scale is usually many times larger than the sediment load measured in a tributary stream, and there may be negligible sediment load measured at the outlet of a whole catchment. Similarly, runoff can be subject to scaling effects too, although the effects are not usually as strong as are the scaling effects with sediment loads. Thus, runoff at paddock scale can be different to the runoff measured at subcatchment and catchment scales. There are no controlled experiments conducted at large catchment scale to check whether the results of forest clearance on hydrology found in paired catchment experiments (typically hundreds of hectares) remain true at larger scales (hundreds of km^2). However, uncontrolled clearing on a large scale in many countries has resulted in hydrologic effects that are consistent with the results from paired catchments. Thus, mean annual flows have been shown to increase and water tables to rise (leading, presumably, to increases in base flows) in Russia (and many parts of Australia) after large catchments (some thousand km^2 in size) have been cleared.

It is most probable that, except for the special cases noted above, large-scale clearance in Kenya would lead to the same hydrologic response as found in the paired catchment experiments at Kericho, Kimakia, Mbeya, and most other places in the world. The clearance of forest in the "Kenyan water towers" below the level of cloud forest is most likely to result in increases in both storm flows and base flows, as seen at Mbeya, as long as the soils retain good infiltration and there is no widespread abstraction of surface and groundwater.

The effects of clearing cloud forest, however, can be different. The loss of mist capture after clearance can lead to decreases in both mean annual flows and base flows, depending on the size of mist capture compared to rainfall. Again, there is little information on this effect in Kenya, although more detailed studies have been carried out in Central and South America. In situations where the cloud cover is permanent and there is continual renewal of cloud (e.g. on certain tropical islands), the mist harvesting can account for up to 20 percent of total precipitation.[43] In Kenya, cloud forest occurs on the upper parts of the Aberderes, Mt. Kenya, and the southwest Mau Ranges, where it is a seasonal feature (about three to four months of the year). There is limited moisture renewal in these areas, implying that the mist harvesting effect will be less pronounced than at most of the sites studied in Central and South America. Thus, it is reasonable to assume that clearance of these forests would lead to a loss of about 5 percent of precipitation, at most, from the mist harvesting effect.

Although the weight of experimental evidence is strongly in favor of increases in both total flow and base flow after forest clearance, the reality is that when forest is cleared for *shambas*, many other hydrological effects occur apart from those arising from the vegetation removal. The density of settlement is usually such that significant groundwater is abstracted; surface runoff is intercepted in pans; and areas (such as paths and around houses) become heavily compacted, although cropped areas retain good infiltration characteristics. Some irrigation areas have been established in areas cleared of forest in the Mau Ranges. Consequently, the widespread observation of riverflows decreasing after forest clearance in Kenya is more likely to be the result of the dense settlement patterns or other causes of abstraction that follow the clearance than the result of the vegetation clearance itself. Thus, the lowered water table in the Njoro catchment and decreases in the flow of the Njoro River feeding Lake Nakuru is most likely to have arisen from the increased use of surface and groundwater in the region rather than from the clearance of forests *per se*. The conversion of permanent rivers flowing into Lake Baringo into intermittent streams is most likely a result of dense settlement in the upper catchment, including the establishment of irrigation areas rather than the removal of trees.

43. Note that it is technically quite difficult to measure the mist harvesting effect in a reproducible way. There remains considerable uncertainty about the relative size of this effect compared to rainfall.

APPENDIX C

Methods and Data for Valuing Economic Losses

Overview

This appendix briefly describes the methodological tools and data sources used to determine the costs of climate variability and water resources degradation in Kenya. In some cases, costs could be established by using values for goods that are traded in markets. However, many of the costs of climate variability and water resources degradation arise from the loss of goods and services that are not traded in markets. In these cases, we used some of the methods that have been developed over the years as surrogates for untraded goods. Bromley (1995) provides more information on these methods. The appendix also discusses the primary and secondary data used in the analysis.

Market Cost Analysis

This approach is appropriate for determining the costs of water resource degradation and climate variability when the impacts affect prices. The method is particularly appropriate when the goods are traded in a formal or informal market. Thus, water is sold by vendors in Nairobi slums in a competitive market and so the increase in the unit price of water (20 liter container) during the La Niña drought multiplied by a basic volume of water consumed (two containers per household per day) provides a direct measure of the extra cost borne by the slum dwellers. In this case, we assume that a basic consumption of water is inelastic with respect to prices.

We also include in this category cases where an increased quantity of a good has to be consumed because of climate variability or water resource degradation, even if the price is inelastic. The preliminary literature and discussions with relevant authorities revealed that most of the water resources degradation impacts fall into this category. Many of these prices are set by some authority. Such impacts include maintenance costs of water reservoirs; health effects due to floods; livestock deaths due to droughts; increased costs of water treatment; and increased costs of hydropower generation.

Change in Production

This method is similar to market price analysis except that the information comes from production rather than from trading. It is particularly valuable when there are major changes in production, where these changes can be unambiguously attributed to a drought and flood. It has been used here to estimate the losses in livestock, crop, industrial, and forest production from the major El Niño and La Niña events.

A base of production was established for the good, where possible by averaging the production quantities over a number of "normal" years, and then subtracting the production in the perturbed year from this base. Secondary data from national statistical abstracts formed the backbone of these estimates. In each case, we used local knowledge and comments in the national statistical abstracts to decide whether the change in production was affected by other influences and needed to be factored down. Even though the reduced production will often be reflected in an increase in unit price for the good in the perturbed year, we multiplied the loss of production by the unit price in the normal year to give an estimate of the losses.

Replacement Cost

In some cases, the good or service lost is not traded in a market, but the cost of replacing the good can still be established. Thus, there is no market for buying and selling items such as bridges, but the replacement value can be established by calling for tenders to determine its direct replacement cost.

The replacement method was used in cases where an asset had been destroyed and had to be replaced. It is particularly appropriate when the asset was a large, long-term capital item such as a bridge or dam. Consequently, the method was used to value assets destroyed by floods. This method assumes that the affected asset is indispensable and needs to be replaced by a physically identical asset. Of course, many long-term assets will have depreciated in value at the time they are destroyed, and so the replacement value will be an overestimate of the long term cost of the destruction. In these cases, the replacement cost is factored down by the fraction of design life remaining in the asset at the time it was destroyed.

Opportunity Cost (Labor)

The opportunity cost measures the loss of income (actual or virtual) that a consumer suffered because of having to spend extra time on an activity. It measures the economic value of foregone productive opportunities due to increased allocation of time to the activity. It is particularly appropriate when the impact of climate variability or water resources degradation is manifested as an increase in the time needed to undertake an activity. For example, it was used to estimate the cost arising from the extra time spent in trekking long distances for water collection in rural areas during the La Niña drought.

A basic assumption of the method is that, in the absence of the impact, the consumer would engage in an alternative income-generating activity. The wage rate for this alternative activity has to be estimated and, in principle, this requires an understanding of the productive activities that consumers spend their time on. In practice, it is too difficult to know what these alternative, foregone activities would have been, so a generally appropriate wage rate is used. In the case of skilled forestry supervisors, we used their forestry wage rate; in the case of rural women seeking water and farmers attending conflict resolution meetings, we used the rural wage rate. There is some dispute in the literature about the appropriate rate to use for water collection in rural areas. Whittington and others (1990) calculated the value of time spent collecting water in Ukunda, Kenya, and concluded that villagers implicitly value that time spent is "… approximately equivalent to the wage rate for unskilled labor."

Proxy or Substitute

This method is conceptually similar to the replacement cost method. It is used where a good or service, rather than an asset, is replaced with a similar or substitute good or service. The method is widely used in the energy sector and was applied here to determine the extra cost of meeting energy requirements during the La Niña drought. The key assumption is that locally produced hydro-based energy costs less in real terms to meet the country's requirements, compared to alternative or substitute sources that had to be utilized during the drought.

The method works well when the substitute good is nearly identical to the replaced good, as it is in the case of electrical energy. However, it will produce over- or underestimates of cost if it is used for imperfect substitutes.

The following table summarizes the use of these methods in this report.

Approach	Valuation Method/Technique	Impact
Observed market	Market cost analysis	– Increased maintenance costs of water reservoirs due to increased siltation. – Health effects of increased flooding in Kano plains and other affected regions. – Livestock deaths due to droughts. – Increased pumping costs of borehole water due to lowered water table. – Cost of water treatment for urban areas due to decreased water quality. – Desalination of saline water for the tourism industry. – The effect of the water hyacinth on water for domestic use (increased treatment cost). – Increased costs of power generation due to drought. – Increased cost of vendor-water based sources.

(*Continued*)

(*Continued*)

Approach	Valuation Method/Technique	Impact
	Replacement cost	– Damage to water systems and road network, bridges, communications, and buildings due to floods. – Reduced economic lifespan of water pumps serving the Mombasa region. – Extension of the Malindi jetty. – Shifting of water intake points due to reduced water flows.
Surrogate markets	Opportunity cost (labor)	– Conflict management. – Increased costs of supervision of forest fire management regimes. – Increased water collection time, particularly within the ASAL areas and Nairobi region.
	Proxy or substitute	– Increased import substitutes for power generation.
	Change in productivity	– Reduced livestock production. – Reduction in crop production in the Budalangi area. – The effect of the water hyacinth on water transport and fisheries. – Increased forest destruction and damage incidence. – Loss of industrial production due to inadequate power supply.

Data Sources for Valuing Economic Loss

Primary Data

Very little primary data were collected for this analysis. Primary data were only collected if the information was not available on major water resource impacts from reliable secondary sources. Collected primary data included maintenance costs of water reservoirs; costs of water treatment; conflicts over water resources utilization and access; extension of the Malindi jetty; tourism statistics; eutrophication of Lake Victoria; groundwater pumping in Nairobi; and water transport on Lake Victoria.

These first six sets of data were obtained during visits to key persons and institutions involved in the relevant aspects of water resources management and development. The data had been collected by those individuals or institutions and were believed to be reliable. Data on the Nairobi groundwater table was obtained from a private contractor and from a published government technical report. These two sources gave consistent results and so the estimate used is believed to be reliable.

Secondary Data

The majority of the data came from secondary sources, primarily government offices, NGOs, and other institutions involved in water resources development and management at district and national levels. Data such as budgetary allocations to the water and other related sectors, agricultural and livestock production levels, fish production, tourism statistics, health statistics (particularly incidences of waterborne diseases), and energy production were obtained from annual government publications such as the budget estimates and the various economic surveys. Other secondary data, such as those detailing the costs of floods and droughts, came from one-off government and NGO reports.

The reliability of the data in the annual government reports depends on the collection and processing procedures. There are known to be errors in these reports because of misreporting at the district level.

We also relied on special publications, often funded by NGOs or UN agencies, to investigate the aftermath of a major event such as the UNEP report on the effects of the drought. Typically, the reports do not detail their methods of data collection and so the accuracy of the data are not known. However, all the reports of this nature used in this analysis were published by credible agencies and so their data are believed to be reliable.

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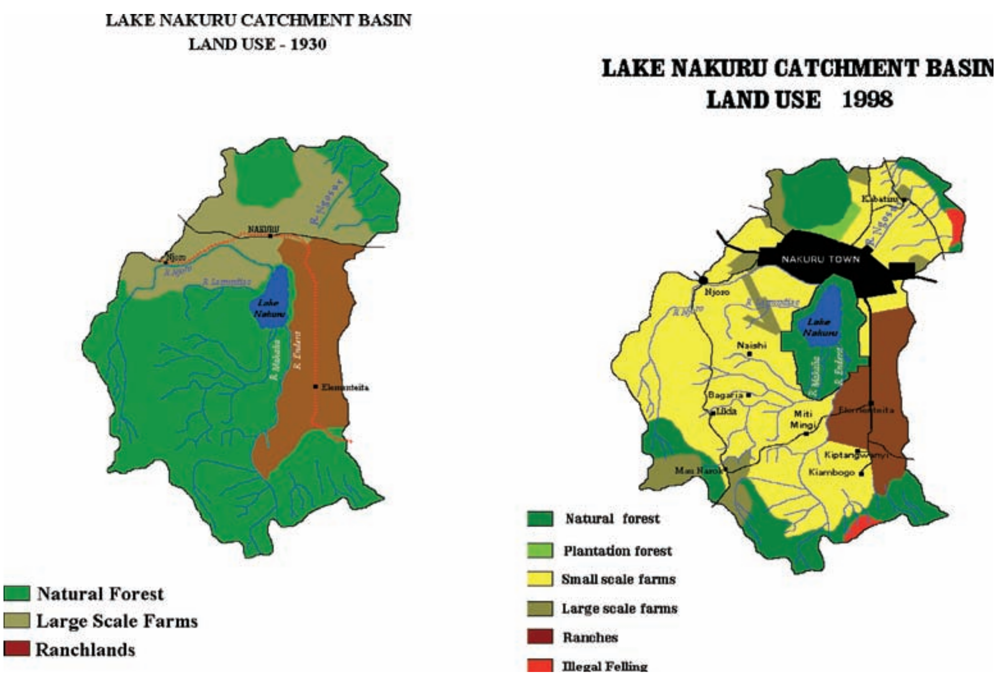
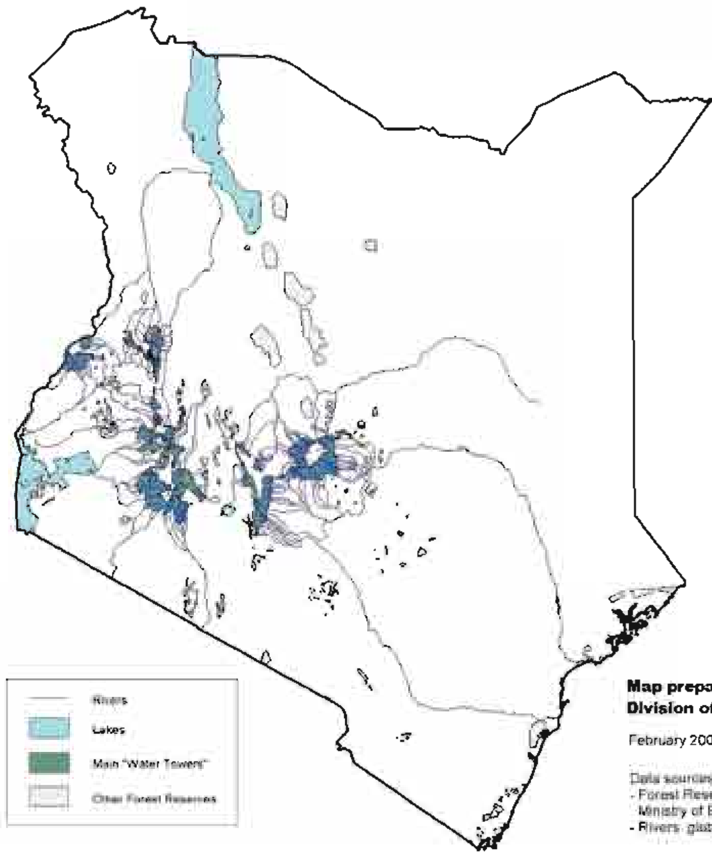
Figure 4.5. Extent of Forest Removal in Lake Nakuru Catchment



MAP 1: Major “Water Towers” of Kenya



FORESTS	Ha	%
Mt. Kenya	200,871	12.3
Aberdares	148,916	9.1
Mau complex	415,977	25.4
Mt. Elgon	73,706	4.5
Cherangani	120,842	20
Total	**960,312**	**58.7**

Map prepared by UNEP
Division of Early Warning and Assessment

February 2001

Data sources:
- Forest Reserve boundaries, KIFCON project, Forest Department Ministry of Environment and Natural Resources
- Rivers, global river datasets at scale 1/1,000,000

Climate Variability and Water Resources Degradation in Kenya is part of the World Bank Working Paper series. These papers are published to communicate the results of the Bank's ongoing research and to stimulate public discussion.

This report, based on a complex analytical methodology, provides a clear economic rationale for investing in improved water resources development and management in Kenya. It is part of the World Bank's policy dialog on water resources management reforms and investment planning in Kenya. The study focuses on the economic implications of two key factors that make the economy and people of Kenya highly vulnerable—the effects of climate variability and the steady degradation of the nation's water resources.

The 1997-2000 El Niño-La Niña episodes cost the country Ksh 290 billion, about 14 percent of GDP during the three year period. Given their regularity, over the long term, floods and droughts are estimated to cost the economy about Ksh 16 billion per annum (2.4 percent of GDP). This is a very serious drag on the country's economic performance. Water resources degradation costs the country at least Ksh 3.3 billion (0.5 percent GDP) annually. The long term annual impact of 2.9 percent of GDP from these two factors has been developed conservatively. While it is not economical to avoid all costs, many of them can be minimized by increased investment in management and infrastructure, and more efficient, accountable, and participatory management and operation of the water resource sector.

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