Economy versus Environment:
How a System with RS & GIS can Assist in Decisions for Water Resource Management

A case study in the Lake Naivasha, Central Rift Valley Province, Kenya

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Economy versus Environment: How a system with RS & GIS can assist in decisions for water resource management
(A case study in the Lake Naivasha, Central Rift Valley Province, Kenya)

By

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In the name of Allah
The Merciful, The Compassionate

Dedication

This work is dedicated to my Father M.A.Quader, Mother Hazera Khatun, Wife Runa and Daughter Sadia.

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ABSTRACT

Water is such an important economic good that, ironically, powerful forces do not want to treat is as such.

Pricing water is a good way to regulate external costs of water use providing a means of financing water service agencies and forcing compensation to users who are harmed by unregulated public and private systems.

But it is very difficult to regulate the external benefits of water use through pricing as return flow or the recharge of aquifers from irrigation systems would require a negative price, or subsidy, to reach the optimal level of water use.

In the present research "Dollars per Drop"- the net economic return from the individual farms using unit cubic meter of water around the Lake Naivasha, Kenya has been used as a Primary Management Information Tool to regulate and manage the use of water resources among the competing sectors and to provide a safe environment.

This is because, in real water pricing the underneath idea is - the higher the price, the lesser the water that will be used and thus, other things remaining the equal, the lesser the pollution.

In the vicinity of Lake Naivasha the impact of growing agricultural economy and agricultural inputs on the environment has been found significant. To maintain the lake level sustainable both for the future environment and increased agricultural water demand the economic benefits from using each cubic meter of water has been selected as a management information tool.

The information needed to get the net return per cubic meter water use was, Where the water is used, By whom and against what financial return?

The digital cadstral boundary map of Physical Planning Department, Ministry of Lands and Settlement, Kenya and the Inventory on water abstractions by Water Resources Assessment Project (WRAP) in 1997 are used in Geo-graphic Information System using ArcView to identify users spatially.

The Landsat TM Image of May 21, 2000 and field observations with Global Positioning System are used to get the irrigated areas and Green house areas of individual farms and information on crops and production using ILWIS.

Supplementary Irrigation water requirement was calculated using RS based crop coefficients by [Mekonnen, 1999].

Finally a dynamic Economic Model is developed using Excel Spread Sheet to show the individual farm outputs in the form of Dollars per cubic meter usage of water for different conditions of abstraction and use of water.

The net return from the irrigated farms and dairy sector on average years is found as 0.98 US $ per cubic water usage of water.

"Water flows uphill, toward power" – Mark Twain

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List of Acronyms

WRAP	Water Resources Assessment Project
ILWIS	Integrated Land & Water Information System
GIS	Geographic Information System
GPS	Global Positioning System
LNROA	Lake Naivasha Riparian Owners Association
L.U.	Livestock Unit
DMI	Dry Matter Intake
M.m3/y	Million Cubic Meter per Year
M US $/yr.	Million US Dollar per Year

Chapter 1: Introduction

1.1 General

The balance of ecosystem and overall environment largely depends on sustained lake level of the Lake Naivasha, Central Rift valley, Kenya. The lake level fluctuation is dependent on water balance components of the lake. The components of water balance for the outflows from the lake are:

1) Open water evaporation
2) Swamp transpiration
3) Ground water outflow, and
4) Abstraction.

The abstraction for irrigation contributes 20% to the out flow. Only the other major abstraction partner from water source of Lake Naivasha is Kenya Power Generation Company. The other three outflow components are natural. So to keep the lake level sustainable water manager should think over the optimum abstraction management.

The long term water balance of [Gitonga, 1999] lake Naivasha also shows that the difference between predicted lake level and actual lake level has changed abruptly after mid 1980. The expansion of irrigated agriculture also took place after mid 1980. In the 1980s, a considerable expansion of Kenya's cut flower industry brought Kenya to a point where the country was recognized as one of the most important "off season" supplier to Western Europe [Konijn, 2000]. The 1990`s have witnessed yet another surge in cut flower production and exports in Kenya with the planting area increasing some 250% and with volume doubling [Konojn, 2000].

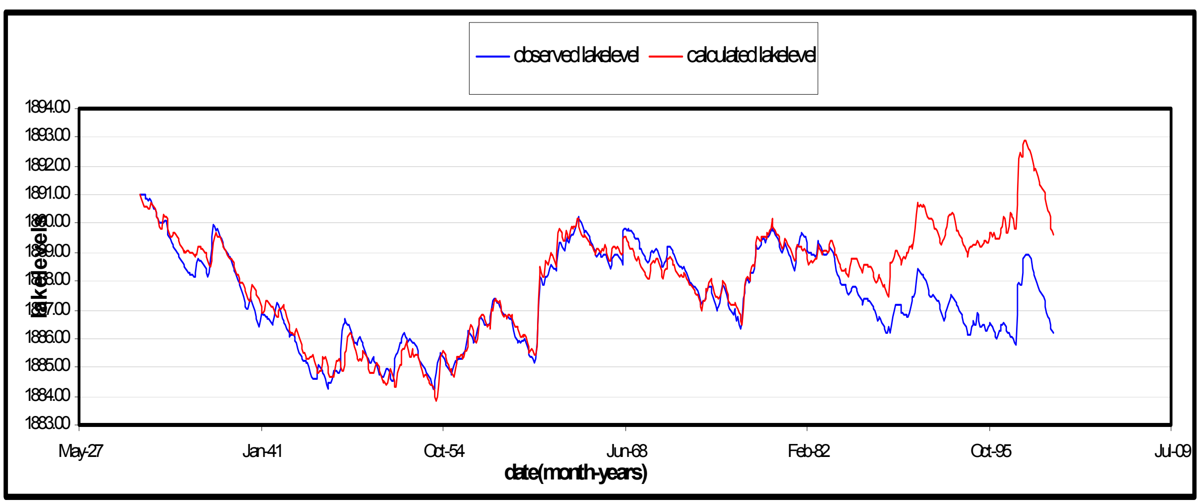


Figure: 1-I (Calculated and Observed Lake level of Gitonga, 1999)

The figure shows clearly that after mid 80 the observed lake level is always noticeably lower than calculated level, where as before that period both observed and calculated level have followed similar variation. Undoubtedly the drop in lake-level is the result of huge and excessive abstraction by the irrigated commercial farms. This drop due to excessive abstraction will cause negative effect to the ecosystem balance of Lake Naivasha and also the future expansion of irrigation.

It has been pointed out again during WRAP survey during 1996-97 that abstraction for irrigation contributes a large amount to the outflow of the Lake, eventually contributing to the lake level fluctuations.

To develop a systematic optimum abstraction by the farms first of all we need proper information on irrigated area of each farm with crop information and to regulate future expansion of irrigated area and water permit, economic analysis of net return from irrigated farms is also needed.
In the present study Satellite Image of landsat of May 21,2000 has been used with sufficient field GPS observations using also cadastral map to get the irrigated area of each farm. Actual evapotranspiration of [Mekonnen,1999] is used to get supplimentary irrigation requirement.
An Economic Model has been developed to get farm outputs in the form of net return in US $ using one cubic meter of water. The outputs of the economic model can be used for future water pricing strategy. The outcome of the study will be to ensure safe environment and a better economy for the region.

1.2 Problem Definition

Using the Landsat Thematic Mapper (TM) Image of January 21st, 1995 the results of supervised classification for the irrigated areas around Lake Naivasha the following figures were achieved by Huaccho in 1998 and Salah in 1999. The irrigated areas declared to Water Resources Assessment Project of 1996-97 are also too different from the obtained results of supervised classification.

Table:1-I(Results of previous studies on irrigated areas and water needs)

WRAP 1996-97		Huaccho 1998		Salah 1999	
Declared Irrigated Area(ha)	Water Abstraction (m.m3/y)	Calculated Irrigated Area(ha)	Theoretical water need (m.m3/y)	Calculated Irrigated Area(ha)	Theoretical water need (m.m3/y)
3445	40.20	7353	23.72	4568	43.46

The theoretical crop water requirement calculated by Huaccho is too different than theoretical crop water requirement estimated by Salah using the actual evapotranspiration rates for the study area [Mekonnen, 1999].

The total water abstraction with in the whole catchment is 77.49 million m3/year and from the Lake is 31.59 million m3/year (WRAP).

The applied amount of water for irrigation calculated by Salah 1999 is 71.56 million m3/year. The total abstraction by the farms around the lake is 49.06 million m3/year (WRAP) and the standard requirements for domestic, livestock, wildlife and industry based upon the policy of the local representative of the Ministry of Water Development (MOWD) and WRAP data is only 1.49 million m3/year, only 3% of total abstraction. So 97% of total abstracted water are being used for irrigated areas around the Lake including dairy farms.

The above figures imply that a balance on estimated irrigated areas and consumptive usage of water should be achieved for the interest of water management by the managers. The yearly economic returns from the surrounding farms are significant in amount. The socioeconomic balance of the Lake vicinity is influenced greatly by the farm owners. But the ecosystem and natural balance of the environment is also largely dependent on lake-level that is being fluctuated by the abstraction for irrigation.

Information on irrigated areas, actual irrigation requirement and economic returns of individual farms will be a good tool for the water managers to regulate water usage and ensure a sustained lake level. Both the environment and the interest of better economy can be served by this way.

1.3 Objectives

The research is focused on yearly economic returns using unit volume of water by the individual farm that can be used as a tool to regulate and manage water among users.

A) Estimating irrigated areas of individual farms spatially in GIS environment.
B) Estimating irrigated areas of the main crops per individual farm.
C) Identifying the users of each abstraction point using GIS.
D) Estimating economic returns of main crops of individual farm including the return from dairies.
E) Estimating total amount of abstraction (WRAP), net total requirement and current total application of water by the individual farms.
F) To get the net economic returns based on the above three types of usage of water.
G) To assess the possibility of using the above outputs as primary tool to regulate and manage water usage and allocation.
H) To develop an Economic Model to estimate the above returns on varying prices and irrigated areas.

1.4 Research Questions

A) What is the underlying problem to get the estimate of amount of usage of water and irrigated areas?
B) Do the farms irrigate more than the declared areas and use water more than the total abstraction declared to WRAP survey?

C) What should be the primary information as a management tool for the managers to regulate the use and abstraction of water from the Lake?

D) Could the information "Dollars per Drop" be used as a management tool regarding abstraction and usage of water?

E) Where the water is being used, by whom and against what financial return?

1.5 Methodology

1.5.1 Pre-field Works

i) Study of previous works related with the subject of interest.

ii) Study of Landsat TM Image of May 21, 2000.

iii) Study of WRAP Inventory 1996-97.

1.5.2 Field Works

i) Field observations were made using GPS, Image, Cadasrtal Map, and WRAP data.

ii) GPS points were used to get irrigated area, crop information, production and farm boundaries together with the help of cadastral map, WRAP data and image.

1.5.3 Post-Field Works

i) Integration of collected field data.

ii) Cadastral Map was digitized by the staff of the Physical Planning Department, Ministry of Lands and Settlement. It was not geo-referenced properly with the original co-ordinate system "Naiv".

iii) Observed GPS points were used successfully to get it geo-referenced with "Naiv".

iv) The newly geo-referenced Cadastral map was cross checked with the geo-referenced image of 2000 and the road map of Dominik, Ministry of Water Resources, Nakuru which was created by the GPS tracks.

v) To identify the water users the inventory table of WRAP survey and the attribute table of Cadastral map was linked using ArcView with the common identification by the land reference numbers.

vi) The number of abstraction points of individual farms were shown successfully using GIS.

vii) Using the field data and GPS points along with the cadastral map, image and road track created by GPS of Domonik, the irrigated area of individual farms were delineated.

viii) Using the field information the irrigated area of the main crops were estimated for individual farms.

ix) Based on recognition of abstraction points of each farm the total abstraction per farm was estimated.

x) Based on crop information and irrigated area the net irrigation requirement and current amount of application for each farm were calculated using the data of Mekonnen 1999.

xi) The total economic return of each farm was calculated using the net returns from main crops and dairies.

xii) The net return for each individual farm was estimated as dollars per cubic meter usage of water against total abstraction (WRAP), net irrigation requirement and present practice of application.

xiii) The full calculation procedure was developed as an Economic Model for future study.

1.6 Review of Previous works

a) Ahmad Salah, 1999 calculated net economic returns in US $ per hectare for flowers, vegetables, and fodder. The derived results are flower (60,109 US $/ ha), vegetables (8,387 US $/ ha), and fodder (117 US $/ ha). Freight cost was not considered in the calculation of net return from flowers. He estimated net return from dairies for the entire catchment as 24,949 US $/yr. He also estimated net return from tourism (6.58 M. US $/yr.), Fisheries (44,322 US $/yr.) and wildlife (1.32 M. US $/yr.). He estimated irrigated area as 4568 hectares for the entire catchment using supervised classification for the Landsat TM Image of the study area of 21st January 1995. He estimated irrigated area crop-wise.

b) Huaccho, 1998 also used the same image and supervised classification to estimate the irrigated area. She found irrigated area as 7,353 hectares around the Lake. She also estimated irrigated area of farms as individual and also as group of farms. Because the correct cadastral boundary of the farm areas were not available. She estimated irrigation water requirement for the main crops using Cropwat version 5.7 (October 1991). She developed a conceptual model to create scenario for maximizing gross income, maximizing employment, and minimizing water use. The results for average condition were 282M US $/year, 800,000 workdays/year, and 8.0M m^3 /year respectively. The estimated irrigation requirement for the main crops were too low and the minimum water use was only 8.0M m^3 /year for 7,353 hectares.

1.7 Data Used

a) Field observations by GPS and collected information, October 2000.

b) Landsat TM Image of the study area of May 21, 2000.

c) Cadastral Map (1:50,000), Physical Planning Department, Ministry of Lands and Settlement, Kenya and digitized cadastral map.

d) Inventory of Water Resources Assessment Project WRAP 1996-97.

e) Different Reports and Research Papers on Lake Naivasha.

f) Journals and Text Books.

g) Road Track Map created by using GPS of Dominik Wambua, Ministry of Water Development, Nakuru, Kenya.

h) ITC Database.

i) Data for thesis from Drs.Robert Becht, (ITC wremdata/Ramirez)

Chapter 2:The Study Area

2.1 The Rift Valley

The Study area is concentrated in the Kenyan Rift valley. The central rift valley of Kenya, shown in Figure 2.1 is of moderate altitude (2000m AMSL). The Naivasha catchment receives drainage from the Nyandarua Mountains (Aberdare Range) in the East, elevation is about 3960m and Mau Escarpment in the West, elevation is above 3000m.

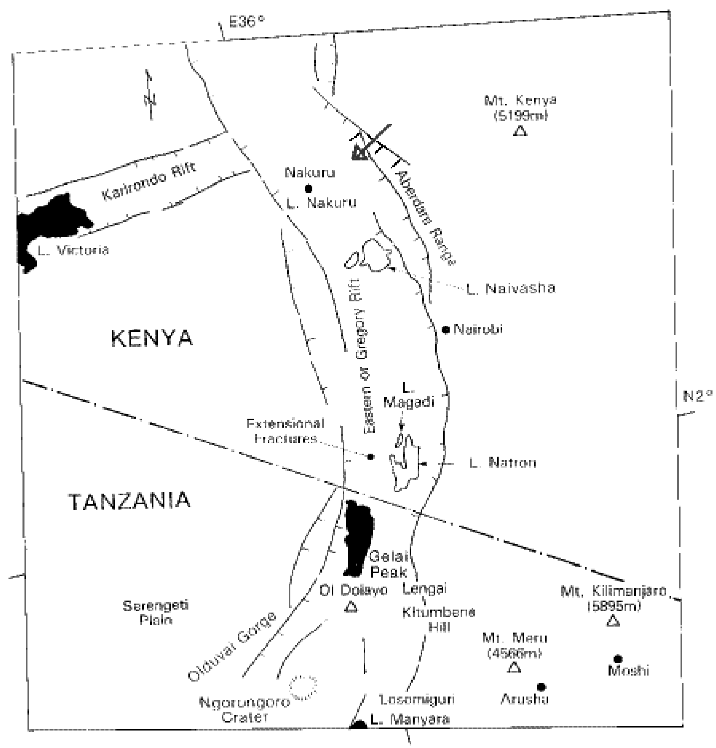


Figure 2.1: Great Kenyan Rift Valley

The African Rift Valley is most prominent structural phenomenon in East Africa. The floor of the rift valley around the lake Naivasha is characterized by Tertiary- Quaternary volcanic suite with associated alkaline sediments. It is characterized by exceptionally long and intense volcanic activity from middle Pleistocene to the last hundred years.

2.2 Geology

Volcanic rocks and quaternary lacustrine deposits from large ancient lakes those were formed during pluvial periods characterize the geology of the area. The Lake Naivasha is situated in the Eastern or Gregory Rift, part of Great Rift Valley, which is stretched from Jordan in the Middle East to Mozambique in southeast Africa. Based on detailed core analysis radio carbon dating Richardson and Richardson (1972) suggest that, in the period 9200 BC to 5700 BC, Naivasha was about four times as extensive and 58m higher as it was in 1960.

The Rift Valley was formed through many episodes of faulting and volcanism some 30M years ago. In geologic terms, the lake is very young, and there is still much evidence of volcanic activities. The geological map of the Naivasha area does not include any formation older than Quaternary, in fact these are not older than lower Pleistocene. Especially the area around the Mount Longonot has very recent features like parasitic cone, the lava field of which is not yet fully covered by the vegetation.

Naivasha Lake is the highest part of the Rift Kenya (1887m AMSL). The older lake sediments are composed of a mixture of volcanic ash and reworked volcanic strata. Soils of the lacustrine plains around the lake have developed from the volcanic ashes. Soils can vary from well to poorly drained, fine to sandy silt and clay loams of varying color, but often pale.

2.3 Location and Description of Lake Naivasha

2.3.1 The Lake

The lake Naivasha is situated in the southwest of Kenya, map reference $0^{o}45'$ S and $36^{o}20'$ E, 80 kms south of the equator and 70 kms northwest of Nairobi the capital of Kenya (Fig. 2.2). Lake Naivasha is situated in the bottom of the eastern or Gregory Rift valley, in the middle of three major centers of geothermal activity- the Eburru hills to the northwest, Mount Longonot to the southeast, and Olkaria to the south. The lake is the highest and the freshest of all Rift valley Lakes in eastern Africa. Administratively the lake and its immediate environs are situated in the Naivasha division of the Nakuru District in the rift valley province of Kenya. Although Lake Naivasha is generally refereed to as one lake, it has been general practice in the scientific literature to distinguish between four components shown in Table 2.1.

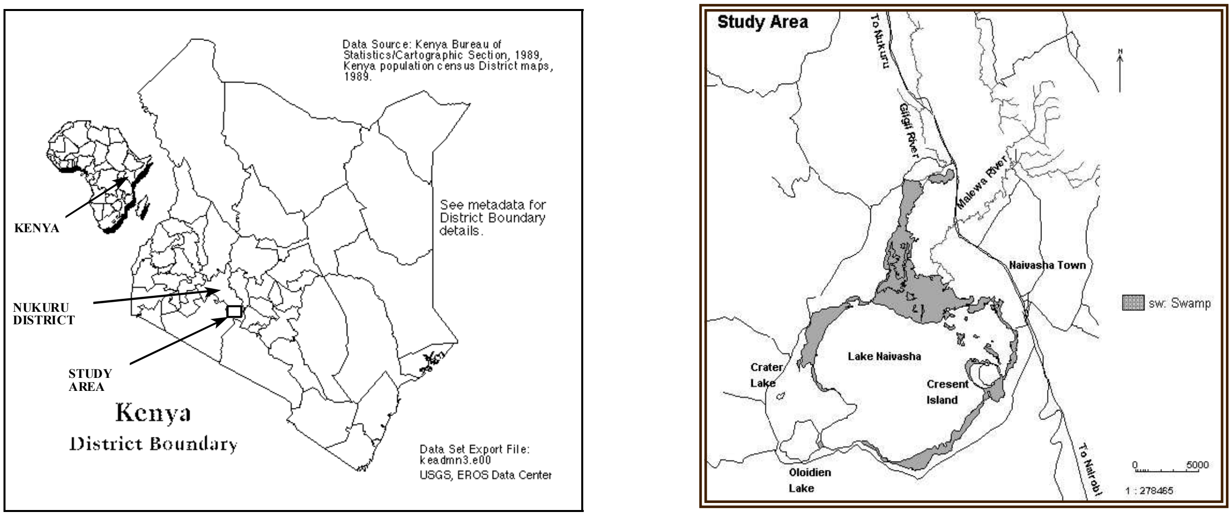


Figure 2.2: Location Map

Table: 2-I(Four components of Lake Naivasha)

component of Lake Naivasha	*Area (km^2)*	*Volume ($m^3 \times 10^6$)*	*Mean depth (m)*
Lake Naivasha	145	680	4.7
Cresent Island basin	2.1	23	11.0
Oloidien	5.5	31	5.6
Sonachi (Crater lake)	0.6	0.62	3.8
Total	*153.2*	*734.62*	

Source: LNROA, 1993.

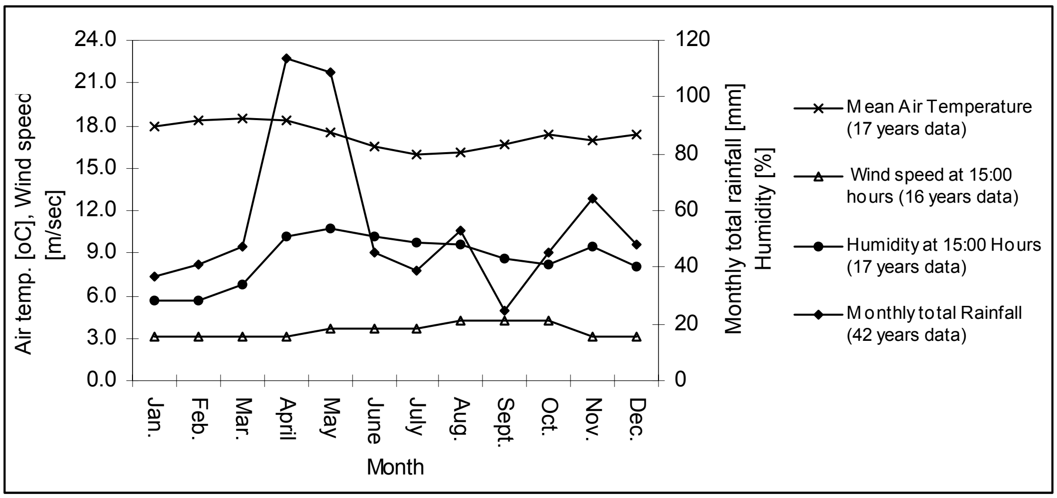
The boundaries of the four bodies have been formed by the tectonic activity associates and with the formation of the Rift Valley (Richardson and Richardson, 1972).

In the most resent history the lake has shown tremendous change in depth, area and volume. From 1909 to 1969 the lake's area has varied from 216.27 to 88.08 km^2, and the capacity from 1702.23×10^6 to 148.02×10^6 cubic meters. In all a fluctuation in area is of 245% and in volume 1150%. However, the general trend for both parameters are downward (LNROA, 1993).

2.3.2 Climate

Climatic condition in the study area is quite diverse due to considerable differences in altitude and landform. The climate of the region is semi arid but locally the climate in the valley varies due to the altitude. Although the lake is located within one degree of equator but it generally experiences cool conditions because of the altitude. A general trend of the climatic data of Naivasha town is presented in Figure 2.3. For numerical value see Appendix A-2-I.

Figure 2.3: A general trend of climatic data of Naivasha Town. (Met. Station: Naivasha DO).



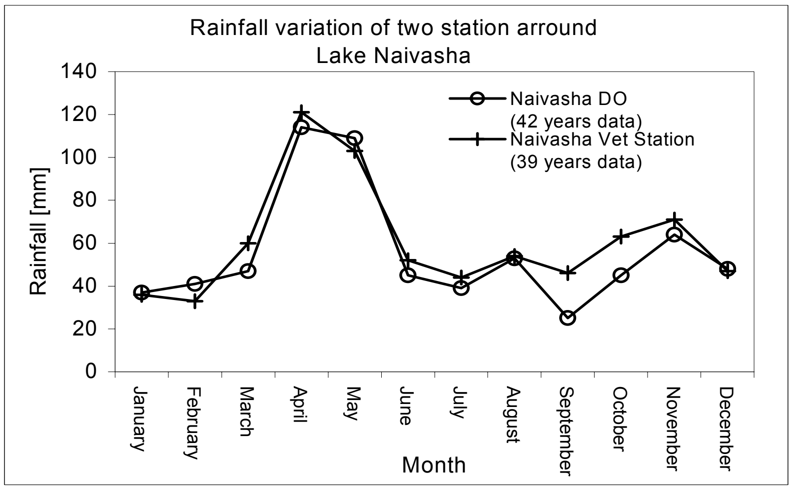
2.3.2.1 Winds:

Winds over the Lake Naivasha are generally weak and come from varying directions in the mornings. In the afternoon winds of 1-2.5 m/sec are typical. Winds are strongest in August to October when they reach a speed of 6 m/sec. There are often violent storms over the lakes leading to serious water movement and high wind speeds. The direction of winds is mainly from the southeast and northeast depending on season. Wind over the lake in the afternoon cause mixing of water down the column, and result in well oxygenated water with equalized temperature from top to bottom. Temporary thermal stratification occurs in calm weather.

2.3.2.2 Rainfall:

Lake Naivasha is situated in the highest part of Rift valley but in spite of this, the lake and its drainage basin are in rain shadow of winds coming from both the west and, more importantly from the east. Rainfall is bimodal with main pulses in April/ May and again in November (Fig. 2.4). The Average rainfall of the lake for the period 1931-1960 was 608mm with a variation round the mean from 443 to 939mm (East African Meteorological Dept.1966, after Ase 1986). Rainfall records of two stations around the lake area are given in Appendix A-2-II.

Figure 2.4*:* Rainfall variation of two stations around Lake Naivasha.



2.3.2.3 Evaporation:

A general trend of free water surface evaporation by using pan data from Naivasha meteorological station are presented in the Figure 2.5. For the present study long term evaporation from free water surface has been taken from [Ashfaque, 1999]. For long term (from May`98 to Jan, 1999) he has estimated daily average evaporation of 4.61 and 4.72 mm/day using Smith's and Slob's method respectively.

Figure 2.5: Daily average evaporation from Class A land Pan data using Pan coefficient 1.0 (Met. Station: Naivasha WDD).

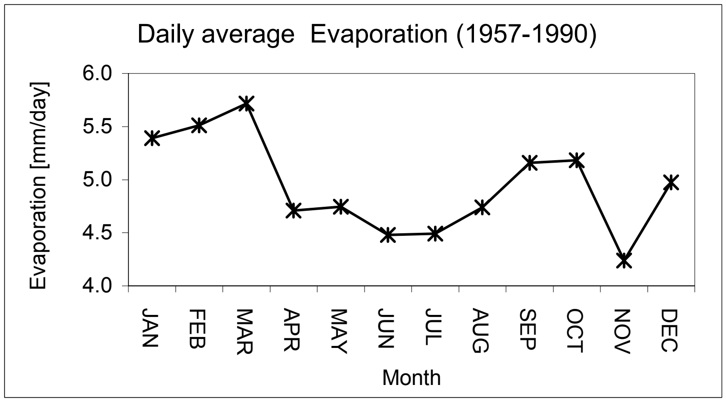
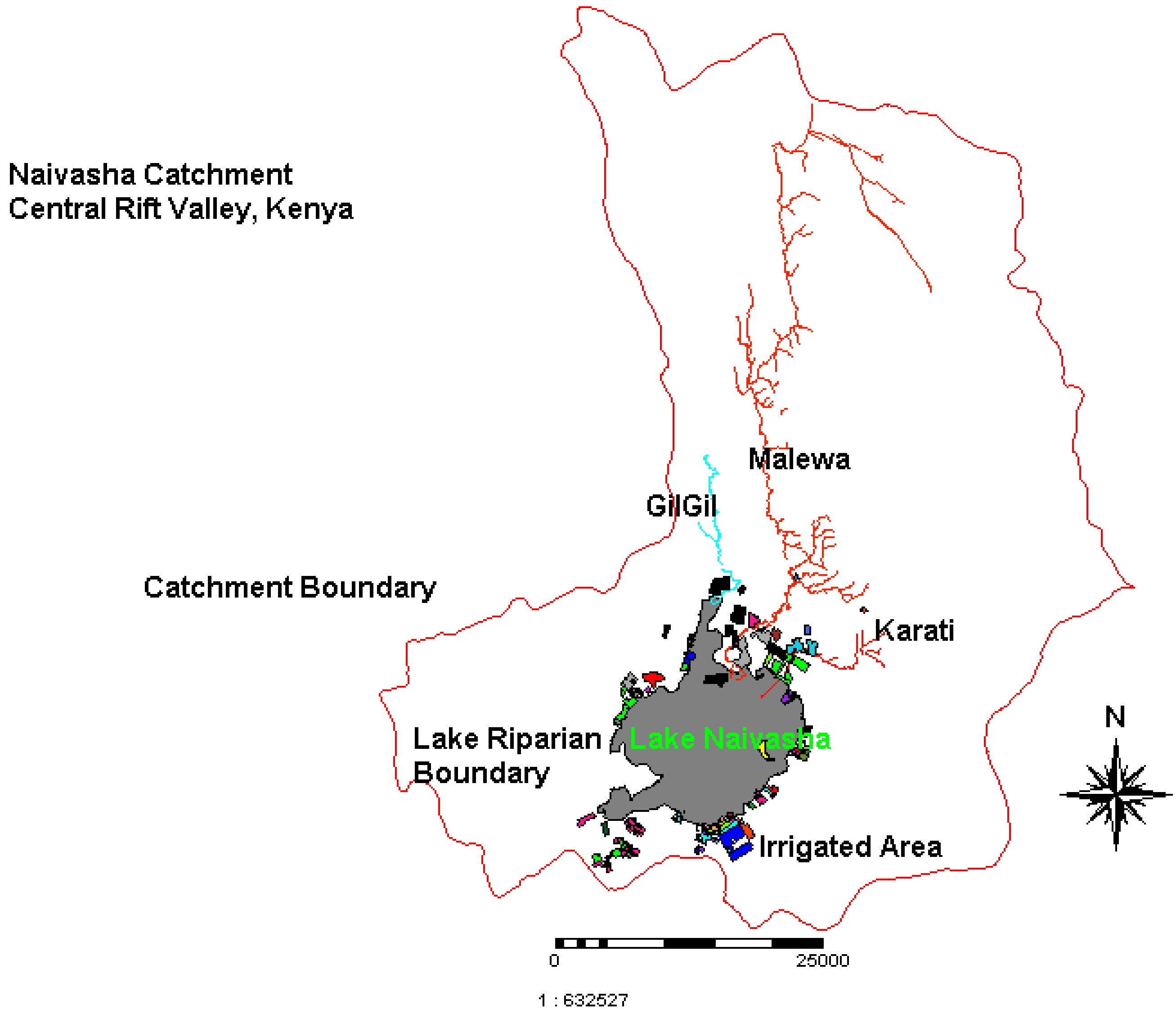


Figure: 2.6 Showing general picture of the study area.



2.4 Water Balance of Lake Naivasha

The water balance of Lake Naivasha is complicated. Lake Naivasha catchment has an internal drainage system. There is no surface outlet. It has underground water inflows and outflows and the freshness of the water can only result of outflows, otherwise the lake water have been salinized. Several attempts have been made at calculating water balance over the last 30-40 years. Many of these have been unsuccessful due to the fact that there are no accurate estimates of how much water goes in and out of the lake underground and how much is evaporating into atmosphere. But Ashfaque, 1999 calculated evaporation from the Lake and Gitonga, 1999 has shown the long-term water balance of Lake Naivasha using rainfall, river discharges, GW outflow and evaporation that has been discussed in chapter 5.

The following terms of the figure 2.6 need explanation.
Lake Riparian Boundary: Refers to the lake area corresponding to the lake-level 1892.7m.
Malewa, Gilgil, & Karati: Main rivers flowing into the lake.
Irrigated area: Irrigated area estimated in the present study.

2.5 Human use of the lake and surrounding area

Following the completion of the East African Railway Line in 1901, which passes close to the lake, the land was given over in large part of settled agriculture as a result of British Policy to recoup the cost of constructing the railway.
Since independence in 1963, the large estates have gradually been divided into small farms by land buying companies and co-operatives and given over to individual farmers. At the moment over 100 large, medium, and small commercial farms are running irrigated floriculture, vegetables, and dairy production. Flowers and vegetables are produced mainly for exports to international markets.

2.6 Local Economy

2.6.1 Irrigated Agriculture

Flowers and vegetables are leading in the regional economy with net yearly return of 63.02 million US $. The present study will focus on Economy being generated from irrigated agriculture by the commercial farms.

2.6.2 Irrigation Practices

Pivot, drip, and sprinkler irrigation practices have been observed. Large farms are using costly pivot irrigation system. Drip irrigation is followed largely in rose cultivation. Sprinkler irrigation is still popular in fodder crop cultivation.

2.6.3 Tourism

The diversity of wildlife contributes to this area being important tourist destination. The yearly return from tourism is estimated as US $ 6.58 million [Salah, 1999].

2.6.4 Fisheries

Lake Naivasha has been for the last thirty years, the site of important commercial fisheries based on introduced species, predominantly Oreochroms leucostrictus, Tilapia Zilli and Micropterus salmoides [Muchiri et al, 1992] as mentioned by [Huaccho, 1998]. The yearly return from fisheries as estimated by [Salah, 1999] is US $ 44,322.

2.6.5 General Environmental Aspects

The total catchment area of Naivasha basin is 3,292 square kilometers. The Lake Naivasha receives the inflow generated in three main rivers Malewa, Gilgil, and Karati. The flow from Gilgil has been diverted already to supply water to Township of Nakuru. The flow from Karati is seasonal. Now a days abstraction from Malewa in the up-stream is increasing day by day.

The safe lifestyle of people, wildlife, and surrounding nature largely depend on the sustainability of the lake-level. The ground water level in the lake vicinity is also dependent on lake-level. During dry condition lake serves as buffering unit to supply flow through fault conduits benefiting downstream areas.

Due to freshness of the water and the fluctuations of water level, a high species richness of aquatic plants, associated with succession on wet mud at the lake edge, exists. Papyrus is the main vegetation in the northern delta of the inflowing rivers. This swamp was shown to affect the whole ecosystem through uptake of nutrients and sediments from the inflowing rivers and its subsequent slow release to the lake water as fine organic particulate matter and accumulation as swamp peat.

Water quality is linked to the lake level in several ways. Water quality is moderated by the presence of swamp vegetation that tends to retain sediments and nutrients and thus smooth out seasonal fluctuations. The drop of lake-level may cause the swamp vegetation to be dried up.

The different plant communities of the lake edge contribute to bird species richness and abundance. During the field visit in October 2000 no flamingo was observed in the Crater Lake. The people informed that only in 2000 the flamingoes are not seen. Up to last year there were abundance of flamingoes.

The wetland plant communities also have direct benefits to human uses of the lake in fisheries and in conservation and tourism.

Due to huge export earnings flower and vegetable production is increasing day by day. The abstraction from the lake is also increasing day by day. Added to this is the use of cooling water by the Geothermal Power Station.
Only irrigation abstraction from the lake has become a significant part (20%) of out flow from the lake that can lead to a substantial environmental impact upon the lake level in the near future.
But the economic return from the irrigated sector is also substantial (63.02 million US $/year).

So the impact of local economy on environmental aspects in relation to water resource management has become a key issue for water managers.

Chapter 3:Estimates and Applied Methods

3.1 General

Supervised classification of TM image was not followed to get the irrigated area of individual farms in the study region. GPS points with field records, Image, and Cadastral map were used to delineate the irrigated area of the farms in GIS operations using ILWIS.

3.2 Field Application

The following materials were used in the field data collection.

a) Handy GPS
b) TM Image 2000
c) Cadastral map
d) WRAP Inventory

A good number of reference points were observed which were clearly identified in the Image and Cadastral Map. Points were observed at each farm boundary (accuracy of Handy GPS was 6 to 7m) and compared immediately with image and cadastral map. Field information on farm production, main crops were recorded and compared with WRAP inventory.

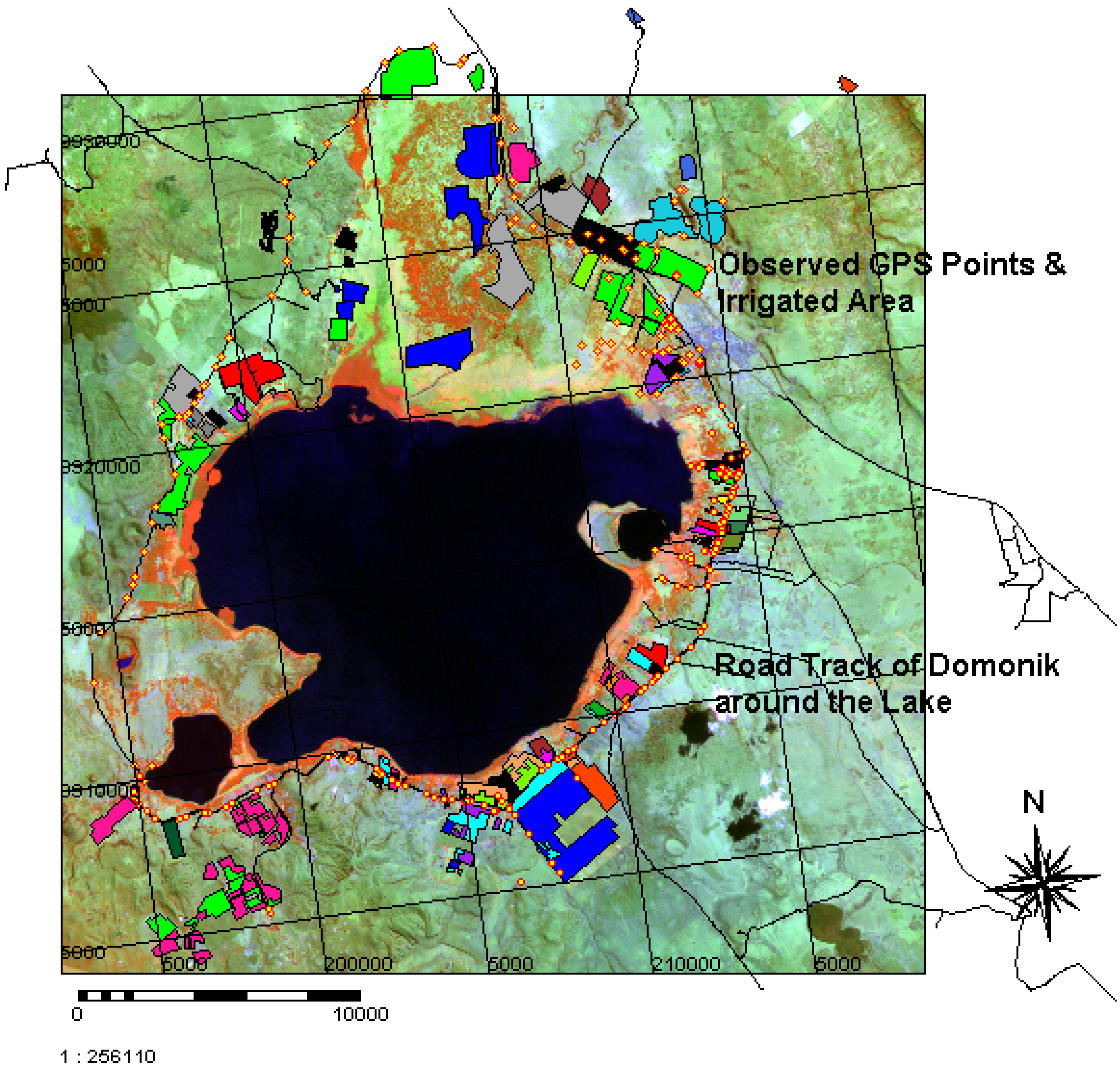
Necessary GPS observations were made to get the irrigated area of each farm. In each observation image and cad map were compared. To get Green House area of each farm due care was taken in GPS observations. Sample observations were also made with GPS for several land cover classes. Information on water abstraction and irrigation application were collected and compared with WRAP inventory.

3.3 Post-Field Work : GIS Applications

3.3.1 Geo-referencing Digitized Caddastral Map

The cadastral map was digitized by the Physical Planning Department, Ministry of Land and Settlements, Kenya. It was not properly geo-referenced with ITC co-ordinate system of Naivasha “Naiv”. Field reference points were successfully applied using ILWIS for geo-referencing cad map with “Naiv”. The geo-referenced Cadastral map and delineated irrigated area using GPS and Image is shown in figure: 3.2.

Figure:3.0 (Showing some of the GPS observation points and Road Track of Dominik using also GPS)

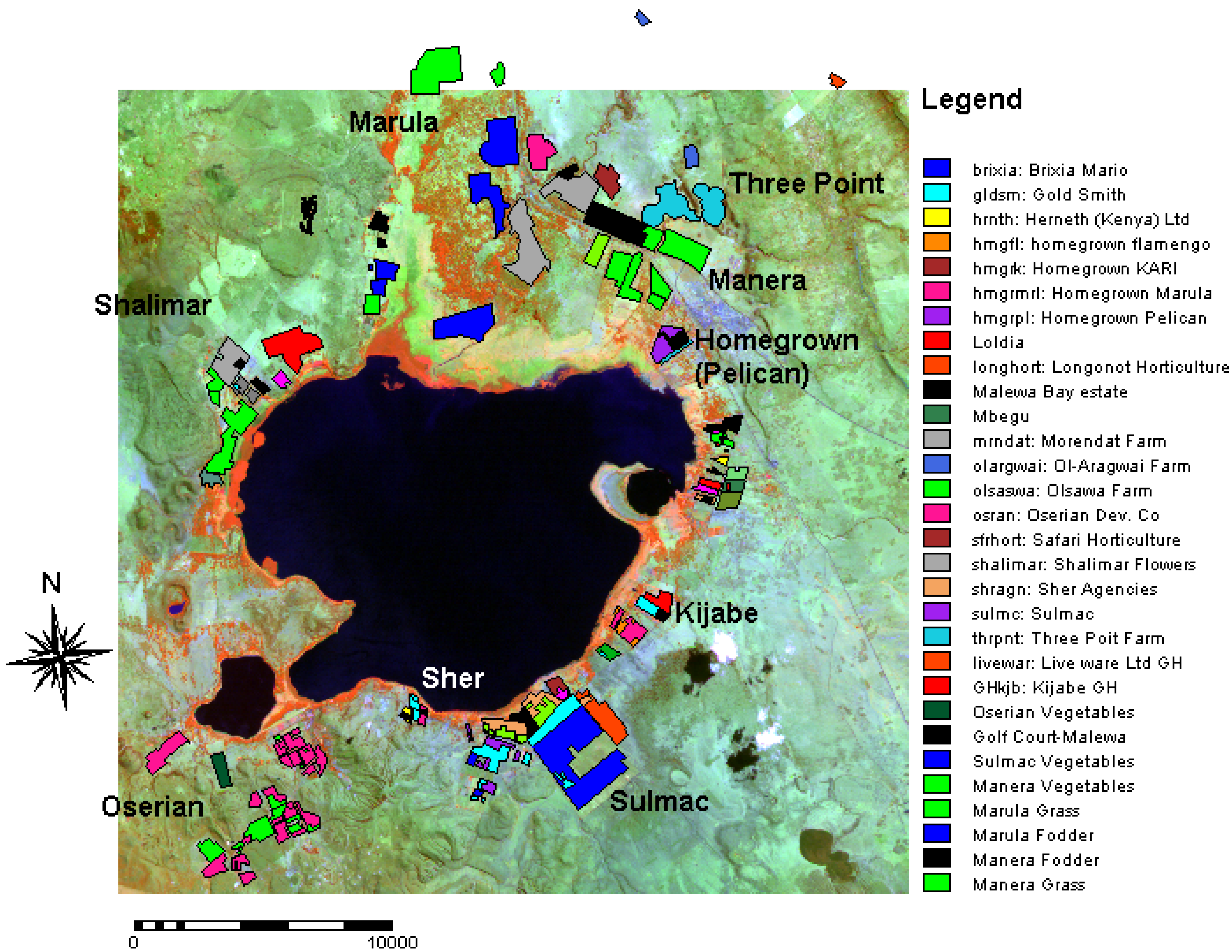


3.3.2 Identifying Water Users

ArcView GIS was used to show the water abstraction points used by each plot of cadastral map. The full inventory of WRAP 1996-97 is used as input table. Common field Land Reference numbers of inventory table and attribute table of cadastral map was linked to show the abstraction poits used by each plot of cad map. The cadastral map was not updated with the recent farm property boundary by the concerned department. The delineated irrigated areas of the farms and WRAP inventory data were used to get the real user of each abstraction ponit.

Figure:3.1 (Estimated Irrigated Area around Lake Naivasha using GPS, TM Image, and cadastral map.

Figure:3.1-Estimated Irrigated Area around the Lake Naivasha using GPS, TM Image and Cadastral Map.

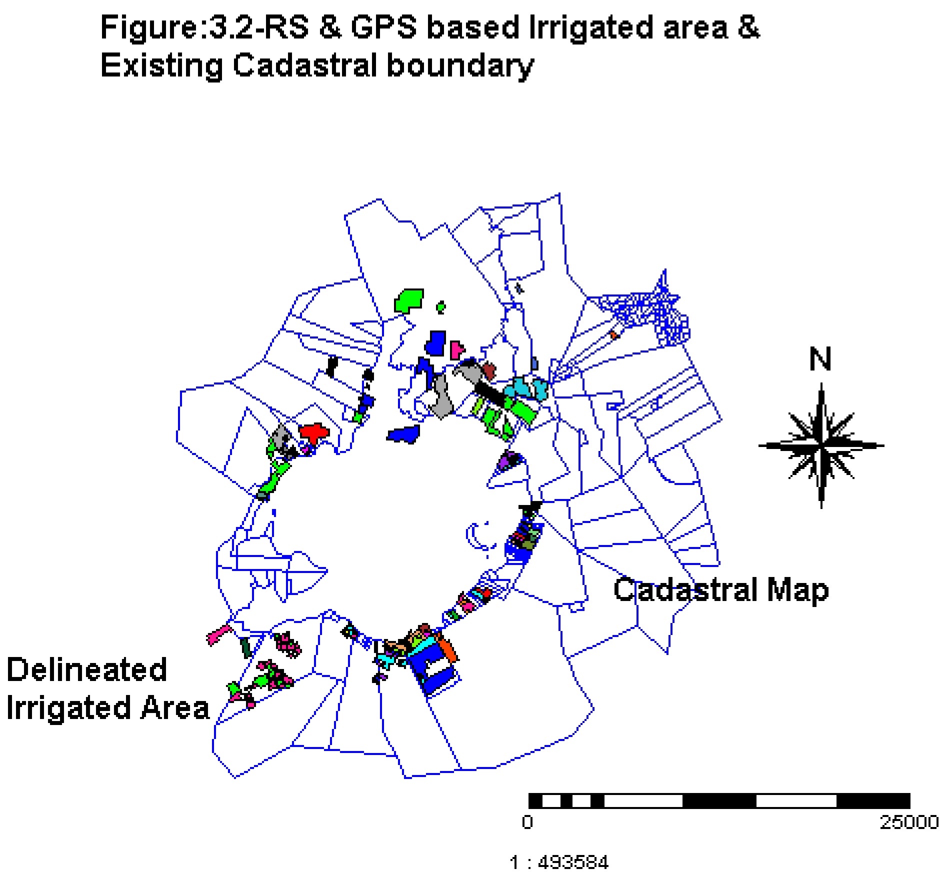


3.3.3 Estimation of Irrigated Area

Dominik Wambua, Ministry of Water Development, Nakuru, Kenya used GPS to get the road track and farm boundary around the Lake.
In ILWIS TM image, Cadastral Map, Road Track of Domonik and point map of observed GPS points were used simultaneously to delineate the irrigated area of each individual

farm using screen digitization in ILWIS. Green House area of individual farms were delineated in the same process. In figure: 3.1 only selected farms are shown in the legend.

Figure:3.2 (RS & GPS based irrigated area and cadastral boundary)



3.3.4 Economic Analysis

The economic analysis of each individual farm has been done with the help of Economic Model developed for this purpose. The detailed analysis of irrigation water requirement, present application of irrigation, production of crops of each farm, crop area of each farm, production cost of crops per hectare per year, gross return of crops per hectare per year and net return of crops per hectare per year of each individual farm in relation to application of unit cubic meter of water have been calculated in this conceptual model. The model has been discussed in detail in chapter 4.

3.3.5 Irrigated Area inside the Lake Riparian Boundary

In figure: 3.2 it can be observed that the irrigated areas are also seen in side the Lake area. The Riparian Boundary is the Lake area corresponding to the Lake level of 1892.70m. The irrigated area inside the riparian boundary has been estimated crossing the raster map of riparian boundary with the estimated irrigated areas. The irrigated area inside the riparian zone was found as 645.3 hectares.

Chapter 4:Economic Model

4.1 General

The economic model has been developed to supply instantly the following outputs upon the entry of necessary changes in the input parameters. Any scenario can be developed upon the single entry of amount of regional rainfall. The final outputs are:

a) Net economic return in US $ and Kenyan Shilling per cubic meter usage of water of each farm in the following three forms;

   i) Net return on the declared abstraction figure to WRAP
   ii) Net return on the current application of Irrigation, and
   iii) Net return expected if consumptive use of irrigation is followed.

b) Other important outputs have been discussed in model component “Return”.

4.2 Model Components

The Model is developed using Microsoft Excel spreadsheet. The following components are developed as single work sheet. Each component is important to get the final outputs and related to each other. The mathematical derivation of the parameters have been presented in the form of equation in the column “math” in each worksheet.

1) **Regional Constants – Contains regional parameters**
2) **Flower – Contains parameters related to crop Flower**
3) **Vegetables – Contains parameters related to crop Vegetables**
4) **Wheat – Contains parameters related to crop Wheat**
5) **Fodder – Contains parameters related to crop Fodder crops**
6) **Grass – Contains parameters related to crop Grass**
7) **Macadamia Nuts – Contains parameters related to crop Macadamia Nuts**
8) **Milk – Contains parameters related to milk production and return with purchased fodder at the rate of calculated market price**
9) **Dairies – Contains parameters related to dairies return with Fodder input at the rate of production cost and the return from Dairies was used to get net return from Fodder crops**
10) **IrrReq – Contains parameters related to irrigation requirement for crops and amount of applied field irrigation.**
11) **Pesticide Price – Contains necessary calculation steps to get the average cost of pesticides applied to the selected main crops.**

12) Farm Data – Contains every necessary data for the farms and most of the input should be done in this sheet.
13) Farm Economics – The economic analysis will be done in this sheet for the individual farms. Needs no input until the model is elaborated or some more output parameter is added to be solved.
14) Returns – Shows the individual farm outputs in short.
15) Analysis – Shows analysis of returns, crop-wise.

4.3 Regional Constants

Contains the following parameters those are applicable in the whole study region.

i) Cost of Electricity
The monthly electricity bill of Delamere Estates as given during field data collection varies from 450,000 to 500,000 Ksh. The yearly bill payment is estimated as
=(450,000+500,000)/2*12=57,00000 Ksh/yr
Yearly abstraction declared=3,432,488 m3 water
Yearly average estimated abstraction=5,240,876 m3 water
The cost of electricity for abstraction of water is estimated as
=(5700000/3432488+5700000/5240876)/2=1.374 Ksh/m3 water
ii) Population
iii) Yearly Rainfall
iv) Cost of fertilizer
v) Cost of pesticides have been entered directly from worksheet “Pesticide Price”
vi) Monetary exchange rate
vii) Standard requirement of water for domestic people, livestock, and wild life are calculated upon the policy of the local Representative of the Ministry of Water Development, which is given below:

Table: 4-I: (Standard Water Requirement, Kenya)

Use	Sub-division	Quantity
Domestic	Urban	227 lt/person day
	Rural	45.5 lt/person day
Livestock	Large	45.5 lt/head day
	Small	9 lt/head day
Wildlife		Same as livestock
Tourism		Same as Urban domestic
Industry		Variable

viii) Standard water requirement for farm population is estimated with the assumption that the domestic population inside the farm is distributed proportionate to the urban and rural population in the whole Naivasha.

Water Requirement per person inside the farm
=% of Rural Population in Naivasha* Domestic Water Req. for Rural + % of Urban Population in Naivasha * Domestic Water Req. for Urban.

Input Parameters for Scenario Development or Final Outputs

1] US $ exchange rate with Kenyan Shilling Ksh
2] Labor Cost per day in US $
3] Population change in Naivasha Town and Rural
4] Cost of fertilizer.

Individual Crop Sheets

Crop sheet of each Individual crop contains the following common main parameters:

i) Labor requirement in workdays/ha.crop, application of fertilizer and pesticide in tons/ha.year and cost of seed/seedling in US $/ha.crop.
ii) Irrigation requirement and present effective irrigation application have been entered directly from worksheet "IrrReq".
iii) Yield, Production cost, Return and Net Return.

4.4 Crop Sheet _ Flower

The following parameters are separate than other Crop sheets.

1] Freight cost – The rates are collected from R.J.Konijn [Konijn, 2000].

Freight Rates for Season is 1.5 – 1.6 US $/Kg & Off-season is 1.3 – 1.5 US $/Kg.
For analysis the average [{(1.5+1.6)/2+(1.3+1.5)/2}/2]=1.475 US $/kg has been used.
The cut flower yield = 27.5 Tons/ha has been used. According to Facts and Figures, Kenya Flowers [05] the production in 1996 was 35,212 tons out of 1280 hectares.
Estimated Freight cost/ha = 27.5*1000*1.475=39,187.5 US $/ha.yr.

2] Cost of Seed/Seedling

It is assumed as 5% of total cost for labor, fertilizer and pesticides.

Cost of seed/seedling=5%*Cost of (labor+fertilizer+pesticides).

3] Cooling Cost of Harvested Flowers

It is taken as 1% of Cost of (labor+fertilizer+pesticides+seed+freight).

4] Cut Flower Price

HCDA statistics in Thoen et al, 2000 as mentioned by [Kinijn, 2000] declared that the return from 30,229 tons of cut flower export in 1998 was little over 80.00 million US $.
So Market price of cut flower=2646.47 US $/ton
For Hectare=Yield/ha*Price/ton=27.5*2646.47=72,777.80 US $/ha.yr.

5] Total cost except cooling cost
= Cost of (labor+fertilizer+pesticides+seed/seedling+freight cost)

6] Total production cost
= Total cost except cooling cost + cooling cost.

Input Parameters for Flower Sheet

i) Labor in workdays/ha.year, application of fertilizer & pesticides in tons/ha.year
ii) Freight cost in US $/ha.year
iii) % of cost for seed/seedlings in the equation of column "value"
iv) % of cost for cooling in the equation of column "value"
v) Cut flower yield in tons/ha.yr
vi) Cut flower price in US $/ha.year

4.5 Crop Sheet _ Vegetables

The following parameters need discussion.

1] **Cost of seed/seedling**=5% * cost of (labor*crops/year+fertilizer+pesticides)
The "crops/year" value has been entered directly from worksheet "IrrReq".

2] **Production cost =**
Cost of (labor*crops/year+fertilizer+pesticides+seed/seedling)

3] **Preservation Cost =** 5%* Production cost*crops/year.
Before supplying to international market harvested vegetables need preservation. The value "crops/year" has been entered directly from worksheet "IrrReq".

4] **Total production cost** = production cost + preservation cost.
5] **Yield/ha.yr =** yield/ha.crop * crops/year

The value “crops/year” has been entered directly from worksheet “IrrReq”.

6] Effective yield in tons/ha.yr

70% of total yield/ha.yr is assumed to be used as effective for return and yield return co-efficient is taken as 0.70.

7] Effective return

=(farm gate price in Ksh/kg)/Exchange rate*1000*effective yield/ha.yr

The value “Exchange rate” has been entered directly from worksheet “Regional constants”.

Input parameters

A] % of cost in the seed/seedling row, “value” column
B] % of cost in preservation cost row. “value” column
C] Yield return co-efficient
D] Farm gate price in Ksh/Kg

4.6 Crop Sheet _ Wheat

1] Cost of Wheat[b+c+d]
=Cost of [labor*crops/yr+fertilizer+pesticide]
The value “crops/yr” has been entered directly from worksheet “IrrReq”.
2] Seed/seedlings = 5%*Cost of Wheat[b+c+d]*crops/yr
The value “crops/yr” has been entered directly from worksheet “IrrReq”.
3] Yield/ha.yr = Yield*crops/yr.
The value “crops/yr.” has been entered directly from worksheet “IrrReq”.
4] Farmgate Price in $ = Framgate price in Ksh/ Exchange rate
The value “Exchange rate” has been entered directly from worksheet “Regional constant”.

Input parameters

A] % Of cost in the seed/seedling row, “value” column
B] Farm gate price in Ksh per ton
C] Return co-efficient

4.7 Crop Sheet _ Fodder

Important Parameters

1] Equivalent L.U.

The equivalent L.U. is estimated here to get the return from the effective yield of wheat in tons/ha.yr. According to [FAO & IIASA, 193] one Livestock Unit consumes 5 tons of fodder crops per year. So the return from effective yield of 22.5 tons of wheat is equivalent to the return from 22.5/5 = 4.5 L.U.

2] **Meat Return per L.U. =** 30 Kg/yr. [FAO & IIASA, 1991]

3] **Dairies Return**
= Net dairies return per L.U. with Dry Matter Intake at the rate of production cost * Equivalent L.U.
The “Net return per L.U.” has been entered directly from worksheet “Dairies”.

4] **Effective Return** = Meat/Protein return + Dairies return.

5] **Market Price of Fodder =** Effective Return/Effective Yield.

It is estimated to get the return from milk production of L.U. with purchased fodder at the rate of market price in the worksheet “Milk”.

6] Cost of [b+c+d]
Same as described in worksheet “Vegetables”.

7] Seed/seedlings
Same as described in worksheet “Vegetables”.

Input Parameters

A] % Of cost in the seed/seedling row, “value” column
B] Yield return co-efficient
C] Average cost of meat/protein in Ksh/Kg

4.8 Crop Sheet _ Grass

Important Parameters

1] **Cost of [b+c+d]**
Same as described in worksheet “Vegetables”.

2] **Seed/seedlings**
Same as described in worksheet “Vegetables”.

Input parameters

A] % Of cost in the seed/seedling row, “value” column
B] Yield return co-efficient
C] Farm gate price in US $/ton

4.9 Crop Sheet _ Macadamia Nuts

Important parameters

A) Total Irrigation Requirement

The yearbook 1996 of South African Macadamia Growers Association has estimated that the total water requirement for macadamia trees is 4000m3/ha.yr. But as the trees are spaced with the density of 200 numbers per hectare only 60% area is needed irrigation water.
Total irrigation requirement = 60%*4000 = 2400m3/ha.yr.

B) **Irrigation Requirement**

As the yearly rainfall during average years is 6080m3/ha.yr, the macadamia nut trees in the study region need no irrigation during average and wet years. The irrigation requirements and applied irrigation have been entered directly from worksheet “IrrReq”.

C) **Production Cost**

The total production cost of macadamia nuts is calculated by the South African Macadamia Growers Association as 1600 South African Rand / ha.yr. The conversion factor for Rand with US $ is 7.835.

D) **Farm gate price**

The farm gate price is taken form the paper “Challenges for horticulture in the tropics: Proceedings of the third Australian society of horticultural science and the first Australian Macadamia society research conference, Broad Beach, Gold Coats, Australia 18-22 August 1996:207-212.

Input parameters

1] Production cost in US $/ha.yr
2] No of trees produced per hectare
3] Macadamia production in Kg/tree
4] Farm gate price in US $
5] Percent of productive trees

4.10 Work Sheet _ Dairies

This sheet has been prepared to get the net milk return from livestock units with supplied fodder from native farm to get the net economic return from fodder crops. This sheet contains parameters regarding net return from milk production of each livestock unit (L.U.) with Dry Matter Intake (DMI) supplied at the rate of production cost. This net return from milk production of each L.U. is added to the meat/protein return of each L.U. in the worksheet “Fodder” to get the Effective return from fodder crops.

Important Parameters

1] Production cost of fodder per ton
= (Production cost of fodder/ha.yr)/(Effective Yield/ha.yr)
It has been entered directly from worksheet “Fodder”.

2] Total cost per L.U.
= Labor cost + Cost of DMI

The production cost of fodder is taken here to get the feeding cost of L.U. in estimating the net return from milk production and this net return from milk is added to protein return in the estimate of return from fodder crops.

Input Parameters

i) Production of milk per day per L.U. in litres
ii) Price of milk in Ksh/Litre
iii) Effective number of productive days per L.U. per year
iv) Percentage of productive L.U.
v) Number of labors required per L.U. per year
vi) Cost per labor per day in Ksh
vii) Dry Matter Intake per L.U. in tons

4.11 Work Sheet _ Milk

This sheet has been prepared to get the net return from milk production of each L.U. by feeding them with fodder crops purchased at the rate of market price. Thus the returns from the dairy farms will be estimated for fodder crops and milk production separately. As a matter of fact some farms need to purchase fodder even after their own fodder production. So this separate estimation of return from fodder and milk will make the calculation easier.

The important parameters

1] Market Price of Fodder per Ton

As the returns from fodder production has been calculated separately, here market price of fodder has been used to calculate the production cost of milk per L.U. This parameter has been entered directly from worksheet “Fodder”.

Input parameters

A] Production of milk per day per L.U. in litres
B] Price of milk in Ksh/Litre
C] Effective number of productive days per L.U. per year
D] Percentage of productive L.U.
E] Number of labors required per L.U. per year
F] Cost per labor per day in Ksh
G] Dry Matter Intake per L.U. in tons

4.12 Work Sheet _ IrrReq

This sheet has been prepared to estimate supplementary irrigation water requirement and currently applied effective irrigation in m3/ha.year for the enlisted main crops Flower, Vegetables, Wheat, Fodder Crops, Grass and Macadamia Nuts.

Important Parameters

1] Required number of days for irrigation per year
The numbers of days have been estimated comparing field data and out lines given in FAO 33.
2] Crops per year
Estimated on the basis of field information.
3] Etact – Actual Evapotranspiration
The actual evapo-transpirations for the crops have been calculated for the study area [Mekonnen 1999]. The actual evapotranspiration for the year for each crop is estimated by multiplying Etact in mm/day by the required number of days for irrigation per year.
Etact (mm/year) = Etact (mm/day) * Irr.Req. (Days/year)
Etact (m3/ha.yr) = Etact (mm/year) * 10
Rainfall (m3/ha.yr) = Regional Rainfall (mm) * 10
The value "Regional rainfall" has been entered directly from worksheet "Regional constants".

4] Assumed Effective Rainfall (m3/ha.yr)
= (Irrigation Reqd (days/yr.)/ 365) * Rainfall (m3/ha.yr)

To get estimate of supplementary irrigation requirement, it has been assumed that the crop concerned will get rain water of yearly rainfall proportionate to the number of required irrigation days to the number of days in a year.

5] Irrigation Water Requirement (m3/ha.yr)
= Etact (m3/ha.yr) – Assumed Effective Rainfall (m3/ha.yr)
The assumed effective rainfall has been deducted from the actual evapotranspiration to estimate the supplementary irrigation water requirement.

6] Applied Irrigation (mm/day)

The figures are based on field information.

7] Applied Irrigation (mm/year)

= Applied Irr (mm/day) * Irrigation Required (days/yr.)

8] Applied Irrigation (m3/ha.yr)

= Applied Irrigation (mm/year) * 10

9] Effective Applied Irrigation (m3/ha.yr)

= Applied Irrigation (m3/ha.yr) – Assumed Effective Rainfall (m3/ha.yr)

To get the effective application of irrigation water the assumed effective rainfall has been subtracted from the current rate of application.

Input Parameters

A] Irrigation Required (days/yr.)
B] Crops/Yr.
C] Etact (mm/day)
D] Applied Irrigation (mm/day)

4.13 Worksheet_ Pesticide Price

This worksheet has been used to get the average cost of pesticide application for the listed main crops. All the information have been collected from “”Data Collection and Field Work Notes, Kenya from 7/9/200 to 2/10/2000” by [Janeth Moncada, 2001].
The amount of application of fungicides, insecticides, nematicides and miticides for flower and vegetables per ha per year in units’ kg and litres has been collected there with respective costs in Kenyan Shilling. The amounts in litres of the agro-chemicals have been transformed to kg using the specific gravity 1 Litre=1.3 Kg [Salah, 1999]. The costs have been transformed to US $. Using the total amount of application in kg and costs in US $, the average application rate of pesticides per ton has been estimated for flower and vegetables.

Wheat production uses herbicides instead of miticides as per field information. Total amount of pesticide needed for wheat per ha per year was collected from [Huaccho, 1998].
This amount was distributed among the pesticide contents according to the field information. The average cost per ton of pesticide for wheat was calculated with the price of each content estimated earlier in kg/US $. The unit price of herbicide was collected from “Table-1, US and World Pesticide Sales at user level, 1997 Estimates, Pesticide Industry Sales and Usage: 1996 and 1997 Market Estimates, EPA, US Environmental protection agency”.

For fodder crops and grass application of herbicides and nematicides are equal as per field information. The average cost per ton was calculated with this information.

This sheet contains the main data collected from the field, necessary WRAP inventory data and the results of irrigated area, area per main crop, domestic, livestock, wildlife number, abstraction points and total abstraction for each individual farm.

4.14 Worksheet _ Farm Data

This sheet contains the main data collected from the field regarding crop information on individual farms, necessary WRAP inventory data regarding location and identity of each abstraction point and the concerned owner, and the estimated open & GH irrigated area in the present study compared to WRAP figures, area per main crop, and domestic, livestock, wildlife number for each individual farm as declared to WRAP.

The surface water abstraction points have been denoted as SW and ground water abstraction points as BH followed by their serial number. The abstraction points belonging to the same owner have been arranged together.

The main information is as below:

4.14.1 WRAP Data

1] Abstraction points belonging to the same farm
2] Name of the farm
3] Land reference number, farm size, irrigated area, source of water for abstraction, UTM co-ordinates of each abstraction point, identified main crops, number of people, livestock, wildlife, and abstraction amount for industrial purpose, estimated abstraction rate in m^3/sec, estimated total time for abstraction per year in seconds and the amount of abstraction in m^3/year. All these information are based on each abstraction point and surveyed by WRAP.

4.14.2 Study Data

1] Land reference number according to cadastral map of the Ministry of Lands and Settlements, Kenya.
2] Farm size of each farm according to the cadastral map.
3] Estimated GH and open irrigation area of each farm using study results.
4] Identified main crops and estimated irrigated area per main crops of each individual farm in hectares.
5] Total irrigated area of each farm in hectares.
6] Total abstraction amount of each individual farm by adding amounts of individual abstraction points belonging to each farm.
7] Addition of seven new farms.

Input Parameters

1] Estimated open irrigated area for the main crops for each individual farm.
2] Estimated Green House area for each individual farm.

4.15 Worksheet _ Farm Economics

The calculation and analysis on net returns for each individual farm have been done here. The parameters are discussed below. Each parameter will belong to individual farms.

4.15.1 Farm name

4.15.2 WRAP survey information on

- Cadastral number
- Farm size in hectare
- People (number)
- Livestock units (number)
- Industrial water abstraction (m^3/year)
- Irrigated area (ha)
- Main crops
- Identity of abstraction points
- Total abstraction

All the parameters have been entered directly from worksheet "Farm Data".

4.15.3 Study Data

- Cadastral area (ha)
- Land use type e.g. natural, uncultivated, built-up and cultivated
- Land use area (ha)
- Open Irrigated area, GH area and rain-fed area of main crops and total area of main crops. Open and GH irrigated area have been entered directly from worksheet "Farm Data".
- Net profit for each crop (US $/year) = irrigated crop area (ha)*net profit (US $/ha.year). Net profit/ha.year has been entered directly from concerned individual crop-sheet.
- Net profit from milk production (US $/year) = L.U. (number)*net return per L.U. Net return per L.U. has been entered from worksheet "Milk".
- Net total profit (US $/year) = Total of net profit from crops + net profit from milk.
- Irrigation water requirement of each crop (m^3/yr) = irrigated area (ha)*Irrigation requirement (m^3/ha.year). Irrigation requirement (m^3/ha.yr) has been entered directly from concerned crop-sheet.
- Net total irrigation requirement (m^3/yr) = sum of irrigation requirement of each crop.

- Water requirement for people, L.U., and wildlife (m^3/yr) = Concerned number * water requirement for concerned type (m^3/head.yr). Concerned water requirement (m^3/head.year) has been entered directly from worksheet "Regional constants".
- Water Usage other than irrigation (m^3/Yr) = water requirement for people, L.U. and wildlife (m^3/yr) + Industrial abstraction (m^3/yr)
- Net total Usage of water (m^3/yr) = Net total irrigation requirement (m^3/yr) + Water usage other than irrigation (m^3/yr)
- Expected Net Return (US $/m^3 Water) = Net total profit (US $/yr.)/Net total usage of water (m^3/yr)
- Net return on Abstraction (US $/m^3 Water) = Net total profit (US $/yr.)/Total Abstraction (m^3/yr)
- Applied Irrigation water of each crop (m^3/yr) = irrigated area (ha)*Applied Irrigation (m^3/ha.year). Applied Irrigation (m^3/ha.yr) has been entered directly from concerned crop-sheet.
- Total Applied irrigation (m^3/yr) = sum of applied irrigation of each crop.
- Total Usage With Applied Irrigation (m^3/yr) = Total Applied irrigation (m^3/yr) + Water Usage other than irrigation (m^3/Yr)
- Net Actual Return/Net Return on Usage with Applied Irr (US $/m^3 Water) = Net total profit (US $/yr.)/Total usage with applied irrigation (m^3/yr)
- Application Times of Irrigation = Applied Irrigation (m^3/yr)/Net Irrigation Requirement (m^3/yr)

Input Parameters

This Worksheet needs no input.

4.16 Worksheet _ Returns

This worksheet summarizes the main outputs **for each individual farm** developed in the worksheet "Farm Economics" in the following order:

1) Total abstraction WRAP figure (m^3/yr)
2) Total Applied Irrigation (m^3/yr)
3) Total Supplementary Irrigation Requirement (m^3/yr)
4) Total Irrigated Area (ha)
5) Net Total Return (US $/Year)
6) Actual Return (US $/m^3 Water) = Net Total Return (US $/Year)/ Total Applied Irrigation (m^3/yr)
7) Expected Net Return (US $/m^3 Water) = Net Total Return (US $/Year)/ Total Supplementary Irrigation Requirement (m^3/yr)
8) Net Return (US $/ha) = Net Total Return (US $/Year)/ Total Irrigated Area (ha)
9) Water Usage Other Than Irrigation (m^3/year)

10) Water Usage with Applied Irrigation (m^3/yr) = Total Applied Irrigation (m^3/yr) + Water Usage Other Than Irrigation (m^3/year)
11) Water Usage with Required Irrigation (m^3/yr) = Total Supplementary Irrigation Requirement (m^3/yr) + Water Usage Other Than Irrigation (m^3/year)
12) Net Return on Usage with Applied Irrigation (US $/m^3 Water) = Net Total Return (US $/Year)/Water Usage with Applied Irrigation (m^3/yr)
13) Net Expected Return on Usage = Net Total Return (US $/Year)/ Water Usage with Required Irrigation (m^3/yr)
14) Net Return on Usage with Applied Irrigation (Ksh/m^3 Water)
15) Net Expected Return on Usage (Ksh/m^3 Water)

In the bottom row named "Regional Aspects" the summation of the above parameters will be presented to give the overall view in the region except parameters 6), 7), 8), 12), 13), 14), and 15). For these parameters average value for the region have been calculated using summation of nominator and denominator.

Input Parameter

No input required.

4.17 Worksheet _ Analysis

This worksheet has been used to analyze output parameters for detailed discussion on results obtained on net returns, irrigation requirement, and applied irrigation crop-wise. It gives the following outputs for main crops open flowers, GH flowers, vegetables, fodder, wheat, grass and macadamia nuts depending on the amount of regional rainfall.

1) Area (ha)
2) Net return (US $/ha.year)
3) Total Return (US $/year) = Area (ha)* Net return (US $/ha.year)
4) Required Irrigation (m^3/ha.yr)
5) Applied Irrigation (m^3/ha.yr)
6) Total Required Irrigation (m^3/yr) = Area (ha)* Required Irrigation (m^3/ha.yr)
7) Total Applied Irrigation (m^3/yr) = Area (ha)* Applied Irrigation (m^3/ha.yr)
8) Net Return Applying Required Irrigation (US $/ m^3 Water) = Total Return (US $/year)/ Total Required Irrigation (m^3/yr)
9) Net Return on Current Applied Irrigation (US $/ m^3 Water) = Total Return (US $/year)/ Total Applied Irrigation (m^3/yr)

4.18 Scenario Generation

The Economic Model can be used to develop following scenarios:

4.18.1 Average, Wet, and Dry Year Scenarios

To get the above discussed all the output parameters for the mentioned years only one input is required. If other parameters are accepted for analysis for any type of year mentioned above, only the required input will be “Regional rainfall in (mm)” in the worksheet “Regional Constants”.
The average rainfall of the lake vicinity for the period 1931-1960 was 608mm with a variation round the mean from 442 to 939mm (East African Meteorological Dept.1966, after Ase 1986).
In the present study dry, average, and wet years have been assumed with respective regional rainfall amount of 442, 608 and 939mm.

4.18.2 Scenario Development for any specified period

To create scenario for any period of time e.g. for any cropping period, only the parameter “Irrigation Required (days/year)” will require input.

Chapter 5:Results and Discussion

5.1 Estimated Irrigated Area

A comparison of results obtained on irrigated area (all figures in ha) in different studies is placed below:

Table: 5- I (Estimated Irrigated Area)

Crops	WRAP 96-97	Huaccho 1998	Salah 1999	Present Study
Flowers GH			1020	614
Flowers Open	1280	3598	180	952
Vegetables	1041	2511	600	1623
Macadamia	440	-	-	361
Wheat	140	231	25	164
Fodder	656	728	1943	756
Grass	24	285	800	561
Total	3581	7353	4568	5031

The irrigated area of Salah 1999 refers to the entire Naivasha catchment. The irrigated area of WRAP, Huaccho 1998 and the present study refer to the irrigated area around the lake vicinity. The irrigated area of Huaccho and Salah were obtained using supervised classification of TM Image of 21st January 1995. WRAP entered irrigated area of individual farms during their project 1996-97 based on field visits.

The total irrigated area around the lake is found as 5031 hectares in the present study.

5.1.1 Observations

It can be observed that irrigated area of vegetables, flowers and grass have increased considerably in the present study compared to WRAP figures. The total figure of present study is also higher than WRAP figure.

During the survey of WRAP, the following farms and their irrigated areas were not entered:

Table: 5- II (Irrigated Area of New farms)

Farm	Main Crop	Irrigated Area (ha)
Herneth (Kenya) Ltd.	Flowers	15.52
Homegrown (Flamingo)	Flowers	72.24
Noordam Roses	Flowers	13.42
Wild Fire	Flowers	41.02
Live Ware Ltd.	Flowers	17.34
Raymonde	Flowers	19.29
Three Point Farm	Vegetables	253.25
Total		432.08

Reasons found for increased vegetable production are:

a) Low investment (Total production cost= 2066 US $/ha.yr) compared to flower (43,954 US $/ha.yr)
b) Reasonable net profit (9054 US $/ha.yr).

Other major observations on changes of irrigated areas are given in table: 5-III:

Table: 5-III (Farms with Extended Irrigated Area)

Farm	Crop	WRAP(ha)	Present Study(ha)
Homegrown-KARI	Vegetables	9.0	62.32
Marula Estates	Fodder, grass	373.93	687.14
Delamere Estates	Fodder, vegetables	285.00	523.49
R.Wilcock/Mbegu	Flowers	7.00	43.03
Nyanjugu	Flowers	2.00	33.86
Northlake Nursery	Flowers, vegetables	1.40	51.30
Sulmac Flowers	Flowers, vegetables	521.00	623.25
Longonot Horticulture	Vegetables	1.20	121.50
Homegrown Marula	Vegetables	20.23	84.10
Osirua/Kijabe	Flowers	20.00	39.78
Nini	Flowers	18.00	37.98
Total		1258.76	2307.75

The above figures of present study are quite reasonable with the field observations made in September 2000. All the farms listed above have extended their irrigated areas after the WRAP survey 96-97.

The trend of increase in flower production as presented by R.J.Konijn [Konijn, 2000] of Wageningen School of management, in his MBA thesis is placed below:

Table: 5-IV (Trend of increase in Flower Production)

Flower	1991(ha)	1993(ha)	1995(ha)	1997(ha)
Rose	47	145	210	550
Alstromeria	50	115	160	180
Spray Carnations	220	185	180	140
Statice(Limonium spp)	118	180	225	85
Standard Carnations	27	48	54	61
Solidster	3	35	50	55
Bupleurum	0	45	50	50
Cut Foliage	16	30	38	45
Chrysan. Cuttings	9	11	10	41
Tuberose	10	22	35	40
Lisianthus	-	-	14	20
Other	138	170	303	343
Total	638	986	1329	1610

The irrigated area of flower in the present study is found as 1566 hectares.

It is also observed that some farms have not extended their irrigated areas after the WRAP survey 96-97 noticeably:

Table: 5-V (Farms without Extension in irrigated Area)

Farm	Crop	WRAP(ha)	Present Study(ha)
KARI-Kenya Agri. Research	Vegetables	40	46.36
Hortitek	Flowers	2	2.80
Loldia	Wheat, fodder	148	159.32
Brixia	Vegetables	78.90	69.25
Olsuswa	Fodder	242.8	191.50
Shalimar	Flowers	120	113.78
Aberdare	Vegetables	21.20	23.79
Boffer	Vegetables	24	18.76
Mwangi Gateri	Vegetables	7.20	8.76
Amoroso/G.N.Nursery	Flower, vegetables	15	14.89
Goldsmith	Flowers	20.20	25.43
Oserian	Flowers	633.40	636.78
Total		1352.70	1311.42

From above discussions and comparisons, the total irrigated area and irrigated area of main crops and irrigated area of each individual farm as estimated in the present study looks quite reasonable.

5.2 Estimated Abstraction

5.2.1 Results of previous studies:

Table: 5-VI (Results of previous studies on Irrigated area and Irrigation need)

WRAP 1996-97		Huaccho 1998		Salah 1999		
Area(ha)	Abstraction ($m.m^3/y$)	Area(ha)	Theoretical Need ($m.m^3/y$)	Area(ha)	Theoretical Need ($m.m^3/y$)	Applied Irrigation ($m.m^3/y$)
3581	49.06	7353	23.72	4568	43.46	71.56

Salah calculated theoretical water requirement for irrigating total 4568 hectares area using actual evapotranspiration of crops estimated from regional crop co-efficient that calculated by Mekonnen 1999. The figure 43.46 m. m^3/yr is not supplementary irrigation water requirement. The figure of applied irrigation 71.56 m. m^3/yr includes the yearly rainfall. The WRAP figure for irrigated area was shown as 5100 (ha) in [Huaccho, 1998]. During present study it is found that 1954.7 (ha) irrigated flower was entered inadvertently against Sulmac Flowers Company. The abstraction figure of WRAP in [Huaccho, 1998] was 40.19. In the present study abstraction from boreholes are also added to the abstraction amount of each farm and the figure is 49.06 million m^3.

5.2.2 Results obtained in the present study:

Table: 5-VII (Irrigation need, Applied irrigation, Total usage of water)

Area	Wet Year		Average Year		Dry Year	
5031 (ha)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)
Only Irrigation	12.32	50.87	24.68	63.67	31.26	70.47
Other Purposes	1.51	1.51	1.51	1.51	1.51	1.51
Total Usage	13.83	52.38	26.20	65.18	32.77	71.98

The wet, average and dry years have been considered as per rainfall condition expressed in [Ase, 1986]. The average rainfall of the lake for the period 1931-1960 was 608mm with a variation round the mean from 442 to 939 mm (East African Meteorological Dept.1966, after Ase 1986).

The total excess abstraction than actual requirement for three scenarios is
Wet year=52.38-13.83=38.55 m. m^3 **/yr.**
Ave year=65.18-26.20=38.98 m. m^3**/yr, and**

Dry year=71.98-32.77=39.21 m. m^3**/yr.**

5.2.3 Lake Water Balance

Table: 5-VIII{Long-term (1932 to 1997) water balance of [Gitonga, 1999]}

Month	Disch. (m.m^3)	Rain (m.m^3)	GW in (m.m^3)	GW out (m.m^3)	Evap. (m.m^3)	Storage (m.m^3)	Level (m)
January	11	4.87	0.0948	4.6	25.4	-14.0	-0.097
February	8.03	5.32	0.272	4.6	24.2	-15.0	-0.103
March	9.19	8.12	0.323	4.6	26.5	-14.0	-0.097
April	21.9	1.69	0.300	4.6	20.8	14.0	0.097
May	34.7	1.16	-0.116	4.6	22.2	19.0	0.131
June	20.1	6.81	-0.339	4.6	20.2	1.80	0.012
July	19.8	5.73	-0.139	4.6	20.3	0.42	0.003
August	24.1	6.79	-0.067	4.6	22.0	4.20	0.029
September	22.1	7.15	-0.125	4.6	23.2	1.60	0.011
October	19.3	7.89	-0.0846	4.6	24.5	-1.90	-0.013
November	19.8	9.22	0.0138	4.6	19.6	4.90	0.034
December	13	6.12	-0.0649	4.6	22.3	-7.90	-0.054
Total	223	70.87	0.068	55.2	271.2	-6.88	-0.047

It can be observed that at the end of year of long-term water balance, the storage is loss of 6.88 m. m^3/year and the drop in Lake Level is 47mm/year. The average lake surface area was used as 145 km^2. With this lake surface area and rainfall of 70.87 million m^3, the long-term average rainfall comes as 489mm.

5.2.4 Abstraction from the Lake

The abstraction figure with 489mm rainfall in the present study will be as follows:

Average Abstraction = 70.05 m.m^3/yr

Using the parameters regarding water balance of [Gitonga, 1999] of Lake Naivasha discussed above the following balance has been achieved.

Table: 5- IX (Long Term Water Balance of Lake Naivasha)

Water Balance

Inputs (m. m^3)		**Ave Year**
Rainfall		70.87
River Inflows		
	Malewa	
	Gilgil	
	Karati	
	Total	223
GW Inflow		0.068
Total Inputs		**293.94**
Outputs (m.m^3)		**Ave Year**
Evaporation		271.2
GW Outflow		55.2
Abstraction		70.05
Total Outputs		396.45
Balance (m. m^3)		-102.51
Equivalent Drop in level (m)		0.707

The balance shows that the drop in Lake level with respect to long term water balance figure of [Gitonga, 1999] is 0.707m.
The contribution of abstraction by the farms in the outflow of lake-water balance is 18%.

5.3 Economic Returns and Usage of Water

5.3.1 Regional Aspects: Economy

The yearly net return from the irrigated and dairy farms = 63.95 million US $
Overall Net return/ha = 12,711 US $

Table: 5-X (Regional Net returns on usage of water)

Year	Net total water Requirement (m. m^3/yr)	Actual Usage of water (m. m^3/yr)	Expected Net return US $/ m^3 water	Net Current return US $/ m^3 water
Wet	13.83	52.38	4.62	1.22
Average	26.20	65.18	2.44	0.98
Dry	32.77	71.98	1.95	0.89

The table shows that the economic value of lake water in the lake vicinity is 2.44 US $/ m^3 of water for normal period. Due to excess application of irrigation water the economic value of lake-water comes down to 0.98 US $/ m^3 of water.

During wet years the economic value of water goes up 189% and during dry year it comes down 80% compared to average years.

5.3.2 Regional Aspects: Usage of Water and Excess Abstractions

Dry year = 71.98-32.77 = 39.21 m. m^3/yr
Ave year = 65.18-26.20 = 38.98 m. m^3/yr
Wet year = 52.38-13.83 = 38.55 m. m^3/yr

These excess abstractions can be valued in net economic loss in terms of wastage of water at the present rate of return as follows:

Dry year =39.21*0.89 = 34.90 million US $
Ave year = 38.98*0.98 = 38.20million US $
Wet year = 38.55*1.22 = 47.03 million US $

The difference of excess abstraction between dry and wet year is only 1.33 m. m^3 of water. The reason behind it, is:
The field application of irrigation for Green Houses does not vary due to season and the application rate is quite high compared to other crops.

5.3.2.1 Surface Abstraction from Lake Naivasha

According to the survey of WRAP 96-97 the direct surface water abstraction from Lake Naivasha is **32.50 million** m^3**/yr** with total abstraction around the lake vicinity **49.06** million.
Present rate of abstraction for average years is estimated regarding long-term water balance of [Gitonga, 1999] as 70.05 million and assuming proportional increment in abstraction from lake the current figure of **direct lake water abstraction is (32.50/49.06*70.05) = 46.40 million** m^3**.**

5.3.3 Causes behind excess abstraction and irrigation

i) The commercial flower and vegetable farms believe that a simple shortage of application can lead to less production and less profit.

ii) During field visit they explained that the excess irrigation goes back to the lake as seepage and the result is good quality water.

iii) Due to excess application of water hazards of fertilizer and pesticide application to the land quality decreases.

iv) Overall the stability of lake level in recent years.

5.3.4 Regional Water Use/Irrigation Efficiency

Table: 5- XI(Regional Irrigation need and Application)

Area	Wet Year		Average Year		Dry Year	
5031 (ha)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)	Net Need (m. m^3/yr)	Applied (m. m^3/yr)
Only Irrigation	12.32	50.87	24.68	63.67	31.26	70.47

One of the irrigation efficiency indices is to divide the theoretical supplementary irrigation water requirements by the actual water use [Meneti, 1990] for the irrigated agriculture. So the obtained efficiencies are:
Wet year = 24%
Ave year = 38.76%
Dry year = 44.4%

5.3.5 Crop Economy: Average Years

Table: 5- XII(Crop-wise Returns, Irrigation need, and application for average year)

Average year			Total	Reqd	Applied
Crops	Area	Net Return	Return	Irrigation	Irrigation
	(ha)	US $/ha	M.US $	M.M^3	M.M^3
Flower Open	952	28824	27.45	6.37	22.01
Flower GH	614	28824	17.69	4.03	11.20
Vegetables	1623	9054	14.70	8.22	20.54
Fodder	756	1097	0.83	3.08	4.58
Wheat	164	613	0.10	0.69	1.51
Grass	561	219	0.12	2.29	3.40
Macadamia Nuts	361	5924	2.14	0.00	0.44
Total Agriculture	5032	12525	63.02	24.68	63.67

Table-5-XII shows the net economic returns from main irrigated crops in average years.
Net return on regional scale from agriculture = 12,525 US $/ha.yr

The net return from flowers = 45.05 million US $ (72% of total agricultural net return)
The water used for flower = 33.21 million m^3 (52% of total irrigation water)

The net return from vegetables = 14.70 million US $ (23% of total agricultural net return)
The water used for vegetables = 20.54 million m^3 (32.26% of total irrigation water)

Water Use/Irrigation Efficiency
Open Flower = 29%
GH Flower = 36%
Flower as a whole = 31%
Vegetables = 40%
Fodder = 67%
Wheat = 46%
Grass = 67%
Macadamia Nuts = (It does not need irrigation other than dry year)
Total irrigation efficiency = 38.8%

5.3.6 Crop Economy: Dry Years

Table: 5- XIII(Crop-wise Returns, Irrigation need, and application for dry year)

Dry year	Total	Reqd	Applied	Irrigation
Crops	Return	Irrigation	Irrigation	Efficiency
	M. US $	M.m^3	M.m^3	%
Flower Open	27.45	7.96	23.60	34
Flower GH	17.69	4.03	11.20	36
Vegetables	14.70	10.65	22.97	46
Fodder	0.83	4.22	5.71	74
Wheat	0.10	0.90	1.71	52
Grass	0.12	3.13	4.24	74
Macadamia Nuts	2.14	0.38	1.04	37
Total Agriculture	63.02	30.88	70.47	44

The net return/ha and total return are assumed same for any year. The prices of crops go up during dry years. The production may come down a little bit. During wet years production may go up. So assumption of same net return/ha and total return will be a good alternative.

Table-5-XIII shows the net economic returns from main irrigated crops in dry years.

The net return from flowers = 45.05 million US $ (72% of total agricultural net return)
The water used for flower = 34.8 million m^3 (49% of total irrigation water)

The net return from vegetables = 14.70 million US $ (23% of total agricultural net return)
The water used for vegetables = 22.97 million m^3 (32.6% of total irrigation water)

5.3.7 Crop Economy: Wet Years

Table: 5-XIV(Crop-wise Returns, Irrigation need, and application for wet year)

Wet year	Total	Reqd	Applied	Irrigation
Crops	Return	Irrigation	Irrigation	Efficiency
	M.US $	M.M^3	M.M^3	%
Flower Open	27.45	3.22	18.86	17
Flower GH	17.69	4.03	11.20	36
Vegetables	14.70	3.36	15.68	21
Fodder	0.83	0.82	2.31	35
Wheat	0.10	0.28	1.10	26
Grass	0.12	0.61	1.72	35
Macadamia Nuts	2.14	0.00	0.00	
Total Agriculture	63.02	12.32	50.87	24

Table-5-XIV shows the net economic returns from main irrigated crops in wet years.
The net return from flowers = 45.05 million US $ (72% of total agricultural net return)
The water used for flower = 30.06 million m^3 (59% of total irrigation water)

The net return from vegetables = 14.70 million US $ (23% of total agricultural net return)
The water used for vegetables = 15.68 million m^3 (31% of total irrigation water)

5.3.8 Irrigation Efficiencies Compared to % of Applied Irrigation

Table: 5-XV (Crop-wise Irrigation Efficiencies Compared to % Applied Irrigation)

Crops	Average year	Applied Irr	Dry Year	Applied Irr	Wet Year	Applied Irr
	Efficiency (%)	% Used	Efficiency (%)	% Used	Efficiency (%)	% Used
Flower Open	29	37	34	33	17	35
Flower GH	36	22	36	16	36	18
Flower Overall	31	51	35	49	24	59
Vegetables	40	31	46	33	21	32
Fodder	67	5	74	8	35	7
Wheat	46	2	52	2	26	2
Grass	67	3	74	6	35	5
Macadamia Nuts	Not reqd	0.00	37	2	Not reqd	1
Total Agriculture	39	100.00	44	100.00	24.00	100.0

Table-5-XV shows that Out of total applied irrigation water flower sector uses over 50% and vegetable sector uses over 30% water. These two sectors are utilizing over 80% of the total abstracted and irrigated water.

It can be observed that the irrigation efficiency decreases during wet periods. The reason is, the reduction of theoretical supplementary irrigation need during wet period is high, but the farms do not reduce their field application up to expectation with proper technical information. So the difference between application need and field application increases and the efficiency reduces.

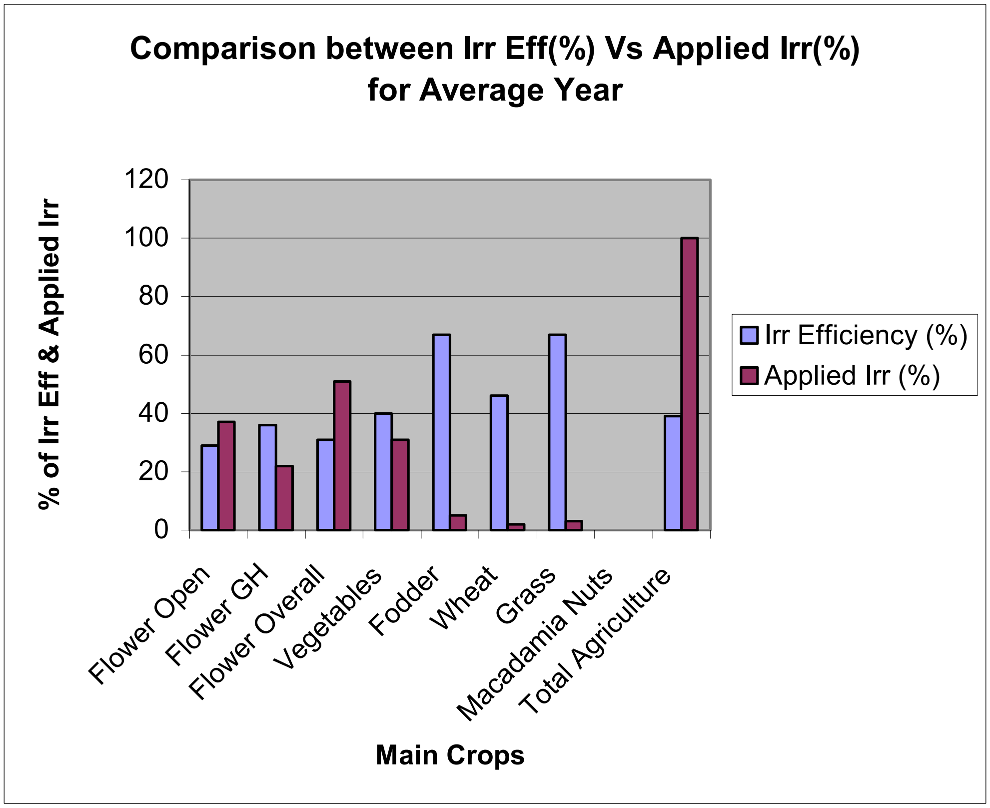


Figure: 5.1 (Comparison between Irrigation efficiency (%) and applied irrigation (%) for the Crops)

The comparison column graph for average years shows clearly that using 50% of the total abstracted irrigation water flower sector has achieved only 30% irrigation efficiency.

The vegetable sector has achieved 40% efficiency using 30% of irrigation water. Irrigation efficiency of fodder and grass production is over 65% and they are using only 8% of irrigation water.

5.3.9 Investments, Gross Incomes and Net Returns

Table: 5-XVI (Crop-wise investment, gross income and net return)

Crops	Area (ha)	Production Cost US $/ha.yr	Total Investment Million US $/yr.	Return US $/ha.yr.	Gross Return Million US $/yr.	Net Return M. US $/yr.
Flower Open	952.2					
Flower GH	613.6					
Flower Overall	1565.8	43954	68.82	72778	113.96	45.13
Vegetables	1623.1	2066	3.35	11120	18.05	14.70
Fodder	756.4	774	0.59	1871	1.42	0.83
Wheat	164.3	371	0.06	984	0.16	0.10
Grass	561.3	296	0.17	515	0.29	0.12
Macadamia Nuts	360.7	204	0.07	6128	2.21	2.14
Total Agriculture	5031.6	14521	73.06	27045	136.08	63.02
Livestock Unit	11633	452	5.25	531	6.18	0.93
Grand Total			78.32		142.26	63.95

It can be seen from table-5-XVI that,

Overall investment in the region = 15,567 US $/ha.yr.
Overall gross income in the region = 28,277 US $/ha.yr

Total regional investment = 78.32 Million US $/yr
Total investment in irrigated agriculture = 73.06 Million US $/yr.
Investment in flower sector = 68.82 M US $/yr. (94% of total agricultural investment)
Total investment in Dairies (Milk production) = 5.25 M US $/yr.
Net total return from milk production = (531-452)*11631 = 0.93 M US $/yr. (18% of investment in milk)

5.3.9.1 Gross Incomes

Gross incomes from region = 142.26 M US $/yr.
Gross incomes from irrigated agriculture = 136.08 M US $/yr.

Gross income only from flower sector = 113.96 M US $/yr. (84% of total agricultural gross)
Gross returns from milk production = 6.18 M US $/yr.
Regional Net return = 142.26-78.32 = 63.94 M US $/yr.

The investment and gross income from vegetables are 4.2% and 13% of total investment and gross income.

Flower
Investment = 68.82 M US $/yr.
Net return = 45.14 M US $/yr. (66% of investment)
Vegetables
Investment = 3.35 M US $/yr.
Net return = 14.70 M US $/yr. (438% of investment)
Gross returns from milk production = 6.18 M US $/yr

This is why production of vegetables with comparatively lucrative amount of net profits/ha and low investment/ha than flower production are increasing day by day.

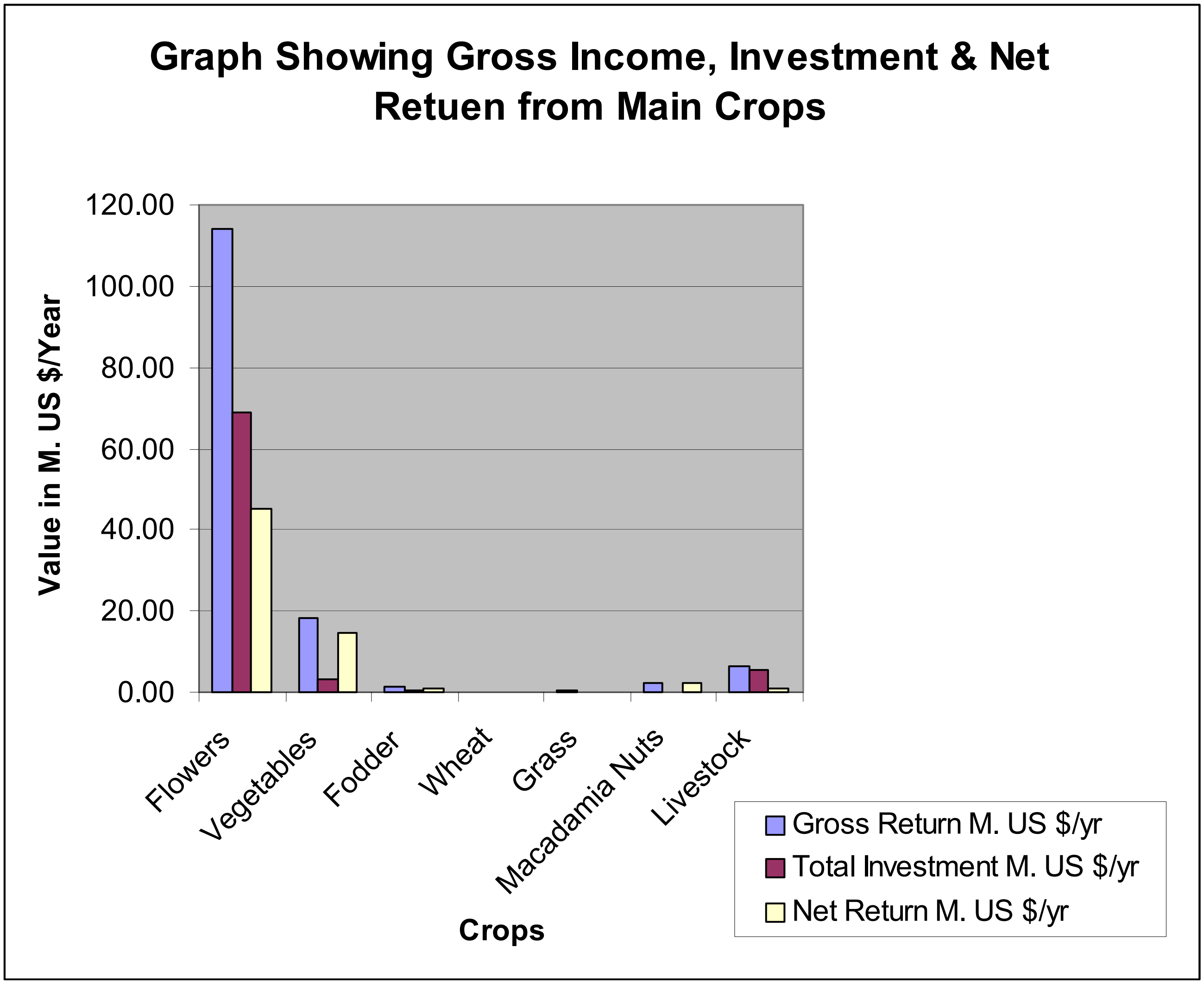


Figure: 5.2(Graph showing gross income, investment & net return from main crops)

The graph clearly shows that floriculture is the single largest economy around the Lake Naivasha. The return from vegetables is significantly higher than total investment.

5.3.10 Fertilizer and Pesticides Application

Table: 5-XVII (Amount of fertilizer & pesticide application for the main crops)

Crops	Area (ha)	Fertilizer Application Tons/ha	Pesticide Application Tons/ha	Fertilizer Application Tons/yr.	Pesticide Application Tons/yr.
Flowers	1565.8	2.4	0.166224	3758	260
Vegetables	1623.09	2.4	0.040836	3895	66
Fodder	756.39	0.08	0.022739	61	17
Wheat	164.30	0.3	0.007978	49	1
Grass	561.28	0.5	0.006095	281	3
Macadamia Nuts	360.70				
Total Agriculture	5031.58			8044	348

Table-5-XVII shows the massive application of fertilizer in floriculture and vegetable sectors per year. These two sectors apply 95% of total fertilizer in the agricultural sector.

The floricultural sector applies 75% of the total applied pesticides. A graph in the next page makes the picture rather clear.

In 4670 hectares of irrigated land (Except Macadamia Nuts), 8,044 tons of fertilizer and 348 tons of pesticides are being applied each year.
Flower and vegetable sectors apply 7,653 tons fertilizer.
Only flower sector applies 260 tons pesticides.

5.3.10.1 Effects of Fertilizer Applications

a) Eutrophication of the Lake water
b) Increase in soil salinity
c) Increase in compactness of soil structure
d) Ground water contamination
e) Some aquatic plants in the lake may grow. This growth will reduce the effective lake area. Transpiration of these plants will be higher than open water evaporation like papyrus swamp. The total outflow contribution to the lake water balance will go up causing drop of water level.

5.3.10.2 Effects of Pesticide Uses

a) Ground water contamination
b) Surface water contamination

c) Fish eggs may get adverse effects due to surface water pollution. Fish culture may get reduced.
d) Decrease in soil quality
e) Air pollution
f) Harmful to the population involved in pesticide application
g) Suspended sediment of lake-water will contain harmful contents of pesticides and lake's fish will take these sediment as food.

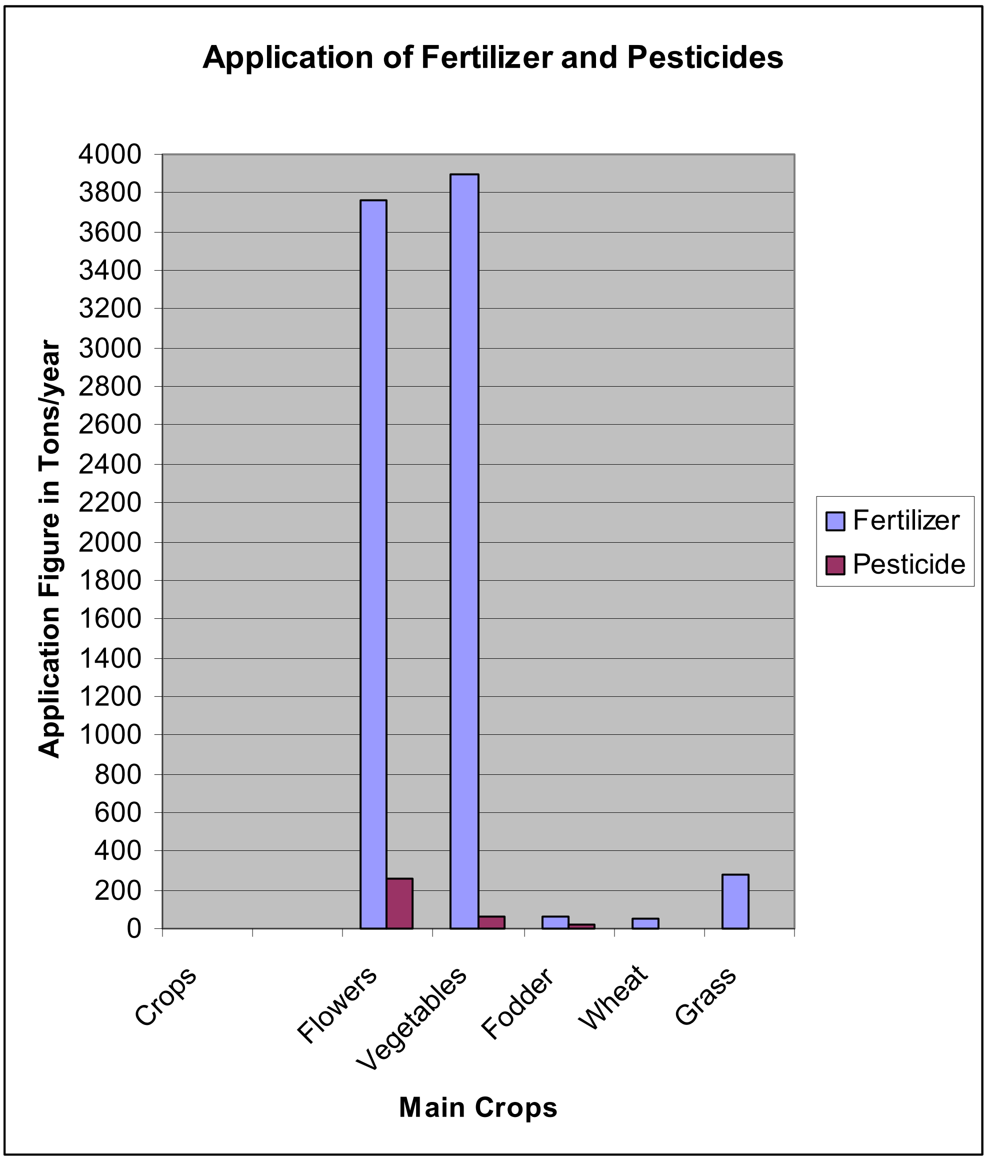


Figure: 5.3 (Graph showing Application of fertilizer & pesticides**)**

Lake Naivasha is the only fresh water source in the region under study. So contamination and pollution of lake-water will contribute immediate adverse effects to the total environment.

The study shows that the influence of floriculture in the total agricultural sector is as follows:

Gross Income = 84% of total gross income in agriculture

Investments = 94% of investments in agriculture

Net return = 72% of total net returns in agriculture

On the other hand floriculture sector applies 75% of total pesticides and floriculture and vegetables together apply 95% of fertilizer.

So the influence of floriculture together with vegetables sector on the total environment in the region compared to their economic returns to the socio-economic developments, as a whole is the main concern of the present study.

5.3.11 Employment

Table: 5-XVIII(Employment in workdays in different sectors)

Crops	Area	Employment	Total	Payment
	(ha)	Workdays/ha.yr	Workdays/yr.	US $/yr.
Flower Open	952			
Flower GH	614			
Flower Overall	1566	150	234900	387585
Vegetables	1623	150	243464	401716
Fodder	756	129	97575	161000
Wheat	164	58	9530	15724
Grass	561	43	24135	39823
Macadamia Nuts	361	50	18035	29758
Total Agriculture	5031	125	627639	1035605
Live Stock Unit	11633	22	255926	422278
Grand Total			883565	1457883

Table-5-XVIII shows only the employment opportunities for labor classes created by the irrigated agriculture sector and dairy farms.

Total employment in agriculture = 883,565 workdays/yr.
In flower sector = 234,900 workdays/yr. (37% of agriculture and 26.6% of grand total)
In vegetable sector = 243,464 workdays/yr. (39% of agriculture and 27.6% of grand total)

Total employment in dairies = 255,926 workdays/yr. (29% of grand total)
Fodder and grass = 121,710 workdays/yr. (19% of agriculture & 14% of grand total)
As livestock production needs more intensive care than agriculture the labor employment opportunity is higher in dairies.

Total payment for labor class employees = 1.46 Million US $/yr. (Only 1.03% of total investment 142.26 Million US $/yr., 2.30% of total net return 63.95 M US $/yr.)

Flower sector = 387,585 US $/yr. (26% of total and 37% of agri sector)
Labor Payment in floriculture is only 0.61% of net total yearly profit.

Vegetable sector = 401,716 US $/yr. (28% of total and 39% of agri sector)
Labor payment is only 0.64% of net total yearly profit.

Dairies, grass & fodder sector = 623,100 US $/yr. (43% of total & 60% of agri sector)
Labor payment is only 1% of yearly total net profit.

In irrigated commercial farms hundreds of staffs at different levels with different pay scales are engaged.

5.4 Dollars Per Drop

Table: 5-XIX (Net returns from the main crops in US $/m^3 water)

	Average Year		Dry Year		Wet Year	
Crops	Reqd Irr	App. Irr	Reqd Irr	App. Irr	Reqd Irr	App. Irr
	Net Return	Net Return	Net Return	Net Return	Net Return	Net Return
Flower Open	4.31	1.25	3.45	1.16	8.52	1.46
Flower GH	4.39	1.58	4.39	1.58	4.39	1.58
Vegetables	1.79	0.72	1.38	0.64	4.37	0.94
Fodder	0.27	0.18	0.20	0.15	1.02	0.36
Wheat	0.15	0.07	0.11	0.06	0.36	0.09
Grass	0.05	0.04	0.04	0.03	0.20	0.07
Macadamia Nuts		4.86	5.61	2.06		
Total Agriculture	2.45	1.15	1.97	1.02	4.72	1.45

5.4.1 Applying Supplementary Irrigation Requirement

Tabble-5-XIX shows that with required irrigation application the net return from **GH** flowers is **4.39 US $** per cubic meter water in any year and from **open flowers** 4.31 in average year, 3.45 in dry year and 8.52 **US $ in wet years.**

Net return from **vegetables** in average year is **1.79** US $ per m^3 of water. In dry year 1.38 and in wet years 4.37 US $ per m^3 of water.

The net return from total agricultural sector using one cubic meter of water is 2.45 in average, 1.97 in dry and 4.72 during wet years.

5.4.2 Returns from Current Applied Rate of Irrigation

From GH net return is constant at 1.58 US $/ m^3. For open flowers in average, dry and wet years are 1.25, 1.16 and 1.46 US $/ m^3 water.

From vegetables 0.72, 0.64 and 0.94 US $/ m^3 water in average, dry and wet years respectively.

The net return from total agricultural sector using one cubic meter of water is 1.15 in average, 1.02 in dry and 1.45 during wet years.

Macadamia nuts do not need irrigation during average and wet years. But they irrigate during average years and dry years and return from macadamia nuts are reasonably higher per drop of water.

5.4.3 Returns from Farms

In the worksheet “Return” of Economic Model the net economic returns of all individual farms have been calculated. The net returns there are slightly different from the above figures. Because some of the farms are producing more than one crop and some are dairy farms. The net returns from floricultural farms are almost similar. Farms with only GH flowers have higher rate of net returns.

The net economic returns from **Marula** and **Loldia** are totally disappointing. The actual and expected net returns from Marula are 0.10 and 0.15 US $ for each cubic meter usage of water while the figures are 0.29 and 0.60 respectively for Loldia.

The estimated abstraction by Marula during WRAP survey was **13.56** million m^3/year and their declared irrigated area was 373 hectares. The irrigated area of Marula in the present study is 687 hectares.

The estimated applied irrigation and other usage of water for Marula is found as 4.39 million and required usage of water is found as 2.83 million m^3 in average years. The similar figures for Loldia are 1.52 and 0.74 million m^3 respectively.

The concerned resource managers must take in farms with very poor economic returns and huge irrigated area and abstraction to consideration.

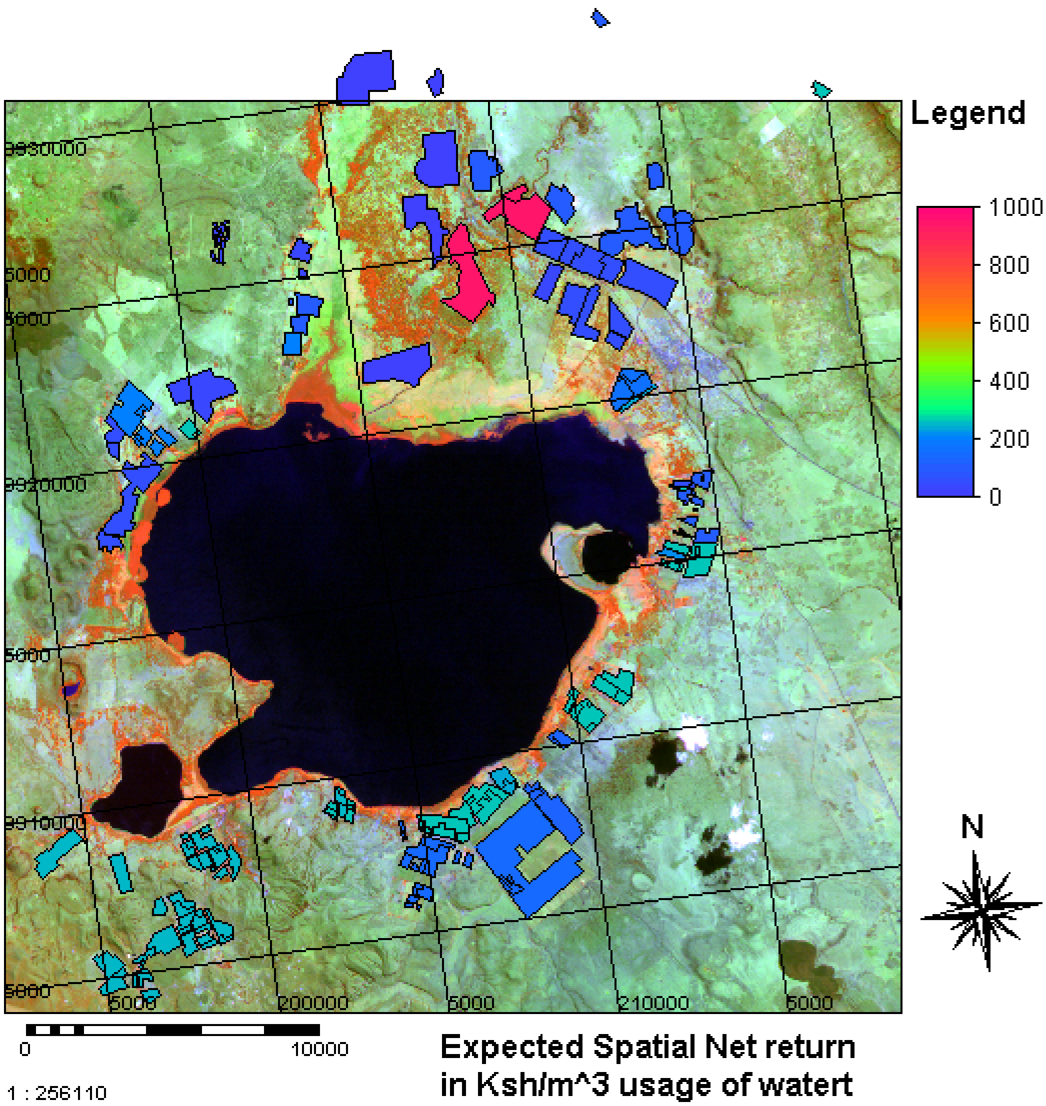
The WRAP abstraction figure of Marula needs thorough investigation.

5.4.4 Expected Spatial Net Return in Ksh/m^3 water

Figure: 5-IV shows that the net expected return in Ksh/m^3 water is higher in the eastern part of the Lake (Range of expected net return 245-265 Ksh/m^3 water). The floriculture industry is in the eastern belt of the lake. Oserian Development Company (246 ksh/m$^{3)}$ is the single largest flower farm in the world situated in the north-western corner of the lake. Sher Agencies (263 ksh/m^3) is one of the most profitable flower farms. Goldsmith, Herneth (Kenya), and Noordam Roses are also profitable (245-262 ksh/m^3). The net returns ranging from 50-60 ksh /m^3 are dairy farms. Vegetables farm are expected to earn at –80-110 ksh /m^3 usage of water.

The graduated color shows the spatial variation of net returns expected around the Lake Naivasha. The red zone is macadamia nuts. As macadamia nut does not require irrigation during average and wet years the net return per cubic meter water is extremely high for it. The blue color zone (0-60 Ksh/m^3 water) shows grass, fodder and dairy production farms. Blue to light green zone (60-120 Ksh/m^3 water) shows vegetable farms. And light greenish zone (235-275) shows floricultural farms zone. Red zone of macadamia nuts is exceptional in relation to net returns from water usage.

Figure: 5.4 (Shows Expected Spatial net return in Ksh/m^3 around the lake vicinity)



Chapter 6:Conclusions

6.1 Irrigated Area and Abstraction

a) The irrigated area around the Lake Naivasha is found as 5031 hectares.
b) Farms, except few, are irrigating more land and abstracting more water than declaration.
c) Farms, except few, have declared the purpose of BH (Ground Water) abstractions only to meet domestic and other minor requirement. The analysis of standard water requirement with the figure regarding domestic and other needs declared by them shows clearly that far more amount of water are being abstracted from BH abstraction points. During field visit it has been observed that those BH abstractions are also being used for irrigation requirement.
d) The supplementary irrigation water requirement for the present cropping pattern during average, wet and dry years are respectively 24.68, 12.32, and 31.26 million cubic meters.
e) The amounts of applied irrigation for the above three cases are 63.67, 50.87 and 70.47 million cubic meters.
f) The amounts of excess abstraction for irrigation are respectively 38.98, 38.55 and 39.21 million cubic meters which can irrigate respectively additional 7946, 15742, and 6213 hectares of land with present cropping pattern.
g) The total water requirement for domestic people (40,378), livestock (11,631), wildlife (1003) and industry as declared during WRAP 96-97 survey by the farms amounts to be 1.51 million cubic meters.
h) The total abstraction figures for average, wet and dry years are 65.18, 71.98, and 52.38 million cubic meters.
i) The total abstraction with rainfall amount 489mm of [Gitonga, 1999] is 70.05 million m^3/year.
j) Total Surface Water abstraction from the lake is 46.40 million cubic meters out of 70.05. From WRAP 96-97 data the figure is found as 32.5 m. m^3.

6.2 Economic Returns

6.2.1 Regional Aspects

6.2.1.1 Net Returns

a) The net total yearly return from the farms is 63.94 million US $.
b) Regional net return per hectare = 12,711 US $/year
c) Regional net return per hectare (only agriculture)= 12,525 US $/year
d) Net return from agricultural production = 63.02 million US $/year.

e) **Net return from non-processed** milk **production =** 0.93 million **US $/year.**

6.2.1.2 Gross Returns

a) Gross return (agriculture) = 136.08 million US $/year.
b) Gross return (milk) = 6.18 million US $/year.
c) Regional gross return = 142.26 million US $/year.

6.2.1.3 Gross Investments

a) Gross investment (agriculture) = 73.06 million US $/year.
b) Gross investment (milk) = 5.25 million US $/year.
c) Regional gross investment = 78.32 million US $/year.

6.2.2 Crop Aspects

6.2.2.1 Net Returns

a) From flowers = 45.05 million US $/year (70% of total)
b) From vegetables = 14.70 million US $/year (23% of total)
c) Macadamia Nuts = 2.14 million US $/year (3.35% of total)

6.2.2.2 Gross Returns

a) From flowers = 113.96 million US $/year (80% of total)
b) From vegetables = 18.05 million US $/year (13% of total)
c) Macadamia Nuts = 2.21 million US $/year (1.6% of total)

6.2.2.3 Gross Investments

a) Gross investment (flower) = 68.82 million US $/year (88% of total).
b) Gross investment (vegetable) = 3.35 million US $/year (4.30% of total).
c) Gross investment (Macadamia) = 0.07 million US $/year (0.09% of total).

The net return from vegetables is 14.7 m. US $/year (81% of gross return and 439% of gross investment). The increase of irrigated vegetable area by more than 600 hectares in the present study than the area declared by WRAP for 96-97 is quite reasonable**.**

6.3 Fertilizer and Pesticides Application

6.3.1 Fertilizer

a) Total application = 8044 tons/year (Excluding Macadamia Nuts)
b) Flowers and vegetables = 7653 tons/year (95% of total)

6.3.2 Pesticides

a) Total application = 348 tons/year (Excluding Macadamia Nuts)
b) Flowers = 260 tons/year (75% of total)
c) Vegetables = 66 tons/year (19% of total)

Both flower and vegetable sectors are contributing 95% to the environmental effects caused by huge fertilizer application described in section 5.3.10.

But floriculture alone is contributing 75% to the effects caused by pesticides application.

6.4 Irrigation Requirement and Application for flowers and vegetables in average years

6.4.1 Floriculture

Irrigated Area of flowers = 1566 hectares (31% of total)
Irrigation requirement = 10.40 million m^3 (42% of total agricultural need)
Irrigation applied = 33.21 million m^3 (52% of total application)

6.4.2 Vegetables

Irrigated Area of vegetables = 1623 hectares (32% of total)
Irrigation requirement = 8.22 million m^3 (33% of total agricultural need)
Irrigation applied = 20.54 million m^3 (32% of total application)

Floriculture and vegetables in the region are using 63% of total irrigated land. They are applying 84% of total applied irrigation. Over 90% of the regional agricultural gross investment, gross returns, and net returns are coming from these two sectors. Absolutely 80% of the regional economy belongs to floriculture. Socio-economic development is dependent on floriculture.

On the other hand these two sectors are also contributing significantly to the regional environmental impacts by abstracting 84% of the total abstraction from lake Naivasha, and applying over 90% of the total applied fertilizer and pesticides. Again floriculture applies 75% of the pesticides.

The total economic wheel around the lake and the regional environment are dependent on the sustained quantity and quality of water of Lake Naivasha.

So the water resource manager must find out the balance between the sustained environment and economy regarding regional water management.

Chapter 7:Recommendations

7.1 Cadastral Map

The existing cadastral map of Naivasha supplied by the Physical Planning Department, Ministry of Lands and Settlement, Kenya (Department Reference number R59/2000/01) must be updated with RS and field GPS data. Some land reference numbers used during the WRAP survey 96-97 are not shown in this cadastral map. Field GPS data of the present study have been used with sufficient accuracy to get the cadastral boundary of each farm. To meet the objective of the study attention was drawn to irrigated area of each farm using TM Image of May 21st, 2000. So an updated cadastral map of Naivasha is required immediately. The information should be built-up in GIS environment.

7.2 Riparian Boundary

The lake surface area corresponding to lake-level 1892.70m is considered as Riparian Zone. But out of estimated irrigated area of 5031 hectares, 645.30 hectares are found within the Riparian Zone. The concerned authority must look into this issue immediately.

7.3 Abstraction

Using the economic model actual water need for each individual farm has been estimated. The authority should develop regular monitoring to reduce excess abstraction. Other wise in future they will be compelled to stop issuing even needed license for irrigation. But proper monitoring will ensure need base abstraction and future extension of irrigated area with a sustained lake-level. The yearly surface water abstraction in relation to long-term water balance [Gitonga, 1999] from the Lake is 46.40M cubic meter. Close monitoring is needed to reduce excess surface water abstraction to maintain the Lake level sustainable.

Boateng, 2001 has shown that ground water abstraction within ½ a Km around the south of the Lake can affect the Lake level within 1 to 4 years time depending on the maximum and minimum hydraulic conductivity. So the GW abstraction within ½ a Km around the south of the lake contribute to the drop of Lake level. GW abstraction within ½ a Km around the Lake should be treated as direct abstraction from the Lake.

7.4 Economic Returns

Due to excess abstraction and irrigation the economic return in relation to usage of water has come down. If supplementary irrigation requirement is followed the economic return in the region will be 2.44 US $ using one cubic meter water. Where as the current rate is

only 0.98 US $ due to excess application for irrigation. So motivation and monitoring must be carried on simultaneously.
Farms with poor economic returns should not get permission to expand their irrigated areas.

7.5 Lake Level

In average years the net abstraction requirement is 32.78 Million m^3 can cause drop of lake-level only 0.27m where as the actual abstraction 65.18 m.m^3 at the moment is causing 0.54m drop. Motivation program must be carried on to inform the users that the drop of level due to natural processes (Evaporation and GW outflow) is almost constant. Human uses need control for a sustained lake level, which can ensure better environment and economy.

7.6 Fertilizer and Pesticides

The floriculture and vegetable sectors are using 95% fertilizer. Floriculture sector is applying 75% pesticides. The further expansion of floriculture should be done after proper investigation on effects of pesticides and fertilizer to the lake environment as well as vegetable production.

7.7 Hydrological Investigation and Monitoring Abstraction and Water Pricing

For future sustainability of the lake environment and lake-level continuous hydrological investigation is a must. The yearly cash transfer for hydrological investigation by the Kenyan authority is not more than US $ 200 per year. The net return from the lake water per year is on average 63.95 Million US $.

Water pricing must be done to develop fund for running the cost of the agency for hydrological investigation and monitoring abstraction. The monitoring should include the upstream abstraction of Malewa. Malewa supplies 63% of total yearly inflow into the Lake.

7.8 Ownership of the Lake

The Kenyan government must decide on the ownership of the Lake Riparian Zone and the Lake. The ownership of rivers flowing in to the lake should also be put under one authority with proper administrative power for management and planning of basin water resources.

7.9 Labor Payment

The major environmental partner in the vicinity of Lake Naivasha is the labor class who serves for 900,000 workdays a year with total payment 1.46 million US $ (only 2.3% of the total yearly net return of 63.95 million US $). They should be paid better rate that will improve the root level of socio-economic structure in the region.

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APPENDICES

APPENDIX A: General Climatic Data of Naivasha

APPENDIX-A-2-I: CLIMATIC STATISTICS NAIVASHA, NAIVASHA DO.

(East African Meteorological Department.1964)

month	Temp (degree Celsius, 1937-54)					RH	Rain (1910-62)	Wind (1938-54)	
	max	Mean max	mean	Mean min	min	% at 1500h	Mean, mm	At 0900h M/s	At 1500h M/s
Jan	30.8	27.7	17.9	8.1	1.9	28.0	22.0	1.5	3.1
Feb	32.1	28.3	18.3	8.2	3.1	28.0	28.0	1.5	3.1
Mar	32.6	27.3	18.5	9.8	2.8	34.0	34.0	1.5	3.1
Apr	30.5	25.1	18.3	11.5	5.6	51.0	51.0	1.5	3.1
May	27.6	23.8	17.5	11.3	6.1	54.0	54.0	1.5	3.6
Jun	27.6	23.0	16.5	9.9	4.4	51.0	51.0	1.5	3.6
Jul	26.8	22.5	15.9	9.3	4.6	49.0	49.0	1.5	3.6
Aug	27.2	22.9	16.1	9.4	4.4	48.0	48.0	1.5	4.2
Sep	28.4	24.5	16.7	8.8	2.2	43.0	43.0	1.5	4.2
Oct	30.3	25.6	17.3	9.1	3.9	41.0	41.0	1.5	4.2
Nov	28.9	24.7	17.0	9.3	3.9	47.0	47.0	1.5	3.1
Dec	30.1	25.8	17.3	8.7	3.3	40.0	40.0	1.5	3.1

Source: (LNROA, 1993)

APPENDIX-A-2-II: Mean Rainfall figure (mm) for selected station

Month	Naivasha Town, Naivasha DO	Naivasha Vet. Station
	(mm)	(mm)
Years	42	39
Average (mm)	666	729
Altitude (m)	1900	1829
January	37.0	36.0
February	41.0	33.0
March	47.0	60.0
April	114.0	121.0
May	109.0	103.0
June	45.0	52.0
July	39.0	44.0
August	53.0	54.0
September	25.0	46.0
October	45.0	63.0
November	64.0	71.0
December	48.0	47.0

Source: (Jaetzold and Schmidt 1983, LNROA, 1993)

Regional constants

Item	value	unit	comments	Mathematics
a) electricity cost for abstraction	1.374	Ksh/m^3	Field work data	
b) KSh exhange rate US$	61	None		
c) casual labour cost	1.65	US $/day	Collected during field works.	
d) interest to borrow money from bank	25	%		
e) interest received from bank	15	%		
f) total population of Naivasha Town	11491	0.228226976	[Huaccho, 1998], 22.82 % of Naivasha	Rigional const[f]/Regional const[h]
g) total population of Naivasha Rural	38858	0.771773024	[Huaccho, 1998], 77.18 % of Naivasha	Rigional const[g]/Regional const[h]
h) total population of Naivasha	50349	Number	[Huaccho, 1998]	
I) total population of Kijabe	9653	Number	[Huaccho, 1998]	
j) total population of Gilgil	35337	Number	[Huaccho, 1998]	
k) water availability				
l) price of water	1	Ksh/m^3	tax	
m) elasticity of price/consumption		dimensionless	diff.price/diff.consumption	
n) cost of fertilizer (all crops)	200	US $/Ton	[USDA]	
o) cost of pesticides (flower & veg.)	20438	US $/Ton		
p) rainfall	608	mm/year	[Ase, 1986]	
q) Pot Evap	1700	mm/day		
r) rate of depriaciation of equipment	20	%		
s) Water req. for Urban & tourism	83.0375	m3/person		
t) Water req. for rural population	16.6075	m3/person		
u) Water req. for Livestock & Wildlife	16.6075	m3/L.U		
v) Water req. for farm population	31.76862	m3/person		Reg.const[f]*Reg.const[s]+Reg.const[g]*Reg.const[t]
w) cost of pesticides (fodder & grass)	16106	US $/Ton		
x) cost of pesticide (wheat)	19246.83	US $/Ton		

All measures per ha (10000 m2)					
flower					
parameter	**min_valu**	**Opt_valu**	**value**	**unit**	**math**
a) managm_weight (alfa)			0.8	dimensionless	
b) labour			150	Workdays [(2),Huaccho, 1998]	
c) fertilizer			2.4	Ton [Huaccho, 1998]	
d) pesticides			0.166224	Ton [Huaccho, 1998]	
e) Freight Cost			39187.5	US $ [Konijn, 2000]	
f) Seeds/seedlings			206.24	US $	(Flower[b]*reg.const.[c]+Flower[c]*reg.const.[n]+Flower[d]*reg.const.[o])*5%
g) Total cost except cooling cost			43518.55	US $	Flower[b]*reg.const.[c]+Flower[c]*reg.const.[n]+Flower[d]*reg.const.[o]+Flower[f]
h) Cooling cost of harvested flowers			435.19	US $	Flower[g]*1%
I) Cut Flower yield			27.5	Tons [(3),Kenya Flowers]	
j) Total Production Cost			43953.73	US $	Flower[g]+Flower[h]
k) Cut Flower Price			72777.8	US $ [Konijn, 2000]	
GH Irrigation Requirement			6570	m3/ha.yr	
Open Irrigation Requirement			6695	m3/ha.yr	
Effective Applied Irrgn GH			18250	m3/ha.yr	
Effective Applied Irrgn Open			23120	m3/ha.yr	
Net Profit			28824.07	US $/ha.yr	Flower[k]-Flower[j]

All measures per ha (10000 m2)					
Vegetables					
parameter	**min_value**	**Opt_value**	**value**	**unit**	**math**
a] managm_weight (alfa)			0.8	dimensionless	
b] labour			50	Workdays/ha.crop [Huacccho, 1998]]	
c] fertilizer			2.4	Tons/ha.yr [Huaccho 1998]	
d] pesticides			0.040836	Tons/ha.yr [Huaccho 1998]	
e] Cost of [b+c+d]			1562.11	US $	Veg.[b]*Reg. Const[c]*crop/yr+Veg.[c]*Reg. Const[n]+Veg.[d]*Reg. Const[o]
f] seeds/seedlings			234.32	US $	Veg[e]*5%*crop/yr
g] Production Cost[b+c+d+f]			1796.427	US $	Veg[e]+Veg[f]
h] Preservation Cost			269.46	US $	Veg[g]*5%*crops/yr
t] Total Production Cost			2065.89	US $	(Veg[g]+Veg[h])
j] Irrigation Requirement			5063.01	m3/ha.yr	
k] Effective Applied Irrigation			12653.01	m3/ha.yr	
l] Yield			3.4	Tons/ha.crop [Ahmad Salah, 1999]	
m] Yield/ha.yr			10.2	Tons/ha.yr	Veg[l]*Crps per Year
n] Yield Return Co-efficient			0.7	Field Data	
p] Effective Yield/ha.yr			7.14	Tons/ha.yr	Veg[m]*Veg[n]
q] Farm Gate Price			95	Ksh/Kg [Ahmad Salah, 1999]	
r] Effective Return			11119.67	US $/ha.yr	(Veg[q]/Reg. Const[b])*1000*Veg[p]
s] Net Profit			9053.78	US $/ha.yr	Veg[q]-Veg[g]

All measures per ha (10000 m2)					
Wheat					
parameter	**min_value**	**Opt_value**	**value**	**unit**	**math**
a] managm_weight (alfa)			0.8	dimensionless	
b] labour			29	Workdays/ha.crop [Huaccho, 1998]	
c] fertilizer			0.3	Tons/ha.yr [Huaccho, 1998]	
d] pesticides			0.007978	Tons/ha.yr [Huaccho, 1998]	
e] Cost of Wheat[b+c+d]			309.25	US $/ha.yr	Wheat[b]*Reg Const[c]*crop/yr+Wheat[c]*Reg Const[n]+Wheat[d]*Reg Const[o]
f] Seeds/Seedlings			61.85	US $/ha.yr	Wheat[e]*10%*crop/yr
g] Production Cost			371.10	US $/ha.yr	Wheat[e]+Wheat[f]
m] Irrigation Requirement			4219.18	m3/yr	
n] Effective Applied Irrigation			9169.18	m3/yr	
p] Yield			2	Tons/ha [Huaccho, 1998]	
q] Yield/ha.yr			4	Tons/ha.yr	Wheat[p]*Crops per Year
r] Farmgate Price			16667	Ksh/Ton [Huaccho, 1998]	
s] Farmgate Price in $			273.23	US $/ton	Wheat[r]/Reg Const[b]
t] Return Co-efficient			0.9		
u] Effective Return			983.63	US $/ha.yr	Wheat[q]*Wheat[s]*Wheat[t]
w] Net Profit			612.52	US $/ha.yr	Wheat[u]-Wheat[g]

All measures per ha (10000 m2)					
Fodder Crops					
parameter	**min_value**	**Opt_value**	**value**	**unit**	**math**
a] managm_weight (alfa)			0.8	dimensionless	
b] labour			43	Workdays/ha/crop [Huaccho, 1998]	
c] fertilizer			0.08	Tons/ha.yr [Huaccho,1998]	
d] Pesticides			0.022739	Tons/ha.yr[Huaccho, 1998]	
e] Cost of [b+c+d]			595.09	US $/ha.yr	Fodder[b]*RegConst[c]*crop/yr+Fodder[c]*RegConst[n]+Fodder[d]*Regconst[o]
f] seeds/seedlings			178.53	US $/ha.yr	Fodder[e]*10%*crop/yr
g] Production Cost			773.61	US $/ha.yr	Fodder[e]+Fodder[f]
h] Irrigation Requirement			4073.01	m3/yr	
j] Effective Applied Irrigation			6053.01	m3/yr	
k] Yield			10	Tons/ha [Ahmad Salah, 1999]	
l] Yield/Yr			30	Tons/ha.yr	Yield/ha*Crops/yr
n] Yield Return C0-efficiecnt			0.75		
q] Effective Yield			22.5	Tons/ha.yr	Fodder[l]*Fodder[n]
r] Equivalent L.U.			4.5		Fodder[q]/Dairies[n]
t] Meat return per L.U.			30	Kg/yr [FAO & IIASA, 1991]	
u] Average cost of meat/protein			188.33	Ksh/Kg [Ahmad Salah, 1999]	
v] Meat/Protein return			416.80	US $/ha.yr	Fodder[r]*[t]*[u]/RegConst[b]
w] Dairies return			1454.25	US $/ha.yr	Fodder[r]*Dairies[k]
p] Effective Return			1871.05	US $/ha.yr	Fodder[v]+Fodder[w]
s] Net Profit			1097.44	US $/ha.yr	Fodder[p]-Fodder[g]
MARKET PRICE OF FODDER			83.16	US $/Ton	Fodder[p]/Fodder[q]

All measures per ha (10000 m2)					
Grass					
parameter	**min_value**	**Opt_value**	**value**	**unit**	**math**
a] managm_weight (alfa)			0.8	dimensionless	
b] labour			43	Workdays [Huaccho, 1998]	
c] fertilizer			0.5	Tons [Huaccho, 1998]	
d] Pesticides			0.006095	Tons [Huaccho, 1998]	
e] Cost of [b+c+d]			269.12	US $/ha.yr	Grass[b]*RegConst[c]+Grass[c]*RegConst[n]+Grass[d]*Regconst[o]
f] seeds/seedlings			26.91	US $/ha.yr	Grass[e]*10%
g] Production Cost			296.03	US $/ha.yr	Grass[e]+Grass[f]
h] Irrigation Requirement			4073.014	m3/yr	
j] Effective Applied Irrigation			6053.014	m3/yr	
k] Yield			6	Tons/ha.yr [Huaccho, 1998]	
m] Farm Gate Price			114.5	US $/Ton [Huaccho, 1998]	
n] Yield Return Co-efficiecnt			0.75		
p] Effective Return			515.25	US $/ha.yr	Grass[k]*Grass[m]*Grass[n]
s] Net Profit			219.22	US $/ha.yr	Grass[p]-Grass[g]

All measures per ha (10000 m2)					
Macadamia Nuts					
parameter	**min_value**	**Opt_value**	**value**	**unit**	**math**
a] managm_weight (alfa)			0.8	dimensionless	
b] labour				Workdays/ha	
c]fertilizer					
d] Nitrogen			69	gm/tree [13]	
e] P205			10	gm/tree [13]	
f] K20			48	gm/tree [13]	
g] Total Irrigation Requirement			2400	m3/ha.yr [6]	
h] Irrigation Requirement			0	m3/ha.yr	
I] Applied Irrigation			1220	m3/yr	
k] production cost			1600	South African Rand/ha.yr [6]	
l] production cost			204.2119	US $/ha.year (1 US $=7.835 R)	Mcadamia Nuts[k]/7.835
m] No of trees produced per hactare			200	no/ha [6]	
n] Macadamia Production			16	Kg/tree [5]	
o] Production per Hacatre			3200	Kg/ha	Mcadamia Nuts[m]*Macadamia Nuts[n]
p] Farm Gate Price			3.83	US $/Kg [4]	
q] Percent of Productive trees			50	%	
r] Return per hactare			6128	US $/ha.yr	Macadamia Nuts[o]*[p]*[q]
s] Net Return			5923.788	US $/ha.yr	Macadamia Nuts[r]-Macadamia Nuts[l]

Dairies				
item	**vaulue**	**unit**	**comment**	Math
a)Production of milk per day per L.U.	30	Litres	Collected from field	
b)Price of milk	18	Ksh/Litre	Collected from field	
c)Effective no of productive days per L.U.	100	days/year	Collected from field	
d)Percentage of productive L.U.	60	%	Collected from field	
e)Production of milk per L.U.	1800	Litres/year		Dairies[a]*[c]*[d]/100
f)No of labours required per L.U.	22	no/year	Collected from field	
g)Return per L.U.	32400	Ksh/year		Dairies[b]*[e]
r] Return per L.U.	531.15	US $/yr		
h)Cost per labour	100	Ksh/day	Collected from field	
l) Labour Costs per L.U.	2200	Ksh/year		Dairies[h]*[f]
m] Production Cost of Fodder per ton	34.38	US $/yr		Fodder[g]/Fodder[q]
n] Dry Matter Intake (DMI) per L.U.	5	Tons	[FAO & IIASA,1991]	
p] Cost of DMI per L.U.	171.91	US $/yr		Dairies[m]*Dairies[n]
q] Total Cost per L.U.	207.98	US $/yr		Dairies[l]/RegConst[b]+Dairies[p]
k) Net Return per L.U.	323.17	US $/year]		Dairies[j]/Regional Const[b]

Milk				
item	**vaulue**	**unit**	**comment**	Math
a)Production of milk per day per L.U.	30	Litres	Collected from field	
b)Price of milk	18	Ksh/Litre	Collected from field	
c)Effective no of productive days per L.U.	100	days/year	Collected from field	
d)Percentage of productive L.U.	60	%	Collected from field	
e)Production of milk per L.U.	1800	Litres/year		Milk[a]*[c]*[d]/100
f)No of labours required per L.U.	22	no/year	Collected from field	
g)Return per L.U.	32400	Ksh/year		Milk[b]*[e]
r] Return per L.U.	531.15	US $/yr		
h)Cost per labour	100	Ksh/day	Collected from field	
I) Labour Costs per L.U.	2200	Ksh/year		Milk[h]*[f]
m] Market Price of Fodder per ton	83.16	US $/yr	From Fodder Sheet	
n] Dry Matter Intake (DMI) per L.U.	5	Tons	[FAO & IIASA,1991]	
p] Cost of DMI per L.U.	415.79	US $/yr		Milk[m]*Milk[n]
q] Total Cost per L.U.	451.85	US $/yr		Milk[l]/RegConst[b]+Milk[p]
k) Net Return per L.U.	79.29	US $/year]		Milk[g]-Milk[l]

Irrigation Water Requirements

IrrReq

									Assumed	Irrigation
									Effective	Water
Crops	Irrigation Required	Ref	Crops/Yr	ETact	Ref	ETact	ETact	Rainfall	Rainfall	Requirement
	Days/yr			mm/day		mm/Yr	m3/ha.yr	m3/ha.yr	m3/ha.yr	m3/ha.yr
Indoor Flowers	365	Field data		1.8	[Mekonnen, 1999]	657	6570	0	0	6570
Open Flowers	365	Field data		3.5	[Mekonnen, 1999]	1277.5	12775	6080	6080	6695
Wheat	275	Field data	2	3.2	[Mekonnen, 1999]	880	8800	6080	4581	4219
Grass	330	Field data		2.9	[Mekonnen, 1999]	957	9570	6080	5497	4073
Fodder Crops	330	Field data	3	2.9	[Mekonnen, 1999]	957	9570	6080	5497	4073
Vegetables	330	Field data	3	3.2	[Mekonnen, 1999]	1056	10560	6080	5497	5063
Macadamia Nuts	365	Field data		1.5	[7]	547.5	5475	6080	6080	0

Field Application				
				Effective
	Applied	Applied	Applied	Applied
Crops	Irrigation	Irrigation	Irrigation	Irrigation
	mm/day	mm/year	m3/ha.yr	m3/ha.yr
Indoor Flowers	5	1825	18250	18250
Open Flowers	8	2920	29200	23120
Wheat	5	1375	13750	9169
Grass	3.5	1155	11550	6053
Fodder Crops	3.5	1155	11550	6053
Vegetables	5.5	1815	18150	12653
Macadamia Nuts	2	730	7300	1220

PESTICIDE PRICE

From Data collection and field work notes									
Naivasha, Kenya									
7/9/00	to	2/10/00							
by	Janeth Moncada, 2001								
			US $ =	61	Ksh	Specific gr =	1.3	kg/litre	Salah, 1999
	Vegetable &								
	Folwer	amount	price/ha	Pesticide	Price	Price			
		kg	US $	%	US $/kg	US $/ton			
	Fungicides	39.56	705	17	17.82				
	nematicides	104	1632	45	15.69				
	Miticides	22.17	650	10	29.32				
	Insecticides	66.63	1762	29	26.44				
				0					
	total	232.36	4749	100	20.438	20438			

Herbicides	Price	Ref
	US $/kg	
	16.52	[22]

Wheat	Use	Application	Price	Price
	%	kg/ha	US $	US $/ton
Fungicides	17	1.356	24.17	
nematicides	45	3.590	56.34	
Herbicides	9	0.718	11.86	
Insecticides	29	2.314	61.18	
Total	100	7.978	153.55	19246.83

Fodder crops	Price	Price	Use	Ref
& Grass	US $/kg	US $/ton	%	
nematicides	15.69		50	Field
Herbicides	16.52		50	Field
Average	16.106	16106		

Fertilizer

SULMAC	N	P2O5	K2O	Ca	MgO	B	Fe	Mn	Zn	Cu	Mo	HNO3 (60%)	S	Total	C. Area (Ha)	Grand total
Roses	29.3	16.6	108.9	62	21.2								75.6	313.6	43.7	13704.32
Carnations	44.9	37.58	26.9	35.4	5.6								16.2	166.58	6	999.48
Gypsophilla	38.7	10.5	37.6	15.2	5.4								19.8	127.2	1.5	190.8
Hypericum	0.1	0.02	0.1	0.1	0.02	0.5	1.2	0.4	0.2	0.1	0.1	3.6		6.44	19	122.36
French beans	43.7	15.56	11	30.6	8.95	0.7	0.1	0.2	0.4	0.2	0		42.8	154.21		
Mange and Sugarsnaps	30.6	12.98	11	26.9	8.89	0.7	0	0.2	0.3	0.2	0		41.2	132.97		
Runner beans	39.3	11.1	23	27.5	6.75	0.6	0	0.3	0.2	0.2	0		38.4	147.35		
Squash	33	19.87	27.8	39.7	4.66	0.6	0	0	0.2	0.2	0		36.9	162.93		
Salads	38.1	20.8	23.6	0	1.07	0	0	0.2	0.1	0	0		2.4	86.27		683.73
Total														1297.55	170.2	
OSERIAN																
Roses	43.7	0.2	56.9		16.1							16.1	29.6	162.6	60	9756
Carnations					5	10.6							7.8	23.4	50	1170
Gypsophilla	7.2		37		6.7							12.2	10.4	73.5	20	1470
Total														259.5	130	12396

Unit				
Kg/ha/month				
		Total		
Flower	Area	Kg/month	kg/ha/month	kg/ha/yr
Oserian	130	12396	95.3538	1144.2
Sulmac	70.2	15017	213.917	2567

Returns						Irrigation	Irrigation		Water Usage	Water Usage	Water Usage	Net	Net	Net	Net
	Total	**Applied**	**Irrigation**	Irrigated	Net Total	Actual	Expected	Net	Other than	With Applied	With Reqd	Return on	Expected	Return on	Expected
Farm	**abstraction**	**Irrigation**	**Requirement**	Area	Return	Return	Return	Return	Irrigation	Irrigation	Irrigation	Usgae	Return	Usgae	Return
	(m3/y)	(m3/y)	(m3/y)	(ha)	US $	US $/m3. water	US $/m3.water	US $/ha	m3/yr	m3/yr	m3/yr	US $/m3.water	US $/m3.water	Ksh/m3. water	Ksh/m3. water
ABERDARE STATES	137700	261745	114559	23.79	172490	0.66	1.51	7251	1883	263628	116442	0.65	1.48	39	89
WETAM INVESTMENTS	12831	80788	45320	10.49	38543	0.48	0.85	3674	3043	83831	48362	0.46	0.80	27	47
BEE'S GARDEN	26407	11440	7698	1.89	3026	0.26	0.39	1601	708	12148	8406	0.25	0.36	14	21
HORTITEC(K) LTD.	60480	63519	18715	2.8	80866	1.27	4.32	28881	1622	65140	20336	1.24	3.98	74	241
LAKE CROPS	11674	17967	7189	1.42	13649	0.76	1.90	9612	1596	19563	8785	0.70	1.55	41	93
THREE POINT OSTRICH FARM	456520	329713	138933	28.27	225542	0.68	1.62	7978	1968	331682	140902	0.68	1.60	40	96
MBEGU	242118	906317	285813	43.03	1241251	1.37	4.34	28846	994	907311	286807	1.37	4.33	82	263
LONGONOT FARM	163500	302778	124788	24.55	249801	0.83	2.00	10175	4202	306980	128990	0.81	1.94	48	117
LONGONOT HORTICULTURE	1225524	1590160	629295	121.45	1288388	0.81	2.05	10608	7307	1597467	636602	0.81	2.02	48	122
SHER AGENCIES LTD.-SIMBA	1869252	3793464	1201753	181	5217157	1.38	4.34	28824	159	3793623	1201911	1.38	4.34	83	263

Returns															
KIMWATU	1134000	662388	191812	28.65	825810	1.25	4.31	28824	0	662388	191812	1.25	4.31	75	261
OSERIAN	7629744	13058315	4112271	636.78	16860565	1.29	4.10	26478	42163	13100478	4154434	1.29	4.06	77	246
HOMEGROWN (PELICAN)	937440	1414221	540535	96.46	1563445	1.11	2.89	16208	45705	1459926	586240	1.07	2.67	64	161
BRIXIA MARIO	1099008	876221	350614	69.25	626974	0.72	1.79	9054	3177	879398	353791	0.71	1.77	42	107
LOLDIA	1050574	1472549	694430	159.32	445604	0.30	0.64	2797	48035	1520584	742465	0.29	0.60	17	35
MALEWA BAY	428133.6	409123	275295	67.59	238440	0.58	0.87	3528	50977	460100	326272	0.52	0.73	30	43
KARI-NAIVASHA STATION	951774	280618	188825	46.36	114312	0.41	0.61	2466	25993	306611	214818	0.37	0.53	21	31
DELAMERE ESTATES LTD.-dairy factory	3432488	4728140	2366099	523.49	2526405	0.53	1.07	4826	512735	5240876	2878835	0.48	0.88	28	52
KORONGO	757014	225852	126677	29.32	114602	0.51	0.90	3909	8416	234269	135094	0.49	0.85	28	50
OLSUSWA	768827	1474896	827344	191.5	826291	0.56	1.00	4315	60761	1535657	888105	0.54	0.93	31	55
NORTH LAKE NURSERIES	822973	874868	297291	51.3	1019387	1.17	3.43	19871	11668	886536	308959	1.15	3.30	69	200
NYANJUGU INVESTMENTS LTD.	1023840	667266	208937	33.86	798368	1.20	3.82	23578	26905	694171	235842	1.15	3.39	69	205
OL-ARAGWAI LTD.	351470	582798	233202	46.06	418920	0.72	1.80	9095	4555	587353	237757	0.71	1.76	42	106

MARULA HOMEGROWN	608893	1008612	417474	84.1	707831	0.70	1.70	8417	3489	1012101	420963	0.70	1.68	41	101
MARULA	13563407	4373416	2808790	687.144	429739	0.10	0.15	625	21401	4394817	2830192	0.10	0.15	5	8
MUGUKU	9720	117912	34145	5.1	147003	1.25	4.31	28824	254	118166	34399	1.24	4.27	75	259
BOFFER	155520	237371	94982	18.76	171514	0.72	1.81	9143	984	238355	95966	0.72	1.79	43	108
MWANGI GATERI	917568	110840	44352	8.76	80104	0.72	1.81	9144	801	111642	45153	0.72	1.77	42	107
GR. PLANET N./AMOROSO-motor vehicle workshop	370931	280725	89928	14.89	330260	1.18	3.67	22180	1532	282257	91460	1.17	3.61	70	219
ELSAGRO/SHAN TARA	194400	278434	88237	13.29	383072	1.38	4.34	28824	0	278434	88237	1.38	4.34	83	263
OSIRUA/KIJABE	381060	725985	261355	39.78	1146621	1.58	4.39	28824	0	725985	261355	1.58	4.39	95	266
NINI	629856	754400	251101	37.98	1094738	1.45	4.36	28824	0	754400	251101	1.45	4.36	87	265
SULMAC FLOWERS	4205520	8995378	3390311	623.25	8634607	0.96	2.55	13854	317686	9313065	3707997	0.93	2.33	55	141
GOLDSMITH	185537	526434	168675	25.43	732996	1.39	4.35	28824	12707	539141	181383	1.36	4.04	82	245
SHALIMER FLOWERS	303264	2597478	760907	113.78	3279603	1.26	4.31	28824	222380	2819858	983287	1.16	3.34	70	202
SAFARI HORTICULTURE	1646179	860409	264744	39.77	1146333	1.33	4.33	28824	31769	892178	296513	1.28	3.87	77	234
LAKE FLOWERS LTD-Flowers industry	155520	321440	111306	16.89	486839	1.51	4.37	28824	11401	332841	122707	1.46	3.97	88	241

HOMEGROWN-KARI	603612	788536	315527	62.32	564232	0.72	1.79	9054	0	788536	315527	0.72	1.79	42	108
HERNETH (KENYA) LTD	0	330333	103175	15.52	447350	1.35	4.34	28824	0	330333	103175	1.35	4.34	81	263
HOMEGROWN(FLAMINGO)	0	1398686	476678	72.24	2082251	1.49	4.37	28824	0	1398686	476678	1.49	4.37	89	265
NOORDAM ROSES	0	297949	89531	13.42	386819	1.30	4.32	28824	0	297949	89531	1.30	4.32	78	262
THREE POINT FARM	0	3204376	1282208	253.25	2292870	0.72	1.79	9054	0	3204376	1282208	0.72	1.79	42	108
WILD FIRE	0	948382	274629	41.02	1182363	1.25	4.31	28824	0	948382	274629	1.25	4.31	75	261
LIVE WARE LTD	0	316455	113924	17.34	499809	1.58	4.39	28824	0	316455	113924	1.58	4.39	95	266
RAYMONDE	0	445985	129147	19.29	556016	1.25	4.31	28824	0	445985	129147	1.25	4.31	75	261
MORENDAT	539782	667968	125752	389.63	2248127	3.37	17.88	5770	19461	687429	145214	3.27	15.48	198	943
Regional Aspects	49064060	63672652	24684271	5031.58	63940930	1.00	2.59	12708	1508439	65181091	26192709	0.98	2.44	58	148

Analysis						Total	Total		
			Total	Reqd	Applied	Reqd	Applied	Reqd Irr	App. Irr
Crops	Area	Net Return	Return	Irrigation	Irrigation	Irrigation	Irrigation	Net Return	Net Return
	(ha)	US $/ha	US $	(m^3/ha)	(m^3/ha)			US $/m^3 water	US $/m^3 water
Flower Open	952.2	28824.1	27445861	6695	23120	6374882	22014529	4.305	1.247
Flower GH	613.6	28824.1	17687025	6570	18250	4031483	11198565	4.387	1.579
Vegetables	1623.1	9053.8	14695132	5063	12653	8217745	20537024	1.788	0.716
Fodder	756.4	1097.4	830100	4073	6053	3080823	4578494	0.269	0.181
Wheat	164.3	612.5	100641	4219	9169	693236	1506551	0.145	0.067
Grass	561.3	219.2	123045	4073	6053	2286101	3397436	0.054	0.036
Macadamia Nuts	360.7	5923.8	2136710	0	1220	0	440054	#DIV/0!	4.856
Total Agriculture	5031.6	12524.6	63018515	5116	10931.1742	24684271	63672652	2.448	1.146
Ilvestock Unit	11633	79.29	922415						
Water other than irrigation						1508439	1508439		
Total usage						26192709	65181091		
Total return			63940930						

FARM DATA

Example on Farm Data

Farm:Aberdare Estates

FARM DATA		CADAS	CADAS	WRAP	WRAP	WRAP		
WRAP	WRAP	LAND	FARM	LAND	FARM	IRR	WRAP	WRAP
Sr.	Name	REF	SIZE	REF	SIZE			
No.							X	Y
SW001	ABERDARE STATES	10855	437.54	10855	392	21.2	213363	9917165

			HUACCHO					
WRAP	WRAP	Estimated	WRAP	Estimated	Estimated	Estimated	WRAP	
Water	Crops	Main Crop	Irrigation	Open Area	GH	Irrigation	Domestic	
Source	Name		(ha)	(ha)	(ha)	(ha)	(People)	
L. Naivasha	Cabbages_gloria, french beans	Vegetables 75%	21.2	17.84	0		30	

								WRAP
WRAP		WRAP	WRAP	WRAP	WRAP	WRAP	WRAP	Total
Livestock		Wildlife	Industry	Tourism	Abstraction Rate	Time	Estimated Abstraction	Abstraction
(L.U)		(Animals)	(m3/y)	(Y/N)	(m3/s)	(s/y)	(m3/y)	
56		0	0	N	0.25	550800	137700	137700

FARM ECONOMICS

Example of the economic calculation on farm level.			(Aberdare Farm)	
For full analysis: farmeconomics.xls sheet				

	WRAP 1997 Inventory data based on on farm interviews/visit								
Farm	**Cadastral_num**	**Farm area**	**Domestic**	**LIVESTOCK**	**WILDLIFE**	**INDUSTRY**	**irr_area**	**crops**	**waterpoint**
		(ha)	(People)	(L.U.)	(Animals)	(m3/y)	(ha)		
ABERDARE STATES	10855	392	30	56	0	0	21.2	Cabbages_gloria, french beans	BHOO1,SW001

Total	ITC (based on cadaster, satelite image, fieldwork, info from farms)							Net Crop	Milk
abstraction	**Cadas_area**	landuse	L_use_A)	Crop	open_irr	greenh	rainfed	Profit	Profit
(m3/y)	(ha)	(Type)	(ha)		area (ha)	area (ha)	area (ha)	US $/yr	US $/yr
137700	437.54								
		Natural	381.873	Flowers	0	0	0	0	
		Uncultivated	10	Vegetables	17.84		0	161519.446	
		Builtup	21.877	Wheat	0		0	0	
		Cultivated	23.79	Fodder	5.95		0	6529.75	

Irrigation Requirement			Other water requirement				Net Total	Expected Net	Net Total
Crop	open_irr	greenh	domestic	livestock	industrial	wildlife	water reqmnt	Return	Return
	cons (m3/y)	cons (m3/y)	cons (m3/y)	cons (m3/y)	cons (m3/y)	cons (m3/y)	m3/yaer	US $/m3.water	US $
			953.0585399	930.02	0	0	116441.7	1.481	172489.60
Flowers	0	0							
Vegetables	90324.16438								
Wheat	0								
Fodder	24234.43151								

Net Return	Applied Irrgn			Applied	Net Actual	Actual	Expected	Application	Other than
On Abstraction	Crop	open_irr	greenh	Irrigation	Return	Net Return	Net Return	Times	Irrigation
US $/m3.water		cons (m3/y)	cons (m3/y)	m3/yr	US $/m3.water	Ksh/m3.water	Ksh/m3.water		m3/yr
1.253				261745.1959	0.659	40	90	2.28	1883
	Flowers	0	0						
	Vegetables	225729.7644							
	Wheat	0							
	Fodder	36015.43151							