ASSESSMENT OF ENVIRONMENTAL DEGRADATION IN A RIVER CATCHMENT WITH A FOCUS ON FORESTRY AND WATER RESOURCES: THE CASE OF NAMADZI RIVER UPPER CATCHMENT

MSc. ENVIRONMENTAL SCIENCE

BY

JACINTA CHINSEU-CHIPENDO

Bsc Agric. (Rural Development)-Bunda College of Agriculture

Faculty of Science, University of Malawi, in partial fulfillment of the requirements for Master of Science Degree in Environmental Sciences.

UNIVERSITY OF MALAWI

CHANCELLOR COLLEGE

MARCH 2010

DECLARATION

I declare that this thesis is a product of my own independent work, except where otherwise stated and this has been acknowledged by references. This thesis has never been accepted previously in substance of any degree and is not being concurrently submitted in candidature of any degree.

I hereby give consent for my thesis, if accepted, to be available for photocopying, and for inter-library loan, and for title and summary of results to be posted on the Internet and be made available to both local and international organizations.

Jacinta Chinseu Chipendo **Date:**

CERTIFICATE OF APPROVAL

The undersigned certify that this thesis represents the student's own work and effort, and has been submitted with our approval.

Main Supervisor:

______________________________________ _________________________

Dr. E.Y. Sambo

Supervisor:

______________________________________ _________________________

Mr C. Ngongondo

DEDICATION

To: ***My Late father:*** *Paul G.A. Chinseu**, you used to say and I quote***

"Investment in Knowledge is the best ever".

You were a source of inspiration.

My Mother: *Elizabeth Chinseu**; you took over from Father.***

Lucius and Praise Chipendo: ***for your Understanding, Encouragement and Support***.

ACKNOWLEDGEMENTS

I would like to thank Dr. E. Y Sambo, Biology Department, the principal Supervisor of this work, for the constructive comments, suggestions and criticisms. The contributions of the co-supervisor, Mr Cosmo Ngongondo, Geography and Earth Sciences Department are also greatly appreciated. Dr T. Chirwa, Mathematics Department is thanked for his comments on the sampling procedure for the socio- economic study.

The following Ministries and Departments are also thanked for providing existing data: Ministry of Water Department for providing river discharge data for the study area; Meteorology Department for providing the Makoka climate data; Forestry Department, Zomba, for forestry data; and Land Husbandry and Crops Sections, Zomba District Development Office. I am also indebted to Mr Thayo, Mbulumbuzi EPA, Mr Suga, Mr Mtaila and Mr H. Matola of Thondwe EPA for coordinating during data collection for the socio-economic study.

I thank Mr C. Tembo of National Herbarium and Botanic Gardens for technical assistance in identification of plant species in the study area; Mr Ngwale, Department of Surveys, for providing the aerial photographs; and Mr J. Gwaligwali, Cartographer, in the Geography and Earth Sciences Department for his assistance in all map work; and Ms Debora Mbano, Chief hydrologist for the Regional Water Office in Blantyre for assisting on the models.

The Dean of Science and the MES Programme Coordinator provided administrative guidance, and I am also very grateful to MEET for the scholarship to undertake the course. Mrs. S. Ndau, Ms Madalo Samati, Mr and Mrs Chidalengwa, Mr and Mrs Imwa gave their unreserved hospitality during my study period. Finally, all my classmates Mrs Shamiso Najira, Mr Alick Kafasalire, Mr Allan Kwanjana and Mr Joshua Chienda; and relatives are acknowledged for their encouragement and support.

Jacinta Chinseu-Chipendo (Mrs)

MES Programme

Chancellor College

University of Malawi

ABSTRACT

Namadzi River catchment with total area of 69,802 hectares is an important river sub-catchment, for both commercial estates and smallholder farming. The Namadzi River feeds into Lake Chilwa, a wetland of international importance under the Ramsar Convention. This thesis report on a study conducted to assess environmental degradation in this river catchment with a focus on forestry cover change impacts on water resources.

Aerial photo interpretation and statistical analysis of historical data and rainfall/run-off modelling using RainRu models were used to analyze forest cover change and the relationship between forest cover change and stream flow. Further, the study also looked at the dependency on forest and water resources in Namadzi catchment to examine the socio-economic characteristics of the area.

Results show that rainfall has decreased over the years and the decrease is also evident in run-off and stream flow, two important rainfall dependent variables. Results from Mann Kendall statistic and Sen's method show that annual decreasing flows are evident, though not significant. At monthly level, decreasing flows were also found in February (significant at 99%), March (significant at 90%), April (significant at 99%), May, July and August (all not significant). In addition, increasing flow trends are found for June, September and November (not significant), October (significant at 95%) and December (significant at 99%). Furthermore, the slopes for all the months are statistically different from zero at 99% confidence interval indicating that stream flow is decreasing over the years.

RainRu model results show that the rainfall/run-off relationship has not changed significantly over the years. The results further show a decreasing trend in forest cover from 1965 to 1974 and an increase since 1995. As noted from the rainfall/run-off relationship, the overall picture for rainfall/run-off relationship has not changed over the years. This suggests a direct effect of forest cover (land cover) change on stream flow.

Results from the socio-economic study indicate environmental degradation in Namadzi catchment has taken place. The larger percentage of the respondents, 60.3% indicated that indigenous forest has decreased by over 85% compared to 20 years ago. This has been shown by the increased trend in area planted with trees in the catchment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAP

LIST OF APPENDICES

ACRONYMS

BD	Base Deficit
CN	Curve Number
EMA	Environmental Management Act
EPA	Extension Planning Area
ESCOM	Electricity Supply Cooperation of Malawi
FAO	Food and Agricultural Organisation
GOM	Government of Malawi
GDP	Gross Domestic Product
IDEAs	Initial District Environmental Action Suggestions.
IFF	Intergovernmental Forum on Forests
IPF	Intergovernmental Panel on Forests
MEET	Malawi Environment Endowment Trust
MGDS	Malawi Growth and Development Strategy
MPRSP	Malawi Poverty Reduction Strategy Paper
NEAP	National Environmental Action Plan
NEP	National Environmental Policy
NFP	National Forestry Programme
NGO	Non-Governmental Organisations
NHBG	National Herbarium and Botanic Gardens
NSOER	National State of Environment Report
NTFPs	Non-Timber Forest Products
SADC	Southern African Development Community
SCS	Soil Conservation Services
UNCED	United Nations Conference on the Environment and Development

CHAPTER 1: INTRODUCTION

1.0 Background

In general, drivers of environmental change vary in nature and scope but can be broadly grouped together as demographic, economic and social, and technological; conflict and governance. At a global level, the world has undergone unprecedented social, economic, political and technological change and the growing integration of finance economies, culture, technologies and governance through globalization is having profound impacts, both positive and negative on all aspects of people's life and the environment (UNEP GEO, 2002). *"Environment"* means the physical factors of the surroundings of the human being including land, water, atmosphere, climate, sound, odour, taste, and the biological factors of fauna and flora, and includes the cultural, social and economic aspects of human activity, the natural and the built environment (GOM, 1996a).*"Environmental degradation"* is broad and is related to the deterioration of the environment both in terms of quantity and extinction of some wildlife species and quality like air, water or land pollution. *"Hotspots"* are characterized both by exceptional levels of plant endemism and by serious levels of habitat loss (Myers 1998).

The economies of African countries have been largely based on primary products of extraction of natural resources. In addition the focus on mineral extraction, cash crops and timber harvesting has also had a detrimental impact on environment (UNEP GEO, 2002). The Malawi National Environmental Policy of 2004 indicates that there is degradation of the environment, causing significant loss of soil fertility, soil erosion, serious deforestation, water depletion, pollution and loss of biodiversity.

Population pressure, heavy dependence on fuel wood, timber and other products, as well as conversion of forest to agriculture, urban and industrial land are the underlying factors of deforestation. (ADB, 2000). For instance, charcoal production accelerates deforestation because unlike firewood, which is mostly from dead branches and stems in rural areas, charcoal production involves the felling of live trees (Kanabahita, 2001). Thus the major causes of deforestation and general degradation of the environment are agricultural expansion, increased wood fuel demands, and forest fires (DREA, 1994).

Forests play a role in watershed conservation including storing excess rainfall through interception of run-off and increasing the infiltration of rainwater, thereby recharging underground aquifers and serving as a source of stream flow. However, in many developing countries, extensive areas are undergoing land use and land cover change including river catchment areas. The largest changes in terms of land area and arguably also in terms of hydrological impacts often arise from afforestation and deforestation activities (Calder, 1992).

Recognising that forestry and water resources are prime resources necessary for sustaining all socio-economic development activities that mainly include industry and agriculture. There is need, therefore, to find ways of reversing the rate of environmental degradation in the country. World leaders responded to the environmental degradation problem through the Earth Summit of 1992. Its principal outcome was an action plan for the whole world, elaborating strategies and integrated program measures to halt and reverse the effects of environmental degradation and to promote environmentally sound sustainable development in all countries.

Following the United Nations Conference on the Environment and Development (UNCED), also referred to as the Earth Summit, held in Rio de Janeiro in 1992, most nations including Malawi subscribed to the new principles that were established for the management of natural resources and environment. In that regard, Malawi is signatory to the various world conventions governing the conservation and sustainable utilization of the environment and natural resources. Some of these conventions and protocols that Malawi is signatory to are the three Rio conventions, namely, the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (CCD); as well as the Ramsar Convention, CITES and the African Convention on the Conservation on Nature and Natural Resources (See Appendix 1).

Conservation and sustainable utilization of the environment and natural resources in river catchments is essential for sustainability of river flows as well. Therefore activities in communities within river catchments need to be better understood by resource managers for proper management of the resources. The upper catchment of Namadzi River is characterized by both estate and smallholder agriculture and their activities heavily rely on forest and water resources. Therefore, understanding the relationship between forestry and water resources in a river catchment where major land use activity is agriculture is of importance because water, forestry and agriculture linkage is a driver for socio-economic growth of a country and managing them properly would lead to environmental sustainability.

It is against this background that the study aims at assessing forest cover change in Namadzi River catchment and its effect on stream flow. The underlying assumptions are: (i) there is a relationship between forest cover and stream flow; (ii) forest and water resources depletion is a process that is fuelled by socio and economic factors.

1.1 Problem Definition

The Namadzi River, one of the major rivers that contribute its water to Lake Chirwa originates from a heavily cultivated area. In its upstream, the river passes through Amika, Msamba, Gala, Kapino, New Farm, Agricola and Costa Estates, which also depend on it for irrigation requirements. In addition, villages surround the estates, with agriculture as their means of subsistence.

Namadzi River gets discharge from Nambala aquifer in Chiradzulu and it has been reported that production of water at Nambala aquifer is throughout the year. The aquifer produces more than 5 litres per second, which is the average amount of water produced by aquifers in basement complex rocks (Kamwaza, 2006). On the contrary, Zomba District Agriculture Development office has reported water use conflicts between the domestic and productive users of the resource like estates. The problem is further compounded by degradation of the riverbanks resulting in siltation of the riverbed and reduced retention of moisture, which has seen the river drying up in some years. The drying up has hampered government efforts to increase area under irrigation farming downstream of Namadzi River. Establishing a relationship between hydrology and watershed characteristics such as forestry would provide the groundwork for assessing the existence of environmental impacts in the study area.

Therefore the purpose of this research is to assess environmental degradation in Namadzi catchment through analysis of forest cover change and its relationship to stream flow. This is important because depletion of water and forest resources in a river catchment is a big threat to sustainable socio-economic development. Hence the requirement for assessment of socio-economic characteristics, factors that influence forestry and water resources use in the catchment.

1.2 Research Questions

- What are the major social-economic characteristics affecting water and forest resources use and management in a river catchment?
- What is the trend in forest cover change in Namadzi River catchment?
- What are the rainfall, runoff and stream flow trends in Namadzi River Catchment?
- What is the impact of forest cover change, if any, on Namadzi River stream flow?
- Where are the major hotspot areas in terms of water and forest resources in Namadzi River catchment?

1.3 Research Hypothesis

- Change in forest cover does not have an impact on stream flow.
- Socio-economic activities do not have an effect on forestry and water resources in a river catchment.

1.4 General Objectives

The main objective of this research is to assess environmental degradation through analysis of forest cover change in Namadzi River catchment and its relationship to stream flow.

1.5 Specific Objectives

- Analyse major socio-economic characteristics in relation to water and forestry resources in Namadzi River catchment.
- Analyse forest cover change in Namadzi River catchment.
- Analyse trends in forest cover change, rainfall, run-off and stream flow.
- Analyze impact of forest cover change on stream flow.
- Identify forest and water resources hotspots in the Namadzi River catchment.

1.6 Value of Research

Information from the study may be useful for Zomba District Agricultural Development Office (DADO) in forestry planning, soil and water resources management activities in the area. Other DADOs may also learn from experiences based on this study. The study is also done in partial fulfilment of Master of Science in Environmental Science.

1.7 Problems and Limitations

The major problem experienced in this study was resource limitation. The study also depended strongly on historical data, in terms of rainfall, river discharge and forestry data, some of which was missing. For instance most recent data readings were not there. Data obtained for this study were from 1968/69 to 2006/07 for area planted with forest; from 1952/53 to 1999/00 for stream flow; and from 1958/59 to 2005/06 for rainfall data. Therefore this study only concentrated on the period between 1952 and 2003.

1.8 Organization of the Thesis

This thesis contains five chapters. The present chapter mainly gives an introduction to the problem, and states the objectives, hypothesis and problem statement. Chapter two is the literature review where information to backup the study with the present state of knowledge on the subject is presented. Chapter three gives some background information to the study area and methods applied to examine the problem. Chapter four presents results and discussion. The conclusions and recommendations are given in Chapter five.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This chapter explores the literature with regard to what has been written so far on how forest and water resources affect socio-economic life of communities and how the change in one of the two resources relate to the other. Various studies looking at forest and water resources have been conducted nationally, regionally and globally. However, the national, regional and global view of the studies is not enough to understand the effects occurring locally. The diversity of socio-economic and biophysical conditions makes it difficult to find similar changes between one locality and another.

2.1 Major Causes of Environmental Degradation

2.1.1 Global and Regional Overview

Degradation of natural resources such as land, fresh and marine waters, forests and biodiversity threatens the livelihood of many people but especially the poor. For instance, water tables are falling fast under the North China plain. In 1997, almost 100 000 wells were abandoned because they ran dry as the water table fell, but 221 900 new wells were drilled. The drilling of so many wells reflects a desperate quest for water (Brown, 2001). At global level, the net loss in forest area during the 1990s was estimated at 9.4 million ha (equivalent to 2.4 percent to total forest). This was a combined effect of deforestation rate of 14.6 million ha per year and a rate of forest increase of 5.2 million ha per year (FAO, 2001).

Globally, it is also estimated that at present there are approximately 840 million undernourished people, of whom some 210 million live in Sub-Saharan Africa and this situation led to the 1996 World Summit to set a goal reaffirmed at the 2000 Millennium summit, of halving the number of hungry people by 2015 (FAO, 2003). Hence fulfilling this objective will have significant implications for forestry and water use in the region. For instance, in Nigeria, the detailed analysis of land use dynamics shows that while agricultural crop land will increase from its present level of 61,900,000 ha in 1995 to 70,652,157 ha by 2020, forest land will decrease by 2,650,000 ha during the same period. It is easy to see that forestland and indeed most woodlands will be heavily depleted and converted to agricultural cropland. At steady state situation even the land use such as flood plain agriculture and water resources development that enjoyed short-term advantage will eventually be depleted (Aruofor, 2001).

It has also been estimated that between 1990 and 2000, Africa lost 52 million hectares of forests and this amounted to a decrease in cover of 0.8% per year and 56% of the global total. It is further estimated that 60% of the tropical forest areas cleared in Africa as a whole between 1990 and 2000 were converted to permanent agricultural smallholdings (Cleveland, 2007). In Northern Africa, 13 % of forest cover was lost during 1972-92 and in Nigeria deforestation of riparian forests and Savannas for agricultural development was estimated at more than 470 000 ha a year during 1978-90 (DOF Nigeria, 1996)

Forestry Outlook study for Uganda has indicated that rapid population growth in Uganda has also led to increased deforestation in peri-urban areas and the densely populated fragile highlands in the east and southwest. The increase in urban population corresponds to the increase in the demand for charcoal of 6% per annum. Charcoal production accelerates deforestation because unlike firewood, which is mostly obtained from dead branches and stems in rural areas, charcoal production involves the felling of live trees (Kanabahita, 2001).

Currently, by far the greatest part of cultivation in southern Africa is rain fed (Table 2.1). Obviously rain fed agriculture is highly dependent on the quantity and temporal distribution of rainfall. Irrigation, if properly designed and managed helps overcome many of the disadvantages inherent in rain fed agriculture. The risk of crop failure is minimized and farmers can hope for higher and more reliable agricultural production and better levels of income (Sally, 2003). Table 2.1 shows the area of cultivated and irrigated land in countries of Southern Africa.

Table 2.1: Area of Cultivated and Irrigated Land in Countries of Southern Africa.

Country	**Total Area (Km^2)**	**Total Cultivable Area (km^2)**	**Total Cultivated Area (km^2)**	**% Cultivated**	**Total Irrigated Area (km^2)**	**% Cultivated**
Angola	1,246,700	-	29,000	-	750	2.6
Botswana	581,730	62,000	32,420	52.2	13.8	0.1
Lesotho	30,350	-	2,093	-	27.2	1.3
Malawi	118,480	36,000	21,055	58.5	280	1.3
Mauritius	2,040	-	854	-	175	20.5
Mozambique	801,590	360,000	36,000	10	1,067	3.6
Namibia	824,900	250,000	2,052	1	61.4	3.6
South Africa	1,221,040	183,200	123,560	67.4	12,700	10.3
Swaziland	17,364	-	1,915	-	67.4	3.5
Tanzania	945,090	400,000	63,000	15.8	1,500	2.4
Zambia	752,610	163,500	10,298	6.3	464	4.5
Zimbabwe	390,760	-	27,500	-	1,166	4.2

Source: FAO Aquastat database adopted in Van der Zaag (2002).

Depending on efficiency, obviously any increase in irrigated area will result in greater water consumption. However water is viewed as a scarce (i.e. limited and finite) resource and for many countries in Sub-Saharan Africa water scarcity either physical or economic is an increasing constraint to economic growth. Boss *et al*, (1996) indicates that irrigation also has a major impact on the stream flow, since it abstracts water from that source.

Apart from irrigation, conversion of land to other agricultural uses may also result in the following changes in the watershed: a) the availability of soil water to plants will be less for short-rooted agricultural crops; b) introducing crops with lower total leaf area index will result in lower evapotranspiration; c) depending on management practices of the farmers, infiltration can increase and replenish the groundwater resources, but it is also possible that the infiltration decreases resulting in a large component of surface runoff and erosion (Calder, 1996).

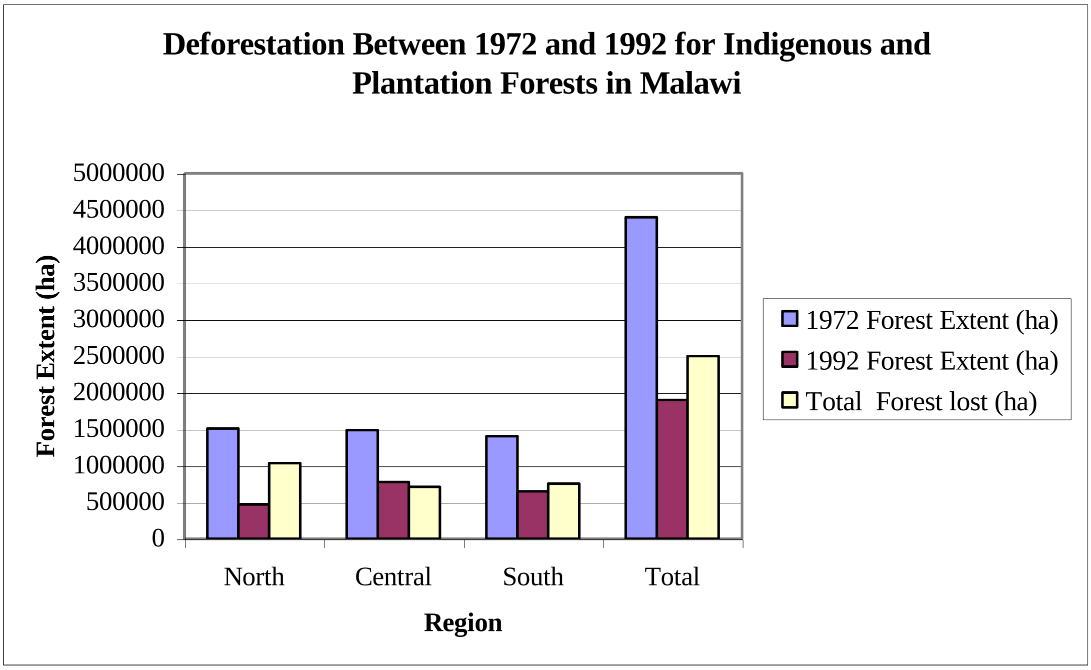
2.1.2 Environmental Degradation in Malawi

Forestry and water resources are under threat due to increasing population that results in more land clearing for agriculture, which further accelerates deforestation. For instance, Zomba and Chiradzulu districts have one of the highest population densities in Malawi. The population densities are 209 and 150 persons per km^2, respectively, compared to the national average of 104 persons per sq km (GOM, 2000b). Each year, the number of people increases, but the amount of natural resources with which to sustain this population, to improve the quality of lives remains finite. It can be concluded that high population densities are associated with severe pressures on the limited natural resources, resulting in serious environmental degradation

Literature further indicates that in 1975, 47 % of Malawi was classified as forests; in 2000, only 28 % was classified as forest of which 21 % was forest reserves, national parks and wildlife reserves, and 7 % was on customary land; it has also been indicated that the previously vast forest resources have been considerably reduced from 4.4 million hectares in 1972 to around 1.9 million in 1992 (GOM 1998a; 2002b). The total forest cover is however, estimated to be declining at 1.0-2.8 percent per year with much higher deforestation rates in certain areas.

Both natural and planted forests in Malawi provide about 94 percent of the country's fuel wood and poles for industrial and domestic uses. This is equivalent to 3.7 million $m^3$of wood against 14.5 million m^3 currently demanded implying a wood deficit of 10.8million m^3 (Kainja, 2000). The Central and Southern regions have the critical fuel wood and pole shortage than the Northern region. In urban and semi-urban areas, high tariffs of electricity by ESCOM and price hikes in electrical appliances is another contributing factor to high wood fuel consumption. Many people cannot afford to use electric power and there is lack of appropriate alternative technologies to substitute firewood and charcoal. Only 2% of the population is now using electricity (GOM, 2000a). There is a decline in electricity use from 4% and corresponds to the increase in wood fuel dependence.

In addition, over 90% of Malawi's energy requirements are met from fuel wood and charcoal, the bulk of which originates from the remaining natural forests (Ngulube *et al*. 1999). It is estimated that in Malawi nearly 70% of all consumed wood is used for rural cooking (World Bank, 1992). There is evidence that forest resources have been subjected to deforestation. Table 2.2 shows deforestation between 1972 and 1992, as determined by comparing Landsat MSS (1972) and Landsat TM (1992) (Kainja, 2000).



Source: Kainja (2000)

Fig 2.1: Deforestation between 1972 and 1992 for Both Indigenous and Plantation Forests in Malawi

Low-income households in Malawi have a higher per capita charcoal consumption, and with and/or fuel wood accounting for three quarters of their total household energy expenditure. The estimated total volume of charcoal consumed in the largest urban areas of Malawi is 6.08 million standard bags per year (Kambewa *et al*. 2007). In addition, demographic change is the major driver of land cover change through opening of new land for agricultural, settlement and infrastructure development.

It has been reported that over 50% of the wood energy comes from customary forests and woodlands, 36% from forest reserves, 15% from plantations, 14% from crop residues and 22% from other sources of biomass (GOM, 2001). It is estimated that 2/3 of the total wood consumption represents rural demand for fuel wood for cooking and heating. The balance is composed of urban wood fuels for cooking and industrial requirements, building poles construction, tobacco and tea curing and building requirements and other miscellaneous uses (Kainja, 2000). It is evident that as forests are displaced and depleted by other forms of land-use such as agriculture, grazing and water management, formation of bare surfaces and general environmental degradation increase.

In rural areas, firewood from adjacent forest remains an essentially free and accessible good and low cost alternative energy sources are generally not available (Brouwer, 1998). It has also been reported that productivity of Malawi's national forests, mostly Miombo, is generally low to meet current levels of demand, as wood harvest rates exceed sustainable yield (GOM, 1998).

2.2 Importance of Forest and Water Resources in Malawi

Forest and water resources are important for the maintenance and growth of industrial and other social activities in any country. For instance, in China it has been stated that Forestry shoulders heavy tasks of treating soil and water erosion, water source conservation, combating desertification, conservation of wild fauna and flora, prevention and alleviation of disasters (Kunshan *et al*, 1997).

At the local level, agriculture is the backbone of the economy and employs over 85% of the population that resides in the rural areas, normally accounts for 35-40% of GDP and contributes over 90% of total export earnings. Smallholder farmers produce about 80% of Malawi's food and 20% of the agricultural exports (World Bank, 1996; GOM, 2002b). Both forestry and water sectors depend on water and forestry resources in terms of plant growth and processing farm produce.

Forests also play a role in conservation of wildlife habitat and biological diversity values. Equally challenging is how to benefit from biological biodiversity while ensuring the sustainability of the resource. For instance, in Botswana, the combined effects of deforestation, overgrazing, and perennial wild fires have resulted in conversion of 20,000ha of productive woodland to less productive grasslands and shrub formations leading to serious soil erosion problems, flash flooding and localized fuel wood and construction wood shortage (Sekgopo, 2001). It has also been estimated that under the current exploitation trend in Nigeria, the natural forest could get completely depleted between 2004 and 2005 especially if the projected demand was to be satisfied (Aroufor, 2001)

One of the roles of forests that are gaining ground is the potential for forests as carbon sinks. This potential offers opportunity for developing countries to get economic return from forests through carbon trading (Leach G, 2004). Both natural and plantation forests play an important role in providing fuel, food, fodder, poles, timber, and pharmaceuticals and provide shelter to wildlife (GOM, 1999a).

It has been reported that people in the Lake Chilwa catchment rely on the forests for Non Timber Forest Products (NTFPs) such as fuelwood, poles, fibre, rodents, honey, mushrrom, thatching grass, game, fruits and insects (Sambo *et.al*, 1999). Most of NTFPs are consumed or traded locally by household (Minae *et al*, 1995). It is estimated that 26, 162 tonnes of cane furniture and other craft products are produced annually (Kainja, 2000). A variety of products are also derived from bamboos (*Oxytenanthera abyssinica*), palms (*Raphia farifera*) and reeds (*Phragmites mauritania*). Bamboos are used for weaving baskets, granaries, chairs, beds, mats and shelves. Reeds are used for making mats, fence making, granary making, making doors and baskets. *Raphia farifera* is used for making chairs, tables, shelves and toys. All these products have a commercial value and provide supplementary income for communities. In many cases, there are middle people who buy these products at wholesale price and bring them either to the urban markets or to tourist attraction centre for sale (Minae *et al.*, 1995).

Forests are also a source of ornamental flowers, plants, shrubs and leaves of commercial value. One way of promoting sustainable management of indigenous trees is to make them a source of revenue without destroying them. For example, from fruits that are produced annually, such as the baobab (*Adansonia digitata*), tamarind (*Tamarindus indica*), and monkey orange (*strychos cocculioides*) (Mauambeta, 1998; Saka, 1994) fruit juices and jams are being produced by communities who are benefiting financially from this venture and, therefore, are motivated to protect this sustainable source of income. Mushrooms are an important source of food and income for rural communities throughout the country (Chipompha, 1985). The habitat for mushrooms is however threatened by deforestation and establishment of exotic species.

Forests provide a wide range of non-consumptive services. Forest services can be categorized into two, namely, those for which a formal market exists (such as clean water, ecotourism and hunting) and those functions that are mostly intangible and sold through markets such as cultural or spiritual values. Both natural and man-made forests play an important role in providing basic human needs such as fuel, food, fodder, pharmaceuticals, employment, income and foreign exchange, hence contributing to socio-economic development. As an integral component of the biosphere, forests help to stabilize natural systems such as biological diversity, providing habitat for fauna and flora. Apart from these, forests also help in maintaining air, water and soil quality, influence biochemical processes, regulate run-off and groundwater, control soil erosion, and reduce downstream sedimentation and incidence of flash flooding (Kainja, 2000). Forests are therefore very important in providing watershed protection and enhancing water resources.

In natural conditions most rivers and streams receive water only from their own topographic catchment area. Each drainage basin can be regarded as an individual system receiving quantifiable inputs of precipitation and transforming these via various flows and storages, into quantifiable outputs of evaporation and stream flow. In some cases leakage from deeper subsurface water may represent either an additional input or (as shown in Figure 2.2) an additional output from the drainage basin.

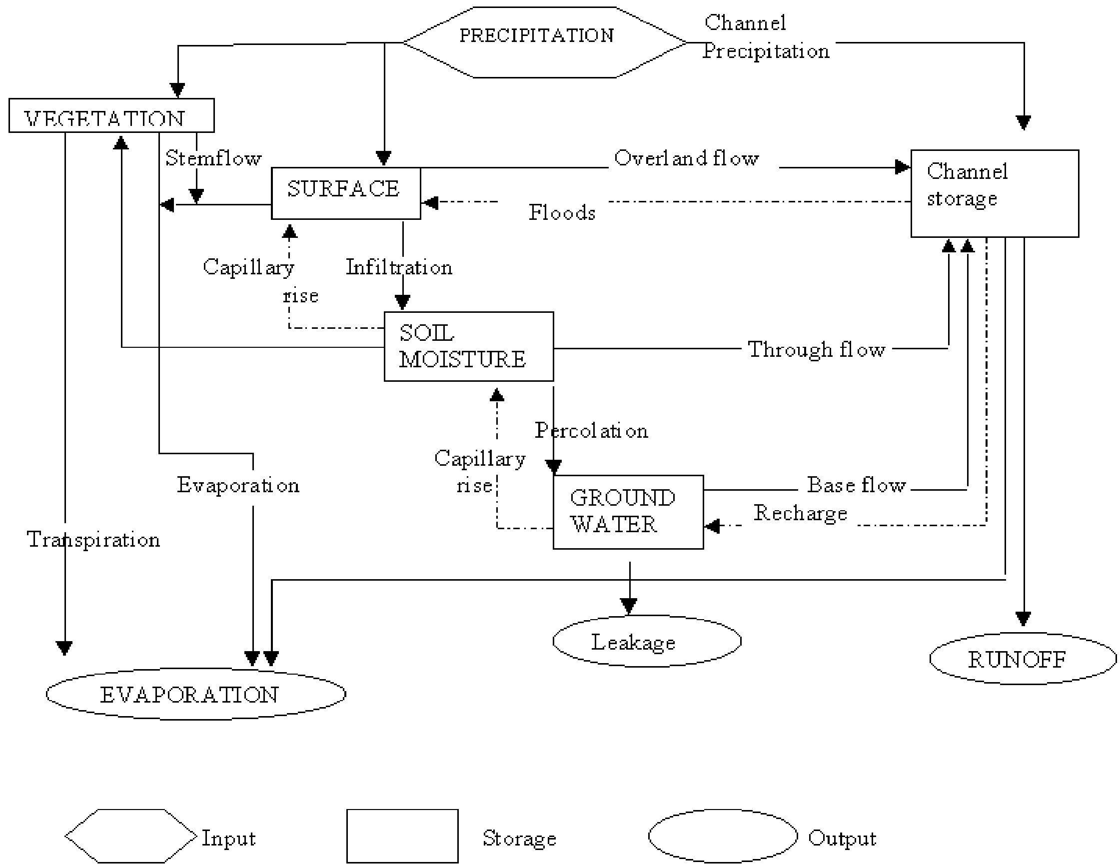


Fig 2.2: Drainage Basin Hydrological System

Source: Adapted from Ward and Robinson (1990)

Boss *et al.,* (1996) indicate that typically, when water falls on a bare field, 60% to 66% is evaporated back to the atmosphere, approximately 25% runs off to ponds, watercourses, lakes and other depression areas, and the remaining 9% infiltrates the soil.

2.2.1 Water Resources and Catchment Water Availability

Water is the source of life as plants and animal life depend on it for survival. The ground covered with trees acts as a sponge, absorbing water during the rains and slowly releasing it over a longer time. Cutting trees in the upper catchment decreases the "sponge effect" with subsequent reduction of river base flow. Kalk *et al.* (1979) stated that seven perennial rivers (Domasi, Likangala, Thondwe, Namadzi, Phalombe, Sombani and Mnembo) together with numerous small seasonal streams flow into Lake Chilwa and its marginal swamps and marshes. Kamwaza (2006) also indicates that flow of water from Nambala aquifer (source of Namadzi River) is sustained throughout the year and that this was the case even during the 1949 national extreme drought conditions and also in the subsequent years of drought of 1982, 1984, 1991 to 1994 and 2001.

2.2.2 The Water Balance Concept

Water balance is often applied to a river basin. A river basin (also called watershed, catchment, or drainage basin) is the area that contributes to the discharge at a particular river cross-section. If no water moves across the catchment boundary, the input equals the precipitation (P) while the output comprises the evapotranspiration (E) and the river discharge (Q) at the outlet of the catchment. Hence, the water balance may be written as:

$$\{P - E\}A - Q = \Delta S / \Delta t \quad \text{.....} 2.1$$

Where ΔS is the change of storage over the time step Δt, and A is the surface area of the catchment upstream of the station where Q has been measured (Savenije, 1999). It is important to recognize that human modifications may be made to virtually every component of the system. At present the most important of these relate to large scale modifications of channel flow and storage e.g. by means of surface changes such as afforestation, deforestation, which affect surface runoff and incidence or magnitude of flooding, the widespread development of irrigation and land drainage and the large scale abstraction of groundwater and surface water for domestic and industrial uses (Ward and Robinson, 1990).

2.3 The Role of Forestry on Hydrology

As noted earlier, the largest changes in terms of land area, and arguably also in terms of hydrological impacts, often arise from afforestation and deforestation activities (Calder, 1992). Observational studies on small watersheds (10s of km^2) in tropical, temperate and boreal region have shown that in general, a decrease in vegetation density (e.g from forest to grassland or crops) can be expected to increase annual mean water yield and discharge, while an increase in vegetation density tends to reduce water yield and discharge, consistent with alterations to total evapotranspiration and soil infiltration rates (Bosch and Hewlett, 1982). Removal of forest cover from a catchment area can result in significant hydrologic changes, including decreased evapotranspiration, decreased rainfall interception by surface litter and increased runoff volumes. Research has shown that the tree canopy can intercept 10-40% of incoming precipitation (commonly 10-20%) depending on factors such as tree species, density of stand, age of stand, location, rainfall intensity and evaporation during or after the rainfall event (Mbano, 2006).

Forests evaporate more water than agricultural lands do and so reduce stream flow (Collet, 2007). Bruijnzeel (1990) discusses the impacts of tropical forests on dry season flows and concludes that the infiltration properties of the forest are critical in how the available water is partitioned between runoff and recharge (leading to increased dry season flows). This study would analyze forest and stream flow relationship in a river catchment where agriculture is the major means of subsistence.

2.4 Environmental Management Framework

There are policies and legislations, which are in place or are being reviewed to address the wood plight and other environmental degradation in the country. These tools are, the Forestry Policy and Act, Decentralization policy, Government policy on poverty alleviation, sustainable agriculture, macroeconomic adjustments and others. Government has also adopted the National Forestry Programme (NFP) whose main aim is to operationalise the National Forestry Policy (Kainja, 2000). It is the aim of the 1996 forestry policy of Malawi to sustain the contribution trees and forest resources make to the quality of life in the country through the conservation of the natural resources base. (GOM,1996). The National Forestry Policy (GOM, 1996b) places an emphasis on providing an enabling framework for promoting the participation of local communities and Community Based Organizations to ensure sustainable utilization of forest resources as a means of alleviating poverty.

On the regional and international scene there are international initiatives to address forest issues at policy level. The Intergovernmental Panel on Forests (IPF) / Intergovernmental Forum on Forests (IFF) are mandated to pursue a consensus and formulate options for further action in order to combat deforestation, and forest degradation, and to promote the management and conservation and sustainable development of all types of forests. There is also a protocol on the Conservation, Sustainable Management and Sustainable Development of Forests and Forest Lands in the Southern African Development Community (SADC) Region, which aims at promoting forest resources and forest lands sustainable management to meet social, economic, ecological and spiritual needs of present and future generations (Kainja, 2000).

There are also laws and regulations that provide the rules pertaining to the use of water as a public resource. Water resources planning involve setting modalities for a systematic and sustainable development of water resources with a view to averting the depletion and degradation of the resource. Water resources management is defined as people's control over water as it passes through its natural cycle, with balanced attention to maximizing economic, social and environmental benefits (GOM, 1998). The 1998 Water Policy for Malawi also emphasizes efficient management of resources and conservation of water in sufficient quantity and acceptable quality.

A study by Chavula (2000) looked at how principle activities of water resources management namely; assessment, planning, development, allocation, conservation, protection and monitoring are being implemented in the whole Lake Chilwa catchment after noting that earlier studies did not either fully address these principles or used very crude methods whose results were noted to be reasonable but with wide error margins. Mulwalfu (2000) concluded that although water resources in Likangala catchment are sufficient, their use and management has become an important site for negotiation and contestation by riverine communities. The Water Resources Policy (GOM, 1999b) advocates community participation in the operation and management of water facilities and resources. The policy vision is to ensure that every Malawian individual and entrepreneur has equitable access to water for his/ her social and economic growth and prosperity.

The Malawi Water Resources Management Policy and Strategies (1998) therefore recognizes that resources like water systems are being continuously threatened from the vagaries of weather, overexploitation, mismanagement, environmental degradation and pollution (GOM, 1998). There is also a growing recognition that greater emphasis must be placed on the management of demand for water as a socio-economic good and make sure that water utilization is as efficient as possible, both in terms of the quantities of water used and the impact of water quality. But in many catchment areas and parts of river basins, however, water availability is frequently less than the demand. Namadzi River is not an exception. It is then necessary to find a suitable allocation decision of the scarce water.

Overall, the environmental management framework gives an overview of the current environmental policy and legislation with reference to river catchment management. Environment and development is a major issue of general concern in the international community, to which the Malawi government has always attached great importance. It is in that regard that Malawi ascribed to the requirement of Agenda 21 as approved at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992.

In accordance with the requirements, Malawi prepared and adopted the National Environmental Action Plan in 1994. The National Environmental Action Plan indicates that high population growth associated with an increase in production is an indicator that environmental degradation is taking place. An initial District Environmental Action Suggestions (IDEAS) presents the implementation strategies for actions in the NEAP.

The National Environmental Policy (NEP) (GOM, 2004a) aims mainly to ensure the promotion of sustainable socio-economic development through sound management of the environment. The National Environmental Policy emphasizes the promotion and support of the conservation and protection of forest ecosystems and the growing of trees by the individual companies, estates, local communities and authorities, including integration of forests and trees into the farming systems, soil conservation activities and land use systems (GOM, 2004a). This would ensure watershed conservation and sustainable socio-economic development. Information on impact of forest cover change on stream flow is essential for proper management of both forestry and water resources. The Environment Management Act (EMA) (GOM, 1996a) deals with implementing sectoral regulations under it. Land use and management regulations were made in 1999 (GOM, 1999a) to control land use in environmentally fragile areas such as mountains and hilly areas, riverbanks, lakes and wetlands.

On the other hand the Malawi Irrigation Development Policy of 1996 aims at improving agricultural production and achieving national food sufficiency by targeting small-scale irrigation development, and yet historically agriculture has been a major driver of ecosystem loss and degradation where people have managed agro ecosystems simply to optimize crop production, without considering the larger landscape such as river depletion and consequent degradation of downstream ecosystems. Best management practices to mitigate the effects of agriculture include various measures such as cover crops, vegetative buffer strips, irrigation scheduling, erosion control structures, grassed waterways, residue management practices, conservation strip cropping and terracing (AARC, 1997).The National Population Policy (GOM, 1994) within the context of the

Statement of Development Policies (1987-1996) aims to improve the standard of living and the quality of life of the Malawian people.

2.5 Summary of the Literature Review

The literature review indicates that globally, there is some relationship between forest and stream flow. Environmental degradation such as forest depletion has a significant impact on stream flow. These large impacts are mainly from deforestation and afforestation, which in return affect runoff and regulate flow. Mulwafu (2000) examined conflicts over water use and management among communities living along Likangala River in Zomba District where the present study was undertaken. The paper argued that although water supply in this area is generally sufficient, its distribution and use is extremely skewed, such that this generates conflicts that underscore the deeply entrenched power relations existing in the area particularly between the primary and productive users of the water resources. Ngongondo (2003) analyzed long-term rainfall variability, trend and water availability in Mulunguzi River catchment area, also in Zomba District, and found that long-term rainfall variability and trend in the Mulunguzi River catchment area suggested a 15% decline between 1953/54 and 1997/98. Chavula (1999) evaluated the present and potential water resources management for the Lake Chilwa basin and found that the water balance equation indicated that 220mm out of the 1000 mm of rainfall received in the catchment area is transformed into surface run-off and that the situation is exacerbated by depletion of vegetation cover through unsustainable agricultural practices and unplanned settlements.

It has also been reported that both natural and man-made forests play an important role in providing basic human needs such as fuel, food, fodder, pharmaceuticals, employment, income and foreign exchange, hence contributing to socio-economic development. As an integral component of the biosphere, forests help to stabilise natural systems, such as biological diversity, and provide habitat for fauna and flora. Forests also help in maintaining air, water and soil quality, influence biochemical processes, regulate run-off and groundwater, control soil erosion, and reduce downstream sedimentation and incidence of flash flooding. Forests are therefore very important in providing watershed protection and enhancing water resources (Kainja, 2000).

The Wetland State of Environment Report (WSOER) (GOM, 2000) indicated that Aerial photographs from early 1970s and mid 1990s are available but photo pairs have not been analyzed to give a clear picture of the extent of degradation in the Lake Chilwa catchment in terms of forest cover. This study will analyze forest cover change in Namadzi sub catchment of the Lake Chilwa Basin.

The study will also assess socio economic contributions of forestry and water resources in a river catchment. The forest resources and stream flow relationship will be analyzed using the long-term historical data on stream flow and rainfall.

CHAPTER 3: MATERIALS AND METHODS

3.0 Introduction

This study was conducted through analysis of historical data like rainfall data for Namadzi River catchment, river discharge and temperature data. Primary data analysis was used for the socio-economic part of the study. This section describes the methods of study employed to determine the state of forest cover change and botanical assessment of Namadzi River catchment and the relationship between forest cover change and stream flow.

3.1 The Study Area

3.1.1 Location

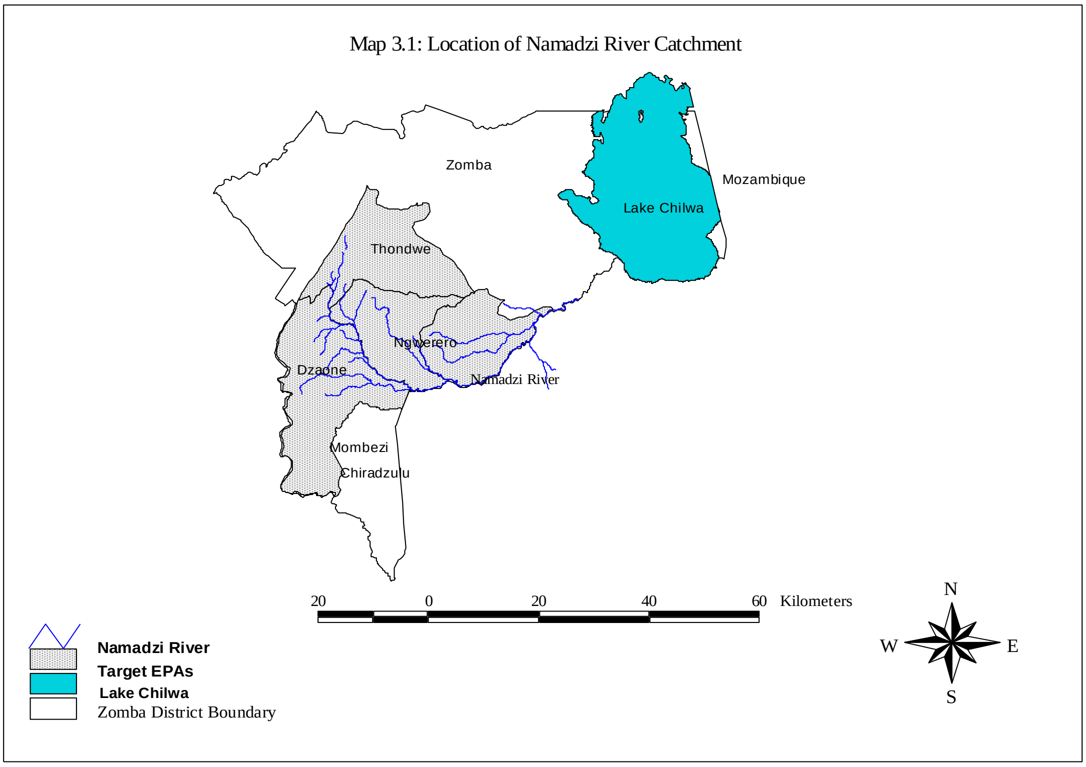
The area under study, Namadzi River catchment, is located in Chiradzulu and Zomba Districts, about 50 and 70 km, respectively, from the City of Blantyre in Southern Malawi. The River marks the boundary of Zomba and Chiradzulu districts and flows through Traditional Authorities (TA) Chitera and Ntchema in Chiradzulu district and Traditional Authorities Mlumbe, Chikowi, STA Ntholowa and Mbiza in Zomba district. Namadzi River catchment falls within the Zomba and Chiradzulu District Agriculture Development Offices, under Thondwe, Dzaone and Ngwerero Extension Planning Areas (EPA) in Zomba and Mbulumbuzi and Mombezi EPAs in Chiradzulu. The Upper catchment (26.7 km^2) of Namadzi River includes Thondwe EPA in Traditional Authority Mlumbe and Mbulumbuzi EPA in Traditional Authorities Chitera and Ntchema in Chiradzulu district. In total the Namadzi River stretches a length of 70-kilometers. Thondwe EPA has a total area of 36461 hactares (ha), of which 36216 ha is arable and

245 ha is non-arable (Thondwe EPA Pers. Comm). Mbulumbuzi EPA has a total area of 13000 hactares (Mbulumbuzi EPA, Pers. Comm)

Namadzi River originates from Chikanguya Village in TA Mlumbe in Zomba and gets more water from Nambala aquifer in Chiradzulu district. The aquifer is located almost 800m from the Blantyre-Zomba road and between latitude 16 degrees 31' south of the equator and 35 degrees 15' East of the Prime Meridian (GOM, 1987).

The river also contributes to Lake Chilwa water, as it is a tributary of Phalombe River, which empties into Lake Chilwa. Namadzi River sub catchment is part of the Lake Chilwa Catchment area, the second largest lake in Malawi which occupies a depression of the East African Rift Valley System located to the east of the study area.

The Lake Chilwa Wetland area was designated a Wetland of International importance under the Ramsar Convention of 1971 and signed in 1997 by the Malawi Government.



Map3.1: Location of Namadzi River Catchment

3.1.2 Altitude and Geology of Namadzi Area

Namadzi River Catchment is within the Shire Highlands, of Southern Malawi at about 1000m above sea level. The area is dominated by plateau and valleys. There are two types of aquifers in Malawi. These are basement complex aquifers and alluvial aquifers. Basement complex aquifers are aquifers found in igneous and metamorphic rocks while alluvial aquifers are fluvial lacustrine sediment successions with variations in both vertical and lateral extent Chimphamba *et al*, 2005 (in publication). Namadzi catchment is in the Shire Highlands that is composed of igneous and metamorphic rocks. This means that the Shire Highlands consist of rocks that form the basement complex and Namadzi catchment in particular has rocks of basement complex of cafenic gneiss, hornblende, proxene gneiss and garnet ferrous rocks (Geological Atlas of Malawi, 1897). The water yielding capacity of these rocks is very low compared to the alluvial.

3.1.3 Population Density in Namadzi River Catchment

Chiradzulu and Zomba districts in which Namadzi catchment area is found are amongst the most densely populated districts in Malawi. The total population of the two districts are 236,050 and 540,428 respectively. Average population density of Namadzi cathment in the two districts are 150 persons per sq.km and 209 persons per sq.km for Chiradzulu and Zomba districts respectively. The national population density is 104 persons per sq.km (http:www.statoids.com/umw.html, Accessed 15/02/07). This means that there is a lot of pressure on the forestry and water resources in the two districts including the study area.

3.1.4 Climate

Namadzi sub-catchment experiences Savanna climate as it is situated in the tropics. The climate has three main seasons. These are hot dry season from August to November, hot wet season from December to April and cold dry season from May to July. Temperatures are mostly mild with average daily temperatures of about 21 degrees Celsius and average rainfall of about 1000mm per annum (Statistical Year Book, 2005)

3.1.4.1 Rainfall

Namadzi River is within the Lake Chilwa Basin. Chavula, (2000) indicated that rainfall in the Lake Chilwa Basin results from one major synoptic system namely the Inter Tropical Convergence Zone (ITCZ) and takes place from November to April. Occasionally rainfall over the catchment area also results from Tropical Cyclones originating from the Indian Ocean off Madagascar Island and cause intense heavy rainfall activities as they sometimes cross the Mozambique Channel into the Eastern sub-continent of Africa. Figure 3.1 is a map showing the cyclone paths since 1946. The Zaire Air Boundary (ZAB) which has its source in the southern Hemisphere Subtropical high pressure belt just off the western coast of the Republic of South Africa and Namibia accounts for a very small amount of the total rainfall that occurs in the basin. This however is more active in the central and northern regions of Malawi (Ngongondo, 2003). It has also been observed that when both the ITCZ and Tropical cyclones are concurrently overhead in the basin, flood disasters are common occurrence as heavy rainfall takes place. This however is more active in the Central and Northern Regions of the country (Ngongondo, 2003).

Considering rainfall and average temperature, four different seasons can be distinguished in Namadzi River catchment (RoM/UNDP, 1986).

- Rainy season from November till March. Rains usually start during November, but are frequently delayed. Rains are frequent and heavy and the temperatures are high. Cloud cover is extensive and persistent.
- End of rainy season in April and May. The rains rapidly become less heavy and are separated by periods of dry and sunny weather. The temperatures drop and there are periods of chilly or cold weather.

- Cool and dry season from June till August. Except for an occasional shower and periods of Chiperoni (periods of heavy clouding and light altitudinal rain that can persist for several days) weather is dry, cool and sunny.
- Warm and dry season in September and October (sometimes November). The temperatures rise rapidly and rain is only occassionary falling during thunderstorms. Air humidity is high and cloud cover and the frequency of thunderstorms is increasing till the rains break in November or December.

3.1.4.2 Temperature and Evaporation

On average, yearly annual temperature for Namadzi catchment for the period 1969-2003 was 20.6^{o}C and evaporation for Namadzi catchment for the period 1981-1998 was 46.07 mm (see Appendix 7a and b; and 8).

3.1.5 State of Water Resources

Surface water in Namadzi River comes from the river catchment, the source being the rains in the rainy season between November and April. The average rain in the catchment is around 1019.5 mm/year as indicated in previous sections. Several small rivers discharge their waters into Namadzi River. Apart from these rivers, it is been reported that Namadzi River also gets water from Nambala aquifer, which produces 39.5 litres per second throughout the year (Kamwaza, 2006 unpublished).

3.1.6 State of Forest Resources

Namadzi catchment is a sub-catchment within Lake Chilwa catchment. Its forests have been subjected to severe pressure by the ever-growing human population as it has been reported for the Lake chilwa catchment (GOM, 2000a). Some large estates have set aside land where natural woodlands have been left nearly intact. Zomba District State of

Environment Report (GOM, 2001) indicated that major causes of deforestation are increased energy consumption due to high population growth and charcoal production. This is because charcoal is taken as a major source of income and fuel for most households.

3.1.7 Other Land Use Practices in Namadzi River Catchment

Major land use categories in Namadzi Catchment include agriculture and forest area, arable area, bare rock, built up area, *Eucalyptus*, miombo in hilly areas (PLUS ,1996). The forests are important in conserving both indigenous flora and fauna and contribute to biological diversity.

3.2 Data Collection and Processing

3.2.1 Socio-Economic Data.

A structured questionnaire (Appendix 2) and observations were used to collect the socio-economic data. The research treated the agricultural household as the basic unit of analysis. The study employed a two stage stratified random sampling approach. The main strata were the Thondwe and Mbulumbuzi Extension Planning areas in upper Namadzi catchment. In each EPA, the study targeted all agricultural extension sections through which the river passes, namely: Chilumpha, Chiunda, Kamalo and Mlumbe sections in Thondwe EPA, and Namadzi and Magomero sections in Mbulumbuzi EPA. Further sample villages were selected randomly from the total list of villages in each Section (Appendix 3). Proportional allocation was used to get sample villages from the sections. Every 5th village was taken as a sampled village and random selection of response units was conducted using farm household lists collected from the respective EPAs. The sample size was 1/10 of the total population from the sampled villages. Descriptive statistics was done on all variables collected including sex, marital status, literacy levels, land ownership, availability of forest area.

3.2.2 Forest Cover Change Data

This information collected was achieved through aerial photo interpretation and ground truthing (field verification). Aerial photos for a period from 1965 to 1995 were interpreted using a stereoscope, scanned and geo referenced. The shape files were imported into arc view for forest area calculation over years, namely: 1965, 1974 and 1995. In addition Malawi GIS database (PLUS 1996) was also used to geo reference the shape files from the aerial photos. The GIS database was analyzed to show forest cover change over the years.

3.2.3 Rainfall Data

The monthly rainfall data for Namadzi catchment that was used in this study was from Makoka Research Meteorological Station. The data was collected from Malawi National Meteorological services in Blantyre (Appendix 4). The longest possible record that was available was from 1958 to 2006. Only data from 1958 to 2003 was used for this research.

3.2.4 Stream Flow Data

The Namadzi River discharge data used in the study was obtained from the Ministry of Irrigation and Water Development, Hydrology section. The record spans the period from 1952 to 1999 for Namadzi station 20206. According to GOM-UNDP (1986), this record is one of the most perfect in Malawi (see Appendix 5).

3.2.5 Tree Cover Data

The Namadzi catchment tree cover data was obtained from the District Forestry Office in Zomba and was augmented with data from Amika, Nsamba, Gala, Nachambo, Kapalasa, New farm and Costa estates that are making boundary with Namadzi River in the upper catchment of the River. This data was in terms of total number of seedlings planted in each year. This data was calculated into area planted with trees each year (see Appendix 6a). The data was then cumulated. The records start from 1968 to 2006 (see Appendix 6b).

3.2.6 Curve Number Method for Estimating Runoff

Runoff is the depth equivalent discharge of a stream and is computed by dividing stream flow (volume units) by associated drainage area (area units) (Ratzlaff, 1994). Runoff data used in the study was calculated from the rainfall data obtained from the National Meteorological Services (Appendix 4) using the Curve Number method. The Curve Number method (SCS), also known as the Hydrologic Soil Cover Complex Method, is a versatile and widely used procedure for runoff estimation. In the past 30 years, researchers have used the SCS method because it gives consistently usable results (Colombo, 1997; Regis, 2001) for runoff estimation. In this method, runoff producing capability is expressed by a numerical value varying between 0 - 100. The differences in the hydrological soil groups are defined by soil type. This would be a sandy, well-drained soil for type A, a sandy loam for type B, a clay loam or a shallow sandy loam for type C, and high plasticity clay for type D (Table 3.1). For most cases, the entire basin will not consist of a single soil type or land cover. For this situation, a composite CN value can be computed by weighting each CN with its respective area in the basin. The SCS Runoff

Curve Number (CN) is an empirical description for infiltration and rainfall excess. The SCS runoff equation is:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S} \quad \text{...4.1}$$

where Q = runoff (mm); P = rainfall (mm); Ia = initial abstraction (mm); S = potential maximum retention after runoff begins (mm).

Table 3.1: Runoff Curve Numbers for Selected Land Use

Land Use Description			**Hydrological Soil Group**			
			A	**B**	**C**	**D**
Cultivated land	Without conservation treatment		72	81	88	91
	With conservation treatment		62	71	78	81
Pasture or range land	Poor condition		68	79	86	89
	Good condition		39	61	74	80
Meadow			30	58	71	78
Wood or forest land	Thin stand, poor cover, no mulch		45	66	77	83
	Good cover		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.	Good condition: grass cover on 75% or more of the area		39	61	74	80
	Fair condition: 50-75% of the area		49	69	79	84
	Commercial and business areas (85% impervious)		89	92	94	95
	Industrial districts (72% impervious)		81	88	91	93
Residential	Average lot size	Average % Impervious				
	1/8 acre or less	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.			98	98	98	98
Streets and roads	Paved with curbs and storm sewers		98	98	98	98
	Gravel		76	85	89	91
	Dirt		72	82	87	89
Open water			0	0	0	0

Source: United States Department of Agriculture (1986)

By removing Ia as an independent parameter: This is based on United States context and has also been used in Africa (Eritrea).

$$Ia = 0.2 * S \qquad (4.2)$$

runoff is:

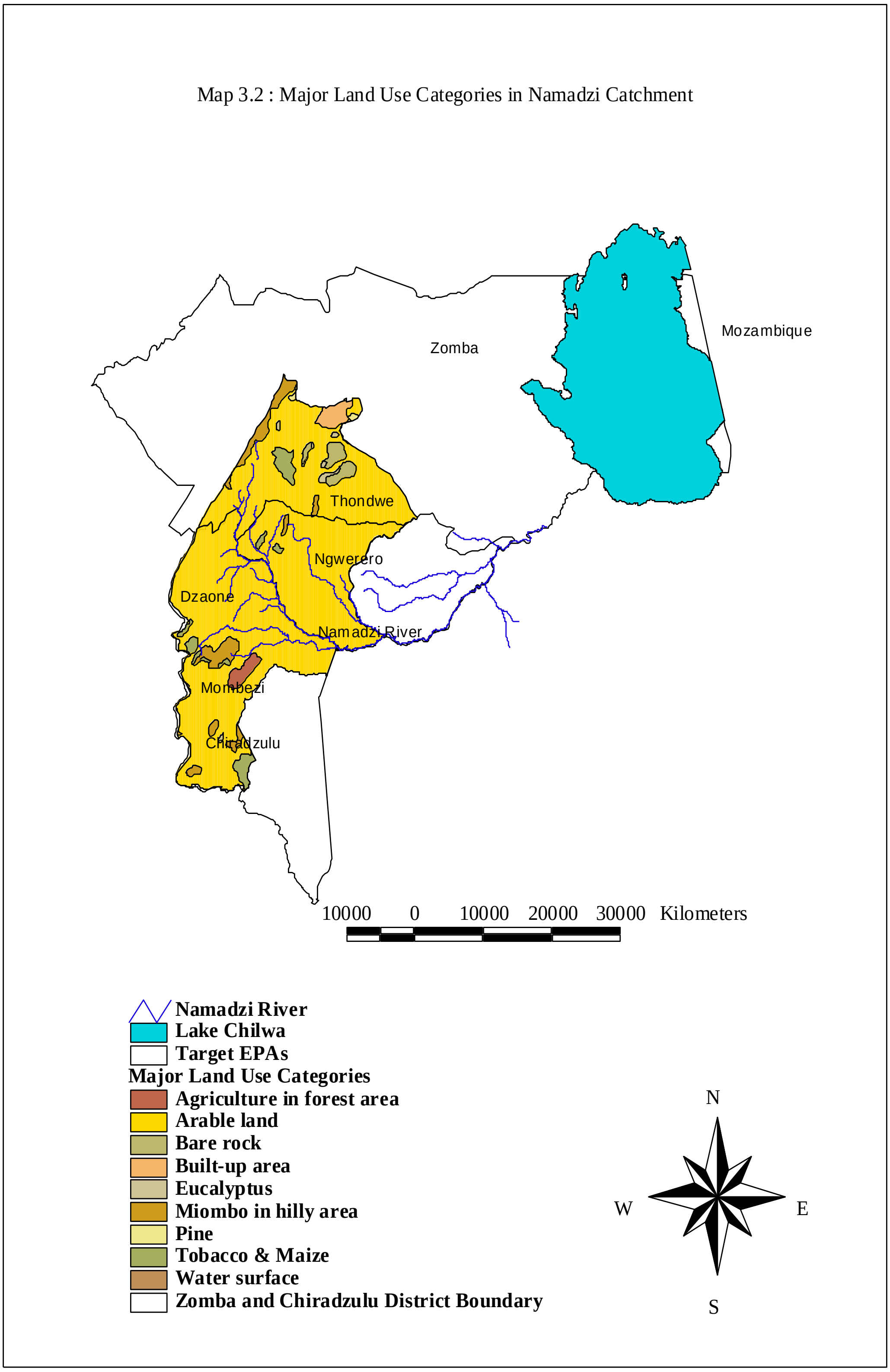
$$Q = \frac{(P - 0.2 * S)^2}{(P + 0.8 * S)} \qquad (4.3)$$

The parameter S is related to soil and cover conditions of the watershed through the Curve Number:

$$S = \frac{25400}{CN} - 254 \qquad (4.4)$$

Where CN = Curve Number

For this study runoff was calculated using a composite CN of 79. This was computed from the different land uses in the area, namely: Agriculture in forest area, arable area, bare rock, built up area, *eucalyptus*, miombo in hilly areas, pine and maize and tobacco cultivation (PLUS, 1996). Type C (shallow sandy loam) for soil was used. The major land use categories are also shown in Map 3.2.



Map 3.2: Major Land Use Categories in Namadzi Catchment

3.2.7 Land Use Data

The Namadzi River catchment land use information was obtained from Thondwe EPA in Zomba and Mbulumbuzi EPA in Chiradzulu. These are the areas under study and the main land use in the area was cultivation, with forest area under estates. The data on area planted with forest from the estates was also used.

3.2.8 Hotspots Identification Data

A number of methods have been developed to estimate populations in a given environment. May (1998) review the kind of information needed to make the answers more precise. The author considers various factors affecting biodiversity, including structure of food webs, relative abundance of species, number of species and individuals in different categories of body size and other determinants of the commonness and rarity of organisms (Sherbinin, 2002). This study considered the relative abundance of species in Namadzi riverine. Environmental hotspots were identified through observations and ground truthing. A Global Positioning System (GPS) was used to mark the hotspot areas. Arc View software was used to mark the waypoints that were used to indicate environmental hotspot areas in Namadzi catchment. The waypoints were marked within 10mX10m quadrants that were drawn at 100 m apart from the source of Namadzi River in Chikanguya village down to where Namadzi River joins Phalombe River in Phalombe.

3.3 Data Analysis

Data processing and analysis was done using the Statistical Package for Social Sciences (SPSS) for the socio-economic part of the study; stereoscope, Arc Map and Arc View GIS 3.3 for forest cover change analysis. Data processing for the relationship between forest cover change and stream flow was done in Microsoft Excel spreadsheets. The monthly runoff and river flow data series were organized into hydrologic year time series. In Malawi, the hydrologic year starts on 1st November and ends 31st October in the other year.

3.3.1 Detection and Estimation of Trends of Rainfall, Run off and Stream flow

Graphical representations of data facilitated observation of general trends and cycles, which assisted in the selection of an appropriate statistical test. Three methods were used in this study to analyze the existence of trends in the rainfall, stream flows and run-off. MAKESENS (Mann Kendall and Sen's Slope Estimate) and linear regression analysis were performed on the data sets. These methods are described in detail below.

3.3.1.1 MAKESENS (Mann Kendall test and Sen's Slope Estimate)

MAKESENS performs two types of statistical analyses. First the presence of a monotonic increasing or decreasing trend is tested with nonparametric Mann-Kendall test and secondly the slope of a linear trend is estimated with the non-parametreic Sen's Method (Gilbert 1987). Mann Kendall test and Sen's Method were chosen because they allow missing data, make no assumptions on distribution of data and are not affected by gross data errors and outlier.

The Mann Kendall test is applicable in cases when the data values *xi* of a time series can be assumed to obey the model

$$Xi = f(t_i) + E_i \quad \text{……} 4.5$$

Where *f (t)* is a continuous monotonic increasing or decreasing function of time and the residuals *Ei* can be assumed to be from the same distribution with zero mean and it is therefore assumed that the variance of the distribution is constant in time. For instance we want to test the null hypothesis of no trend, H_0, that is the observation x_i are randomly ordered in time, against the alternative hypothesis, H_i, where there is an increasing or decreasing monotonic trend. In the computation of this statistical test MAKESENS exploits both the so called *S* statistics given in Gilbert (1987) and normal approximation (Z statistic). For the time series with less than 10 data points the S test is used, and for time series with 10 or more data points the normal approximation is used.

When number of data values is less than 10, the number of annual values in the studied data series is denoted by *n*. Missing values are allowed and *n* can thus be smaller than the number of years in the studied time series. The Mann –Kendall test statistic *S* is calculated with the formula:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} Sgn(X_j - X_k) \quad \text{...4.6}$$

Where x_i and x_k are the annual values in years j and k, j>k, respectively and

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases} \quad \text{.....................4.7}$$

If n is 9 or less, the absolute value of S is compared directly to the theoretical distribution of S derived by Mann and Kendall (Gilbert, 1987). In MAKESENS the two tailed test is used for four different significance levels α: 0.1, 0.05, 0.01 and 0.001. At certain probability level H_0 is rejected in favour of H_1, if the absolute value of S equals or exceeds a specific value $S_{\alpha/2}$, where $S_{\alpha/2}$ is the smallest S which has the probability less than $\alpha/2$ to appear in case of no trend . A positive (negative) value of S indicates an upward (downward) trend. The minimum levels of n with which these four significance levels can be reached are derived from the probability table for S as follows:

Significance level α	**Required *n***
0.1	≥4
0.05	≥5
0.01	≥6
0.001	≥7

The significance level 0.001 means that there is a 0.1% probability that the values x_i are from a random distribution and with that probability we make a mistake when rejecting H_0 of no trend. Thus the significance level 0.001 means that the existence of a monotonic trend is very probable. Respectively the significance level 0.1 means that there is a 10% probability that we make a mistake when rejecting H_0.

If n is at least 10 the normal approximation test is used. However, if there are several tied values (i.e. equal values) in the time series, it may reduce the validity of the normal approximation when the number of data values is close to 10.

First the variance of S is computed by the following equation, which takes into account that ties may be present

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad \text{....4.8}$$

Where:

n = number of data points

tp = the number of ties for the pth value

q = the number of tied values

The values of *S* and *VAR (S)* were used to compute the test statistic Z as follows:

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{s+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \quad \text{..............4.9}$$

The presence of a statistically significant trend was evaluated using the *Z* value. A positive (negative) value of *Z* indicated an upward (downward) trend. The statistic *Z* has a normal distribution. To test for either and upward or downward monotonic trend (a two tailed test) at α level of significance, H_0 is rejected. If the absolute value of *Z* is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from the standard normal cumulative distribution tables. In MAKESENS the tested significance levels are 0.001, 0.01, 0.05 and 0.1.

According to Sen (1968) and Thiel (1950) Sen's method for the estimation of slope requires a time series of equally spaced data. To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear. This means that *f(t)* in equation (4.5) is equal to

$$F(t) = Qt + B \ldots\ldots 4.10$$

Where Q is slope and B is a constant.

To get the slope estimate Q in equation (4.10), we first calculate the slopes of all data valuepairs.

$$Q = \frac{X_{j'} - X_k}{j' - k} \ldots\ldots 4.11$$

Where:

Q = slope between data points $x_{j'}$ and x_k

$X_{j'}$ = data measurement at time i'

X_k = data measurement at time i

i' = time after time I

If multiple data measurements are collected at a given time, two options exist as follows; the first option is to simply combine the measurements for a given time step into a single measurement of central tendency (e.g. mean, median) and proceed as above. The second option is to calculate a slope for each individual measurement, as shown in Appendix 10. Note that the slope between measurements collected at the same time is not calculated.

If there are *n* values x_j in the time series we get as many as $N = n(n-1)/2$ slope estimates Q_i. The Sen's estimator of slope is the median of these *N* values of Q_i. The *N* values of Q_i are ranked from the smallest to the largest and the Sen's estimator is as shown below as:

Sen's Estimator of Slope = median slope = Q'

$$= Q_{[(N'+1)/2]} \quad \text{if N' is odd,}$$

$$= (Q_{[N'/2]} + Q_{[(N'+2)/2]})/2 \quad \text{if N' is even} \ldots .4.12$$

Where: **N'** = number of calculated slopes

Sen's Method also allows determination of whether the median slope is statistically different from zero. A confidence interval is developed by estimating the *rank* for the upper and lower confidence interval and using the slopes corresponding to these ranks to define the actual confidence interval for Q'. For a two-sided confidence interval about the median slope, first find the $Z_{statistic}$ for a two-tailed normal distribution test.

In this analysis a two-sided confidence interval of 95% was chosen. $Z_{(1-0.05/2)} = Z_{0.975} = 1.96$.

Estimating the range of ranks for the specified confidence interval C was done as follows:

$$C_{\alpha} = Z_{1-\alpha/2} * \sqrt{VAR(S)} \ldots\ldots\ldots 4.13$$

Using the value of Equation 4.12, the ranks of the lower (M1) and upper (M2 + 1) confidence limits were found.

Finally, the slopes corresponding to M1 and M2+1 as the lower and upper confidence limits were chosen, respectively. If the upper and lower confidence intervals are all positive, then it is an increasing trend, if both are negative then it is a decreasing trend and if the two are different then there is no trend.

Note that the median slope is then defined as statistically different from zero (for the selected confidence interval) if the zero does not lie between the upper and lower confidence limits.

Potential Difficulties in Using Sen's method

Missing Data: For Sen's test, simply do not calculate a slope for the missing data point (making sure not to count missing data points in with the total number of samples, n). If large amounts of data are missing, Sen's method is not recommended.

No Detection (ND) or Trace Data: Sen's method may still be used to predict a median slope if the number of ND measurements is less than (n-1)/2, but may severely limit the prediction of a confident interval about this estimate.

3.3.1.2 Regression Analysis

This was used to investigate the relationship between rainfall and runoff; area planted with trees and stream flow and area planted with trees and run off. A scatter diagram of the realization of the random pair (x,y) was plotted. The distribution of the plotted points (x,y) produce a certain line. The shape of the line indicates the type of the functional relationship (linear, parabolic, and exponential) to which the association approximates more or less roughly. This line is called a regression line.

The general form of the linear regression equation is given as follows:

$Y' = a + bx$……………………………………………………………………4.10

Where:

Y' = the predicted value of the y variable for a selected x value.

X = any value of the independent variable that is selected.

a = the y-intercept or constant.

b= the slope of the line or constant.

Values of a and b are also referred to as regression coefficients. The values of a and b can be found using the following formulae:

$$a = \frac{(\sum x^2)(\sum y) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x)^2} \quad \ldots\ldots 4.11$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad \ldots\ldots 4.12$$

Where: x= the value of the independent variable

y= the value of the dependent variable

n = the number of items in the sample.

3.3.1.3 Rainfall- Run-off Relationship

This study also looked at the relationship between rainfall and run-off. This was done in order to see if rainfall/runoff relationship has changed according to the change in tree cover in Namadzi catchment. In this study Rainru model, which is a spreadsheet based rainfall-runoff model, was used. This model gives a relationship between rainfall and runoff based on a given set of the two data, with a pre-entered value for the amount of months and the interception value taken into account. The following equation is applied; the runoff R in time step t is a function of rainfall P in the current time step and the previous time steps:

$$R_t = b_1 \text{ Max } (P_t - T, 0) + b_2 \text{ Max } (P_{t-1} - T, 0) + b_3 \text{ Max } (P_{t-2} - T, 0) \ldots\ldots\ldots\ldots 4.13$$

In the Max (P_t-T, 0), T represents the interception losses and part of the transpiration. As long as the rainfall P is less than T all rainfall is evaporated, without becoming 'blue water' first. The T represents interception threshold. In this study T was calculated to be 46. Rainfall minus interception is in agriculture and in many fields of hydrology often called effective rainfall. However in some fields of runoff modelling only a portion of water that changes to rainfall is effective rainfall.

The partial runoff coefficients b_i is found through multiple stepwise backward regression. The b's are defined for the best fit with a least square error method. It also provides the error by which one can see which time memory of the system gives the best result. The total amount of months taken into account should not exceed 6 months because of the fictive correlation because of seasonality (De Groen, 2002).

3.4 Results Output

The results of the study are presented using tables, graphs and maps using the original and secondary data in SPSS, Microsoft excel spreadsheets and Arc View GIS. Data which could not be shown in the text for presentation reasons can be found in the Appendices.

CHAPTER 4: RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the findings of the study. The first section presents findings of the socio-economic part of the study. These findings explain socio and economic characteristics of the respondents, factors influencing forestry and water resources use, respondents' perception of forest cover change; species variability and availability in the study area, demand and access of forest products and water resources in the study area. The first part of the third section looks at trends in rainfall, stream flow, tree cover, runoff and runoff coefficients. The second part of the section looks at the relationship of forest cover with stream flow and runoff coefficient then rainfall and runoff; and rainfall-run-off relationship using Rainru model. Finally the last section presents the environmental hotspot analysis done in the area.

4.1 Socio-economic Characteristics

4.1.1 Sex, Marital Status and Age of Respondents

The respondents composed of 67.0% female and 33.0% male. Among these 74.3% were married, 12.2% were widowed, 8.7% were divorced and 4.8% were single. One factor that might have contributed to this is that the main means of livelihood in Namadzi catchment area is subsistence farming (87%) whose economic returns has declined over the years, therefore more men have resorted to work in the nearby estates to improve their livelihood. A larger percentage of the respondents, 57.4% were within the age group of 21 – 40 years (Table 4.1). The average age of the sample population was at 39.09 years.

This was considered old enough to be able to give in depth knowledge of environmental degradation in the area. Demographically, it can be concluded that Namadzi area is dominated by a young generation. This is consistent with national population composition that has more than 60% of the Malawian population comprising the young generation (GOM, 2004b)

Table 4.1: Sex, Marital Status and Age of the Respondents

Characteristic		
Sex	**Count**	**Percentage (%)**
Male	76	33.6
Female	154	67.0
Marital Status		
Married	171	74.3
Single	11	4.8
Divorced	20	8.7
Widowed	28	12.2
Age group of the Respondents		
0-20 years	9	3.9
21-40 years	132	57.4
41 – 60 years	64	27.8
61-80 years	23	10.0
81-100 years	1	.4

4.1.2 Education Level and Relationship with the Community

Results in Table 4.2 shows that 66.1% of the respondents of the sample had undergone primary education indicating that most people in the community were literate, also evidenced by the 55.2% of the respondents who were able read and write. The high level of education of the sample indicates easy perception of information on environmental issues. This is because in absence of access to formal education, opportunities available to most people will continue to be limited, with possible negative influence on the environment. Results also show that 69.6% of the respondents were clan members and 21.7% were linked to the community through marriage and the average household size of the sample was 4.83. This observation has an impact on investment in forestry resources, as clan members are likely to invest in tree planting as they are assured that they will partake the benefits from the forests.

Table 4.2: Education, Literacy Level and Linkage to the Community

Characteristic		
Level of Education	**Highest Level of Education**	
	Count	**Percentage (%)**
Never attended	35	15.2
Primary education	152	66.1
Secondary education	38	16.5
College/ University	3	1.3
Literacy classes	2	.9
Level of literacy		
Not literate	53	23.0
Read only	50	21.7
Read and Write	127	55.2
Linkage to the community		
Outside with no kinship relations	20	8.7
Clan member	160	69.6
Through marriage	50	21.7

4.1.3 Primary and Secondary Occupation.

The major primary activity of the respondents were domestic work and work on family farm, as registered by about 87% responses. Results also show that the respondents were not engaged in any secondary activity, 27.4%. The major secondary activity is paid employment, as registered by 24.8% of the respondents being wage earners (see Table 4.3). This situation has an implication on natural resources use and management in Namadzi catchment. This is because without other means of livelihood, most of the activities by the local communities are based on natural resource such as charcoal manufacturing and trade of non-timber forest products (NTFPs). The results also show that 17.0% of the respondents are involved in local merchandizing. This is due to their close proximity with estates.

Table 4.3: Primary and Secondary Occupation

	Primary Activity		**Secondary Activity**	
Activity	**Count**	**Percentage (%)**	**Count**	**Percentage (%)**
Not applicable			63	27.4
Work on estate or family farm	10	4.3	3	1.3
Food sales /local merchant	1	.4	39	17.0
Offfarm agricultural labour	1	.4	3	1.3
Wage earner	1	.4	57	24.8
Domestic work	9	3.9	20	8.7
Paid household help	1	.4		
Part time farming	4	1.7	15	6.5
Domestic work and work on family farm	200	87.0	8	3.5
Blick laying	1	.4	7	3.0
Civil servant	2	9		
Tailoring			4	1.7
Small scale business			1	.4
Weaving/knitting			3	1.3
Welder			1	.4

4.1.4 Factors Influencing Forest and Water Resources Use and Management.

4.1.4.1 Access to Land

Results indicate that majority of the respondents, 75.7% own more than one parcel of land with an average land holding size of .93 ha. Majority of the respondents, 73.0% own less than 1 ha of land (see Tables 4.4). The small land holding size does influence decisions on investing in natural resources such as tree planting. Usually the available land is used for food production.

Table 4.4: Respondents Access to Land.

Land Ownership		
	Does your farm consist of more than one parcel	
	Count	Percentage (%)
Yes	168	75.7
No	51	24.3
Total own farm		
< than 1 hactare	168	73.0
1.1 – 2 hactares	51	22.2
2.1 – 3 hactares	5	2.2
3.1 – 4 hactares	3	1.3
4.1 – 5 hactares	1	0.4
5.1 – 6 hactares	1	0.4

4.1.4.2 Land Tenure Arrangements

Household land ownership is largely customary with 97.4% of the respondents holding land under customary tenure. Land allocation is mostly through inheritance either through parents or as a gift as shown by the results that 73.5% and 16.5% of the sample got their land units through inheritance or gift, respectively. Further, it is indicated that 95.7% of the respondents are smallholder farmers on customary land (Table 4.5). The same shows that 96.1% of the sample have unlimited access to their land units. Under customary land tenure one can invest in natural resources such as tree planting as usually members of the community have unlimited number of years to hold the land units. As indicated earlier, decisions to invest in natural resources such as tree planting could be hampered by small size holdings.

Table 4.5 Land Tenure Arrangements

Type of Land Tenure at or Before Acquisition		
	Count	Percentage (%)
Not applicable	5	2.2
Customary	224	97.4
Estate land	1	.4
Type of Land Acquisition (How the Land was Acquired)		
Not applicable	2	.9
Inherited	169	73.5
Gift	38	16.5
Allocated by traditional chief	11	4.8
Allocated by government/ formal authority	3	.4
Purchased	1	.4
Rent/lease	6	2.6
Tenancy and Farming Status at Present		
Not applicable	7	3
Smallholder farmer on customary land	220	95.7
Smallholder farmer on private (freehold land)	2	.9
Smallholder farmer on private (leasehold land)	1	.4
Number of Years to be held		
Not applicable	6	2.6
Unlimited	221	96.1
Do not know/uncertain	3	1.3

4.1.4.3 Type of Land Use

A larger percentage of the respondents, 59.7% indicated that they do not own dimba (marsh land) plots compared to 18.3% who have more than 75% of their land under dimba cultivation. Results also show that 93.9% of the respondents indicated that more than 75% of their land is used for maize cultivation and 93.9% do not engage in tobacco production. None of the respondents indicated that they grow coffee and tea. 81.7% of the respondents had no land units under forestry and 86.5% had no land under fallow (see Table 4.6). In general, results of the sample show that most people in Namadzi River catchment are subsistence farmers with maize as their major crop. The percentage that do not own Dimba plots implies that they do not engage in winter cropping

A larger percentage of the respondents, 58.7% do not apply manure on their land units compared to 36.1% that do manure application. Similarly, a larger percentage of the respondents, 47.8% do not engage in tree planting activities compared to 46.1% who do tree planting on their plots. 98.3% practice intercropping (see Table 4.7); this agrees with the finding that the respondents have small land holding sizes. Therefore they plant more crops on the same piece of land with less tree planting. In general, the results show that there is minimal engagement in land conservation practices in the area.

The majority of the subsistence farmers do not practice irrigation farming, do not engage in tree planting activities and have no land under fallow. This could be explained by the fact that most of the respondents have small land holding sizes (mean is .93 ha) as indicated in the earlier sections.

Table 4.6: Percentage of Land under Different Land Use.

	Percentage land under dimba	Percentage land under maize	Percentage land under tobacco	Percentage land under coffee	Percentage land under tea	Percentage land under forest	Percentage land under fallow
	%	%	%	%	%	%	%
Not applicable	59.6	2.2	93.9	100	99.6	81.7	86.5
Less than 5%	1.3				.4	8.2	1.3
5-10%	2.2					1.3	.4
10-15%	3.0					1.3	.9
15-20%	7.8		2.2			2.2	.4
20-25%	3.0		.9			1.3	.9
25-30%	3.0					.9	1.3
30-35%	.4		.9				1.3
35-40%	.4						
40-45%							.4
45-55%	.4	.4	.4			.4	.9
55-65%	.4	3.0	.4			2.6	
>than 75%	18.3	93.9	1.3				5.7

Table 4.7: Soil and Water (Land) Conservation Practices.

	Manure Application	Irrigation	Intercropping	Tree Planting	Dry Planting
	%	%	%	%	%
Not applicable	5.2	8.3	1.3	6.1	26.1
Yes	36.1	56.5	98.3	46.1	10.9
No	58.7	35.2	.4	47.8	63.0

4.1.5 Respondents' Perception of Forest Cover Change.

4.1.5.1 Availability of Forest Area.

Availability of forest areas in the catchment is very minimal. 55.2% of the respondent indicated non-availability of indigenous forest areas while 44.8% indicated that they have an indigenous forest area. This is confirmed where 74.3% of the respondents indicated that there are no communally managed forests or woodlots in the area and 92.6% indicated non availability of major forests on public land as well. Majority of the respondents, 92.6% indicated availability of wooded graveyards in the area (see Table 4.8). The results are similar to the observation made in the Lake Chilwa Wetland State of Environment Report (2000) that woodlands in the catchment area are found on estate land and graveyards in addition to forest reserves. These findings indicate land use change in Namadzi catchment since the respondents are able to distinguish the past and present in terms of indigenous forest cover.

Table 4.8: Availability of Forest Area

	Any indigenous forests in this village?		Any wooded graveyards in the area?		Any communally managed forests/woodlots?		Any major forestland on public land?	
	Count	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Yes	103	44.8	213	92.6	59	25.7	17	7.4
No	127	55.2	17	7.4	171	74.3	213	92.6

4.1.5.2 Access to fuel Wood

Table 4.9 shows that 55.7% of the respondents collect fuel wood from own holdings only. Their source of energy is fuel wood, maize cobs, maize stalks and tobacco stems. 16.7% of the respondents indicated that they get fuel wood from estates closer to their village and 5.3% do purchase fuel wood. This indicates an indirect impact on the forest resources on the estates that have remnants of forest area. Those that sell fuel wood collect it from the estates through licenses permitting them to collect the wood. 14.0% collects fuel wood from own holdings, communal woodlands/Village forest areas within and outside the village. That is, they have multiple sources of fuel wood. The results reveal scarcity of fuel wood in the area and confirm earlier indications by the respondents that the region under study does not have indigenous forest areas, communal forest areas and forest areas on public land where they can easily collect firewood. This suggests there is inadequate forest area.

Table 4.9: Access to Fuel Wood

	Where the Respondents Obtain Fuelwood and Other Forest Products	
	Count	**Percentage (%)**
Own holdings only	127	55.7
Own holdings and communal woodland/Village Forest Area (VFA)	9	3.9
Own holdings and communal woodlands/VFA within and outside the village	32	14.0
Estate closer to the village	38	16.7
Namadzi Riverine	1	.4
Private forest owned by village headman	6	2.6
Village forest area in other village	3	1.3
Purchase	12	5.3

4.1.5.3 Forest Cover Change

In general forest cover in the area has been decreasing. 60.3% of the respondents indicated that the current forest cover is less by 85 percent compared to 20 years ago, 24.9% views that the current forest cover has changed by 100 percent and 10% of the respondents said forest cover is less by 75 percent compared to 20 years ago (see Table 4.10). The results suggest that there has been considerable deforestation over the years leading to environmental degradation. The results agree with Sambo and Munyenyembe (1999) and Sambo *et al*. (1999) who reported that local people are quite aware of the vegetation changes that have taken place over the years. On average the respondents have indicated that most trees have disappeared in the area the past 14 years (see Table 4.11).

This finding augments the result from the aerial photo interpretation that showed forest cover change during the period 1965 to 1995. The household survey reveals that indigenous forest in Namadzi catchment has decreased during the period between 1995 and 2006.

Table 4.10: Forest Cover Change Relative to 20 Years Ago

	Current total forest cover relative to 20 years ago	
	Count	**%**
About the same	2	.9
Less by 35 percent	3	1.3
Less by 55 percent	6	2.6
Less by 75 percent	23	10.0
Less by 85 percent	138	60.3
100 percent	57	24.9

Table 4.11: Loss of Forest Area over Years

	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Approximate time species have disappeared in years	530	1	57	14.33	8.75

4.1.5.4 Respondents' Perception on Plant Species Variability

Results show that a larger percentage of the respondents, 8.4% indicated availability of *Eucalyptus spp* (bluegum) trees in the area followed by *Mangifera indica* (mango) trees, 7.7%, Avocado pear 6.3%, *Khaya anthotheca* (Mahogany), 4.7%, *Ficus exasperate* (Kachere), 4.3% and *Toona ciliata* (Cindrea) 4.1%. This suggests that households perceive that there are more of introduced species of trees in the area than indigenous species except for *Khaya anthotheca* species (Mahogany/mbawa) and *Ficus exasperate* (Kachere) trees. In total 95 plant species were reported to be available in the area (see Appendix 12)

4.1.5.5 Availability of Indigenous Fruits and Mushrooms

Results show that a larger percentage of the respondents, 29.8% indicate that *Flacourtia indica* (Nthema /Nthudza) is seen in abundance at present, 15.5% indicate availability of *Vitex doniana* (Mbulukututu) and 12.8% indicated *Annona senegalensis* (Mpoza) being available. In total there were 34 different indigenous fruit species mentioned by the respondents (see Appendix 13).

Results in Table 4.12 indicate a higher percentage, 58.6% of respondents indicated availability of mushrooms in the area. Further results show that 69.3% of the respondents get mushrooms from gardens during the rainy season. This is a reflection of absence of mushroom types that are associated with forests.

Table 4.12: Access to Other Forest Products like Mushrooms

Access to other forest products like mushrooms		
	Count	**Percentage (%)**
Yes	133	58.6
No	94	41.4
Where and when exactly the mushrooms are collected?		
None	15	13.2
Rainy season in gardens	79	69.3
Rainy season in Estate forest	7	6.1
Rainy season in anthills	1	.9
Rarely not as before	11	9.6
In graveyards	1	.9

4.1.6 Demand for Domestic Water Use and Irrigation Water in Dry Season

4.1.6.1 Access to Water for Domestic Use and Irrigation

The results show that a larger percentage of the respondents, 41.4% draw water from boreholes, 29. 2% from unprotected shallow wells and 21.9% from rivers (see Table 4.13). It is further indicated that approximately households use between 20000 and 30000 liters of water per year for domestic purposes as shown by the high percentage, 40.4% in this category.

Results in Table 4.14 also show that a larger percentage of the respondents, 51.3% use water from rivers for irrigation in the dry season and 18.7% use water from shallow wells. The shallow wells are either along rivers or in small streams. The rivers include Mlombozi, Muluma, Naisuyu, Naziwale, Namadzi, Namitwana, Namiwawa, Nangómbe, Mpumbe, Chimwankhuku, Nachambo, Sanje, Namichimba, Chingale, Linjizi, Mbatamila, Thondwe, Namikango, Nsamba, Kambwiri and Namiseche. The small streams include Chiperere, Kalimbuka, Nazale, Ngonje and Bula. Most of these are tributaries to Namadzi River except Chingale, Linjizi, Thondwe and Namikango rivers. Most of the respondents, 45.4% indicated that they draw less than 1000 litres of water per year for irrigating their dry season crop. In general, results show that not much water is used for agriculture during the dry season. This agrees with earlier findings that majority of the respondents, 59.7% do not own dimba gardens. It further agrees with observation by Zomba agriculture office that estates in the area draw too much water during the dry season (Mr H. Hunga, Per.Com, 2006). It also agrees with findings by Kamwaza (2006) that, estates in the area pump water during the dry season. The findings stated that Agricola alone pumps 19642.9 cubic metres per month for irrigating about 70 acres of land and Costa Estate pumps water downstream to irrigate about 110 acres of land and that the water table at Nambala acquifer varies from 5 metres to 6 metres in wet season and 18 to 20 metres in dry season.

Table 4.13: Demand and Access to Water Resources for Domestic Use

Water Resources Access for Domestic Use in the Area		
	Count	**Percentage (%)**
Unprotected shallow wells	108	29.2
Protected wells	1	.3
Borehole	153	41.4
River	81	21.9
Stream	17	4.6
Spring	4	1.1
Tap	6	1.6
Time Taken to get to a Water Source		
10 minutes	60	26.2%
20 minutes	67	29.3%
30 minutes	19	8.3%
40 minutes	2	.9%
50 minutes	39	17.0%
1 hour	37	16.2%
2 hours	4	1.7%
Approximate Amount of Water for Domestic Use by Households in the Previous Year.		
< than 1000 liters /year	6	2.6%
1000-10000 liters/year	4	1.8%
10000 - 20000 liters /year	22	9.6%
20000 - 30000 liters /year	92	40.4%
30000 - 40000 liters /year	34	14.9%
40000 - 50000 liters /year	24	10.5%
50000 - 60000 liters/year	15	6.6%
60000 - 70000 liters/year	4	1.8%
70000 - 80000 liters /year	14	6.1%
80000 - 90000 liters /year	7	3.1%
90000 - 100000 liters /year	1	.4%
> 100000 liters /year	5	2.2%

Table 4.14 Demand and Access to Water for Irrigation in Dry Season

Water Resources Access for Irrigation in Dry Season		
	Count	**Percentage (%)**
Unprotected shallow wells	43	18.7
Protected wells	0	
Borehole	1	.4
River	118	51.3
Stream	51	22.2
Spring	17	7.4
Tap	0	
On Average How Often Do You Collect Water for Irrigation		
None	99	43.0%
1 to 2 days/week	79	34.3%
more than two days /week	49	21.3%
Once a year	3	1.3%
Approximate Amount of Water for Irrigation by Households in the Previous Year.		
< than 1000 litres /year	104	45.4%
1000-10000 litres/year	21	9.2%
10000 - 20000 litres /year	26	11.4%
20000 - 30000 litres /year	14	6.1%
30000 - 40000 litres /year	24	10.5%
40000 - 50000 litres /year	9	3.9%
50000 - 60000 litres/year	4	1.7%
60000 - 70000 litres/year	1	.4%
70000 - 80000 litres /year	4	1.7%
80000 - 90000 litres /year	4	1.7%
90000 - 100000 litres /year		
> 100000 litres /year	18	7.9%

4.1.6.2 Water Shortage Experience

Results indicate a larger percentage of respondents, 21.7% are not experiencing any water problem and 19.6% perceive water shortage had hit the area in less than 5 years. Water shortage had occurred in the area as indicated by 17.8% of the respondents, who indicated that water shortage occurred 6-10 years and 11 – 15 years (see Table 4.15). This is in line with the report by Zomba District Agriculture Development office of 2006 that indicated acute shortage of water in the area.

Table 4.15: Water Shortage Experience in the Study Area

Time in Years, the Village has been Experiencing Water Shortage.		
	Count	**Percentage (%)**
None	50	21.7%
< than 5 years	45	19.6%
6 - 10 years	41	17.8%
11 - 15 years	41	17.8%
16 - 20 years	22	9.6%
21 - 25 years	6	2.6%
26 - 30 years	6	2.6%
31 - 35 years	2	.9%
46 - 50 years	6	2.6%
> than 50 years	3	1.3%
Not applicable	8	3.5%

4.1.7 Non Governmental Organizations in Forestry and Water Sectors

Majority of the respondents indicated that Non Governmental Organizations (NGOs) are not working in the area, 71.6% for forestry and 54.2% water sectors, respectively. NGOs that were mentioned by respondents in relation to the forestry sector include Concern Universal, DAPP, Goal Malawi, Interaide, MEET, Millenium Village project, Malawi Rural Finance Company (MRFC), Namadzi AIDS Support Organisation, NASFAM, Political parties, Sasakawa Global 2000, Self Help International and World Vision International. DAPP, MEET and World Vision International had assisted communities with seedlings and the rest had provided information on the need for tree planting as a land conservation measure.

The respondents, 22.0% indicated that Inter-aide is providing safe water through protected wells. Other NGOs mentioned in the water sector were Concern Universal, Millenium Village Project, World Vision International, Emmanuel International, MASAF, Indians and Population Services International, who have just indicated their interest in the water sector. (See Table 4.16). The lager percentages that indicated non availability of NGOs in forestry and water sectors indicates non availability of programme to support in mitigation of resource degradation in the area.

Table 4.16: NGOs in Forestry and Water Sectors in the Study Area.

	NGOs on Forestry Sector Already in the Study Area		NGOs Working in the Water Sector in the Study Area	
	Count	**%**	**Count**	**%**
None	169	71.6	128	54.2
Concern Universal	2	.8	1	.4
DAPP	13	5.5		
Goal Malawi	1	.4		
Inter Aide	1	.4	52	22.0
Makoka Research Station	1	.4		
MEET	12	5.1		
Millenium Village Project	4	1.7	15	6.4
MRFC	1	.4		
Namadzi AIDS Support Organisation	1	.4		
NASFAM	1	.4		
Political Parties	1	.4	5	2.1
Sasakawa Global 2000	2	.8		
Self Help International	2	.8		
World Vision International	21	8.9	11	4.7
Emmanuel International			4	1.7
MASAF			11	4.7
Indians/Mosque			8	3.4
Population Services International			1	.4

4.1.8 Respondents Preference for Alternative Income Generating Activities

Results show that 44.9% of the respondents would indulge in small-scale business as an alternative income generating activity. The small scale businesses included baking, beer brewing, selling secondhand clothes, fish mongering, selling metal scraps, farm produce trade, small grocery and other food sales such as pork selling. Beef production and dairy, goat, pig and poultry farming were indicated as alternative income generating activity by about 22.8% of the respondents. In addition, 18.0% indicated agribusiness for the alternative income generating activity. These included horticultural, cassava, fruit tree, banana and tomato farming (see Table 4.17). Involvement of the communities in income generating activities could ease dependence on forestry resources and encourage communities to engage in environmental conservation activities.

Table 4.17: Proposed Alternative Income Generating Activities

	Alternative Income Generating activities	
	Count	**%**
None	3	1.1%
Livestock farming	62	22.8%
Bee keeping	2	.7%
Agricultural loans	3	1.1%
Small business loans	22	8.1%
Smallscale businesses	122	44.9%
Carpentry	1	.4%
Casual labour	2	.7%
Tree planting	3	1.1%
Agribusiness	49	18.0%

4.2 Forest Cover Change Analysis Using Aerial Photo Interpretation

Figure 4.1 shows forest cover change over the years. It shows more area under forest in 1965, a drop in 1974 and an increase in area under forestry in 1995. This is attributed to tree planting activities in recent years mostly done by the estates in Namadzi upper catchment. The results complimented by the observation by the respondents (60.3%) who indicated that the current forest cover is less by 85 % compared to 20 years ago. In addition, 24.9% of the respondents observed that the current forest cover has changed by 100% compared to 20 years ago. Further analysis of the results indicated forest disappeared in the area about 14 years ago. Similar results are shown on Map 4.1.

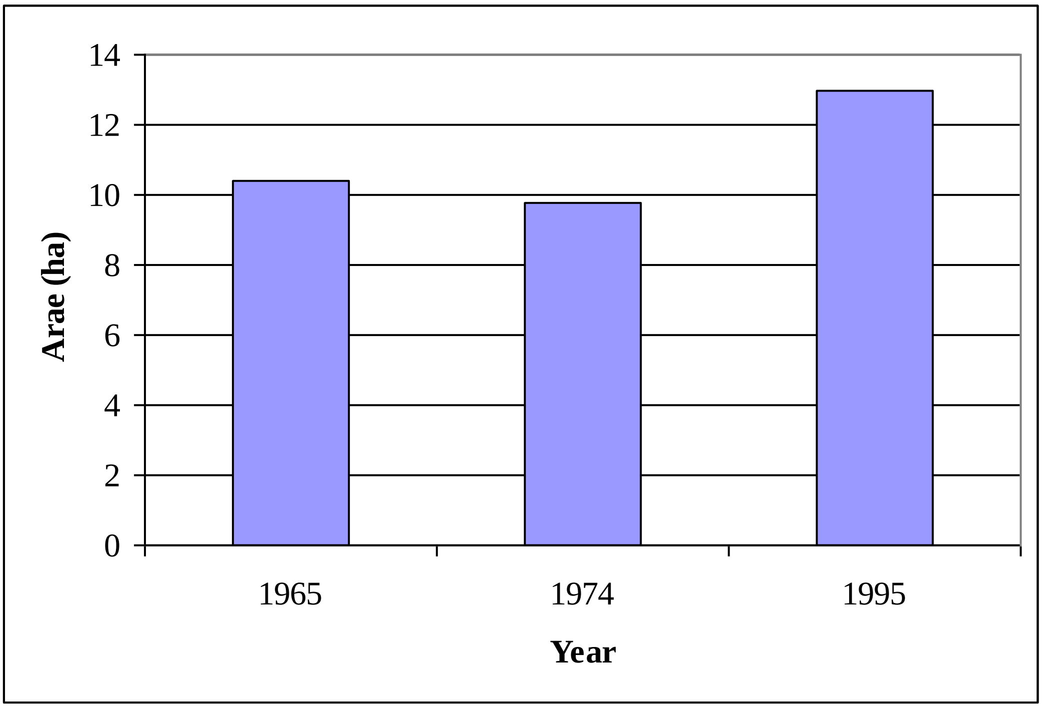
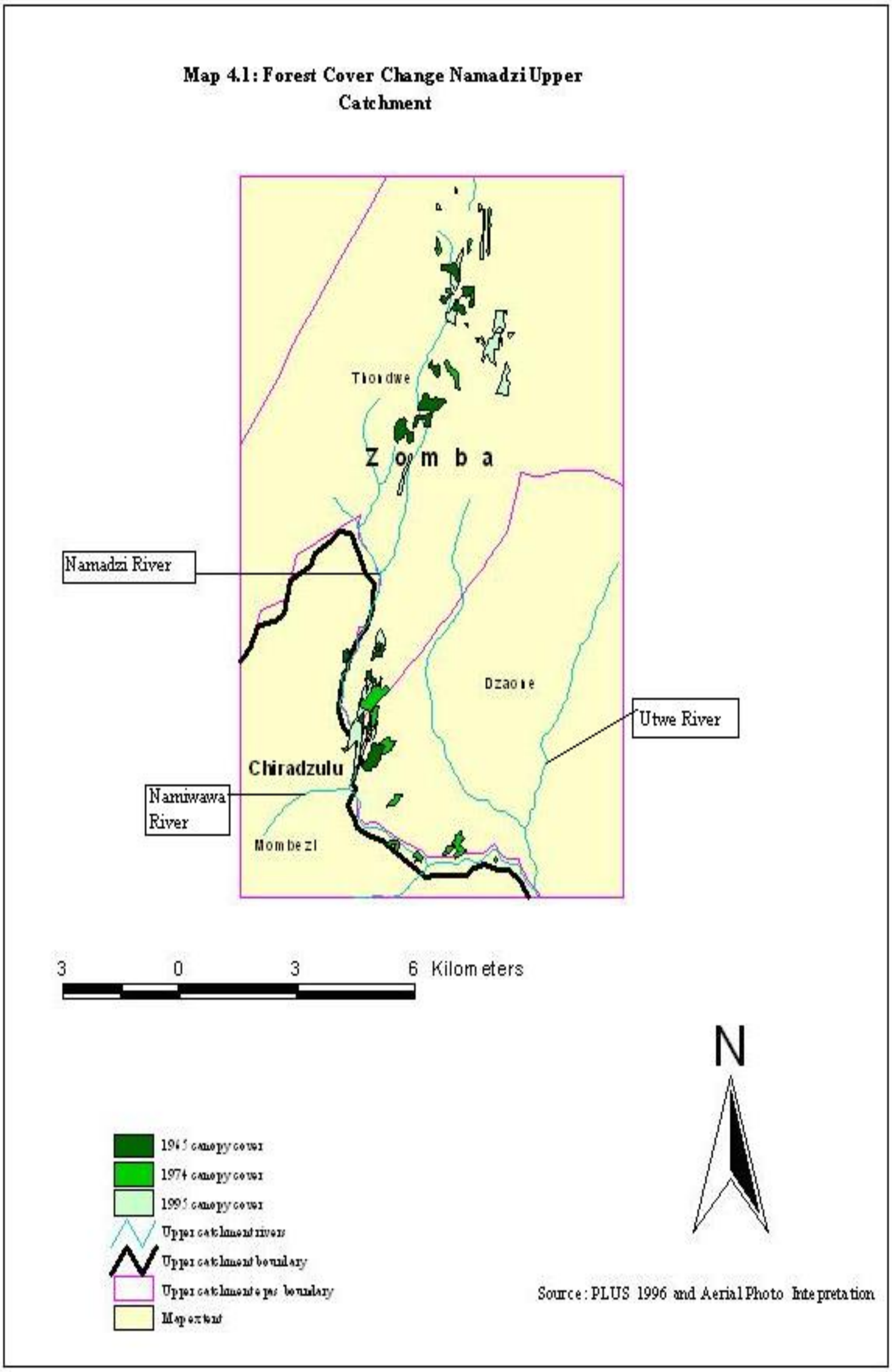


Fig 4.1: Forest Cover Change over Years (1965 to 1995)



Map 4.1: Forest Cover Change over Years (1965 to 1995)

4.3 Trend Analysis

4.3.1 Rainfall

4.3.1.1 Rainfall Data Quality Check

Double mass analysis was used to check consistency of rainfall data. Yearly accumulated rainfall data for Makoka Research station was plotted against yearly-accumulated rainfall data for Zomba plateau, which is in the same district, for a period of 1958 – 2003. Figure 4.2 shows that there is a straight line, which indicates that rainfall data for Makoka and Zomba plateau are consistent.

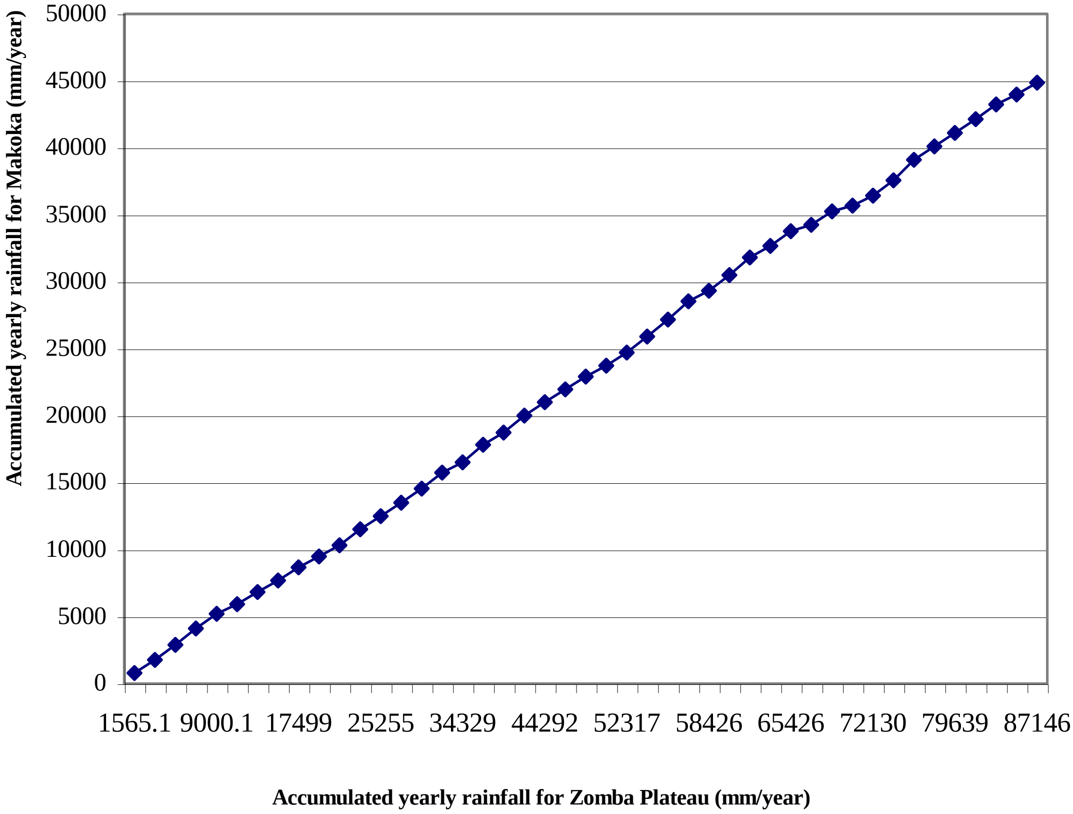


Fig 4.2: Double Mass curve for Makoka and Zomba Plateau

4.3.1.2 Mean Monthly Rainfall 1959 – 2003

Average annual rainfall in Namadzi catchment for the station at Makoka for the period 1959 to 2003 was 997 mm/year. Recorded minimum was 417.2 mm in 1994; a maximum was 1522.0 mm in 1997. Figure 4.3 shows the mean monthly rainfall between 1959 and 2003. As expected for Malawi, January had the highest mean rainfall (245.9 mm) and August had the lowest (3.0 mm).

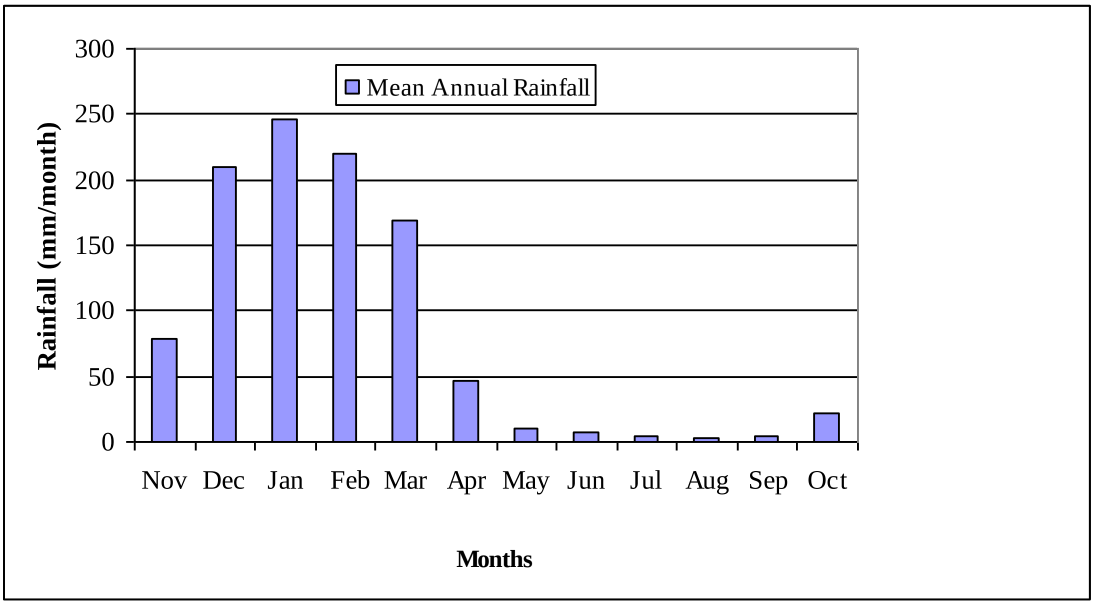


Fig 4.3: Makoka Mean Monthly Rainfall 1959-2003

4.3.1.3 Rainfall Hydrograph

Figure 4.4 shows annual rainfall time series from 1959 to 1999 for Makoka Station. A linear trend in rainfall over the years is evident. A ten-year rainfall series indicates higher rainfall in January. The hydrograph also indicates a similar behavior in rainfall pattern over the years as shown in figure 4.5. Rainfall peaks are indicated between January and March every year.

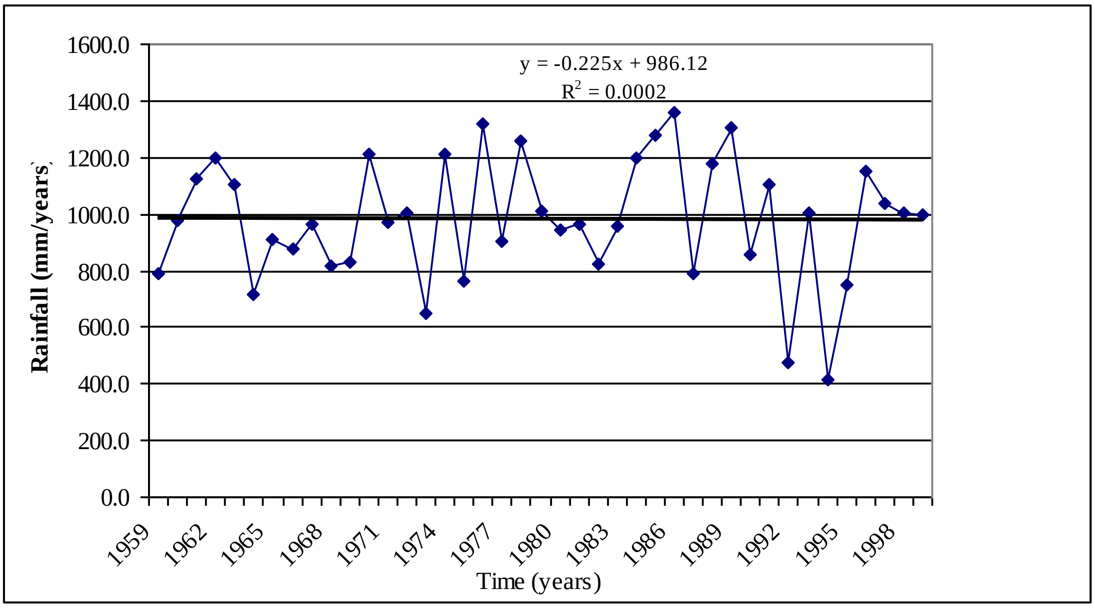


Fig 4.4. Namadzi Rainfall Series 1959-1999

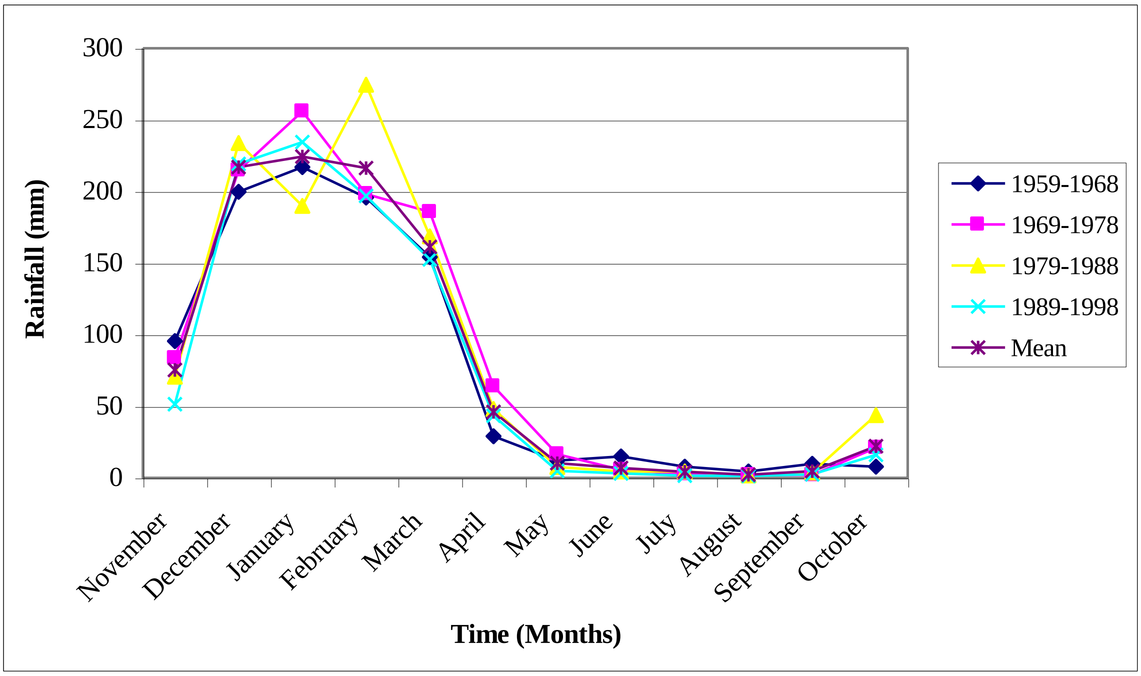


Fig 4.5. Namadzi 10 Year Period Rainfall Series

4.3.1.4 Linear Trend in Annual Rainfall

From the linear trend line in figure 4.4, there is no trend in the Makoka annual rainfall although a slight negative slope is evident. From figure 4.6, there is a cyclic pattern of high and low rainfall after approximately every 7 years. The largest positive rainfall anomaly is in 1997. Droughts are also evident especially in the late 1960's and early 1990s. The period between 1990 and 1996 records the lowest rainfall anomalies with average rainfall of 823.5 mm/year. These anomalies coincide with those of the rest of Malawi (Ngongondo, 2006). The years after the maximum total rainfall indicates lean years in terms of rainfall.

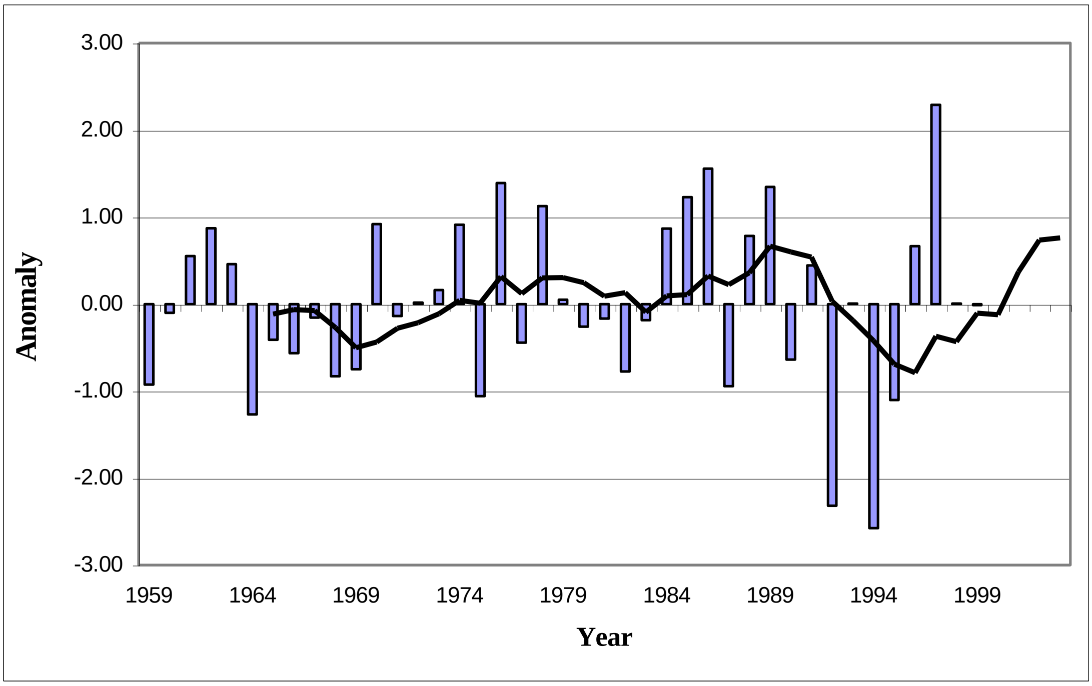


Figure 4.6: Rainfall Anomalies for Makoka and 7-Year Moving Average

4.3.1.5 Trend in Annual and Monthly Rainfall

At annual timescale, the Mann-kendall test suggests a positive trend in rainfall for Makoka (Z = 0.53) though not significant at any significance level. This is the same for Sens' Slope Estimator (Q= 2.06), which is also not significant at 99% and 95% levels. The linear trend constant B at 99% and 95% significance level are all positive, agreeing with the Sens' Slope. Figure 4.7 shows the slopes that suggest randomness in the slope and no trend. At monthly scale, all the months have no significant trends except for November (Fig 4.8), which has a positive significant trend at 0.1% as compared to December with no trend (Fig 4.9). The results of the other months are shown in figure 4.10 and are summarized in table 4.18.

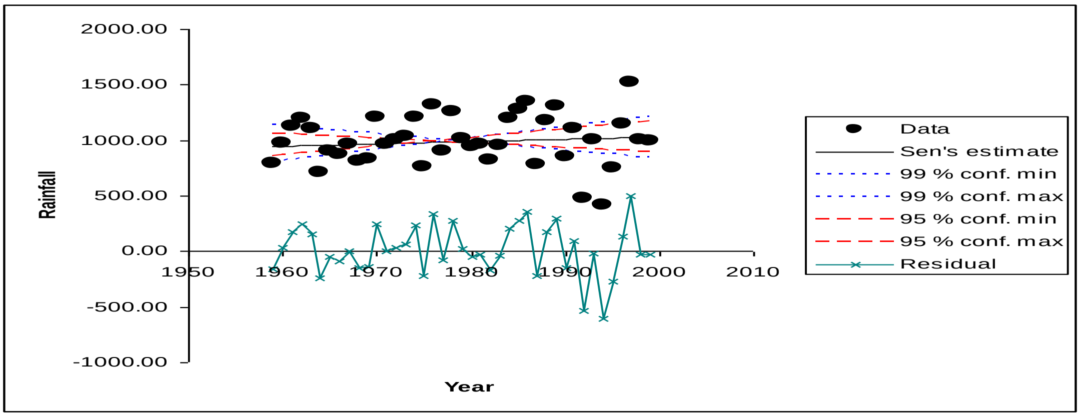


Figure 4.7: Annual Rainfall Sens Slope Trends

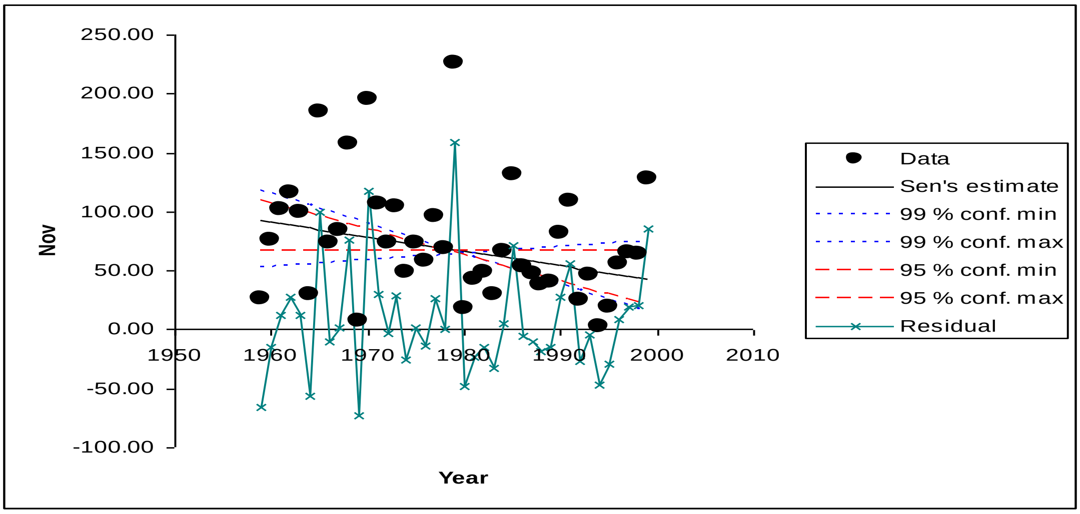


Figure 4.8. November Rainfall Series Slope Trends (Negative Trend)

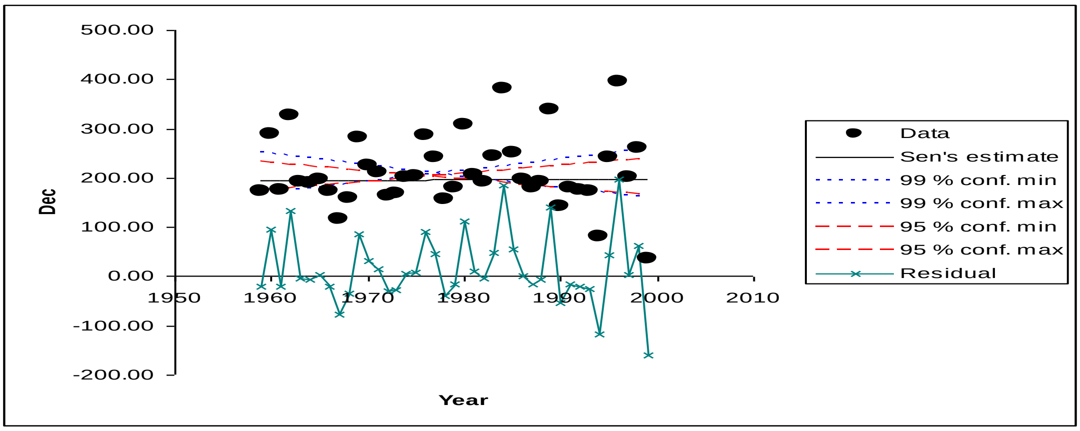


Figure 4.9: December Rainfall Series Slope Trends (No Trend)

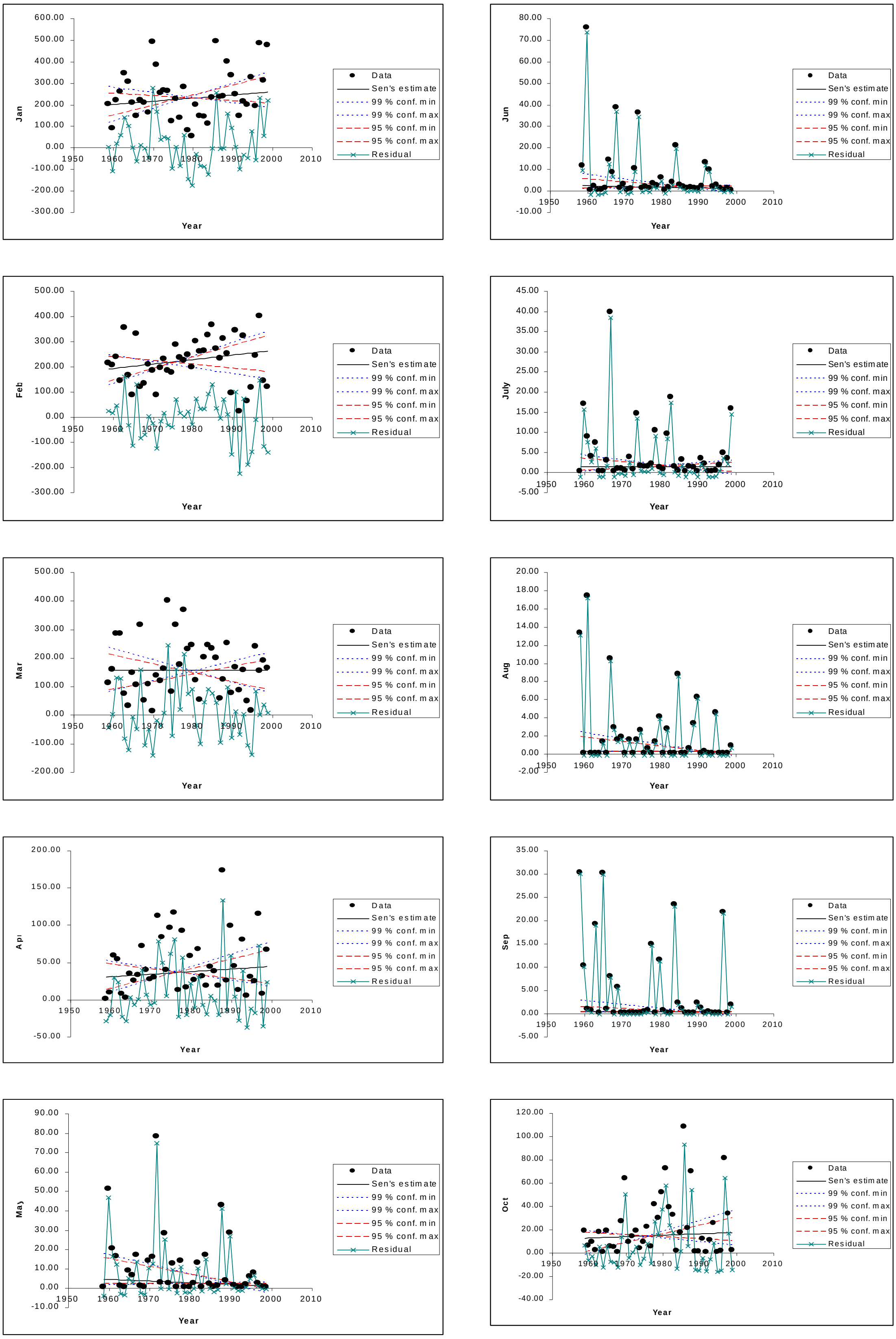


Figure 4.10: Sens' Slope Trends for January, February, March, April, May, Jun, July, August, September, October (No Trend)

Table 4.18: Summaries of Trends for Makoka Monthly Rainfall

Makoka rain fall 1959-1999				Mann-Kendall trend			Sen's slope estimate									
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Sig.**	**Q**	**Qmin 99**	**Qmax 99**	**Qmin 95**	**Qmax 95**	**B**	**Bmin 99**	**Bmax 99**	**Bmin 95**	**Bmax 95**
Jan	*1959*	*1999*	*41*		1.08		1.46	-2.35	5.78	-1.16	4.630	196.85	279.52	114.79	251.29	142.98
Feb	*1959*	*1999*	*41*		1.10		1.78	-2.37	5.36	-1.52	4.564	188.10	243.46	124.40	238.74	138.68
Mar	*1959*	*1999*	*41*		0.00		-0.00	-3.94	3.40	-3.12	2.645	155.05	235.26	79.80	211.69	85.09
Apr	*1959*	*1999*	*41*		0.72		0.34	-0.85	1.68	-0.65	1.304	29.54	51.78	7.37	47.72	12.76
May	*1959*	*1999*	*41*		-1.5		-0.08	-0.50	0.03	-0.39	0.000	4.32	17.51	1.38	15.34	2.10
Jun	*1959*	*1999*	*41*		-0.8		-0.02	-0.21	0.04	-0.13	0.024	2.09	7.55	0.57	5.30	1.03
July	*1959*	*1999*	*41*		-0.2		0.00	-0.12	0.06	-0.08	0.050	1.30	4.26	0.06	3.39	0.30
Aug	*1959*	*1999*	*41*		-1.0		0.00	-0.06	0.00	-0.04	0.000	0.20	2.36	0.20	1.83	0.20
Sep	*1959*	*1999*	*41*		-1.5		0.00	-0.08	0.00	-0.04	0.000	0.30	2.75	0.30	1.39	0.30
Oct	*1959*	*1999*	*41*		0.67		0.12	-0.30	0.94	-0.18	0.736	12.11	18.52	-1.97	17.21	0.19903
Nov	*1959*	*1999*	*41*		-1.9	+	-1.22	-2.57	0.56	-2.21	0.013	92.4	118.03	52.40	109.4	66.1822
Dec	*1959*	*1999*	*41*		0.12		0.07	-2.33	2.25	-1.67	1.639	194.8	252.01	167.59	231.8	174
Annual	*1959*	*1999*	*41*		0.53		2.06	-7.38	10.04	-4.21	7.845	946.5	1136.4	803.67	1061	856.59

4.3.2 Stream Flow

4.3.2.1 Stream Flow Data Quality Check

Double mass analysis was used to check consistency of stream flow data. Yearly accumulated stream flow data for Namadzi River were plotted against yearly-accumulated stream flow data for Mulunguzi River, which is in the same catchment for a period of 1954 to 1993. Figure 4.11 shows that there is an approximate straight line, that is stream flow data for Mulunguzi River and that of Namadzi River are consistent.

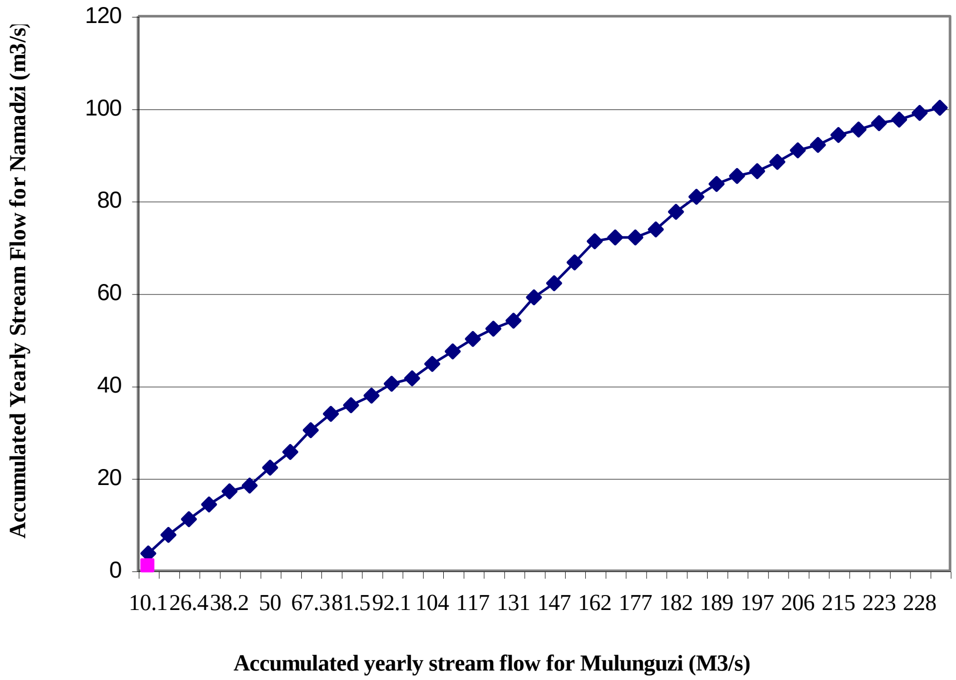


Fig 4.11: Double Mass Curve for Namadzi and Mulunguzi Stream flow

4.3.2.2 River Hydrographs and Trend in Stream Flow

Figure 4.12 show that the annual river hydrograph has shown a decreasing trend over the years, 1959 – 1999. Figure 4.13 shows the flow distribution in a hydrological year and 10 year intervals. The ten-year interval annual hydrograph indicates that the river had a higher discharge in 1962 while the rest of the years were within the mean flow. It indicates discharge peaks between January and March every year. This is the rainy season for Malawi. It agrees with reports that rainy season is from November till April or May each year (ROM/UNDP, 1986)

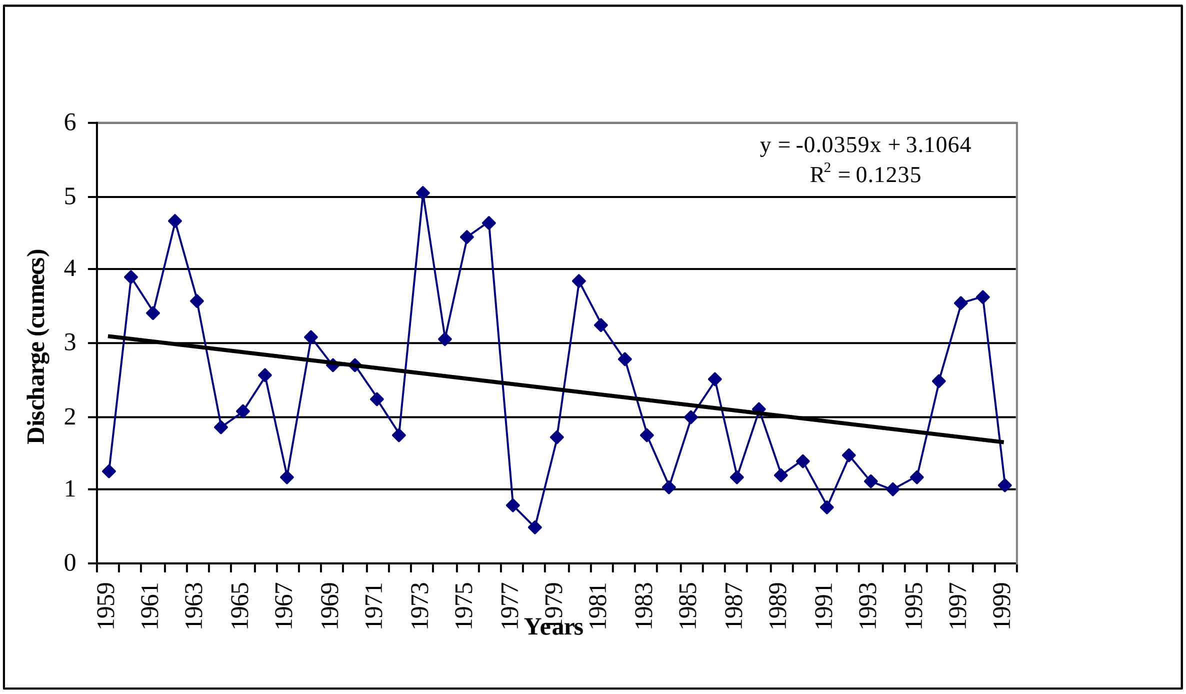


Fig 4.12: Namadzi River Stream flow Hydrograph 1959-1999

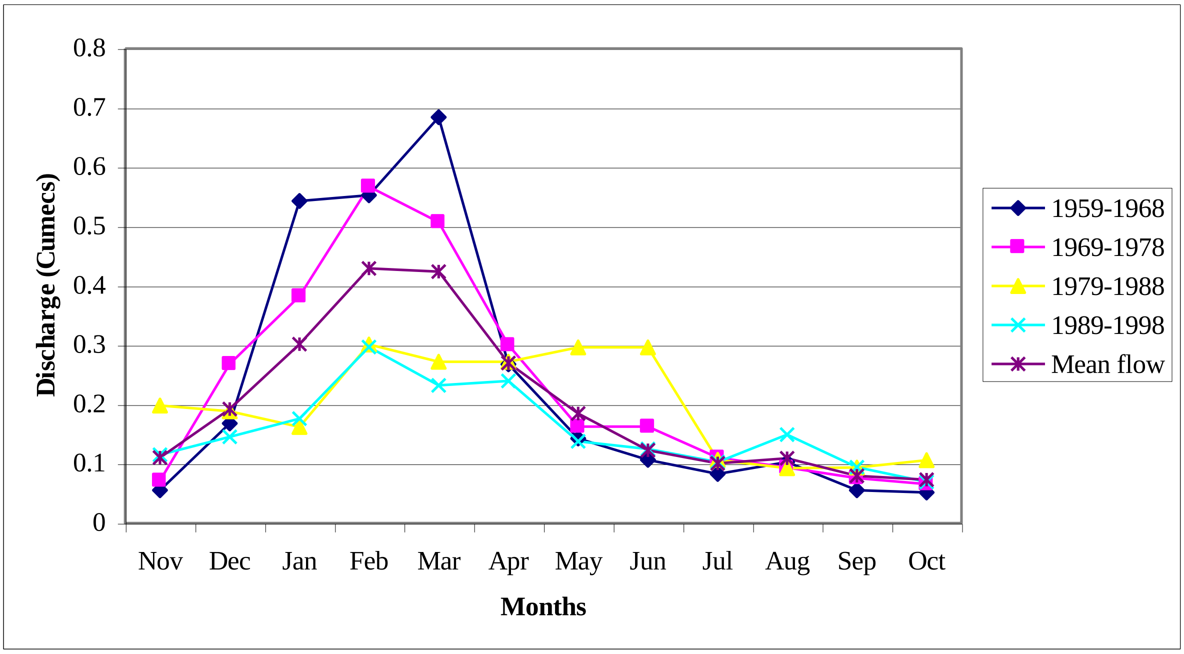


Fig 4.13: Namadzi River Ten-Year Period Hydrograph

Mean stream flow for the period 1959- 1999 was 242 mm/year with a maximum of 498mm in 1973. Minimum stream flow for the period was 73.2 mm in 1978.

4.3.2.3 Linear Trend in Mean Wet and Dry Season Flow

Average wet season flow for the period 1952 – 1999 was 360 mm. The average dry season flow for the same period was 133.5 mm. Mean wet season flow indicates a decreasing trend over the period and mean dry season flow indicates a linear trend over the period. As expected for seasonal rivers, wet season flows are higher than those in the dry season as shown in figure 4.14. It can also be noted that the trend in wet season flows have decreased than the dry season flow which is more linear. The situation is expected because of the seasonality of the area's rainfall and groundwater sustains flow in the dry season.

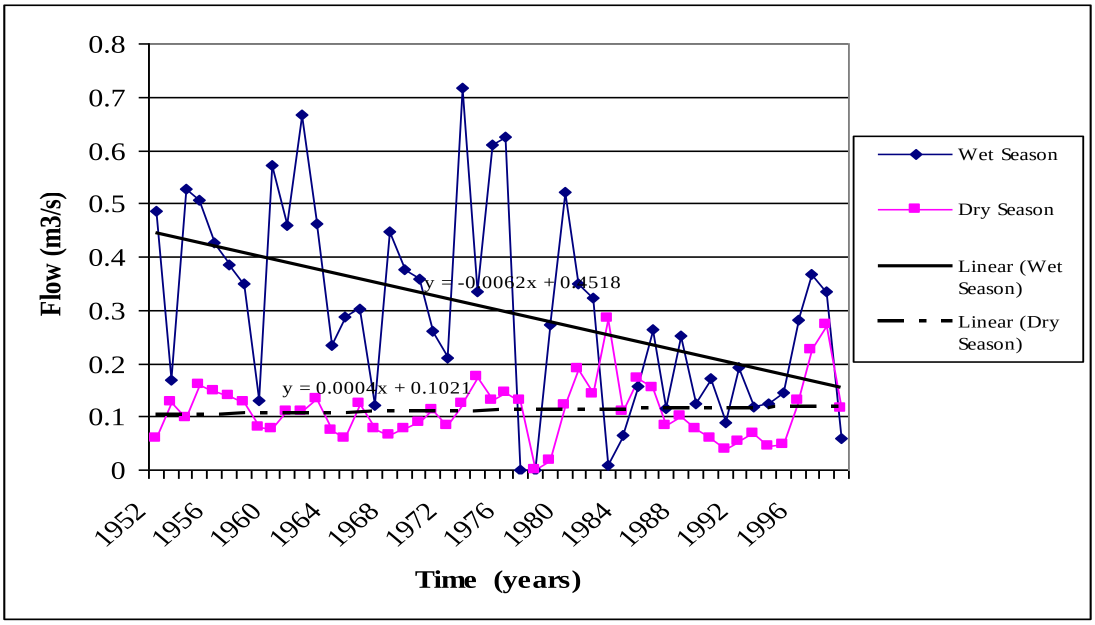


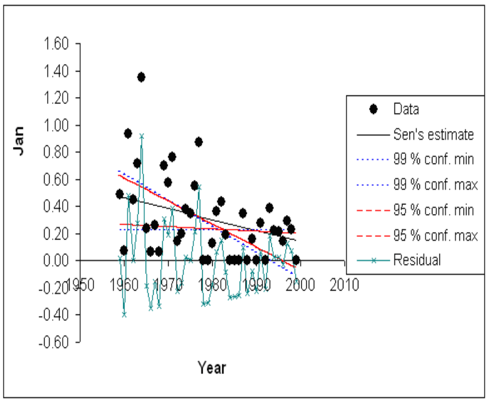
Fig 4.14: Mean Dry and Wet Season Stream Flow from 1952 -1999

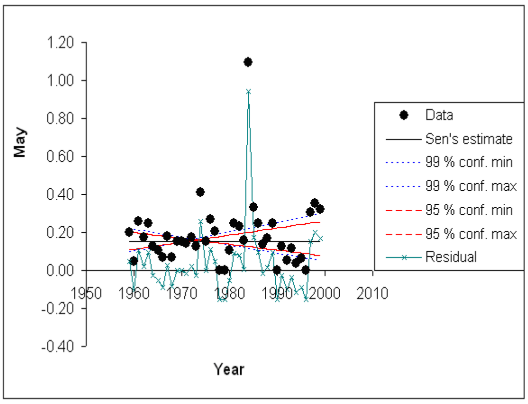
4.3.2.5 Trend in Stream Flow Using Sen's Method

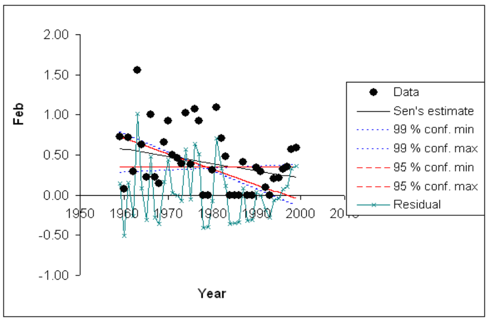
Results in Table 4.19 shows Mann Kendall (□ = 0.05) and Sen's slope results (□□= 0.1 and 0.5) from 1959 –1999 for annual mean and monthly mean flows. Annual decreasing flows are evident, though not significant. At monthly level, decreasing flows are also found in February (significant at 99%), March (significant at 90%), April (significant at 99%), May, July and August (all not significant). On the other hand, increasing flow trends are found for June, September and November (not significant), October (significant at 95%) and December (significant at 99%). Furthermore the slopes for all the months are statistically different from zero at 99% confidence interval. The conclusion can be made that stream flow is decreasing over the years. The results are also shown in figure 4.15.

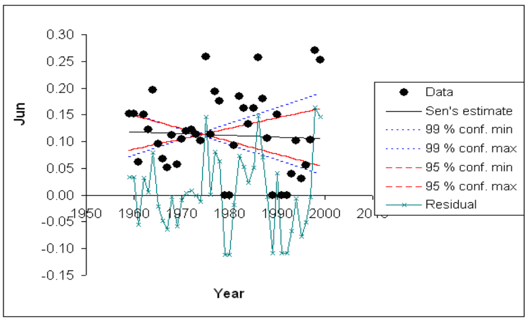
Table 4.19: Summaries of Trends for Namadzi Annual and Monthly Discharge

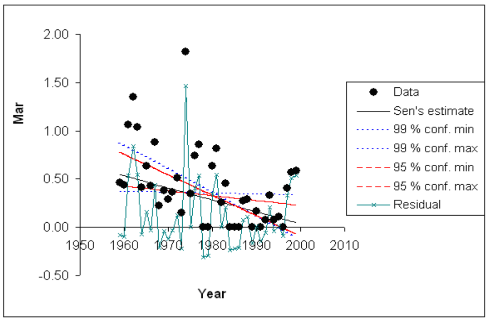
Namadzi 1959-1999				Mann-Kendall trend			Sen's slope estimate										
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Signific.**	**Q**	**Qmin 99**	**Qmax 99**	**Qmin 95**	**Qmax 95**	**B**	**Bmin 99**	**Bmax 99**	**Bmin 95**	**Bmax 95**
Jan	*1959*	*1999*	*41*		-2.63	**	-0.008	-0.019	0.000	-0.017	-0.002	0.47	0.67	0.23	0.63	0.27
Feb	*1959*	*1999*	*41*		-1.91	+	-0.009	-0.023	0.003	-0.019	0.000	0.58	0.80	0.29	0.73	0.35
Mar	*1959*	*1999*	*41*		-3.06	**	-0.012	-0.025	-0.001	-0.021	-0.005	0.54	0.89	0.37	0.78	0.44
Apr	*1959*	*1999*	*41*		-0.22		0.000	-0.007	0.006	-0.005	0.004	0.27	0.39	0.14	0.35	0.17
May	*1959*	*1999*	*41*		0.08		0.000	-0.004	0.005	-0.003	0.004	0.15	0.22	0.10	0.20	0.11
Jun	*1959*	*1999*	*41*		-0.44		0.000	-0.003	0.003	-0.002	0.002	0.12	0.16	0.07	0.15	0.08
July	*1959*	*1999*	*41*		-0.02		0.000	-0.002	0.003	-0.002	0.002	0.09	0.13	0.06	0.12	0.07
Aug	*1959*	*1999*	*41*		0.96		0.001	-0.001	0.003	-0.001	0.002	0.07	0.11	0.04	0.10	0.05
Sep	*1959*	*1999*	*41*		2.00	*	0.001	0.000	0.003	0.000	0.003	0.05	0.07	0.03	0.07	0.03
Oct	*1959*	*1999*	*41*		1.15		0.001	-0.001	0.003	-0.001	0.002	0.05	0.09	0.0245	0.08309	0.031
Nov	*1959*	*1999*	*41*		2.67	**	0.002	0.000	0.004	0.000	0.004	0.052	0.072	0.02191	0.06612	0.024
Dec	*1959*	*1999*	*41*		-0.42		0.000	-0.006	0.004	-0.004	0.003	0.162	0.2786	0.07762	0.25148	0.111
Annual	*0*	*0*	*0*		-2.46	*	-0.003	-0.006	0.000	-0.006	-0.001	0.243	0.3073	0.17974	0.29238	0.192

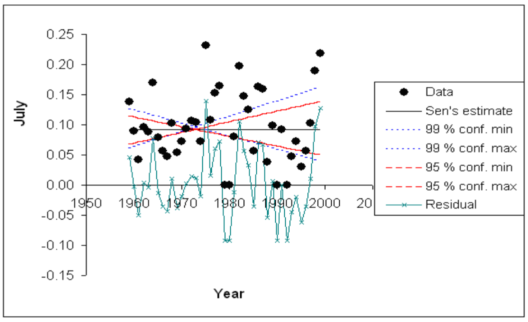

Jan
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual

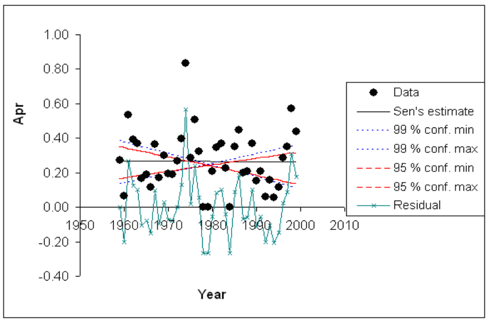

May
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual

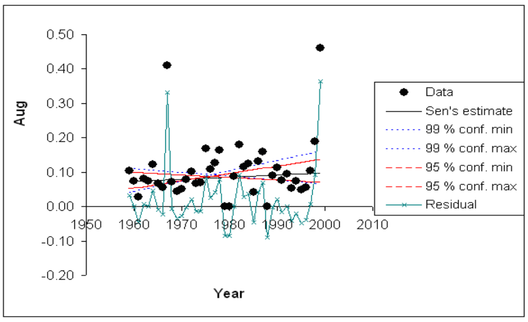

Feb
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual


Jun
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual


Mar
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual


July
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual


Apr
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual


Aug
Year
Data
Sen's estimate
99 % conf. min
99 % conf. max
95 % conf. min
95 % conf. max
Residual

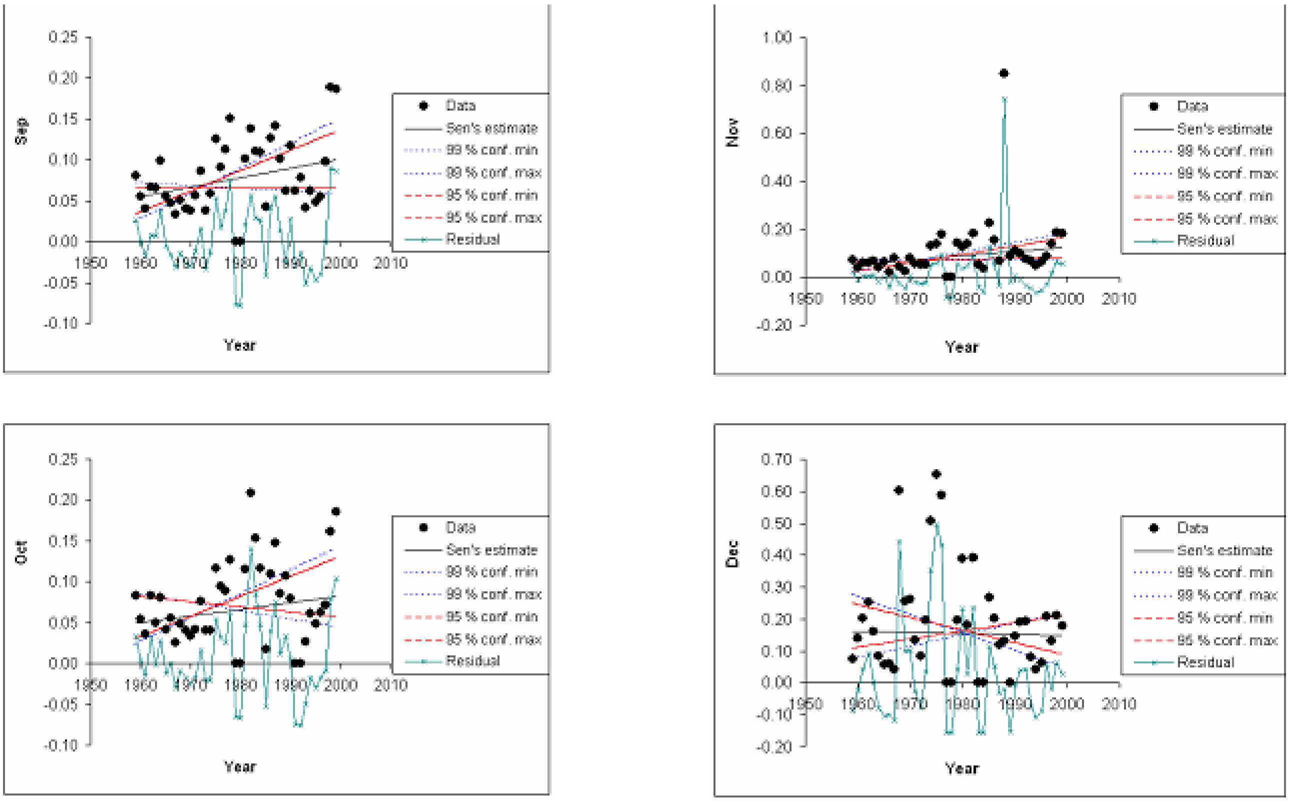


Figure 4.15: Sens' Slope Trends for January, February, March, April, May June, July, August, September, October, November and December (Negative Trend)

4.3.3 Tree Cover

4.3.3.1 Trend in Annual Tree Cover

Total area planted with trees has been increasing with passing years (see Figure 4.16). Before 1968, a total of 6 hactares were planted with trees. The trees were planted by estates that are located in the upper catchment of Namadzi River. By 1996 there were a cumulative total 114 hactares of trees planted. This rose to a cumulative total of 7250 hactares representing 1200 times the original hectares planted. The remaining area is cultivated both for smallholder subsistence and estate farming. Forest cover hactarage has increased over the years. This agrees with findings from aerial photo interpretation that indicate a fall in area covered with forest from 1965 to 1974, but an increase in area in 1995. In addition, the household survey indicates a decrease in indigenous forest the past 14 years.

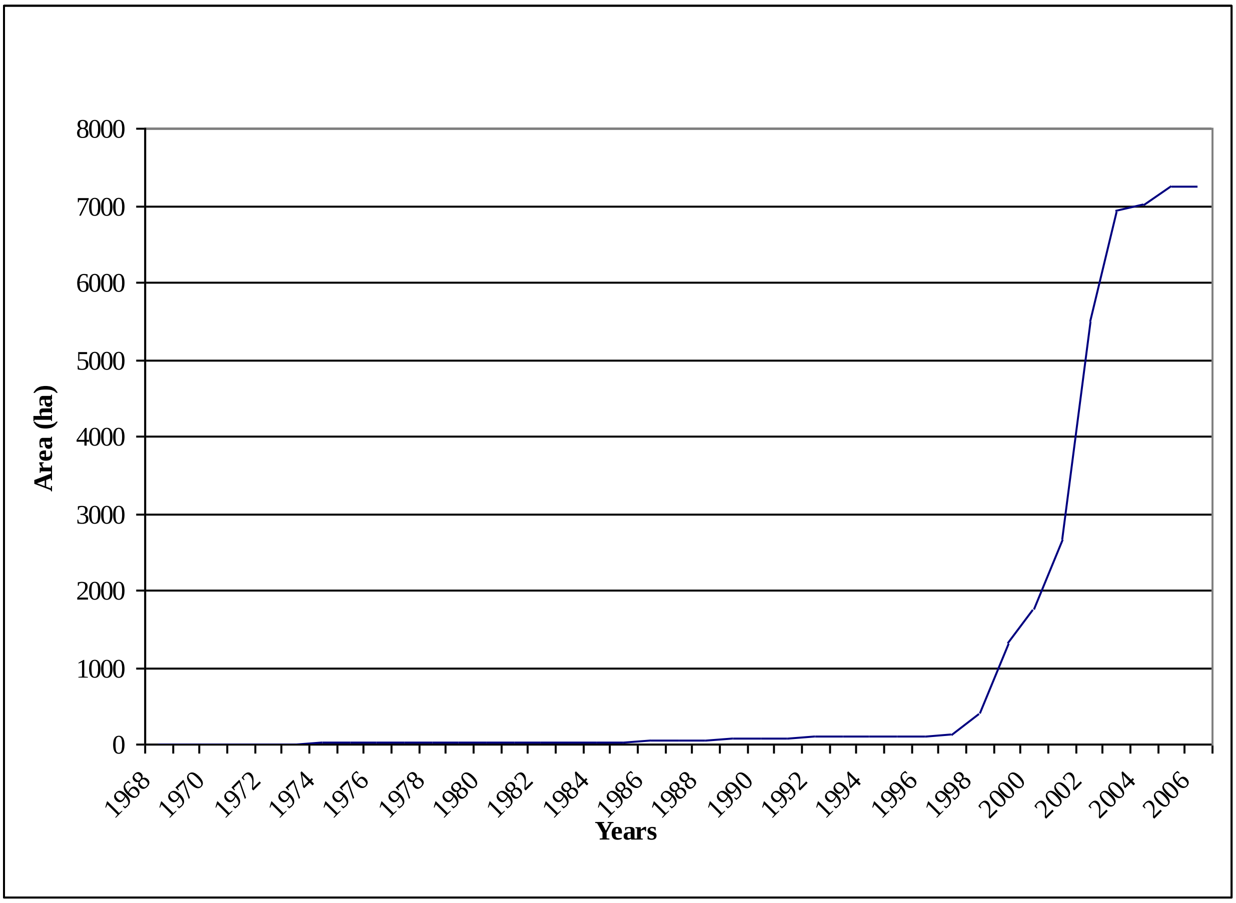


Fig 4.16: Cumulative Area Planted With Trees from 1968 - 2006

4.3.4 Run-off by Curve Number Method

For this study run-off was calculated using a composite Curve Number (CN) of 79. This was computed from the different land uses in the area namely; Agriculture forest area, arable area, bare rock, built up area, eucalyptus, Miombo in hilly areas, pine and maize and tobacco cultivation (PLUS, 1996). Type C (shallow sandy loam) for soil was used and figure 4.17 shows the various land use type distribution.

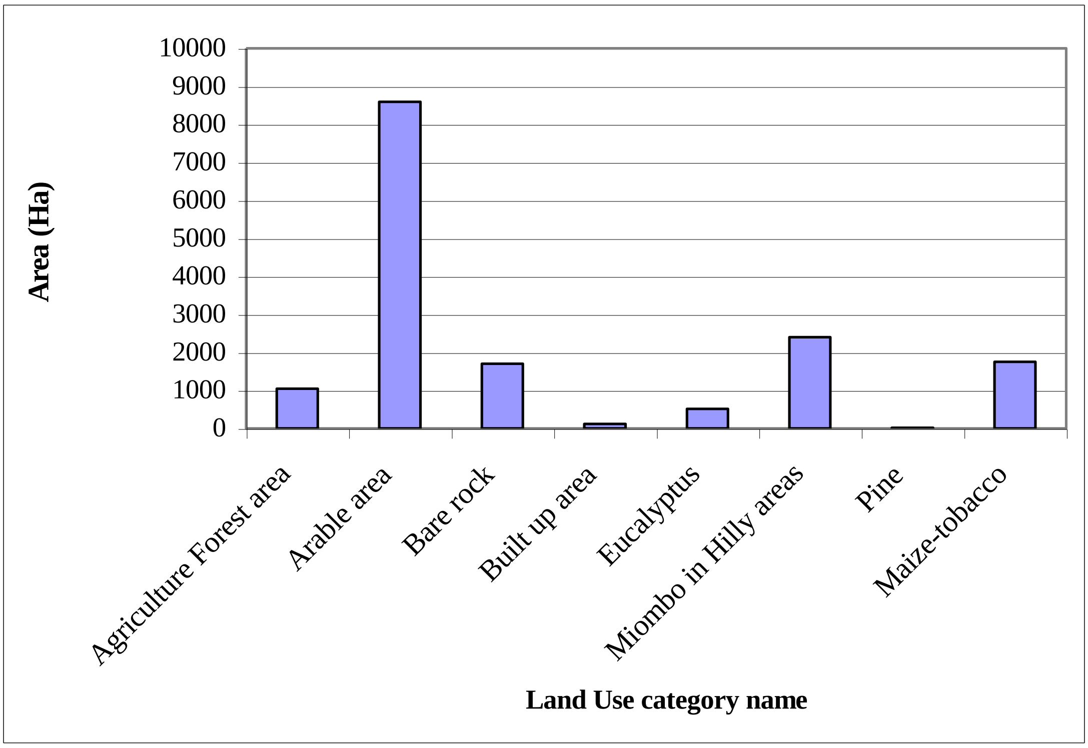


Fig 4.17: Major Land Use Categories in Namadzi Catchment.

4.3.4.1 Trend in Run-off against Time

The mean calculated runoff from the CN number for the period 1959 to 2003 was 949.30 mm/year with a maximum of 1443.87 mm/year in 1997 and a minimum of 345.85mm/year in 1994. These years do correspond to the years when there were lowest and highest total amount of rainfall, respectively. Results from Figure 4.18 indicate that there has been a decreasing trend in runoff over the years. As this method bases the run off on the rainfall only, it clearly indicates that no trend in rainfall input contributes to constant flows. Comparing the steepness, the observed stream flow has lower values than the calculated runoff values (see Figure 4.19). This could be attributed to exotic trees that have been planted in the catchment as forestation practices cause decreases in water yield due to increases in evapotranspiration. Farley et al. (2005) reported that *Eucalyptus* reduced water yield by 75% when planted in grasslands. In addition Namadzi River is a catchment area for some other rivers like Nachambo, Sanje, Namichimba, Nsamba, Naziwale and Naisuyu rivers and this affects the runoff values.

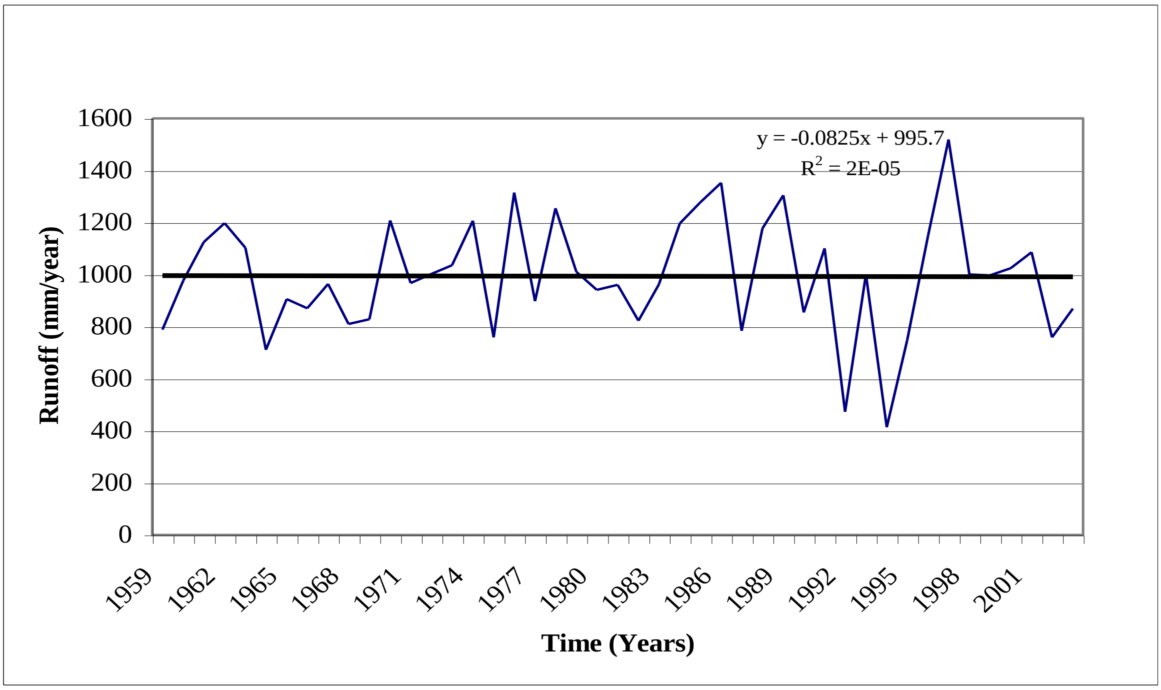


Fig 4.18: Run-off Against Time

Fig 4.19: Comparison between Stream Flow and Calculated Run-off.

4.3.5 Trend in Run-off Using Sen’s Method

Results in Table 4.20 shows Mann Kendall (□ = 0.05) and Sen’s slope results (□□= 0.1 and 0.5) from 1959 –1999 for Namadzi annual and monthly run-off. At annual time scale, the Mann Kendall test suggests a positive trend in run-off for Namadzi (Z=0.53) though not significant at any significance level. This is the same for Sen’s Slope Estimator (Q=2.048), which is also not significant at 99% and 95% levels. The linear trend constant B at 99% and 95% significance level are all positive, agreeing with the Sen’s Slope Estimate. At monthly level, results show a positive trend together with those of January, February, April, May, July, August, September, October and December. The rest of the months show slight negative trends but not very significant.

Table 4.20: Summaries of Trends for Namadzi Annual and Monthly Run off

Namadzi 1959-1999				Mann-Kendall trend			Sen's slope estimate									
Time series	**First year**	**Last Year**	**n**	**Test S**	**Test Z**	**Signific.**	**Q**	**Qmin 99**	**Qmax 99**	**Qmin 95**	**Qmax 95**	**B**	**Bmin 99**	**B max 99**	**Bmin 95**	**Bmax 95**
Annual	*1959*	*1999*	*41*		0.53		2.048	-7.351	10.008	-4.196	7.813	870.04	1059.21	727.83	984.17	780.49
Jan	*1959*	*1999*	*41*		1.08		1.354	-2.175	5.375	-1.085	4.287	134.20	209.71	60.55	184.73	84.34
Feb	*1959*	*1999*	*41*		1.10		1.638	-2.102	5.084	-1.374	4.356	126.37	175.04	67.66	173.16	79.85
Mar	*1959*	*1999*	*41*		-0.01		-0.016	-3.249	2.837	-2.436	2.118	96.25	160.26	31.64	136.67	43.22
April	*1959*	*1999*	*41*		0.13		0.013	-0.210	0.566	-0.128	0.289	4.70	9.14	-0.43	7.56	1.35
May	*1959*	*1999*	*41*		0.63		0.003	-0.031	0.072	-0.016	0.054	2.54	3.30	0.63	3.01	1.13
June	*1959*	*1999*	*41*		-0.73		-0.007	-0.046	0.031	-0.034	0.017	2.91	3.68	1.95	3.48	2.30
July	*1959*	*1999*	*41*		-0.26		0.000	-0.039	0.040	-0.028	0.027	2.69	3.38	1.74	3.26	2.06
Aug	*1959*	*1999*	*41*		1.01		0.000	0.000	0.032	0.000	0.022	3.26	3.26	2.20	3.26	2.54
Sept	*1959*	*1999*	*41*		0.97		0.000	0.000	0.013	0.000	0.008	3.24	3.24	2.91638	3.239	3.069
Oct	*1959*	*1999*	*41*		2.16	*	0.065	-0.008	0.161	0.001	0.129	1.032	2.47855	-0.59356	2.4108	-0.312
Nov	*1959*	*1999*	*41*		-1.91	+	-0.744	-1.533	0.261	-1.376	0.004	39.24	54.5982	16.7834	51.256	23.22
Dec	*1959*	*1999*	*41*		0.12		0.072	-2.132	2.081	-1.548	1.520	132.1	184.269	107.01	166.24	112.9

4.4 Relationship Analysis

4.4.1 Relationship between Areas Planted With Trees and Stream Flow

Results from linear regression show that there is negative linear relationship between stream flow and area planted with forest. As area planted with trees increase, stream flow decreases, implying the trees could be using up more water from the stream. The R squared indicates a weak relationship between the stream flow and area planted with trees as shown in figure 4.20. This confirms the relationship between forests and stream flow. However, the magnitude of effects of forestation in reducing water yield varies as a function of vegetation, climate, soil and management practices (Wei et.al, 2008).

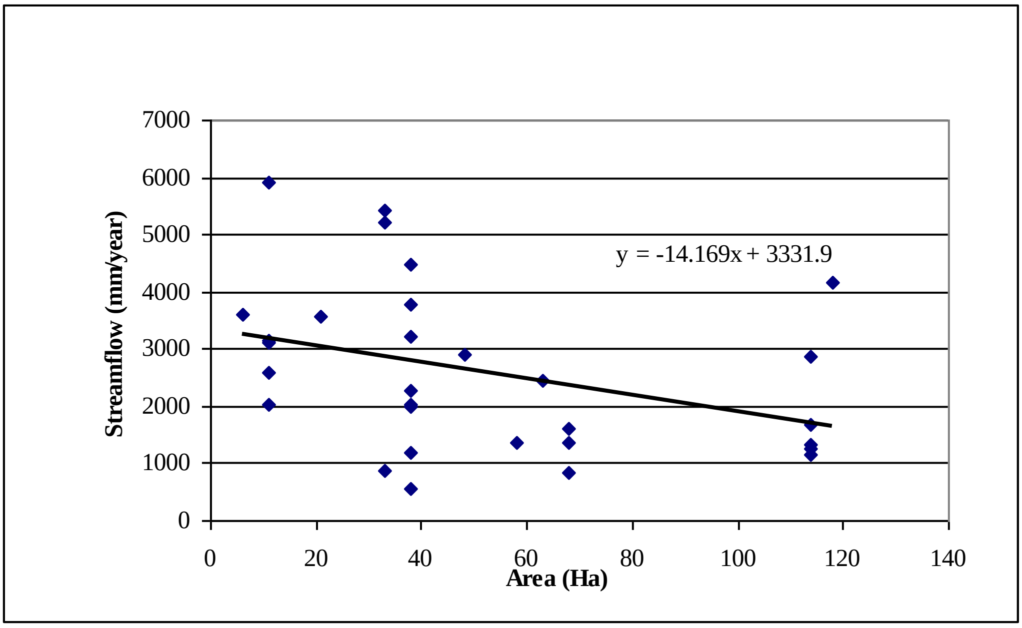


Fig 4.20: Relationship between Area Planted With Trees and Stream Flow (1968-1999)

4.4.2 Relationship between Areas Planted With Trees and Run-off

Results from linear regression show that there is a negative linear relationship between runoff and tree cover area. As area planted with forests increases, runoff coefficient shows a small decreasing trend. The R squared indicates a weak relationship between runoff coefficient and area planted to forest. See fig 4.21. That is the runoff coefficient does not change much with an increase in area planted to forest.

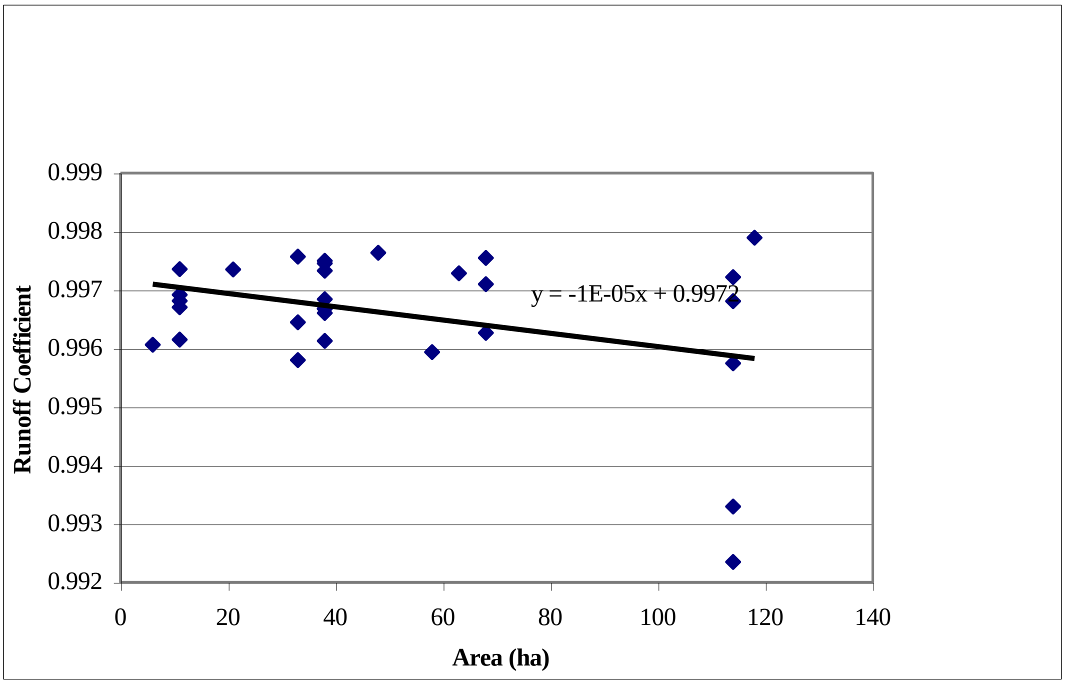


Fig 4.21: Relationship between Area Planted With Trees and Run-off Coefficient

4.4.3 Relationship between Rainfall and Run-off

As shown in Figure 4.22 results indicate that there is a positive linear relationship between rainfall and runoff. As annual rainfall increases, so does annual runoff. As the value of R squared is 1, it indicates an excellent linear relationship and a significant slope. The rainfall runoff relationship has therefore not changed over the years.

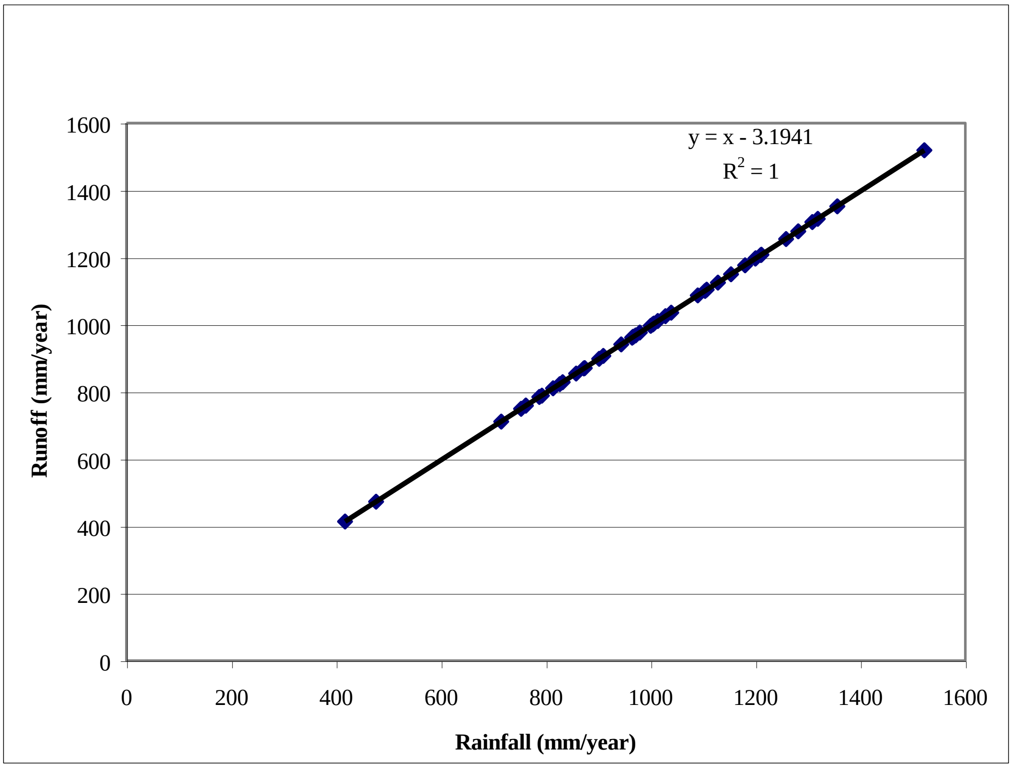


Fig 4.22: Relationship between Rainfall and Run-off

4.4.4 Rainfall-Run-off Relationship Using Rain-Ru Model

Results from the Rainru model indicate that the first ten years 1959 – 1968, a good number of memory months is 7. For the other years, a good memory month is 4. (see Table 4.21). Results also indicate that there is a fast runoff in the first months and then decreases. Results of the equations indicate that there is low-observed runoff than the simulated run-off over the ten year periods. This could be an indication that there is significant land use change contribution to the observed stream flow over the years as shown in figures 4.23- 4.26.

Table 4.21: Rainru Calibrated b's for Different Time Steps

Interception = 46			Time Step	t	t-1	t-2	t-3	t-4	t-5	t-6	t-7
Time	Memory	r2	Sum of b's	b1	b2	b3	b4	b5	b6	b7	b8
1959-1968	7	0.9758	1.3441	1.1596	0.0879	0.0283	0.0129	0.0233	0.0081	0.006	0.0179
1969-1978	4	0.9779	1.2721	1.1515	0.0702	0.0064	0.0094	0.0345			
1979-1988	4	0.977	1.2902	1.1357	0.0841	0.0252	0.0311	0.014			
1989-1998	4	0.9782	1.3067	1.1446	0.0355	0.0516	0.0568	0.0182			

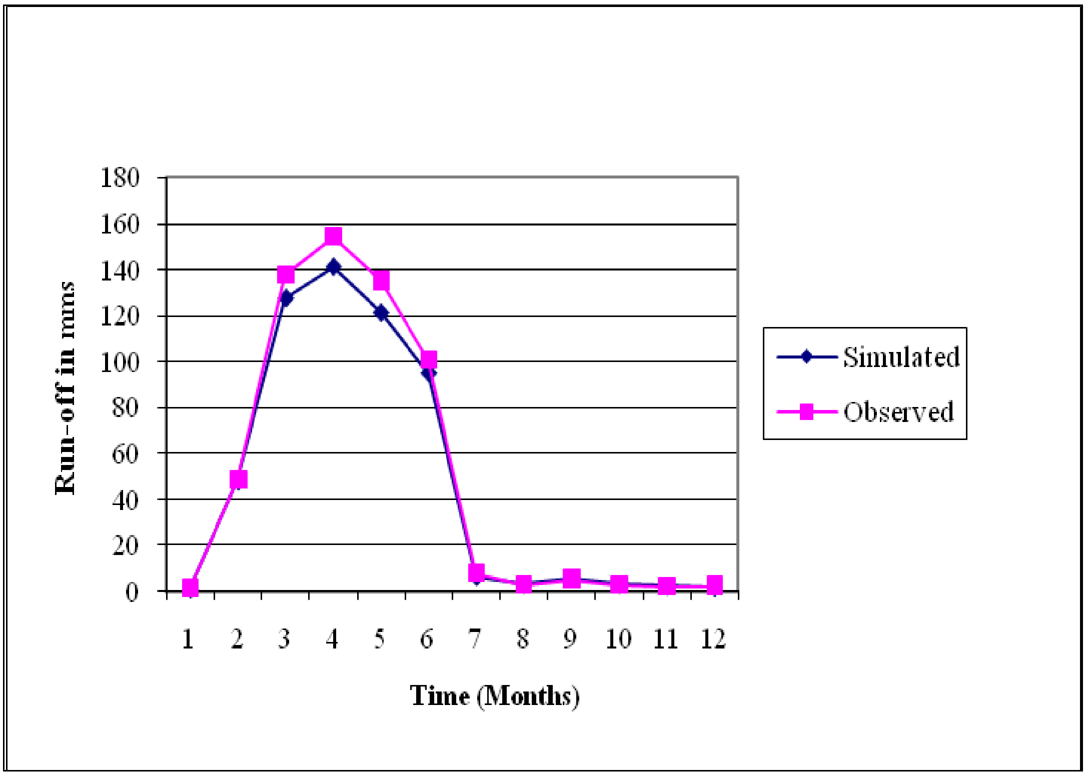


Fig 4.23: Observed and Simulated Run-off for Period 1959-1968

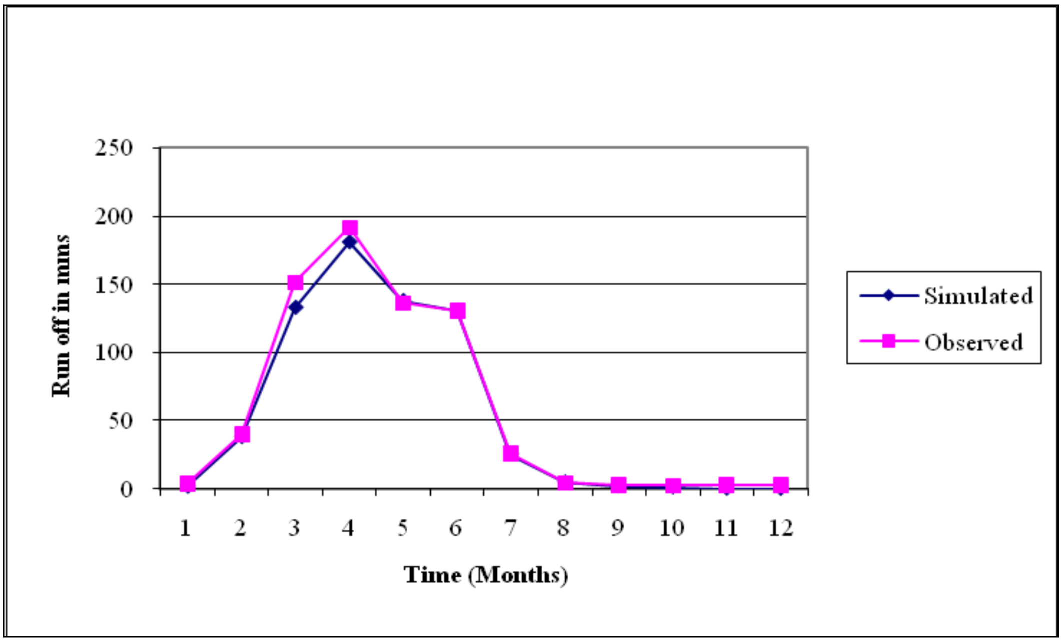


Fig 4.24: Observed and Simulated Run-off for Period 1969-1978

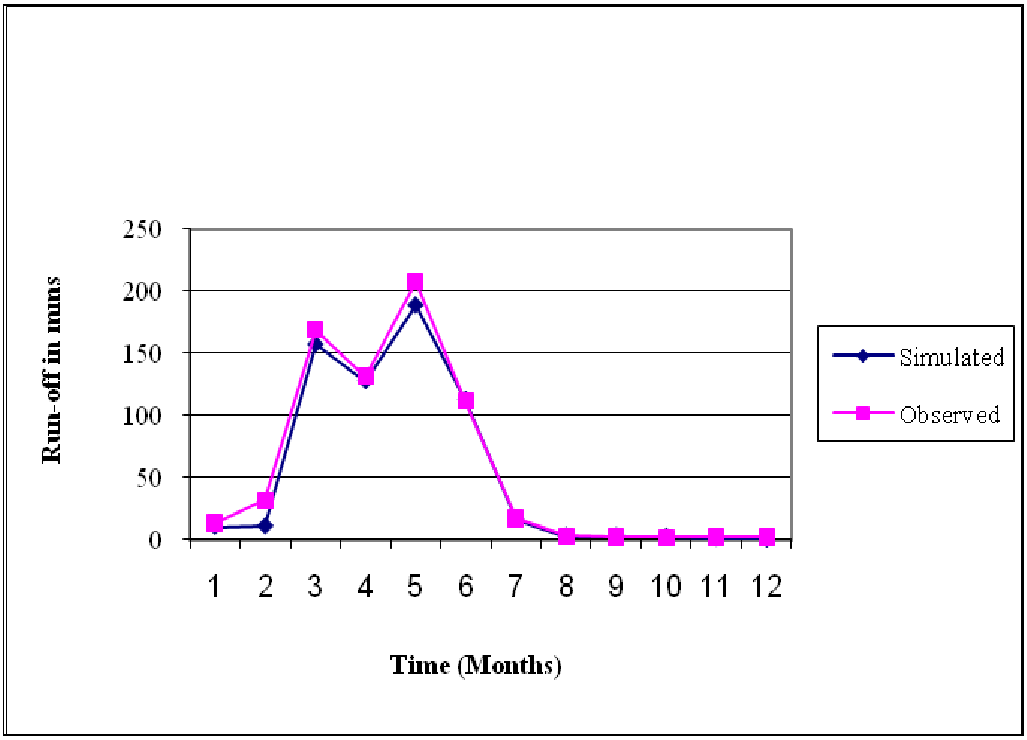


Fig 4.25: Observed and Simulated Run-off for Period 1979-1988

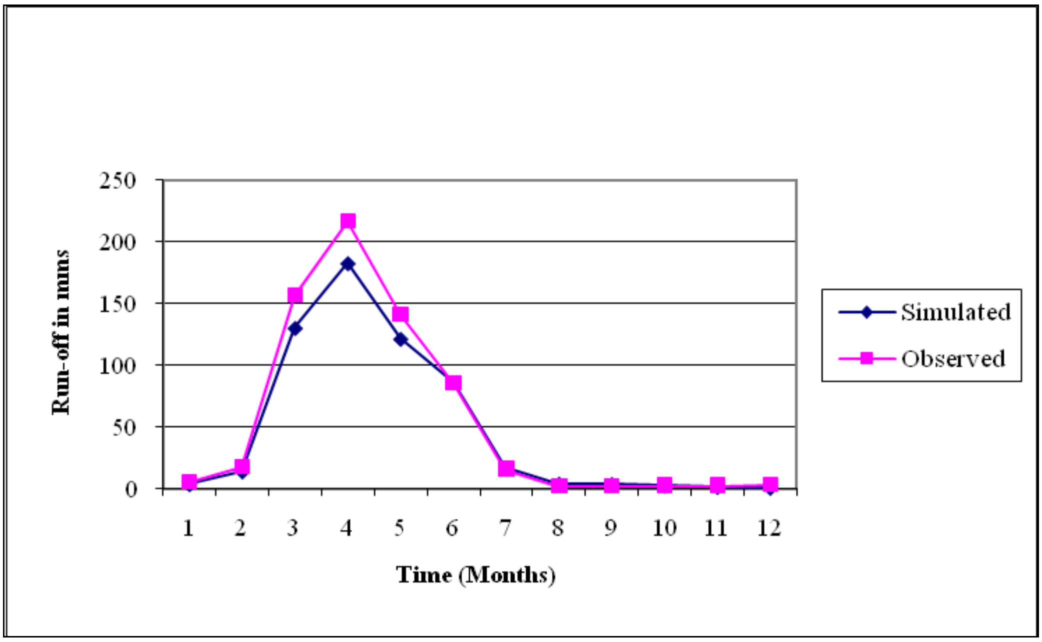


Fig: 4.26: Observed and Simulated Run-off for period 1989-1998

There is a fast component runoff (first month). As such it adds relatively small amounts of base flow. As noted from the rainfall-run-off relationship, results show that the overall picture for rainfall- run-off relationship has not changed over the years. This indicates that there is direct effect of forest cover change on stream flow. The aerial photo analysis indicates that forests reduced from 1965 to 1974 and area planted with forest increased from 1974 to 1995. Respondents to the household survey perceive indigenous forest have decreased over the past 20 years and there is an increasing trend in area planted with forest. The decrease in stream flow could be attributed forest cover change. This is because with younger forests, there is a high evapotranspiration rate as the younger forests will draw on subsurface zone water more rapidly to deplete the soil profile (Honeysett et. al., 1992). In addition, drier soil profile conditions in younger forests expose the landscape to dieback as trees have a reduced water storage reservoir during times of drought. (Jurskis, 2005). This disagrees with results on Mulunguzi catchment that there is no direct effect of pine tree cover change on hydrology (Mbano, 2006).

4.5 Environmental Hotspot Identification

Results from the observations made on the ground with expertise from the National Herbarium and Botanic Gardens (NHBG) indicated that only 26.7% of the plant species along Namadzi Riverine were trees. Herbs cover 33.5% of the area and 18.6% for grass species. The rest was for shrubs, climbers, clippers and crops (see Figure 4.27). Figure 4.28 shows that most of the plant species, 35.1% currently existing in Namadzi riverine as observed were for medicinal purposes and 11.6% were indicated as species for edible fruits (see Appendix 15)

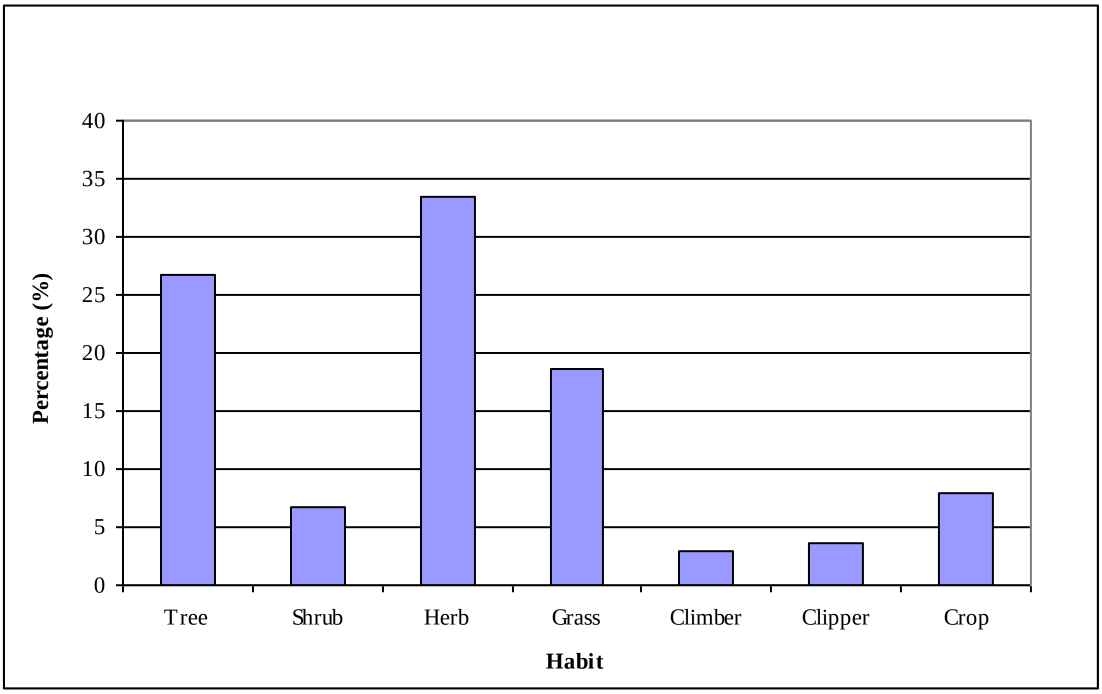


Fig 4.27: Percentage of Species Reported Based on Habit

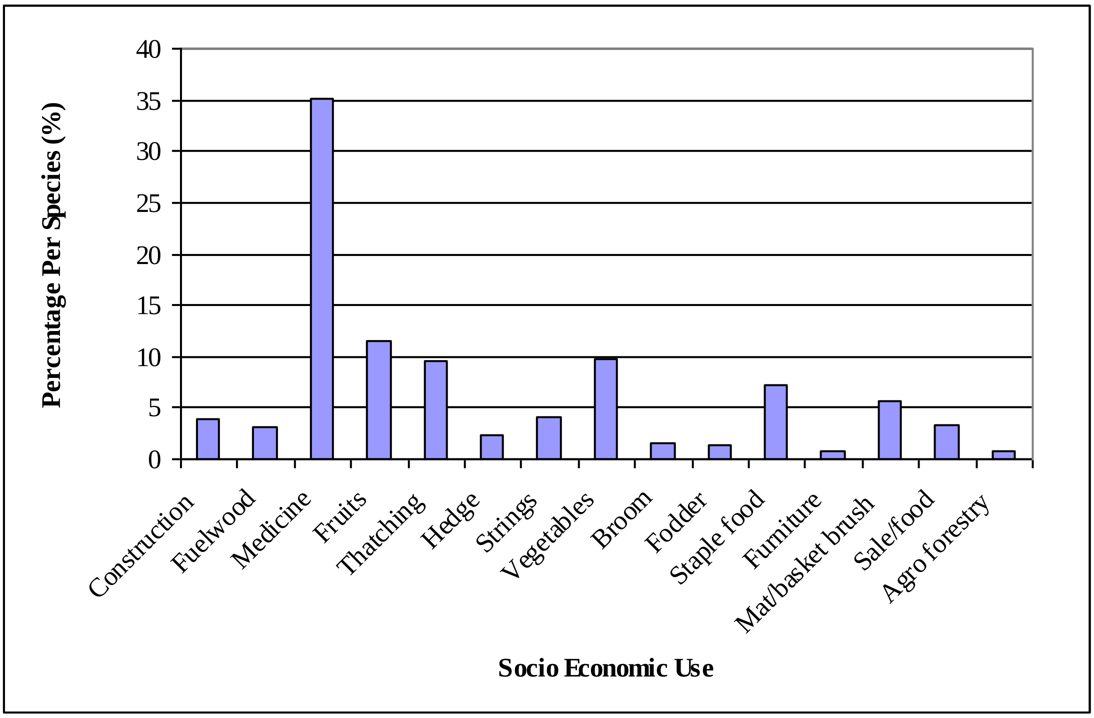
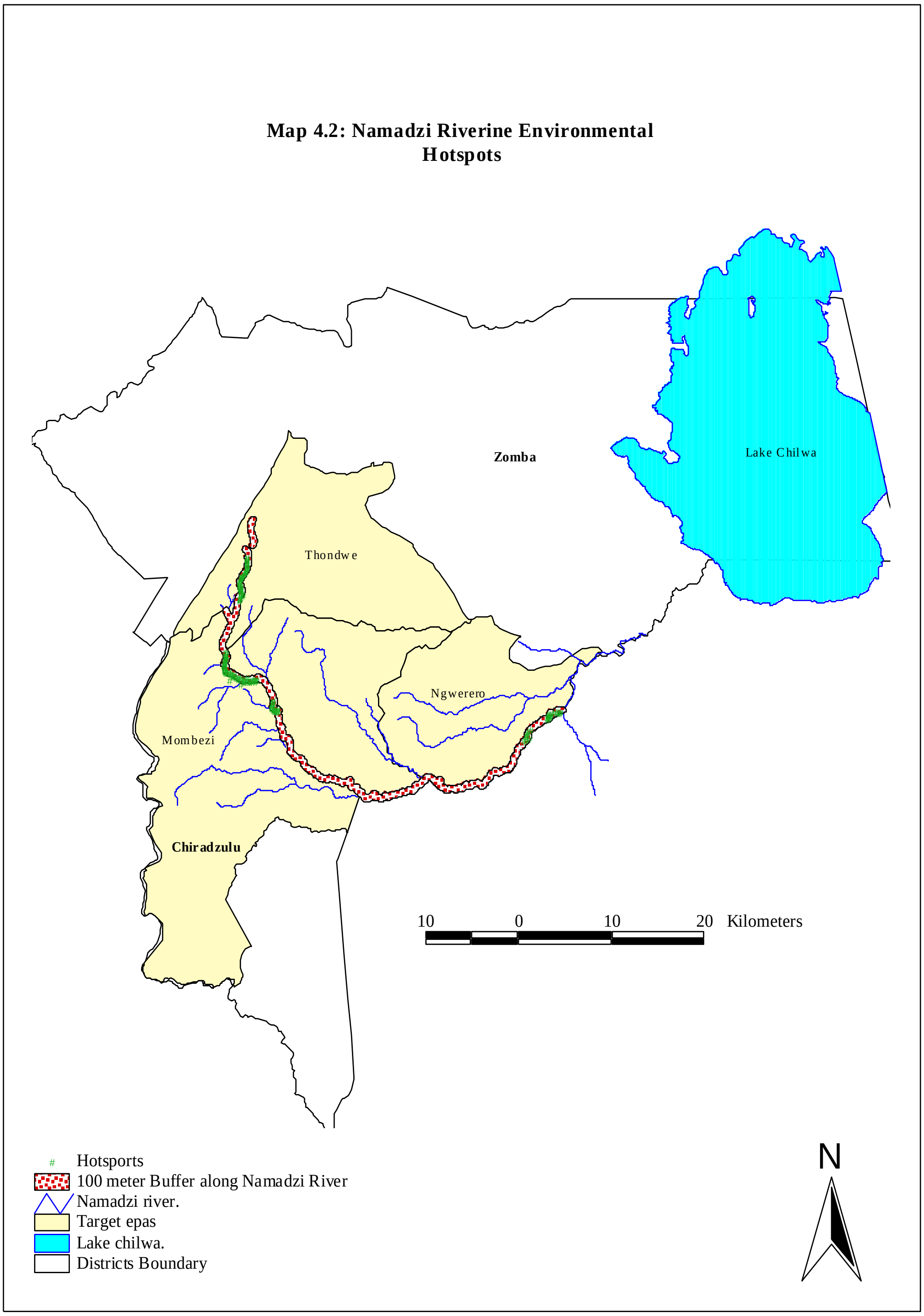


Fig 4.28: Socio-Economic Use of Plant Species in Namadzi Riverine Area

Further, it was observed that 96 out of 152 quadrants fell on cultivated fields for maize, tobacco and sugarcane indicated as staple food and sale/food (see Appendix 16). Having in mind that the quadrants were drawn with 20m radius from Namadzi River, which is the recommended buffer zone for a river by the forestry sector, it was concluded that the whole Namadzi riverine was an environmental hotspot. Using Arc view software, the way points were used to indicate environmental hotspot areas in Namadzi catchment. All quadrants were marked within 20 m radius from the river and found that cultivation was done within 10 m radius all along the river (see Map 4.2).



Map 4.2: Namadzi Riverine Environmental Hotspots

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In general, results show that environmental degradation has taken place in the Namadzi River Catchment. Specifically, indigenous forest has decreased and area planted to exotic *(Eucalyptus)* trees has increased over the years. Forest cover change has had an impact on Namadzi River stream flow, which has shown a decreasing trend over the years.

The socio economic study indicates that Namadzi catchment is dominated by a young generation as majority of the respondents were aged between 21-40 years with average age of 39.09 years. This was found to be consistent with national population composition that has more than 60% of the Malawian population comprising the young generation. This was considered old enough to be able to give in depth knowledge of environmental degradation in the area. The means of livelihood in Namadzi catchment is subsistence farming (87%) with more than 75% of their land on maize production. Household land ownership is largely customary with 97.4% of the respondents holding land under customary tenure. Respondents, 73% indicated their land holding sizes to be of less than 1 ha of land. Therefore decisions to invest in natural resources such as tree planting could be hampered by the small size holdings.

Majority of the respondents indicated that Non Governmental Organizations (NGOs) are not working in the area for forestry and water sectors, 71.6% and 54.2% respectively. Finally, results show that 44.9% of the sample would indulge in small-scale business as an alternative income generating activity. The small scale businesses included baking, beer brewing, selling secondhand clothes, fish mongering, selling metal scraps, farm produce trade, small grocery and other food sales such as pork selling.

Findings from aerial photo interpretation indicated a fall in area with forests from 1965 to 1974, but an increase in area planted in 1995. The majority of the respondents, 55.2% also indicated non-availability of indigenous forest area. The increase in forest cover is attributed to exotic trees planted in the area as a result of decline in indigenous forest cover.

It has been found out that stream flow, runoff, runoff coefficient has decreased over the years and there has been an increase in the area planted with trees. Rainfall indicated no significant trend over the years. That is the decreases can be explained in terms of decrease in forest cover over the years.

Rainfall runoff relationship has not changed over the years indicating that forest cover change (land use change) in a catchment have an effect on stream flow as indicated by results from Namadzi River catchment. It is evident that forest cover change has an impact on stream flow in Namadzi river catchment.

The study also reveals that the upper catchment and downstream Namadzi river are environmental hotspots with total habitat loss. In general, 26.7% of the plant species that were found along Namadzi riverine area were tree species of medicinal value. 73.3% of the plant species in the study area included shrubs, herbs, grass, climbers, and clippers.

The results confirm an observation by the Zomba District Agriculture Development Office that there is a deficit in water resources for irrigation for some stakeholders in the catchment mostly in dry season. This indicates the need for regulated allocation of the water resources. It should be noted that finding suitable allocation key for water can be complex and a large number of parameters have to be considered including issues of supply and demand. This is because the generation of water in a catchment area naturally fluctuates both within years and between years and the demand for water fluctuates, but normally much less than its generation.

5.2 Recommendation

It is recommended that further research should be considered in the study area on calculating water requirements for basic human needs; agricultural water demand (crop water requirements) and environmental water requirements. This would assist in water allocation decisions for the different stakeholders (domestic and productive sector) and also ensure environmental sustainability in the study area.

Environmental Conservation activities should be planned and implemented in the area. It is recommended that Zomba District Agriculture Development Office should link up with the District Forestry Office and the Non Governmental Organizations that are already in the area to properly plan and implement conservation activities in the area.

REFERENCES

AARC (Agriculture and Agri food Research Center) (1997). Best Management Practices- food cropping practices. Science Department. Canada.

Aruofor R. (2001). A Brief on the Forestry Outlook Study (FOSA). Country Report for Nigeria. Federal Department of Forestry PMB 135, New Secretariat, Area 11, Garki. Abuja.

Barbour, M. G, J.H Burk, F.S Gilliam, W. D Pitts and Mw Schwartz (1999). Terrestrial Plant Ecology. Benjamin Cummings: USA, 1999.

Bekele M, (2001). Forestry Outlook studies in Africa (FOSA). Malawi Country Report originated by the Forestry Department. http://www.fao.org/DocREP/004/AB585E/AB585E00.htm#TOC. Accessed: 23/01/07.

Brouwer I.D, (1998). When households ran out of fuel; Responses of rural women in Malawi to decreasing fuelwood availability. Energia 2; 1-6.

Brown L.R, (2001). Eco –economy. New York. W.W Norton.

Bosch, J. M and Hewlett, J. D. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. J. Hydrology; 55,3-23, 1982.

Boss M.G,Vos J. Feddes R. (1996). CRIWAR 2.0 A simulation model on crop irrigation Water Requirement. Wageningen. Interaction Institute for land re clarification and improvements (ILRI). Netherlands, 1996.

Bruijnzeel, L. A. (1990). Hydrology of moist tropical forests and effects of conversion: A state of knowledge review. UNESCO.

Calder, I. R. (1992). Hydrologic effects of land-use change. Maidment, D.R. (Ed. in Chief) .*Handbook of Hydrology* 13.1–13.

Calder, I. R. (1996). Water use by forests at the plot and catchment scale. *Commonwealth Forestry Review* 75(1): 19–30.

Calder, I.R. (1998). Water-resources and land-use issues. SWIM Paper 3. Colombo, SriLanka: International Water Management Institute.

Chavula, G.S. M. (2000). The Evaluation of the Present and Potential Water Resources Management for the Lake Chilwa basin. Environmental Affair Department.

Chimphamba J. B. Ngongondo C and Mleta P. (2005). Ground Water Chemistry of Basement aquifers in Africa. A case study of Malawi. Department of Geography and Earth Sciences. UNESCO, Paris (in publication)

Chipompha N.W.S and Ingram C. L. (1987). The Silvilculture Guide Book of Malawi. Forestry Research Institute of Malawi. Zomba.

Chipompha, N. W. S. (1985). Some Mushrooms of Malawi. Forestry Research Record No. 63.

Chipompha, N. W. S., Belo, W. S. and Mjojo, D.P.K, (1993). Deforestation in Malawi, its Nature, Causes and Corrective methods. Forestry Department, Lilongwe. Malawi.

Chow, V. T. (1964). Handbook of Applied Hydrology, Mc-Graw-Hill Book Company, U.S.A.

Cleveland, C. J. (2007). Environmental Change and socio economic factors. United Nations Environment Programme. In Encyclopedia of Earth. Eds. Washington D.C. Environmental Information Coalition, National Council for science and the Environment.
http://www.eoearth.org/article/Environmental_change_and_socioeconomic_factors_in_Africa. Accessed:12/12/06

Collet M. E. W. (2007), External costs Arising from effects of Forests upon Stream Flow in Britain. Department of Forestry, University of Oxford. Oxford journals. Oxford University Press.
http://forestry.oxfordjournals.org/cgi/content/abstract/43/2/181 Accessed: 31/05/07.

Colombo, R. (1997). Hydrological Analysis of two sub catchments of the Mareb River (Eritrea). Instituto Agronomico per I'Oltremare, Firenze, Italy.

Davidson J, (1992). The Earth Summit, The UN Conference on Environment and Development (UNCED), Development In Practice, Vol 2, Number 3-1992

De Groen M, (2002). Workshop on Rainfall/runoff modelling 'Rainru". MSc Lecture notes. University of Zimbabwe, Harare.

DREA (Department of Research and Environmental Affairs), (1994). National Environmental Action Plan. Environmental Affairs Department. Lilongwe, Malawi.

Drayton, R.S. (1981). A Preliminary Survey of the Water Resources of Malawi. Water Resources Branch, Department of Lands, Valuation and Water, Office of the President and Cabinet, WRB No. TP. 11.

DOF Nigeria (1996). Preliminary Report on the Assessment of Land Use and Vegetation Changes in Nigeria Between 1978 and 1993/95. Lagos, Federal Department of Forestry.

FAO (Food and Agricultural Organization). (2003). Unlocking the water potential of Agriculture, Rome; FAO

FAO (Food and Agricultural Organization). (2001). Global Forest Resources Assessment 2000. FAO Forestry Paper 140. Rome. Food and Agriculture Organisation.

Gilbert, R.O. (1987). Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Rienhold Company, Inc., New York.

GOM (Government of Malawi), (2006). Malawi Growth and Development Strategy; From Poverty to Prosperity 2006-2011. Lilongwe, Malawi

GOM (Government of Malawi), (2005). Draft final Report, Environment and Social Management Framework for proposed Irrigation Activities. Vol II. Irrigation Rural Livelihoods and Agriculture Development Project. Ministry of Agriculture. Lilongwe.

GOM (Government of Malawi), (2004a). National Environmental Policy. Environmental Affairs Department, Ministry of Mines Natural Resources and Environment. Lilongwe.

GOM (Government of Malawi), (2004b). Malawi Demographic and Health Survey, Government Printers, Zomba.

GOM (Government of Malawi), (2002a). Malawi poverty Reduction Strategy Paper. Ministry of Finance and Economic Planning. Lilongwe.

GOM (Government of Malawi), (2002b). National State of the Environment Report, 2002. Environmental Affairs Department. Ministry of Natural Resources and Environmental Affairs. Lilongwe.

GOM (Government of Malawi), (2001a). Malawi's National Forestry Programme. Priorities for improving Forestrey and Livelihoods. Forestry Department, Ministry of Natural Resources and Environmental Affairs.

GOM (Government of Malawi), (2001b). Zomba District State of the Environmental Report, Zomba District Assembly/ Environmental Affairs Department

GOM (Government of Malawi), (2000a). Lake Chilwa Wetland State of the Environment Report. Environmental Affairs Department. Zomba, Malawi.

GOM (Government of Malawi),(2000b). 1998 Malawi Population and Housing census report of final census results. National Statistics Office, Zomba.

GOM (Government of Malawi), (1999a). Malawi Agricultural and Natural Resources Research Master Plan. National Research Council of Malawi. Agricultural Science Committee. Lilongwe.

GOM (Government of Malawi),(1999b). National Water Resources Policy. Ministry of Water Development. Lilongwe.

GOM (Government of Malawi), (1998a). National State of Environment Report for Malawi, 1998. Environmental Affairs Department, Lilongwe, Malawi.

GOM (Government of Malawi), (1998b). Water Resources Management Policy and Strategy. Ministry of water Development. Lilongwe.

GOM (Government of Malawi), (1996a). Environmental Management Act, No. 23. Environmental Affairs Department. Ministry of natural Resources and Environmental Affairs. Lilongwe. Malawi.

GOM (Government of Malawi), (1996b). National Forestry Policy. Ministry of Natural Resources and Environmental Affairs. Lilongwe.

GOM (Government of Malawi), (1987). Atlas of Malawi. Macmillan Publisher Limited. London.

GOM (Government of Malawi)/UNDP, (1986). Water Resources Master Plan; Ground water Resources of Malawi. Department of Water, Ministry of Works and Supplies. United Nations of Technical Cooperation for Developments. MLW_79_105/mlw_84_003, Lilongwe.

GOM (Government of Malawi), (1964). Geological Survey of Malawi Report 1964, Zomba. Geological Survey of Malawi.

GOM (Government of Malawi), (1897). Geological Atlas of Malawi Zomba, Malawi.

Honeysett,T.L., Beadle, C.L and Tunbull,C., R. A., (1992). Evapotranspiration and Growth of Two Contrasting Species of Eucalptus Under Non-Limiting and Water Availability. Forestry Ecology and Management, 50:2003-216.

Jurskis,V., (2005). Eucalyptus decline in Australia, and a General Concept of Free Decline and Dieback. Forest Ecology and Management 215: 1-20.

Kainja S. (2000). Forestry Outlook studies in Africa (FOSA). Malawi Country Report originated by the Forestry Department. ftp://ftp.fao.org/docrep/fao/004/ab585e/ab585e00.pdf. Accessed: 28/05/07.

Kambewa P; Mataya B; Sichinga K; and Johnson T.(2007). Charcoal: the reality. A Study of charcoal consumption, trade, and production in Malawi, Zomba. Malawi.

Kamwaza E. (2006). (unpublished) Assessment of Groundwater and its Impact on Water Supply at Nambala Aquifer. Bachelor of Education (Geography); Department of Geography and Earth Sciences, Chancellor College, Zomba. November 2006.

Kanabahita C, (2001). Forestry Outlook Studies for Africa (FOSA), Country Report for Uganda. Forestry Department, Ministry of Water, Lands and Environment. ftp://ftp.fao.org/docrep/fao/003/X6647E/X6647E00.pdf .Accessed 29/05/07.

Kendall, M.G. (1975). Rank Correlation Measures. Charles Griffin, London.

Kidd, C. H.R. and Hill J. L (1980). Rainfall- Run off Relationships for 47 Malawi Catchments. Malawi Water Resources Department. Report TP7 Lilongwe, Malawi.

Kunshan S, Zhiyong L, Fenming L, Zheng R, (1997). Asia- Pacific Forestry Outlook Study. China's Country Report on Forestry. Working Paper Series. Ministry of Forestry. Beijing. Working Paper No: APFSOS/WP/14.

Leach G, and Leach M, (2004). Carbonizing Forest landscapes? Climate Change Mitigation to Rural Livelihoods. IDS Bulletin; 35, 3. http://www3.interscience.wiley.com/journal/121648338/abstract?CRETRY=1&SRETRY=0. Accessed : 6/03/2007

Mauambeta, D. D (1998). Utilization and Commercialization of Non Timber Forest Products as a Tool for Sustainable Management Indigenous Forests. A Paper Presented at a Coordination Unit for the Rehabilitation of the Environment Meeting held at Shire Highlands Hotel, 27th November 1998.

Mbano, D. (2006). Land Use Land Cover Changes: Impact of Pine Forest on Rainfall Runoff of Mulunguzi Catchment Area, Malawi. MSc Dissertation. University of Zimbabwe, Harare.

Minae,S, Sambo, E. Y, Munthali, S. S,and Ng'ong'ola, D.H, (1995). Selecting Priority Indigenous Fruit Tree Species for Central Malawi Using Farmers' Evaluation Criteria, Primex Printers, Nairobi.

Mulwafu, W. (2000). Conflicts over Water Use in Malawi, A socio Economic Study of The Likangala River in Zomba District. 1st WARFSA/WATERNET Symposium, Sustainable use of Water Resources; Maputo, November 2000.

Myers, N. (1980). Conversion of Tropical Moist Forest. A Report Prepared for the Committee of Research Priorities in Tropical Biology of the National Research Council. Washington DC. National Academy of Sciences.

National Statistical Office, (1998). 1998 population and Housing Census Preliminary Results. National Statistical Office, Zomba, Malawi. Available online (http://unstats.un.org/unsd/demographic/sources/census/2010_PHC/Malawi/Malawi_Report.pdf. Accessed : 26/11/2006

Ngongondo C.S. (2003). An Analysis of Long Term Rainfall Variability Trends and Catchment Water Availability in the Mulunguzi River Catchment Area. Unpublished MSc Dissertation. University of Zimbabwe, Harare

Ngulube , M, Mwabumba L and Makungwa S.D, (1999). Promotion and Evaluation of Self Help Tree Planting in the Lake Chilwa Wetland and Catchment Management Project Area. State of the Environment Report No.14. Lake Chilwa Wetland Project, DANIDA, Zomba, Malawi.

Orr B, Eiswerth B, Finan T, Malembo L, (1998). Malawi Public Lands Utilization Study. Final Report. University of Arizona and Forestry Research Institute of Malawi, USAID and Malawi Government.

Petheran C, Zhang L, Walker, G and Grayson R, (2000). Towards a framework for Predicting Impact of Land Use on Recharge. A review of Recharge Studies in Australia. CSIRO. Land and Water Technical Report /28/00.

Pike and Rimmington (1971). Malawi a geographical study. Oxford University Press. Second Edition.

Ratzlaff J. R. (1994). Mean Annual Precipitation, Runoff, and Runoff ratios for Kansas, 1971-1990.Department of Geoscience, Fort Hays State University, Hays, Kansas.

Regis, U. C. (2001). Runoff Curve Number (RCN) for San Mateo Creek Watershed. Biodiversity Research Consortium Data. Califonia.

Sambo, E. Y., Dudley, C. O. and Chikuni M. F. (1999). Evaluation of Impact of Degradation of Woodlands and Forests in the Lake Chilwa Catchment. State of Environment Report study No. 17. Lake Chilwa Wetland Project. DANIDA, Zomba. Malawi.

Sally, H. (2003). Advances in intergrated Water Resources management Research in Agriculture. In Mc Cornick, P. G., Kamara, A. B. and Tadasse, G. (eds). Integrated Water and Land Management Research and Capacity Building Priorities for Ethiopia. Proceedings of a MWR/EARO/IWMI/ILRI International Workshop. Addis Ababa, 2-4 December 2002. ILRI; Addis Ababa.

Saka, J. D and Msonthi, J. D (1994). Nutritional Value of Sixteen Edible Wild Fruits Growing in Malawi. Forest Ecology and Management 64.245-248

Savenije, H. and Laat, P. (1999). Principles of Hydrology. University of Zimbabwe MSc lecture notes. Harare.

Schwab, G.O., Fangmeier, D.D., Elliot, W.J. and Freveret, R.K. (1993). Soil and Water Conservation Engineering. J. Wiley and sons. New York. 507 pp

Sekgopo M, (2001). Forestry Outlook Study for Africa (FOSA). Country Report for Botswana. Ministry of Agriculture. Department of Crop Production and Forestry. Division of Forestry and Range Ecology. Forestry Sector.

Sen, Pik. (1968). Estimates of the Regression Coefficient based on Kendall,s Tau. Journal of the American Statistical Association. (63: 1379 – 1389).

Shah T, Molden D, Sakthivadivel R, Seckler D, (2000). The Global Situation of Groundwater, An overview of Opportunities and challenges, Colombo, Sri Lanka, International Water Management Institute.

Sherbinin A. (2002). A guide to Land use and Land Cover Change (LUCC). A Collaborative Effort of SEDAC and IGBP/IHDP LUCC Project.

Statistical Year Book, (2005). National Statistical Office, Zomba, Malawi. Available Online. http://www.nso.malawi.net/data_on_line/general/yearbook/yearbook_2005/Chapter_2.xl.Accessed 25/07.2007.

Thiel, H (1950). A rank – invariant method of linear and polynomial regression analysis, part 3. Proceedings Koninalijke Nederlandse Akademie Van Welnenschatpen A.53: 1397 – 1412.

UNEP GEO, 2002). United Nations Environment Programme. Global Environmental Outlook, 3, 2002. Chapter "Socio Economic Background" PP. 30-61.

US Department of Agriculture (1986). Urban Hydrology for Small Watersheds (TR-55) http://www.cset.sp.utoledo.edu/~nkissoff/pdf/CIVE-3520/Modified-tr55.pdf. Accessed: 10/10/2007

Van der Zaag, P. (2002). Water Using Activities, MSC WREM Lecture Notes, Department of Civil Engineering. University of Zimbabwe in collaboration with Infrastructure Hydraulic Environment (IHE)

Ward, R.C., Robinson, M. (1990). Principles of Hydrology, McGraw-Hill, Cambridge.

Wei, X., Ge Sun., Liu, S., Jiang, H., Zhou, G., and Dai, L., (2008). The Forest-Streamflow Relationship in China: A 40 year Retrospect. Journal of the American Water Resources Association (JAWRA).

Whitmore (1971). SouthAfrica's Water Budget. South African Journal of Science 67. 166-176

Williamson. J, (2005). Useful Plants of Malawi. Government Printers, Zomba. 3rd Edition.

World Bank, (1992). Economic Report on Environment Policy. Vols I and II, Lilongwe. Malawi.

World Bank, (1996). African Development Indicators 1994-95, World Bank, Washington.

ZDADO (Zomba District Agricultural Development Office), (2005). Zomba District Agriculture Development office Annual Report. Ministry of Agriculture and food security. Zomba, Malawi.

APPENDICES

Appendix 1: Conventions to which Malawi is Signatory

Name of Convention/treaty	International Objectives	Status
African Convention on the Conservation of Nature and Natural Resources	To encourage individual and joint action for the utilization and development of soil, water, flora and fauna for the present and future welfare of mankind, from an economic, nutritional, scientific, educational, cultural and aesthetic point of view.	Signed on 5th January 1982.
Convention on Biological Diversity.	To conserve biological diversity, promote the sustainable use of its components and to encourage equitable sharing of the benefits arising out of the utilisation of genetic resources.	Signed on 10th June 1992
Convention to Combat Desertification	To combat desertification and mitigate the effects of drought in countries experiencing serious drought and /or desertification particulary in Africa through effective action at all levels, supported by	Ratified in June 1996.

	international cooperation and partinership arrangements in the framework of an integrated approach which is consistent with agenda 21, with a view to contributing to the achievement of sustainable development in affected areas	
Ramsar Convention	To conserve and promote the wise use of wetlands by national action and international cooperation as a means to achieving sustainable development	Adopted in March 1997

Appendix 2: QUESTIONAIRE FOR SOCIO ECONOMIC STUDY ON FOREST AND WATER RESOURCES USE IN UPPER NAMADZI RIVER CATCHMENT.

HHID#-------------

Date of Interview:------/-----/-------

Section (T/A)-------------------------- Code----------------

Village---------------------------------- Code----------------

EPA------------------------------------- Code----------------

District---------------------------------- Code----------------

Name of Respondent

Name of Enumerator

A. QUESTIONNAIRE IDENTIFICATION OR ENUMERATOR REPORT.

Questionnaire Number:…………………………………………………

Full Name of Household Name…………………………………………

Sex: Male…………………………...   Female…………………………

Distance from: a. Closest main road……………………………..

District Head quarters………………………….

Household Land tenure Status:

Customary Tenure:……………………….…………………………..
Private (Freehold):………………………………………………………
Private (Leasehold):…………………………………………………….
Other (Specify) :…………………………………………………………..

who is responding to this questionnaire?

Male household head only.
Female household head only
Senior male and female members jointly
Eldest child of the household only
Other relation in the household.

Were there any other people present during the interview?

Yes…………………
No…………………

If yes, who?……………………………

Relatioship to the respondent……………………..

Notes or comments about the interview:………………………………..
……………………………………………………………………..……………………………………
……………………………………..
Enumerators Initials/Signature……………………………………

B. SOCIO AND ECONOMIC CHARACTERISTICS.

Thank you for taking time to participate in this survey. This survey is designed to assess the socio economic contributions on forest and water resources in your community.

What is your name?…………………………………………………..

Sex: Male……………………………………………..
Female:………………………………………….

Marital Status Codes

Married…………….	Married: 1
Single………………	Single: 2
Divorced…………..	Divorced: 3
Widowed……………	Widowed: 4

Age………………………………………………………………..

What is the highest level of education you have completed?…………

Codes.
Never attended
Number of Years.

Primary School	……………….
Secondary school	……………….
College/University	……………….
Other (Specify)	……………….

How would you describe your linkage to the community?……………..

Codes
Outside with no kinship relations
Clan member
Linked to the community through marriage.
Other (Specify)

Including yourself, how many members are there in your family who
Are living with you and dependent on your support (i.e. for food)?…………………….

1.0 **Household Composition, Education and Occupation**.

For all members of the household, list the relationship to head of household, sex, age, number of years of formal education, level of literacy achieved, primary and secondary activities(start with the head of the house).

	1	2	3	4	5	6	7
	Relationship with Head	Sex	Age	Years of Schooling completed	Level of Literacy	Primary activity	Secondary activities
	1- n.a 2- Spouse 3- Child 4- Other relative 5- Not related	1- n.a 2- Male 3- Female	Years	Last year completed	1-n.a 2-Not literate 3. read only 4. read and write 5. Other specify	See codes below	See codes
1	Head						
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

If there are more than 11 members, record the total number of household members here. ………………	Columns 6 and 7 Activity Codes 1- n.a 2- Work on estate or family farm. 3- Food sales/ local merchant. 4- Firewood and charcoal sales. 5- Off farm agricultural labour. 6- Wage earner. 7- Domestic work. 8- Paid household help. 9- Physically unable to work. 10- Full time student. 11- Parttime farming. 12- Domestic work and work on family farm. 13- Other (Specify)…………………………………………..

C. FACTORS INFLUENCING FORESTY AND WATER RESOURCES USE AND MANAGEMENT

Land Tenure Arrangements

9. How long has your household resided here, including previous generation?

………………………………..Years.

10. Does your farm or estate consist of more than one parcel?

Yes………………………..
No………………………..

Note: A parcel is a primary unit of land acquisition and normally non contiguous. But separate parcels may have been acquired to form a farm or household total holdings.

11. If yes, how many parcels in this village?……………………………

How many outside this village?…………………………………

Note: Holding or a farm is an aggregate of all parcels held by estate owner or all family members within house hold, that may have been acquired through inheritance, purchase, gifts, marriage, rental, pledge, borrowed, leased, settled on unclaimed customary land, or encroached on estate or public land.

12. Starting with first parcel that your household may have acquired, describe the size , number of years held, number of years to be hold, mode of acquisition.

Parcel where household lives	1	2	3	4		5	6
	Size	Number of years since you have acquired	Type of land tenure at or before acquisition	Mode of acquisition		Your tenancy and farming status at present	Number of years to be held
				a. How acquired	From whom acquired		
	Hactares	Years	See codes	See codes	See codes	See codes	See codes
1, Parcel #1							
2, Parcel #2							
3,Parcel # 3							
4,Parcel # 4							
Sub total							
Parcels in other EA/Villages							
5,Parcel # 1							
6, parcel # 2							
Total own farm or Estate holding							
Codes		For column 3		4a	4b	5	6

Parcel where household lives	1	2	3	4		5	6
		1-customary a. Gardens and dimbas. b. Dambos c. Claimed arable/farmland d. wood land e. village forest area. 2-stateland a.unclaimed b. claimed by households 3-Private (leasehold/estate land 4-Private (freehold)		How acquired 1-inherited. 2-gift. 3-Allocated by Traditional local chiefs 4-Allocated by government/formal authority. 5-Purchased 6-Rent /lease 7- Borrowing	From Whom acquired. 1-wifes'parents 2-Wifes'uncle 3-Wifes grandparents 4-Other relatives of wife. 5-V.headman or Chief 6-Husbands parents 7-Husbands Uncle 8-Husband grandparents 9-Other rel;atives of husband 10-Self 11-Government / formal authority 12-Other	1-Smallholder farmer on customary land 2-Smallholder/Estate on private(freehold land) 3-small holder /estate on Private (leasehold) 4-Other (Specify)	1-Unlimited 2-Limited and for……..Years 3-do not know/uncertain 4-Other specify

II. Soil and water (land) conservation Practices

13. In 2005/2006 season, approximately (on average) what hactarage and percentage of your total land/farm holdings were under the following land use.

	Hactarage	Percent
Garden and Dimbas	…………….	………..
Maize	…………….	………...
Tobacco	……………	…………
Perenial crops cultivation		
Coffee	…………….	………..
Tea	…………….	………..
Forests	…………….	…………
Fallow	…………….	…………

E.g: Less than 5%, 5%, 5-10%, 15%, 20%, 20 –25%, 25 – 35%, 40%, 45%, 50%, 55 – 65%, 75%, other (specify).

14. Soil and water conservation Practices on Households' on farm Land

		1	2	3	4
	Types of agricultural land use or conservation practices	Do you use any of the following land use or conservation practices on your farmland	If yes, on which of your plots	For how long have you been using these practices	If not, why are you not using it
		n.a yes No	See codes	Years	
1	Manure application				
2	Irrigation				
3	Crop Rotation/ Inter cropping				
4	Tree planting				
5	Dry planting				
6	Others (specify)				

Codes for Column 2

1- n.a
2- on all farm plots
3- Grazing land only

Codes for column 4:

1- Do not know how
2- Too much work/ labour intensive.

3- No sufficient land
4- Weather/ climate conditions.
5- Other (specify)

D. FOREST COVER ANALYSIS.

15. Are there any indigenous forest areas in this Village?

    Yes…………………..
    No……………………

16. If yes, approximately, what is the total area of indigenous forest in this village?………………..Hactares

17. Are there any wooded graveyards in this area?

    Yes……………………

    No……………………...

18. If yes, indicate the total area for wooded graveyards in the village?

    …………………….Hactares

19. Are there any communally managed forests, wood lots (exotic) beside the indigenous forest area that you have mentioned above?

    Yes…………………………………..
    No………………………………….

20. If yes, indicate the total area in this village (including forestland on your own holding)?……………………………… Hactares.

21. Are there any major forestland or wood lot on public lands in this village?
    Yes…………………………….. No………………………….

22. In your opinion, compared to forest cover of 20 years ago, the current total tree cover in this village is:

About the same.
Less by about 25%
Less by about 35%.
Less by about 55%
Less by about 75%
Less by about 85%
Other…………………………. Specify…………………………..

23. Where does the household obtain fuel wood and other tree products ?

Own holdings only………………..
Own holdings and communal wood land /village forest area within the village…………………..

Communal woodland/village forest area in this village only………………

Own holdings and communal woodland/village forest areas within and outside the village.………………………..

Own holdings and unprotected woodland on State/public land within the village………………………………………...

Protected state forests………………………..
Other…………(Specify);

Codes for area where they collect firewood and forest products.

1 – Yes
2 - No

24. Plant species Variability.

Which types of trees or other plant species are available in this village?
(**List as many as possible) will be coded later.**
………
………
………

25. Utilisation and value of tree species in Namadzi River catchment.

Name of specie (Tree types)

……………………………	…………………………………………
……………………………	………………………………………….
……………………………	………………………………………….
……………………………	………………………………………….

Codes for utilization:

1- ag : agroforestry
2- am : amernity, aesthetic, ethical values.
3- co: soil and water conservation
4- nm: non wood products (gums, resins, medicines, dyes,tannins et)
5- fo: food
6- fd: fodder.
7- po: posts, poles, roundwood.
8- pu: pulp and paper.
9- sh: shade and shelter.
10- ti: timber production
11- wo: fuelwood, charcoal.
12- XX: other

Value Codes

1- Species of current socio economic importance
2- Species with clear potential or future value.
3- Species of unknown value.

26. Are there other plant species that not available that the community was using in the past years?
Name them?
……
……

27. Provide approximate time the plant species have disappeared in the area?

28. What type of indigenous fruits are collected in this area, if any?

……
……

29. Does your household have access to other forest products like mushrooms?

E. DEMAND AND SUPPLY OF FORESTRY PRODUCTS.

30. Forestry and Use of Forest Products

	1	2	3	4	5	6
What other Forest Products are available in this area	Where do you get the forest products	On average how long do you or your household have to travel to get these forest products	On average how often do you collect these materials	Approx. how much of these forest material did your household use last year.	Approx. how much of these forest material did your household sell last year	Approx. how much of these forest materials did your household sell last year
	See codes	Hours	See codes	Kgs	Kgs	M/K
	Codes for column 1 1- n.a 2- Private land only 3- Communal land only 4- Public land only 5- Private and communal land **6-** Private, communal and public land		**Codes for column 3** 1- n.a 2- 1 to 2 days /week 3- more than two days/week 4- once a month 5- once in 3 months 6- Once a year **7-** Other specify**.**			

31. In your opinion, what alternative Income Generating Activities would you require in the area apart from sales from forest products?
……
……

32. Are there Non Governmental Organisations that are working in the forestry sector in this village? **List them.**

……
……
………

F. DEMAND AND SUPPLY OF WATER RESOURCES.

I. Water Resources availability, Demand and use.

33. What water resources are available in this area? (**List them)**

……
……
……

34. Demand and Use.

1	2	3	4	5	6
Where do you get the water for domestic use.	Approx. how much of domestic water did your household use last year. (Litres)	On average how long do you or your household have to travel to get water for domestic use (Km)	Where do you get the water for agriculture use in dry season.	On average how often do you collect water for irrigation	Approx. how much of Irrigation water did your household use the previous season. (Litres)
			Codes for column 5 1-n.a 2-1 to 2 days /week 3-more than two days/week 4-once a month 5-once in 3 months 6-Once a year 7-Other specify**.**		

35.According to your knowledge, for how long have you been experiencing water shortage in the area?
……
……………………………………………………………….

36. When did the river started drying up?

………
…………………………………………………………

37. Are there Non Governmental Organisations that are working in the water sector
in this village? **List them.**

Appendix 3: Sample Size Calculation for Socio Economic Study.

The study was conducted in Thondwe and Mbulumbuzi Extension Planning Areas Chiradzulu and Zomba District Agriculture Development Offices which makes up Namadzi River upper catchment (see Map 1). Sampling points were selected from all agricultural sections in the two EPAs that makes a boundary with Namadzi River.

1/5 of N were the Sampled villages and were drawn from all sections that make boundary to Namadzi River and response units were selected randomly from the list of farming families from the sample villages. 1/10 of N was taken as the sample size of the response units.

A structured questionnaire and observations were used to collect the socio and economic data. The following are names of Sections that makes boundary to Namadzi River in the Upper catchment and the total number of Villages that were involved.

Source of Namadzi River	
Thondwe EPA (Zomba)	
Name of section	No. of Villages
Chiunda	20
kamalo	12
Chilumpha	10
Mlumbe	15
Total	**57**
Mbulumbuzi EPA (Chiradzulu)	
Namadzi	12
Magomero	22
Total	**34**
Grand Total	**91 Villages**

Number of Villages to be sampled

Total Villages	=	No. from Mbulumbuzi EPA + No. from Thondwe EPA
	=	57 + 34
	=	**91 villages**

No. of sample Villages	=	1/5 x 91
	=	**18 villages**

Proportional allocation will be used to get the sample Villages.

% villages from Chiradzulu (Mbulumbuzi EPA)	=	34/91 x 100
	=	37.4%

% villages from Zomba (Thondwe EPA)	=	57/ 91 x 100
	=	62.6%

No. of Villages to be involved from each district

From Mbulumbuzi EPA (Chiradzulu)	=	37.4% of 18 villages
	=	37.4 /100 x 18
	=	7 villages

From Thondwe EPA (Zomba)	=	62.6 % of 18 villages
	=	62.6/100 x 18
	=	11 villages

Therefore:

Total population	=	PopCZ + PopZA
	=	1663 + 643
	=	**2306**

Sample Size	= 1/10 x Total Pop
	= 1/10 x 2306
	= **231**

Appendix 4: Makoka Monthly Rainfall Totals.

Makoka Monthly Rainfall totals

Units in mm

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual
1959	199.1	210.3	109.0	0.0	0.0	11.2	0.0	13.2	30.2	18.3	26.9	174.0	792.2
1960	86.9	202.2	156.2	8.4	50.8	75.4	16.8	0.0	10.2	5.3	76.7	290.6	979.4
1961	217.2	235.7	283.2	58.4	20.1	0.0	8.6	17.3	0.8	8.9	102.4	175.5	1128.0
1962	256.8	140.5	281.7	53.1	16.0	2.0	3.8	0.0	0.5	1.8	116.8	327.4	1200.4
1963	340.9	352.3	71.1	6.9	0.8	0.0	7.1	0.0	19.1	17.3	99.3	192.3	1106.9
1964	301.2	161.5	30.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	30.5	190.0	714.8
1965	204.7	82.6	146.1	34.0	8.6	0.8	0.0	1.3	30.0	18.5	185.4	197.6	909.6
1966	142.7	326.9	103.6	24.4	6.1	14.0	2.8	0.0	0.8	4.6	73.9	174.2	874.0
1967	217.9	115.3	312.4	32.3	16.8	8.1	39.6	10.4	7.9	4.3	84.6	117.3	966.9
1968	203.5	130.8	48.3	71.1	0.8	38.4	0.0	2.8	0.0	0.0	158.0	160.0	813.7
1969	159.5	205.2	104.1	39.1	0.0	1.0	0.8	1.5	5.6	26.4	7.4	281.4	832.0
1970	487.9	181.4	11.4	25.9	13.5	2.8	0.8	1.8	0.0	63.0	196.1	226.3	1210.9
1971	380.7	82.8	135.1	28.4	15.7	0.0	0.3	0.0	0.0	8.9	107.2	212.1	971.2
1972	250.7	192.3	115.8	111.3	77.7	0.5	3.6	1.5	0.0	13.7	73.9	165.1	1006.1
1973	262.6	227.8	160.5	82.8	2.5	10.2	0.5	0.0	0.0	18.5	104.4	169.2	1039.0
1974	260.4	180.1	397.3	38.9	27.9	35.8	14.5	1.5	0.0	3.3	48.8	201.4	1209.9
1975	120.9	172.2	79.2	95.5	2.0	0.8	1.5	2.5	0.0	8.9	73.9	204.7	762.1
1976	221.7	285.0	313.4	115.3	12.2	1.5	1.3	0.0	0.3	21.6	58.4	287.8	1318.5
1977	135.1	233.7	173.7	11.7	0.0	0.8	1.3	0.5	0.5	4.6	96.8	242.8	901.5
1978	279.1	222.0	365.3	91.4	13.5	3.0	2.0	0.0	14.7	40.9	69.1	157.2	1258.2
1979	77.2	243.6	227.8	15.2	0.0	2.3	10.2	1.3	0.0	29.0	226.8	180.1	1013.5
1980	48.5	193.5	243.1	57.4	0.0	5.8	1.1	4.0	11.4	51.3	18.5	309.4	944.0
1981	196.4	298.3	119.1	25.2	2.1	0.0	0.6	0.0	0.5	72.1	42.6	207.4	964.3
1982	143.7	257.9	51.7	66.9	12.5	1.3	9.4	2.7	0.0	38.2	49.1	193.1	826.5
1983	141.1	260.0	199.7	29.9	0.3	3.6	18.5	0.0	0.0	31.9	30.6	244.4	960.0
1984	106.2	321.4	242.3	17.7	16.8	20.6	1.2	0.0	23.2	1.1	66.5	382.5	1199.5

1985	230.4	362.5	230.4	42.8	1.7	2.6	0.3	8.7	2.1	16.6	132.0	251.1	1281.2
1986	489.9	268.5	196.5	36.8	0.0	1.7	2.9	0.0	1.0	107.7	53.8	196.9	1355.7
1987	231.0	231.0	56.1	17.8	0.8	0.8	0.0	0.0	0.0	20.8	48.0	181.4	787.7
1988	234.9	307.8	121.0	171.9	42.5	1.1	1.3	0.5	0.0	69.3	38.6	191.4	1180.3
1989	397.2	248.5	249.7	24.4	3.5	0.9	1.1	3.3	0.0	0.4	41.2	338.1	1308.3
1990	331.5	92.1	73.4	98.2	28.2	0.6	0.0	6.2	2.1	0.4	82.4	142.7	857.8
1991	244.5	341.2	164.5	43.4	1.3	1.8	3.2	0.0	1.1	11.4	109.4	181.9	1103.7
1992	143.0	19.8	84.7	12.0	0.0	12.8	1.9	0.2	0.0	0.0	25.6	176.4	476.4
1993	211.7	318.0	154.9	79.4	0.0	9.6	0.0	0.0	0.3	10.5	46.7	172.7	1003.8
1994	196.4	58.3	46.9	3.8	1.4	1.5	0.0	0.0	0.0	24.6	3.2	81.1	417.2
1995	323.0	113.1	12.9	29.2	5.7	2.4	0.2	4.5	0.0	0.0	19.5	241.9	752.4
1996	190.2	240.8	236.8	23.4	7.4	1.0	1.6	0.0	0.0	1.2	56.0	394.9	1153.3
1997	481.4	397.8	153.1	114.1	2.0	0.0	4.7	0.0	21.6	80.3	65.5	201.5	1522.0
1998	307.0	139.2	188.0	6.6	0.6	0.9	3.3	0.0	0.0	33.2	64.7	260.5	1004.0
1999	471.3	115.3	161.3	65.7	0.0	0.1	15.6	0.8	1.7	1.8	128.7	37.5	999.8
2000	170.3	238.8	120.2	99.9	2.2	1.8	3.0	11.7	0.3	30.3	164.9	184.8	1028.2
2001	130.6	381.8	294.7	3.8	0.8	0.0	0.1	7.0	1.6	6.2	53.9	209.3	1089.8
2002	248.4	171.5	106.3	38.0	0.3	10.2	0.0	11.2	0.6	15.4	61.2	98.8	761.9
2003	344.3	120.8	288.5	6.6	1.5	1.0	1.4	13.6	0.0	0.0	49.5	45.4	872.6

Appendix 5: Summary of Namadzi River Discharge (Monthly) Data

Summary of Namadzi River Discharge (Monthly) Data: Mean Monthly flow

Station Name : Namadzi at Namadzi (20206)

Station Number : 20206

Time Series Type : Flow (Cumecs)

Latitude : 15:33: 0s Longitude : 35:10:15 E Elevation : 0.0 Metres

Area : 26.7 sq Km

	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	**Total**	**Mean**
1952	0	0	0.938	0.866	0.704	0.41	0.352	0	0	0	0	0	3.27	0.272
1953	0.081	0.0136	0.097	0.158	0.508	0.153	0.113	0.183	0.147	0.123	0.106	0.093	1.7756	0.148
1954	0.032	0.258	0.476	0.955	0.995	0.441	0.279	0.088	0.072	0.062	0.049	0.038	3.745	0.312
1955	0.063	0.225	0.305	0.727	0.678	1.04	0.387	0.176	0.131	0.106	0.086	0.076	4	0.333
1956	0.145	0.434	0.802	0.616	0.271	0.287	0.176	0.239	0.171	0.127	0.104	0.064	3.436	0.286
1957	0.086	0.161	0.433	0.964	0.392	0.271	0.17	0.153	0.145	0.141	0.129	0.096	3.141	0.262
1958	0.066	0.068	0.489	0.73	0.466	0.272	0.202	0.152	0.138	0.104	0.081	0.083	2.851	0.238
1959	0.072	0.075	0.07	0.071	0.436	0.066	0.05	0.152	0.09	0.073	0.056	0.054	1.265	0.105
1960	0.042	0.14	0.934	0.722	1.06	0.536	0.257	0.062	0.042	0.028	0.04	0.036	3.899	0.325
1961	0.06	0.204	0.448	0.293	1.35	0.394	0.174	0.15	0.096	0.081	0.067	0.083	3.4	0.283
1962	0.062	0.254	0.718	1.56	1.04	0.37	0.247	0.123	0.088	0.075	0.066	0.05	4.653	0.388
1963	0.068	0.161	1.35	0.625	0.413	0.165	0.127	0.197	0.17	0.123	0.099	0.081	3.579	0.298
1964	0.042	0.083	0.241	0.223	0.632	0.191	0.104	0.096	0.079	0.068	0.056	0.042	1.857	0.155
1965	0.063	0.057	0.067	1	0.427	0.117	0.066	0.068	0.057	0.055	0.047	0.055	2.079	0.173
1966	0.022	0.061	0.258	0.228	0.882	0.366	0.18	0.052	0.048	0.41	0.033	0.026	2.566	0.214
1967	0.081	0.042	0.068	0.143	0.221	0.173	0.069	0.112	0.103	0.072	0.051	0.048	1.183	0.099
1968	0.044	0.602	0.702	0.661	0.382	0.298	0.154	0.057	0.054	0.045	0.04	0.04	3.079	0.257
1969	0.024	0.257	0.576	0.92	0.288	0.193	0.153	0.105	0.073	0.052	0.038	0.033	2.712	0.226
1970	0.079	0.262	0.765	0.498	0.364	0.19	0.14	0.119	0.094	0.078	0.057	0.042	2.688	0.224
1971	0.055	0.134	0.141	0.465	0.509	0.267	0.174	0.123	0.107	0.102	0.086	0.076	2.239	0.187
1972	0.051	0.083	0.198	0.388	0.149	0.398	0.127	0.114	0.104	0.068	0.038	0.04	1.758	0.146

1973	0.054	0.196	0.379	1.02	1.82	0.835	0.41	0.102	0.073	0.069	0.059	0.041	5.058	0.422
1974	0.132	0.508	0.35	0.382	0.345	0.286	0.154	0.259	0.231	0.168	0.126	0.116	3.057	0.255
1975	0.14	0.654	0.549	1.07	0.742	0.508	0.267	0.114	0.108	0.108	0.091	0.094	4.445	0.370
1976	0.18	0.587	0.869	0.929	0.86	0.323	0.204	0.194	0.153	0.126	0.113	0.089	4.627	0.386
1977	0	0	0	0	0	0	0	0.175	0.164	0.164	0.151	0.127	0.781	0.065
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0.144	0.198	0.128	0.317	0.631	0.21	0.103	0	0	0	0	0	1.731	0.144
1980	0.127	0.389	0.36	1.091	0.812	0.347	0.245	0.093	0.08	0.087	0.101	0.115	3.847	0.320
1981	0.139	0.182	0.437	0.708	0.259	0.368	0.232	0.185	0.197	0.18	0.138	0.208	3.233	0.269
1982	0.184	0.391	0.194	0.482	0.455	0.225	0.158	0.163	0.148	0.115	0.111	0.153	2.779	0.232
1983	0.052	0	0	0	0	0	1.094	0.133	0.125	0.125	0.11	0.117	1.756	0.146
1984	0.037	0	0	0	0	0.352	0.33	0.162	0.057	0.042	0.043	0.017	1.04	0.087
1985	0.227	0.269	0	0	0	0.449	0.247	0.257	0.163	0.131	0.127	0.11	1.98	0.165
1986	0.155	0.204	0.344	0.413	0.274	0.197	0.139	0.18	0.159	0.159	0.142	0.147	2.513	0.209
1987	0.067	0.121	0	0	0.291	0.206	0.168	0.106	0.038	0	0.102	0.085	1.184	0.099
1988	0.85	0.133	0.156	0	0	0.367	0.248	0	0.099	0.09	0.062	0.107	2.112	0.176
1989	0.088	0	0	0.339	0.17	0.151	0	0.15	0	0.113	0.118	0.08	1.209	0.100
1990	0.112	0.146	0.279	0.291	0	0.209	0.128	0	0.092	0.076	0.062	0	1.395	0.116
1991	0.099	0.192	0	0.099	0.075	0.062	0.052	0	0	0.094	0.078	0	0.751	0.062
1992	0.078	0.195	0.384	0	0.333	0.158	0.118	0.04	0.047	0.053	0.042	0.027	1.475	0.123
1993	0.069	0.082	0.22	0.202	0.074	0.057	0.039	0.101	0.072	0.075	0.062	0.061	1.114	0.093
1994	0.049	0.043	0.211	0.214	0.11	0.114	0.064	0.03	0.03	0.048	0.049	0.049	1.011	0.084
1995	0.064	0.064	0.145	0.321	0	0.284	0	0.056	0.056	0.056	0.056	0.062	1.164	0.097
1996	0.088	0.209	0.293	0.348	0.402	0.351	0.304	0.103	0.103	0.104	0.098	0.071	2.474	0.206
1997	0.138	0.132	0.229	0.565	0.57	0.57	0.354	0.27	0.189	0.189	0.189	0.161	3.556	0.296
1998	0.186	0.212	0	0.587	0.587	0.439	0.321	0.252	0.219	0.462	0.187	0.186	3.638	0.303
1999	0.183	0.178	0	0	0	0	0	0.249	0.221	0.221	0	0	1.052	0.0887

Appendix 6a: Calculation of Area Planted to Forest

The table below gives the numbers of trees per hactare corresponding to a range of Espacements given in meters. The stems per hectare are rounded to the nearest 10. Note that all spacings are reversible i.e. 1.75 x 3.5 = 3.5 x 1.75.

Stems per Hactare

Spacing - m	**3.5**	**3.25**	**3.0**	**2.75**	**2.5**	**2.25**	**2.0**	**1.75**	**1.5**
3.5	820	880	950	1040	1140	1270	1430	1630	1900
3.25		950	1030	1120	1230	1370	1540	1760	2050
3.0			1110	1290	1330	1480	1670	1900	2220
2.75				1320	1450	1620	1820	2080	2420
2.5					1600	1780	2000	2290	2670
2.25						1980	2220	2540	2960
2.0							2500	2860	3330
1.75								3270	3810
1.5									4440

Source: Chipompha and Ingram (1987).

Stocking equivalents to espacements not given above can be found from the formula

Stocking (stems/ha) = 10000/(axb)

Where a and b are the spacings in metres.

e.g for 2.4 x 2.1 m espacement.

Stocking = 10000/2.4x 2.1

= 10000/5.04

= 1984.127

= 1980 s.p ha to the nearest 10.

To get the area from the seedlings planted.

= No. of seedlings planted/ Recommended seedlings/ha.

= 10200/1320 (using the table above 2.75x2.75)

Appendix 6b: Trends in Area Planted With Trees in Namadzi Catchment.

Trends in planted area (ha)

	Per year	Cumulated
1968	6	6
1969	5	11
1970	0	11
1971	0	11
1972	0	11
1973	0	11
1974	10	21
1975	12	33
1976	0	33
1977	0	33
1978	5	38
1979	0	38
1980	0	38
1981	0	38
1982	0	38
1983	0	38

1984	0	38
1985	0	38
1986	10	48
1987	10	58
1988	5	63
1989	5	68
1990	0	68
1991	0	68
1992	46	114
1993	0	114
1994	0	114
1995	0	114
1996	0	114
1997	4	118
1998	300	418
1999	910	1328
2000	443	1771
2001	905	2676
2002	2824	5500
2003	1445	6945
2004	66	7011
2005	233	7244
2006	6	7250

Appendix 7: Makoka Mean Monthly Maximum Temperature (Degrees Celcius)

MAKOKA MEAN MONTHLY MAXIMUM TEMPERATURE (°C)													
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**MEAN**
1969	26.2	26.7	26.3	25.8	23.6	23.2	22.1	23.6	26.3	30.6	30.0	26.3	**25.9**
1970	26.6	26.5	26.8	25.4	25.0	22.4	23.2	24.6	28.3	28.2	27.9	25.6	**25.9**
1971	25.0	25.9	26.6	27.1	23.4	22.0	22.7	25.0	26.6	28.7	28.2	27.0	**25.7**
1972	26.2	25.7	26.0	25.7	24.2	21.3	21.2	24.0	27.4	29.0	28.0	28.1	**25.6**
1973	26.2	26.7	27.8	23.8	24.7	21.4	21.7	23.3	28.3	29.7	28.4	26.2	**25.7**
1974	25.7	25.5	25.1	24.0	22.0	0.0	20.7	24.4	25.9	28.8	29.3	26.3	**23.1**
1975	26.6	26.5	25.7	25.6	25.1	21.9	22.0	22.7	27.0	27.4	29.0	27.3	**25.6**
1976	26.2	26.0	25.6	24.5	21.9	21.5	21.9	23.8	27.8	27.9	27.9	25.6	**25.1**
1977	26.6	27.0	25.8	24.2	25.9	23.3	21.9	23.8	27.8	30.7	29.1	27.4	**26.1**
1978	26.5	26.5	25.7	24.6	24.3	21.2	20.6	25.8	27.9	27.9	27.9	25.6	**25.4**
1979	26.9	27.3	26.2	26.0	24.6	21.8	21.2	24.6	27.7	29.9	27.9	25.9	**25.8**
1980	27.1	27.5	26.2	25.9	24.8	21.1	20.7	23.6	27.2	28.7	30.8	26.3	**25.8**
1981	27.4	26.6	25.9	24.8	22.8	21.9	21.6	24.6	26.7	27.0	30.5	27.8	**25.6**
1982	26.8	26.4	27.6	26.3	23.4	23.6	22.0	24.4	25.8	27.2	28.9	28.4	**25.9**
1983	28.7	27.0	27.9	27.4	26.9	24.9	22.8	26.7	28.7	28.1	31.4	27.1	**27.3**
1984	27.4	26.2	26.4	25.3	24.2	22.0	22.3	23.7	28.6	29.8	27.1	26.5	**25.8**
1985	26.7	26.3	26.5	25.1	24.1	22.3	22.8	23.8	27.4	28.5	26.4	25.7	**25.5**
1986	26.0	26.6	26.5	25.8	25.0	22.0	22.2	25.1	26.7	28.0	27.2	26.8	**25.7**
1987	26.5	27.9	28.1	27.4	26.3	22.5	22.7	25.3	28.4	28.1	30.4	29.3	**26.9**
1988	27.5	26.4	27.2	26.9	23.5	23.2	23.2	24.4	27.7	28.5	27.2	26.6	**26.0**
1989	26.7	25.9	26.1	24.9	24.4	22.9	23.4	24.8	26.6	28.8	29.4	27.2	**25.9**
1990	26.5	27.4	28.3	26.8	24.1	24.4	22.9	23.8	23.8	29.5	28.5	28.9	**26.2**
1991	26.9	27.2	26.2	24.8	24.8	22.7	22.3	24.7	27.8	29.2	28.2	26.3	**25.9**
1992	27.8	29.2	28.3	27.8	25.6	23.4	22.6	23.4	28.1	30.0	29.8	28.0	**27.0**
1993	26.2	27.1	26.1	26.8	25.8	22.6	22.1	23.4	27.2	29.4	28.8	28.7	**26.2**
1994	27.1	26.6	22.0	26.8	25.4	22.6	22.0	23.9	27.8	28.3	30.6	28.7	**26.0**
1995	26.1	27.2	28.0	26.7	24.1	23.0	23.3	25.9	28.4	31.5	30.8	26.9	**26.8**
1996	26.9	26.6	25.5	24.6	23.9	22.5	22.6	25.4	28.7	29.6	32.0	27.5	**26.3**

1997	26.7	25.5	27.0	25.3	24.3	24.8	22.2	25.3	27.2	27.6	30.0	26.7	**26.1**
1998	27.6	27.8	28.4	26.8	26.7	24.0	23.2	24.7	27.8	30.1	29.8	28.5	**27.1**
1999	26.5	26.3	26.7	25.0	24.7	23.3	22.4	23.2	26.5	27.7	28.8	30.5	**26.0**
2000	27.2	26.5	27.1	25.8	24.0	23.4	21.9	22.0	27.9	28.9	27.2	26.9	**25.7**
2001	26.3	26.8	26.8	26.3	24.7	23.1	22.6	25.4	28.0	29.5	31.0	28.4	**26.6**
2002	26.2	26.9	27.9	26.1	24.0	22.3	24.5	24.3	26.8	29.4	28.7	27.6	**26.2**
2003	27.9	27.8	27.2	25.7	25.4	22.8	21.6	25.0	29.1	30.2	30.2	28.7	**26.8**
2004	27.9	26.6	27.3	25.5	23.0	22.0	22.1	25.4	27.5	29.1	28.5	26.6	**26.0**
2005	27.3	28.4	28.4	27.8	25.8	23.3	22.8	26.2	27.4	29.9	31.3	28.4	**27.3**
2006	26.3	28.2	26.6	26.3	24.8	23.6	23.2	26.4	27.1	30.5	28.9	28.5	**26.7**
MEAN	**26.8**	**26.8**	**26.7**	**25.8**	**24.5**	**22.1**	**22.3**	**24.5**	**27.4**	**29.0**	**29.1**	**27.3**	**26.0**

Appendix 8: Evaporation for Makoka 1981- 1998

Makoka (mean Evaporation.)

	Jan	Feb	March	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1981	50	34	87	82	51	56	32	25	27	79	93	91
1982	71	79	0	0	0	0	0	53	0	65	0	0
1983	0	63	62	60	45	44	56	37	67	74	78	45
1984	56	59	48	42	35	30	30	46	70	78	50	45
1985	46	42	33	39	39	35	41	43	62	67	46	32
1986	38	53	34	31	39	33	36	54	61	52	48	44
1987	39	48	39	46	43	35	36	47	67	61	81	55
1988	41	35	38	37	29	29	32	41	67	56	43	68
1989	39	35	39	35	32	49	31	49	58	70	66	43
1990	40	42	55	39	37	31	46	48	57	81	77	57
1991	41	45	36	42	35	32	33	47	67	72	53	41
1992	44	55	48	45	42	32	44	47	76	86	75	55
1993	41	35	35	37	34	27	33	39	58	66	53	56
1994	42	44	43	41	42	33	35	41	62	56	79	56
1995	35	40	45	45	33	31	37	47	62	92	67	41
1996	41	43	36	31	22	29	32	43	62	71	83	47
1997	41	42	41	35	34	35	29	43	48	53	61	35
1998	34	48	42	40	41	33	34	41	57	67	64	46
Mean	41.056	46.778	42.278	40.39	35.17	33	34.28	43.9	57.11	69.22	62	47.6
Std Dev	13.339	11.579	16.697	15.51	10.94	11.1	10.88	6.54	17.62	11.27	21	17.9

Appendix 9: Calculation of Composite CN Number for Namadzi Catchment

Major Land Uses

Land use	**Area (ha)**	**CN(From table)**	**Ratio of land use area to Basin area**	**Weighted CN**
Agriculture Forest area	1047.39	78	0.064823313	5.056218391
Arable area	8596.991	74	0.53207061	39.37322512
Bare rock	1702.56	98	0.105372	10.32645602
Built up area	122.138	79	0.007559161	0.597173729
Eucalyptus	515.174	77	0.031884289	2.455090241
Miombo in Hilly areas	2404.436	77	0.148811337	11.45847298
Pine	19.06	77	0.00117963	0.090831486
Maize-tobacco	1749.864	88	0.10829966	9.530370111
Totals	**16157.613**		**CN value =**	**78.88783807**

Appendix 10: Data Manipulation for Sen's Method With One Data Measurement per Time Series.

Time ***Data***	**1** ***X1***	**2** ***X1***	**3** ***X1***	 **...**	**5** ***X1***	**T** ***XT***
		X2-X1 2-1	X3-X1 3-1 X3-X2 3-2	...	XT-1-X1 T-2 XT-1-X2 T-3 : XT-1-XT-2 1	XT-X1 T-1 XT-X2 T-2 XT-X3 T-3 : XT-XT-2 2 XT-XT-1 1

Appendix 11: Data Manipulation for Sen's Method With Multiple Data Measurements per Time Series.

Time ***Data***	**1** ***X1,1***	**1** ***X1,1***	**2** ***X2,1***	**2** ***X2,2***	**2** ***X2,3***	**3** ***X3,1***	 **...**	**T** ***XT,J-1***
		NC	X2,1- X1,1 2-1	X2,2- X1,1 2-1	X2,3- X1,1 2-1	X3,1- X1,1 3-1	...	XT,J- X1,1 T-1

			$\frac{X_{2,1}-X_{1,2}}{2-1}$	$\frac{X_{2,2}-X_{1,2}}{2-1}$ NC	$\frac{X_{2,3}-X_{1,2}}{2-1}$ NC NC	$\frac{X_{3,1}-X_{1,1}}{3-1}$ $\frac{X_{3,1}-X_{2,1}}{3-2}$ $\frac{X_{3,1}-X_{2,2}}{3-2}$ $\frac{X_{3,1}-X_{2,3}}{3-2}$		$\frac{X_{T,J}-X_{1,2}}{T-1}$: : : : $\frac{X_{T,J}-X_{T-1,J-1}}{1}$ NC : NC

Appendix 12: Household Perception of Plant Species Variability.

Species Variability			
Local/English name	**Scientific name***	**Count**	**Percentage (%)**
Masuku Exotic		47	3.1
Masuku Indigenous	Upacca kirkiana	34	2.3
Maula	Parinali curatelliforia	10	.7
Mtondo	Cordyla Africana lour	1	.1
Luzi/Tsamba	Brachystegia longifolia	10	.7
Bulugamu/Bluegum	Eucaryptus spp	128	8.6
Malaina/Gmelina	Gmelina arborea	55	3.7
Peyala/Avocado pear	Persea americana	96	6.4
Mango	Mangifera indica	117	7.8
Jeke food		10	.7
Guafa/Guava	Psidium guajava	30	2.0
Papaya/Pawpaw	Carica papaya	9	.6
Nthochi/Banana	Mussa paradisiacal	1	.1
Mbawa/ Red Mahogany	Khaya anthotheca	72	4.8
Chimanga cha chizungu	Punica granatum	2	.1
Kachere	Ficus exasperate	66	4.4
Mphinyankhwangwa/phingo	Dalbergia melanoxylon	3	.2
Naphini	Terminalia serieceae	36	2.4
Glue		2	.1
Tsamba	Brachystegia spicuformis	25	1.7
Citrus trees	Citrus aurantium	11	.7
Nyowe	Sygium cordatum	7	.5
Pichesi/Peaches	P. persica	36	2.4

Species Variability			
Local/English name	**Scientific name***	**Count**	**Percentage (%)**
Mbwabwa	Cordia abyssinica	12	.8
Mulindimira	Erythrina abyssinica	7	.5
Nkuyu	Ficus capensis	36	2.4
Mpoza	Annona senegalensis	29	1.9
Accassia		41	2.7
Gililisidiya	Glilicidia sepium	5	.3
Mchenga	Diospyros mespiliformis	46	3.1
Mphandula/Chitimbe	Bauhania petersiana	44	2.9
India		44	2.9
Sendeleya/Cindrea	Toona ciliata	63	4.2
Mombo	Brachystegia longifolia	27	1.8
Ngongomwa/Msambamfumu/pod mahogany	Afzelia quanzensis	5	.3
Nkundi	Parkia filicodea	3	.2
Nthethe		16	1.1
Muwanga	Pericorpsis angolensis	40	2.7
Mpasa/Msopa	Bridelia micrantha	43	2.2
Zikanga		1	.1
Zamaluwa	Dombeya rotundifolia	1	.1
Nsangu	Faldherbia albida	8	.5
Nkungudza	Widdringtonia cupressoides	9	.6
Thombozi/ Rubber tree	Diplorhchus condylocarpon	12	.8
Nthema/Nthudza	Fracourtia indica	34	2.3
Mbulukututu/ Mbirima/Mzilu	Vanguena infausta	18	1.2
Mbalitsa		5	.3

Species Variability			
Local/English name	**Scientific name***	**Count**	**Percentage (%)**
Matemeteme	Strochynus spinosa	3	.2
Mulunguzi/Mauritious thorn	Caesalpinia decapetala	1	.1
Jelejele	Sesbania sesban	3	.2
Apulesi/Apples	Malus domestica	1	.1
Mlombwa	Pteroccarpus angolensis	29	1.9
Ntwana		4	.3
Mswaswa/ Mpakasa	Lonnchocarpus capassa	4	.3
Mpolowoni	Steganotoenia araliacea	5	.3
Chinama		5	.3
Chiumbu	Lannea discolor	4	.3
Ntonongoli	Vitex mombassae	21	1.4
Mjomboti		2	.1
Chinyenje		1	.1
Mkalati	Burkea African hook	1	.1
Jagalasi	Pseudolachnostyylis maprouneifolia	2	.1
Msolo		2	.1
Minga/ Kankhande	Z. mucronata	4	.3
Mpapa	A. karroo . hayne	2	.3
Ombwe	Tephrozia vogelli	4	.3
Mablesi	Morus nigra	2	.1
Matowi	Anzanza garckeana	11	.7
Gwemba		1	.1
Mgwalangwa	Hyphaene spp.	1	.1
Ntenthanyerere	Cassia senguena	1	.1

Species Variability			
Local/English name	**Scientific name***	**Count**	**Percentage (%)**
Pine	Pinus spp.	5	.3
Tsatsache	Cussonia kirkii	1	.1
Chandimbo	S.spicata	1	.1
Mpinjipinji	Ximenia americana	1	.1
Mvunguti	Kigelia africana	2	.1
Mlilira		2	.1
Futsa	Vernonia glabra	1	.1
Chiwale	Caphia farinifera	1	.1
Ntonya		1	.1
Kamphoni		1	.1
Malambe/ Baobab	Adansonia digitala	2	.1
Mtondowoko/ Mfula	Sclerocarya caffra	2	.1
Nakasonde/Hedge	Lantana camara	1	.1
Bwazi	Ectadiopsis oblongifolia	3	.2

***** Source : Williamson , 1955

Appendix 13: Availability of Indigenous Fruits

Type of indigenous fruits collected in the area at present			
Local/English name	**Scientific name**	**Count**	**Percentage (%)**
Masuku Indigenous	Upacca kirkiana	59	10.5
Maula	Parinari curatelbiforia	15	2.7
Guava	Psidium guajava	9	1.6
Kachere	Ficus exasperate	2	.4
Nyowe	Sygium cordatum	11	2.0
Nkuyu	Ficus capensis	6	1.1
Mpoza	Annona senegalensis	72	12.8
Nkundi	Parkia filicodea	3	.5
Mpasa/Msopa	Bridelia micrantha	1	1.3
Nthema/Nthudza	Fracourtia indica	168	29.8
Mbulukututu/Mbirima/Mzilu	Vanguena infausta	88	15.7
Matemeteme	Strochynus cocculoides	18	3.2
Mulunguzi	Caesalpinia decapetala	1	.2
Chitimbe	Bauhania petersiana	4	.7
Ntonongoli	Vitex mombassae	49	8.7
Matowi	Anzanza garekeana	31	5.5
Gwemba	Tamarindus indica	1	.2
Chandimbo	S.spicata	1	.2
Mpinjipinji	Ximenia americana	5	.9
Malambe/Baobab	Adansonia digitala	1	.2
Mpindimbi	Pachystela brevipes	2	.4
Mpembu		1	.2
Phimbinyolo		1	.2
Sonjera		1	.2
Kanjinga		1	.2

Type of indigenous fruits collected in the area at present			
Local/English name	**Scientific name**	**Count**	**Percentage (%)**
Makaikai		1	.2
Mapirakukutu	Rhusnatalensis bernh	1	.2
Masawi	Ziziphus mauritiana	1	.2
Ngulungutiche		1	.2
Njululu		1	.2
Fisi		1	.2

***** Source : Williamson , 1955

Appendix 14: Monthly Mean Water Quantities Extracted by Namadzi Water Supply.

	2003-2004		2004-2005		2005-2006	
MONTH	**Production**	**Consumption**	**Production**	**Consumption**	**Production**	**Consumption**
JULY	4700	3889	4622	3571	5471	4506
AUGUST	4881	3400	5111	4287	6032	5002
SEPTEMBER	4594	3779	5193	4803	4786	3668
OCTOBER	4712	4059	4882	3993	5739	4758
NOVEMBER	4794	4129	5435	4766	5040	4041
DECEMBER	5144	4110	5151	4358	3830	2755
JANUARY	4803	3841	5126	4519	4364	3279
3FEBRUARY	4810	3767	4699	3538	4064	3154
MARCH	4555	3693	5056	4181	4225	3108
APRIL	4350	3516	5002	3958	4685	3600
MAY	4933	4006	5141	4151	4689	3668
JUNE	5275	4056	5469	4519	5578	3625

Source: Southern Region Water Board, Namadzi Water Supply,2006 adopted from Kamwaza, 2006

Its quantity for 3 year period is (58000 + 61000 + 59000)=178000m³

Therefore average water quantity extracted for a month is:

(17800m³/36 months)= 4944m³ approximately.

Water discharge in the river at 99%

=0.03 cumecs, =0.03m³/sec

If 1 sec.=0.03m3

Therefore1 month=(0.03x 60x60x24x30)m³

=77760 m³

Water quantity produced by aquifer per month=(77760+4944+18150)m³

=100854m³

Therefore production of water by Nambala aquifer per sec. Is :

100854/(60x60x24x30)

0.0389m³sec

=38.9litrers/sec.

Appendix 15: Results from Observation on Namadzi Riverine Area through Transect Walk.

Namadzi Riverine Species Variability			
Genus and Species	**Local Name**	**Count**	**Percentage**
Ficus capensis	Nkuyu	1	.1%
Lantana camara	Nakasonde	22	2.2%
Oxygonum sinatum	Kalasaweni	29	2.9%
Solanum panduiforme/delagoeme	Nthula	15	1.5%
Eurphobia heterophyla	Mpira	23	2.3%
Nicandra physaloides	Makhalabwinja	6	.6%
Eucalyptus spp	Bluegum spp	8	.8%
Sygium cordatum	Nyowe	8	.8%
Ficus sycomorous	Ntonongoli	15	1.5%
Vitex mombassae	Msipya	4	.4%
Cissus trothae	Mwanamphepo	3	.3%
Hyperrhenia filipedula	Tsekera	17	1.7%
Heteropogon shirense	Nsanu	7	.7%
Crotalaria nataletia	Thusya	2	.2%
Euphobia hirta	Chala cha nkhwali	6	.6%
Vangueria infausta	Mvilu	4	.4%

Namadzi Riverine Species Variability			
Genus and Species	**Local Name**	**Count**	**Percentage**
Annona senegalensis	Mpoza	21	2.1%
Bridelia micrantha	Mpasa	19	1.9%
Mucuna stans	Chitedze	29	2.9%
Sporobolus pyramidalis	Mtsindi	2	.2%
Panicum maximum	Msonthe	12	1.2%
Commelina african	Khovani	1	.1%
Crotalaria globifera	Thusya	1	.1%
Indigofera antunesiana/abyssinica	Matusibila	5	.5%
Cissampelos mucronata	Chilambe	27	2.7%
Ageratum conyzoides	Mtawetawe	57	5.7%
Vernonia glabra	Nakamoto	7	.7%
Eragrotis ciliaris	Kambiri	3	.3%
Parinari curatellifolia	Maula	1	.1%
Flacourtia indica	Nthema/Nthudza	7	.7%
Brachystegia spicuforms/bochmii	Tsamba	7	.7%
Brachystegia longifolia	Mombo	1	.1%
Vitex doniana	Msipya	6	.6%
Steganotoenia araliacea	Mporowoni	10	1.0%
Dichrostachys cinerea	Chipangula	1	.1%
Hyperrhenia shirense	Tsekera	5	.5%
Diospyros whyteana	Nakasisiira	2	.2%
Combretum fragrans	Mulama	8	.8%
Markhamia obstusifolia	Nsewa/Mwambewe	9	.9%

Namadzi Riverine Species Variability			
Genus and Species	**Local Name**	**Count**	**Percentage**
Lonchocarpus capassa	Mswaswa	2	.2%
Tithonia daversifolia	Introduced	6	.6%
Crotalania recta	Chiwere	7	.7%
Cyphostemma buchanai	Namwalicheche	1	.1%
Diospyros squarrosa	Mdima	1	.1%
Asparagus spp.	Katsitsinzukwa	2	.2%
Panicum miliaceam	Nkwanje	2	.2%
Bidens pilosa	Chisoso	59	5.9%
Carex spp	Chetsa	1	.1%
Tagetes minuta	Nankaku	9	.9%
Sida acuta	Masake	15	1.5%
Celosia trgyna	Chikanya	1	.1%
Galinsonga parviflora	Mamunaaligone	21	2.1%
Mormodica foetida	Chinkhaka	5	.5%
Zea mais	Chimanga	67	6.8%
pennisetum purpureum	Senjere	64	6.5%
Trichodesmazeylanicum	Chilungumwamba	12	1.2%
Harungana madagascariensis	Mbuluni	1	.1%
Tephrosia aequilata	Ntutu	1	.1%
Aeschnomene cristata	Nakayumbe	1	.1%
Triumfetta rhomboidea	Chikatambuzi	11	1.1%
Psidium guajava	Gwafa	4	.4%
Parkia filicodea	Mkundi	5	.5%
Diosyros kirkii	Mdima	7	.7%

Namadzi Riverine Species Variability			
Genus and Species	**Local Name**	**Count**	**Percentage**
Raphia farinifera	Chiwale	6	.6%
Strochynus spinosa	Matemeteme	2	.2%
Ricinus communis	Msatsi	25	2.5%
Setaria verticiliata	Chimata	5	.5%
Hibiscus cannabinus	Sonkhwe	1	.1%
Mangifera indica	Mango	8	.8%
Guatamala spp.	Introduced	1	.1%
Imperata cylinduca	Nansongole	1	.1%
Ziziphus abyssinica	Kankhande	1	.1%
Toona ciliata	Sendeleya	8	.8%
Cassia senguena	Ntantanyerere	5	.5%
Vellozia splenders	Chewo	2	.2%
passiflora rumicifolia	Chipohola	2	.2%
Anzanza garckeana	Matowo	9	.9%
Corchorus Olitorius	Denje	8	.8%
Nicotiana tabacum	Fodya	12	1.2%
Boehavia coccinea	Nambenawo	1	.1%
Dombeya rotundifolia	Naduwa	2	.2%
Leonitis spp	Nlongandundu	3	.3%
Khaya anthotheca	Mbawa	12	1.2%
Pericorpsis angolenses	Muwanga	3	.3%
Cyperous alterniforius	Mululu	6	.6%
Bauhouria peteriana	Chitimbe	9	.9%
Dichrostachys cimera	Chipangala	1	.1%
Acacia macrothysa	Namfungwe	3	.3%

Namadzi Riverine Species Variability			
Genus and Species	**Local Name**	**Count**	**Percentage**
Eragrostis hispida	Kabatika	1	.1%
Acalypha ornate	Chigaga	1	.1%
Gladiohus spp	Nangulungunde	1	.1%
albilzia vescolor	Ntangatanga	12	1.2%
Erythrina abyssinica	Mulindima	3	.3%
Phragmates mauritianus	Bango	47	4.7%
Xanthium pungens	Introduced	12	1.2%
S.officinarum l.	Mzimbe/Sugarcane	18	1.8%
Amaranthus spinosus	Bonongwe	5	.5%
Mussa paradisiaca	Nthochi	10	1.0%
Terminalia sericeae	Naphini	1	.1%
Hibiscus acetosela	Lumanda	1	.1%
Euphorbia prostrata	Namwalinyala	1	.1%
Ficus matalensis /exasperate	Kachere	3	.3%
Ocimum canum	Chanzi	4	.4%
Sesbania sesban	Mjerejere	6	.6%
Albizia harveyi	Njenjete	1	.1%
Xeroderris stuhlmanni	Mlonde	1	.1%
Kigelia africana	Mvunguti	4	.4%
Monotes africana	Nkhalakate	2	.2%
Sclerocarya Caffra	Mtondowoka/Mfula	3	.3%
Gnandropis gynandra	Luni	1	.1%
Sterculia appendiculata	Njale	2	.2%

SOURCE: TRANSECT WALK, APRIL 2007

Appendix 16: Family, Habit and Socio-Economic Use of Plant Species in Namadzi Riverine Area

Family	Count	Percentage (%)
Moraceae	19	2.1%
verbenaceae	32	3.5%
Polygonaceae	29	3.2%
Solanaceae	21	2.3%
Eurphobiaceae	74	8.1%
Myritaceae	21	2.3%
Vitaceae	4	.4%
Poaceae	186	20.4%
Papilionoideae	78	8.5%
Rubiaceae	4	.4%
Annonaceae	22	2.4%
Commelinaceae	1	.1%
Menispermaceae	7	.8%
Compositae	174	19.0%
Chrysobalanaceae	1	.1%
Flacourticeae	7	.8%
Caesalpinioideae	20	2.2%
Umbelliferae	10	1.1%
Mimosoideae	23	2.5%
Ebenaceae	10	1.1%
Combretaceae	9	1.0%

Family	Count	Percentage (%)
Bignoniaceae	13	1.4%
Liliaceae	2	.2%
Cyperaceae	7	.8%
Malvaceae	26	2.8%
Amaranthaceae	6	.7%
cucurbitaceae	5	.5%
Boraginaceae	12	1.3%
Guttiferae	1	.1%
Tiliaceae	19	2.1%
Palmae	6	.7%
Loganiaceae	2	.2%
Anacardiaceae	11	1.2%
Rhammaceae	1	.1%
Meliaceae	20	2.2%
Velloziaceae	2	.2%
Passifloraceae	2	.2%
Nyctaginaceae	1	.1%
Sterculiaceae	2	.2%
Labiatae	7	.8%
Censalapinodea	1	.1%
Iradaceae	1	.1%
Musaceae	10	1.1%
Dipterocarpaceae	2	.2%
capparidaceae	1	.1%
Sterculiaceae	2	.2%
Habit		

Family	Count	Percentage (%)
Tree	265	26.7%
Shrub	66	6.7%
Herb	332	33.5%
Grass	185	18.6%
Climber	29	2.9%
Clipper	37	3.7%
Crop	78	7.9%
Socio Economic Use		
Construction	37	4.0%
Fuelwood	29	3.1%
Medicine	324	35.1%
Fruits	107	11.6%
Thatching	89	9.6%
hedge	22	2.4%
Strings	38	4.1%
Vegetables	90	9.8%
Broom	14	1.5%
fodder	12	1.3%
staple food	66	7.2%
furniture	6	.7%
Mat/Basket brush	53	5.7%
Sale/ food	30	3.3%
Agroforestry	6	.7%

Source: Transect Walk, April 2007

ASSESSMENT OF ENVIRONMENTAL DEGRADATION IN A RIVER CATCHMENT WITH A FOCUS ON FORESTRY AND WATER RESOURCES: THE CASE OF NAMADZI RIVER UPPER CATCHMENT

MSc. (ENVIRONMENTAL SCIENCE) THESIS

JACINTA CHINSEU-CHIPENDO
Bsc Agric. (Rural Development)-(Mlw)

UNIVERSITY OF MALAWI
CHANCELLOR COLLEGE

MARCH 2010