INTEGRATED WATERSHED MANAGEMENT (IWM): A PARADIGM FOR SUSTAINABLE WATER SUPPLY IN IVETI NORTH HILLS, MACHAKOS DISTRICT.

LAZARUS KIVAI NTIWA

A Research Project Report Submitted in Partial Fulfillment for the Requirement for the Degree of Master of Environmental Planning and Management of Kenyatta University

SCHOOL OF ENVIRONMENTAL STUDIES AND HUMAN SCIENCES
KENYATTA UNIVERSITY
P.O. BOX 43844 – 00100
NAIROBI, KENYA

Nthiwa, Lazarus
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Declaration

This research is my original work and has not been submitted for examination for a degree in any other university.

Signature ___________________________ Date __________________

Lazarus Kivai Nthiwa

University Reg: No N50/13743/05
Department of Environmental Planning, Management and Community Development.
Kenyatta University

Approval

This research project has been submitted for examination with our approval as the University Supervisors.

Signature ___________________________ Date __________________

Dr. Simon Onywere
Department of Environmental Planning, Management and Community Development.
Kenyatta University

Signature ___________________________ Date __________________

Mr. Wilson Nyaoro
Department of Environmental Planning, Management and Community Development.
Kenyatta University
Dedication

This work is dedicated to my parents and siblings.
Acknowledgement

I extend my gratitude to Kenyatta University for offering me the opportunity to pursue my graduate studies. Particular thanks go to the Department of Environmental Planning and Management for all the support. The Department provided a conducive environment to carry out this research work.

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Abstract

Watersheds, world over are of importance. They are valued for their critical functions. They provide terrestrial and aquatic habitats. They have a health function, through the provision of safe drinking water. Water from the watersheds performs a carrier function within the ecosystem by transporting dissolved and suspended materials. Some solid and liquid wastes that are products of human activities can be purified in a watershed. The importance of watershed has however, not been fully understood, appreciated, nor has adequate attention been placed on using water wisely and efficiently. As a result watersheds have been degraded. The root cause of these changes is continued increase in human population. With rising human population, more and more land is required for shelter, food production, forage requirements and fuel wood. People are forced to use marginal land, often in upper catchment areas. A stage has been reached where water issues have become the limiting factor for sustainable development and often result in conflicts amongst the various competing sectors. In order to achieve the anticipated economic growth, decent and civilized life in water scarce regions, innovative approaches should be adopted. Integrated management of catchments is the best solution to these problems. In an attempt to realize adequate water supplies, and to ensure protection of the watersheds in Iveti North Hills, the study explored the following objectives: it analysed the policy and institutional framework on water management, examined the causes of watershed degradation, evaluated measures that have been put in place to address watershed degradation, and developed an Integrated Watershed Management Plan for improved water supply. A survey was undertaken focusing on the core and pertinent variables ranging from land use, population growth, to the methods of irrigation. Stratified random, simple random and purposive sampling techniques were used to draw the sample. Probability sampling procedures was used to achieve a representative sample of ninety households for the study. Analysis, conclusion and recommendations were made based on the findings of the study. The survey established that the watersheds in Iveti North Hills have seriously been degrade, a phenomenon that has reduced stream water supplies in the area. The survey recommends that an integrated approach should be adopted in order to manage and conserve the watersheds.
Abbreviations

AWWA: Australian Water and Waste Water Association
FAO: Food Agricultural Organization
GEF: Global Environment Facility
GoK: Government of Kenya
ICRAF: International Centre for Research on Agro-forestry
IWM: Integrated Watershed Management
NEMA: National Environment Management Authority
RBA: River Basin Approach
SADC: South Africa Development Commission
SPSS: Scientific Package for Social Science
TARDA: Tana River Development Authority
UN: United Nations
WRMA: Water Resource Management Authority
MOA: Ministry of Agriculture
MOW: Ministry of Water
MLS: Ministry of Lands and settlement.
N.D: Not dated
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CHAPTER 1

1.0 Introduction

1.1 Background Information

Watersheds denote different things to different people and their definitions vary considerably. A watershed is defined as an area from which rainwater flows into a watercourse GoK, (2002). Similarly, it is any land area drained by a river, stream, or fixed body of water with its tributaries having a common source of surface run-off (GoK, 2005). Chidumayo, (2000) defines a watershed as an area that comprises of several interconnected elements: vegetation, slopes, weathered rocks and river channels. Other synonymous terms to watershed as shown by Chidumayo, (2000) are catchment, river basin and drainage basin.

Watersheds are treasured for their critical functions. These functions span from terrestrial and aquatic habitats, SADC, et al. (2002) to health functions through the provision of safe drinking water. Water performs a carrier function within a watershed; transporting dissolved and suspended materials. Besides, some solid and liquid wastes that are products of human activities can be removed in a watershed. In addition, watersheds play a critical role in the water cycle. They allow water to flow downstream, hold and allow it to percolate to the ground, thus enhancing groundwater recharge.

The importance of watersheds as sources of surface water that should be protected and conserved has not been fully appreciated, SADC, et al. (2002), nor has adequate attention been placed on using water wisely and efficiently. Consequently, watersheds have been degraded. Both anthropogenic and natural factors are responsible for watershed degradation. Globally, SADC, et al. (2002) show that apparent change in land use patterns affect soil and water regimes of any watershed. Unplanned activities are the major challenges in land and water degradation. Continued increase in human population has further exacerbated watershed degradation. The ever rising human population has placed more demand for land, shelter, food production, forage requirements and fuel wood. Because of these, people have been forced to settle and cultivate in marginal land such as wetlands, (SADC, et al. 2002), and in upper catchments areas with steep slopes.
Pereira, *et al.* (2002) observes that water scarcity can limit a country’s ability to maintain public health, and to develop its industry and agriculture. While water has many uses, and people depend on it for various things, its high demand inevitably leads to scarcity. Scarcity of water lead to lower crop yields, less industrial production, and less daily water consumption at the household level, all of which directly leads to both economic and social impact. Water scarcity may impacts on an economy by diminishing the production in both the agricultural and the industrial sectors. When this happens, jobs are lost, and this is by itself has a huge impact on society. A lost job can drive an entire family into poverty (Pereira, *et al.* 2002). Poverty, in return, leads family members to eat poor food quality and poor drinking water quality, thus affecting their health.

Biswas, *et al* (1987), cites anthropogenic activities and increase in livestock numbers to increased pressure on watersheds as it is exemplified by Sudan. In the 20-year period of 1957-1977, human population in Sudan increased more than six-fold, cattle numbers increased by twenty-one-fold, Camels sixteen-fold, sheep-twelve-fold, and goats eight-fold. Such a large increase in population has added pressure on water and land resources that are inelastic and consequently resulted in water deficits that seriously degraded the land.

The scenario is not different in Kenya where like other countries of the world, water resource development contributes enormously to economic productivity and socio-economic well being of human population. With the increasing growth in population and the subsequent socio-economic pursuits (including urbanization, industrial production, tourism and agricultural activities) demand for water has increased rapidly. A stage has been reached where freshwater issues have become the limiting factor for sustainable development and often leading to conflicts amongst the various competing sectors. This is compounded further by the fact that implementation, coordination and management of water responsibilities are fragmented on sectoral basis, GoK, (1999).
Indiscriminate clearance of vegetated land, (UNESCO, 2002) is the reason why water availability remains a challenge in arid and drought prone areas. Statistics show that per capita water availability in Kenya stands at 650 m$^3$ per year. Other estimates show that Kenya's water supply will shrink by 50% by 2025. Future projections show that by 2020, per capita water availability will have dropped to 359 m$^3$ per person per year as a result of population growth and the pollution of the existing water resources. All the observed and anticipated decrease in water supplies is partly linked to destruction of watersheds.

This study explores integrated watershed management paradigm and seek to bring to the fore watershed degradation issues in North Iveti Hills. It recognizes that both conventional measures to address soil and water degradation, and national policies have not been quite successful to address watershed degradation.

1.2 Statement of the Problem

Iveti Hills are located in Machakos District, which is regarded as an Arid and Semi Arid area. Iveti Hills however rise to a higher altitude than the surrounding lowlands, is cooler, and receive higher rainfall than the surrounding low land areas. The Hills are therefore an important water source that gives rise to several springs and streams. Kithima, Kalua and Ngelani streams are sourced at Mutondoni and Kisekini springs, emerging from the Iveti Hills.

The perennial rivers that rise from Iveti Hills have attracted residents who have tapped the areas potential for agricultural production. Most of the residents own less than an acre of land that is rather uneconomical for food and horticultural production. The high population density in the Hills has added pressure on both land and the water resources. Soil erosion has occurred in the cultivated and bare land where conventional conservation measures have not been adequately undertaken. Lack of vegetation has reduced the ability of water to percolate to the ground, reducing ground water recharge and hence a subsequent reduction in spring and stream yield.
Excess abstraction of water for irrigation has exposed residents downstream to acute water shortage, especially during dry season that manifests in the long distances covered in search of water. The need for food has increased three-fold, because of the increased population. More land has been cleared for agricultural production, with streams being tapped for irrigation by up-stream residents especially during the dry seasons. This has reduced both the quality and quantity of water in the streams. Exotic trees, that are bulky water consumers, have replaced indigenous vegetation on the riverbanks and hill slopes. It is against this background that the research sought to find effective measures that should be put in place to address watershed degradation in the Iveti North catchment in order to ensure continued water supply.

1.3 Research Questions

The research will seek to answer the following questions

i. How do policy and institutional framework influence watershed management and development in North Iveti Hills?

ii. Why does watershed degradation persist in North Iveti Hills despite the knowledge of its causes and effects?

iii. Which measures can be put in place to address watershed degradation and water scarcity in North Iveti Hills?

1.4 Objectives of the Study

The objective of the study was to determine the reasons for persistent watershed degradation in North Iveti Hills. The specific objectives that formed the focus of the study were:

i. To analyze the influence of policy and institutional framework on watershed management.

ii. To examine the causes of and the effects of watershed degradation in North Iveti Hills.

iii. To evaluate measures that the community is using to manage watersheds in North Iveti Hills.
To develop an Integrated Watershed Management Plan for improved water supply in North Iveti Hills.

1.5 Research Premises

The research assumed that watershed degradation is persisting in North Iveti Hills and will continue to have serious ramifications, despite the policy and institutional measures put in place.

1.6 Justification of the Study

Integrated Watershed Management (IWM) provides a framework for participation of local communities and other stakeholders in the management of watersheds. This helps fill the gap that is left by conventional approaches to water and soil management that are characterized by lack of involvement of local communities in identification and prioritization of watershed problems.

Watershed degradation has been a problem in different parts of the country due to lack of a holistic approach to the utilization and management of land and water resources. Previously, rarely have there been any coordination efforts by various government agencies. There has been also lack of clear cut mandate of the various ministries. IWM, therefore, creates an opportunity for coordinating efforts of different government agencies and stakeholders.

Presently, there has been a common belief that water scarcity in North Iveti and other semi arid areas in Machakos District is a natural cause. This study served to determine the link between anthropogenic causes and water scarcity in North Iveti Hills.

1.7 Significance of the Study

In addition to providing an insight on sustainable watershed management, the study played a critical role in determining the actual causes and effects of watershed
degradation in Iveti North Hills. The study offers possible solutions to address the causes identified.

The findings of the study, though specific to Iveti North Hills, can be replicated in other areas to solve similar problems in addition to providing a framework and a guide for the implementation of policies and other legislation on water and watershed management. IWM acknowledges that many problems cannot be solved with regulations. It recognizes that partnerships are essential and greater attention needs to be paid to the interconnectedness of the environment, social needs and the economy.

1.8 Scope of the Study

The study was limited to North Iveti Hills, cutting across Kathiani and Machakos Central Divisions, and covered three locations - Mitaboni, Ngelani and Mutituni, with a total population of 44,543. The study covered all the hilly areas of the three locations that include Ngelani, Kisekini, Mutondoni and Thinu. These formed the source of Kithima, Kalua and Ngelani streams. Other areas covered was the middle zone and the lower areas of Mitaboni, Kwale, and Muvaa.

In analyzing the policy, legislations and institutional framework on watershed management and development, the Kenya Water Act of 2002, Sessional Paper No 1 of 1999, on National Policy on Water Resources Management and Development, Agriculture Act of 1965, the draft land policy, Forest Act of 2005 and the Physical Planning Act of 1997 were reviewed. Institutional structures in catchment management were examined. The Tana, Athi River Development Authority and the Athi Catchment Management Authorities were evaluated to determine their adequacy and effectiveness in the watershed management. Their responsibilities and mandates were scrutinized. Any deficiency, inadequacy, conflict and overlap of responsibilities and implementation weaknesses was evaluated.

To determine the cause of watershed degradation, various Variables were considered. They ranged from trends in population growth, economic activities, water use survey, land use survey, changes in land use, methods of irrigation, irrigation rates, use of
riverbanks, source of fuel wood, type and level of employment, and land size. Watershed degradation variables were also examined. They included but not limited to conflicts over water, distance covered in search of water, incidences of water scarcity, levels of stream flow. All conventional measures of watershed management ranging from digging terraces, planting napier grass, and building gabions were examined.

1.9 Limitations of the Study
The survey had some limitations. There was inadequate financial supply for data collection and purchase of the stationery. Data collection was also faced with difficulties since in most cases the research team had to move through hilly terrain. Data collection coincided with the December short rains and therefore it was rather inconveniencing to walk in the muddy and slippery steep slopes. It was also difficult to gather data from the water resources management office since the WRMA was recently established and therefore did not have most of the required data which could show the trends in watershed management. It was also difficult to gather spatial maps showing land uses in the study area from the lands office; the staff was rather suspicious.

1.10 Definition of Terms and Concepts

Water scarcity:
A situation where water availability in a country is below 1000m$^3$ per.

Watershed:
Any land area drained by a river, stream, or fixed body of water and having a common source of surface run-off.

Watershed degradation:
A long-term reduction in the quantity and quality of water resources in the watershed.

Integrated watershed management (IWM):
It is a holistic approach in the management watersheds for their economic benefits.
CHAPTER 2

2.0 Literature Review

2.1 Global Water Crisis

Water crisis has many dimensions and varies considerably across regions. Water supplies are scarce in some regions and relatively abundant in others. Over the past century, the world population tripled, but the aggregate use of water rose six-fold. Just 35 years ago, people were using about one-forth of readily available fresh water. Today they are using roughly half. Most fresh water is used for agriculture. Shiklomanov, (1999) estimates that about 41% of the world population lives in water stressed areas Assuming the UN’s low range population projection of 2.27 billion people, some 48% of the population will live in water scarce areas by 2025. This is likely going to complicate water availability for the people. Africa is particularly a vulnerable continent when it comes to water resources compared to the rest of the world. A report by the Global Water System Project (GWSP(n.d) indicates that over 400 million people are expected to be living in at least 17 water scarce African countries by the year 2010. The report adds that lack of water will severely constrain food production, ecosystem protection and socioeconomic development.

2.2 Population and Water Stress

An area is considered to suffer from water stress when its annual supplies are below 1,700 cubic meters per person per year. UNESCO (2002) defines water scarcity as a situation where water availability in a country is below $1000\text{m}^3$ per person per year. When water availability is below $500\text{m}^3$ per person per year there is an acute shortage.

In recent years, a range of problems have affected water resources. Over extraction of water from rivers on hill slopes, destruction of forests, illegal cultivation, and illegal grazing are mentioned as some of the problems (Saenyi (not. dated). Horticultural farming in the watersheds has grown quickly in recent years, as traditional farming activities such as livestock rearing and coffee farming has declined. Much of this production takes place along riverbeds and requires huge quantities of water for irrigation. This significantly affects stream water flow.
2.3 Policies and Legislations in Watershed Management in Kenya

Catchment management is dealt with under several acts and legislations in Kenya. For instance, the Agricultural Act, (Cap 318), has several provisions on water resources especially in relation to catchment conservation. Other legislation that have a bearing on the management of watersheds are the Forests Act (Cap 385), the Lakes and Rivers Act (Cap 409), and the River Basin Development Authorities Act (Cap 443).

2.3.1 Water Act, 2002

The Water Act, 2002 is an act of Parliament that provides for the management, conservation, use and control of water resources in Kenya and for the acquisition and regulation of rights to water use. It defines a watershed as an area from which rainwater flows into a watercourse. Section 14 of the Act provides that a Water Resource Management Authority (WRMA) be formed to manage the catchment areas. WRMA has the mandate to formulate a Catchment Area Management Strategy for each catchment, which shall be consistent with the National Water Resources Management Strategy. Section 10 of the Authority requires WRMA to establish regional offices in or near each catchment area as illustrated in figure 2.1. Section 16 mandates the Authority to appoint a committee of up to fifteen persons in respect of each catchment area to advise its officers at the appropriate regional office on matters concerning water resources management, including the grant and revocation of permits. The regulatory functions over water resources management currently performed by the District Offices of the Ministry of water and irrigation, under the new legal framework, to be transferred to the Catchment area offices of the Authority.

The Water Act 2002 imposes a permit requirement on any person wishing to acquire a right to use water from a water body. Section 27 makes it an offence to construct or use works to abstract water without a permit. The act however, makes three exceptions on the permit requirement. These relate to minor uses of water resources for domestic purposes; uses of ground water in areas not considered to face groundwater stress and therefore not
declared to be groundwater conservation areas; and to uses of water drawn from artificial dams or channels (GoK, 2005).

The water act has good intentions to control the use of water by requiring that every person intending to use or abstract water from a water source acquire a permit. However, it does not define the extend to which water should be abstracted from streams. It has also been difficult to implement and monitor the permit requirement and as a consequence people continue to abstract water without the permits. Farmers continue to extract water from small streams despite the fact that this still impact on the residents downstream.

![Figure 2.1: Institutional Structures for Watershed Management in Kenya.](image)

Source: WRMA, 2005.

### 3.3.2 The Forest Bill, 2005

The Forest Bill, 2005 defines a watershed as any land area drained by a river, stream, or fixed body of water and whose tributaries have a common source of surface run-off. The Forest Bill, 2005 provides for the management of forests (GoK, 2005). It requires indigenous forests and woodlands to be managed on a sustainable basis for purposes of:

- Conservation of water, soil and biodiversity;
- Riverines and shoreline protection;
- Cultural use and heritage;
• Recreation and tourism;
• Sustainable production of wood and non-wood products;
• Carbon sequestration and other environmental services:
• Education and research purposes.
• Habitat for wildlife in terrestrial forests and fisheries in mangrove forests

The Forest Bill only recommends that forests should be protected for these values. It has not put in place structure and measures to manage catchments. It deals much with the management of large forests. The management of small watershed and individual plots that act as the very source of the big rivers are not addressed in the act. This is likely to complicate efforts for the management of privately owned farms in watershed.

2.3.3 Agriculture Act (Cap.318) (1986).

Land and water resources are protected under the agricultural basic land usage rules. The Act sets out provisions for the management of hillsides and watercourses. In its provisions to conserve hillsides and catchments, the act empowers authorized agricultural officers to:

- To authorize a landowner to cultivate, depasture, cut-down or destroy vegetation on the land subject to such conditions as he may decide.
- By written order, prohibit cultivation, cutting down, or destruction of vegetation on any land whose slope exceeds 20%.
- Where the soil on any slope exceeding 12% is not in the opinion of an authorized officer, adequately protected against erosion, he may, by written order, require the owner to construct such works or to carry out such repairs, as he deems necessary within such reasonable period as specified in the order.

The agriculture act also list activities that are considered an offence and that if undertaken will destroy and degrade a watershed, and lower its potential as a water tower. They include:

- Cultivating, cutting down or destroying any vegetation, or depasturing any livestock on land whose slope exceeds 35%.
- Cultivating any land of which the slope exceeds 12% and does not exceed 35 percent, when the soil is not protected against erosion by conservation works to the satisfaction of an authorized officer.

- Cultivating by ploughing or other means on any land of whose slope exceeds 12% except along the contour or, except with the written permission of an authorized officer to dig or plough any boundary furrow, trenches or ditches on such land.

The agriculture act provides for a buffer zone of two metres of a water course, or, in the case of a watercourse more than two metres wide, within a distance equal to the width of that watercourse to a maximum of 30 meters. This measure is intended to protect streams and riverines from human encroachment that seriously degrades them, lowering their potential as water sources.

The Agriculture Act requires that the owner of any land takes steps that an authorized officer may specify to prevent water from flowing on to any adjoining land in such manner that may cause soil erosion. It also requires landowners to comply with orders given by an authorized officer to carry out the measures that prevent soil erosion.

In spite of the agriculture act being very clear on conservation of watersheds, hill sides and riverines, the residents have indiscriminately cultivated in the riverines and on steep slopes. Control by the agricultural officers has been minimal and in many cases of control being completely absent.

2.3.4 The Draft Land Policy (2005)

The overall objective of the National Land Policy is to provide for sustainable growth and investment and for reduction of poverty in line with the Government’s overall development objectives. Section 135 of the policy has provisions for watersheds and drainage basins protection. It states that protection of watersheds and drainage basins will be guided by the following principles:

- Settlement in the water catchment areas be discouraged and catchment protection shall be undertaken.

- All watercourses and wetlands be identified, delineated and gazetted in line with the recommendations of International Conventions.
• Strict control of agricultural activities in catchment areas.

The land policy, if well implemented will save the watersheds that have been degraded in Iveti North and enhance improved stream water flows. The land policy is however coming in place during a time when the catchments in Iveti North Hills have been densely settled and almost all vegetation cut. The watersheds in this area have consequently been degraded. Implementation of the land policy in this area is therefore going to be a big challenge, especially considering that the land in the watersheds is under private ownership.

2.4 Watersheds as a System

Watersheds comprise of several interconnected elements. The biophysical elements comprising of vegetation, slopes, weathered rocks, bedrock and channels. Each can be treated as a sub-system depending on the scale of analysis. An output of one element becomes an input of another element. Water that flows from slopes becomes an input to channels. Similarly, soil eroded on slopes becomes an input into channels. Movement of mass and energy links the elements that make up a watershed. Changes in the conditions of these linked elements will effect how inputs are transformed to outputs. Changes in upstream elements will affect downstream elements. For example, a change in the amount of water that infiltrates into the soil will affect the amount of water that flows into stream and also affect the amount of water available to vegetation and groundwater (SADC, et al. 2002).

Human activities form an important social element of the watershed system that interacts with the biophysical elements of the watershed. These interactions affect processes occurring within watersheds. As an example, human activities can increase or decrease areas under vegetation. Such changes will affect the flow of mass (water and debris) and energy within a watershed. These relationships are demonstrated in the Figure 2.2.
2.5 Single Sector Approach to Water Resource Management

Previously, water management institutions in Kenya have tended to be centralized and technically oriented in support of one or two specific aspects of management. The single sector approach to water management led to long-term environmental degradation because it failed to account for all components of the ecosystem. It typically sought to maximize the benefits of water use, such as irrigated agriculture, without considering the
effects of other sectors such as water quality and quantity. In addition, this approach
tended to rely heavily on technical and engineering solutions, making little or no attempts
to address related policy and institutional issues (GEF, 2002). The single sector approach
however, has its shortcomings when it comes to watershed management. By emphasizes
that each sector takes its own approach becomes an issue especially when it comes to the
coordination of the activities of the various agencies. It is a problem since the activities of
one sector may degrade the catchment. This has consequently resulted in conflicts,
specifically when the ministry of agriculture promotes cultivation disregarding the
impacts on watershed conservation.

2.6 Water Balance Equation

According to SADC, et al. (2002), transfer of water into and out of a watershed is
described by the water balance equation: \( P = Q + E + \Delta S \), Where

- \( P \) is precipitation,
- \( Q \) is runoff,
- \( E \) is evapotranspiration and
- \( \Delta S \) is the change in water storage in the watershed.

Precipitation occurs as rain in the region. A portion of the precipitation falling over a
vegetated watershed is intercepted by vegetation and evaporate back into the atmosphere.
The remainder that reaches the soil surface is divided into three sub-components:

- Runoff into watercourses that is stored in reservoirs, lakes or eventually flows
to oceans.
- Water that evaporates from the soil, channels, reservoirs and lakes, and
  transpired from leaf-surfaces after being absorbed by plant roots.
- Water stored in soils and groundwater.

In order for a system to function properly, these variables should not be interfered with.
Alterations in any of these variables make the system not to function properly, or may
even fail. For instance, clearance of vegetation in the watersheds may reduce water
infiltration rates and subsequently lower river yields.
2.7 Vegetation in Watersheds.
Vegetation is one important element of the watershed system (SADC, et al. 2002). Vegetation cover intercepts rainfall, therefore reducing the potential energy of raindrops when they hit the ground surface. This generally minimizes soil movements through raindrop impact. This role can be well played by both plant canopy and grass vegetation cover. Changes in the status of this element will have several effects on other components of the watershed, in particular on water resources. The watershed protective function of the different vegetation types and the associated transpiratory water losses depend on vegetation density and its leaf area measured as Leaf Area Index, SADC, et al., (2002).

2.8 Watershed Degradation
Watershed degradation is a long-term reduction in the quantity and quality of water resources due to anthropogenic and natural factors. Watershed degradation resulting largely from poor land-use practices that poses significant threat to water resources of many countries in Africa. Watershed degradation is associated with huge economic costs. These costs are caused by many factors ranging from loss of soil cover, nutrients and agricultural production, altered hydrology, deteriorated water quality, reduced economic life of storage dams, and damaged water infrastructure due to sediment transport and deposition (SADC, et al. 2002).

2.9 Anthropogenic Causes of Watershed Degradation
According to Darkoh (1987) watershed degradation result from land pressure arising from inequitable land distribution and the resultant overloading of the carrying capacity, followed by modernisation of agricultural production that marginalize subsistence agriculture. The causes of watershed degradation are complex and not always universally applicable. The most common causes of watershed degradation in Africa are:

- Over-cultivation;
- Overgrazing;
- Deforestation;
- Poor waste disposal systems; and
• The invasion by alien plants.

In addition, watershed degradation generally may result from a combination of some of the following (Darkoh, 1987):

- Social and economic factors;
- Natural events;
- Short term pressures and land uses;
- Short-sighted policies of governments and donor agencies; and
- An increase in both human and animal populations

Efforts should always be made to ensure that these factors either singly, or in combination do not occur. Where they have occurred, measures should be undertaken that will restore the watersheds to their original state, hence ensuring sustainability in water resources.

Overpopulated domestic livestock is reported to cause more than half of the soil erosion in Southern Africa (UNEP, study in Chenje and Johnson, 1994) and it is likely to be the major contributor to watershed degradation in the region. Overgrazing and compaction of soils occur when stocking rates exceed the capacity of the relevant area to sustainable support the number of animals. This leads to a reduction on vegetation cover and compaction of soil through trampling, which promotes soil erosion.

Deforestation caused by cultivation, bushfires, timber and fuel wood harvesting and the development of settlements and infrastructure, (SADC et al. 2002) is a major cause of watershed degradation. Deforestation directly affects vegetation and soil. The reduction of vegetation cover reduces infiltration rates and increases the amount of water delivered to channels. In effect, deforestation accelerates soil erosion and increases the amount of debris delivered to channels. Watershed degradation due to deforestation, (SADC,et al 2002) is especially serious problem in countries with very high livestock densities

Cultivated lands are without any vegetation cover at the beginning of the growing season (Lele and Stone, 1989) without adequate soil conservation measures, soils are susceptible to erosion and this is particularly serious in vulnerable areas, for example, on steep slopes
or near stream banks. Excessive erosion may impair the quality of water and reduce the capacity of streams to store, and convey water.

Most rural people in Africa use fuel wood for cooking and heating, and this often result in cutting trees if no under-bush or deadwood is available. This contributes to deforestation, with annual rates ranging from 0.03 to 2.2 percent. Misana and Nyaki (undated) estimates that 60 million cu m of fuel wood would be required annually in Tanzania by the year 2000, but the natural forests can only supply 20 million cu m of fuel wood. They estimate that this imbalance between the demand and supply will result in the deforestation of between 300,000-400,000 hectares every year.

According to Lacaux, et al, (1993), fire is a major cause of watershed degradation in dry savannah in Africa. Vegetation in Southern Africa is subjected to annual or periodic burning. Depending on the severity of the burn, fire degrades forests by converting them to grassland or wooded grassland. Apparently, fire is frequent on grasslands, and dry savannah in South Africa. The areas affected by fire are difficult to estimate but global estimates indicate that 440-505 million ha of African savannah are burnt annually. The effects of bushfires have been analysed for watersheds in South Africa, where stream flows increased immediately after the burning of vegetation. Wet season monthly flows increased by between 7 - 15 percent after the burning.

2.10 Ecological Impacts of Watershed Degradation

2.10.1 Soil Erosion

Soil erosion is a natural process accelerated by overgrazing, deforestation and inadequate soil conservation measures on cultivated lands, (Stocking, 1986). Andrews and Bullock (1994) in their catchment studies set up to examine the effects of vegetation clearance on water resources, showed that clearance of vegetation results in an increase in runoff from watersheds. In Zambia, it has been shown that 95 percent deforestation of miombo woodlands increased annual flows by 56 to 74 percent. Shama, (1985) and Mumeka (1986) concluded that clearing 75 percent of wet miombo woodland in the Copper Belt
area of Zambia and temporary conversion to subsistence agriculture had the following effects:

- surface runoff increased by 10-18 percent;
- peak flows increased;
- annual evapotranspiration was reduced; and
- Base flow increased.

Misana and Nyaki, (not dated) have shown that deforestation reduces infiltration rates of some soils. Peak flows increase because of deforestation. However, the increase in peak flow is usually not beneficial since it is available in most rivers during the wet season. Reduction in infiltration rates lowers groundwater levels and depletes dry season flows in those areas with permeable formation. Misana and Nyati, (no date) further note that 90% of streams outside catchment forest reserves in parts of Tanzania are no longer flowing due to vegetation clearance. Overgrazing has similar effects to clearing of trees. Stromquist (1985) observes that infiltration rates increased peak flows which decreased after an overgrazed catchment in Uganda had been allowed to recover by excluding cattle and allowing the re-growth of the grasses.

2.10.2 Decreased Stream Flows

Kienzle, et al. (1997) undertook a detailed analysis of the impacts of land-use change on the Mgeni Catchment. Commercial forest or sugar plantations decreased stream flows by up to 60 percent in those sub-catchments with high proportions of land uses. The reduction in flows is attributed to high transpiration losses. Extension of land under maize production increases stream flow due to the sparse canopy of maize, particularly during the early stages of its growth.

2.11 Action Agenda for Water Resources.

The last decade has seen a growing acceptance of changes in management policies and institutions that sustain fresh water ecosystems. The agenda for fresh water consists of
two steps: enacting of national policy, legal and institutional reforms and improving water use efficiency to protect ecosystems.

Governments in the world should redirect an approximately $33 billion annual (ref) expenditure on irrigation improvements. The funds should be used to improve the productivity of irrigated land in an effort to balance conflicting uses of water within the river basins (GEF, 2002). Improved productivity should be encouraged through the use of water efficient technology, water use organizations, pricing policies and productivity gains (GEF, 2002). Investment in low cost agricultural technologies provides important benefits for the poor. The human powered water pump and other cost effective options are available to improve the productivity of irrigation.

(AWWA, 1999), presents two main approaches to watershed management.

- River basin as a planning and development unit.
- Integrated watershed or catchment management approach.

In the river basin planning approach, the river basin authorities are established to manage the basins. The main objective of forming these authorities is to coordinate development of water resources projects within watershed, to maximize benefits such as the provision of water for hydropower generation and irrigation. These authorities often fall within a ministry responsible for water development or irrigation, and have no mandates over the utilization of other resources such as forests and land within watersheds.

Regional Water Authorities are faced with severe problems of soil erosion and siltation. For those river basin authorities that have responsibilities for the management of problems such as deforestation and soil erosion, (SADC, et al. 2002) this management is undertaken to protect downstream dams, and not necessarily to enhance the potential of arable lands to produce crops. River basins authorities have also tended to emphasize benefits that are too distant in both space and time to local communities. Peasant farmers are often told to put in place soil conservation measures for the purposes of ensuring water to downstream urban communities. These local communities do not perceive any immediate benefits from such approaches (SADC, et al. 2002). In some cases local
communities are told to stop clearing forests/woodlands for the benefit of future generations and yet they cannot obtain sufficient food for their immediate benefit. Local views and indigenous knowledge systems have rarely been taken into account in some of the watershed management approaches.

The river basin authorities approach has therefore not been successful in managing watersheds as these authorities have not been given a mandate to maintain and enhance the potential to produce various goods and services, but instead have had their mandate constrained.

Integrated watershed management is a ‘holistic natural resources management system comprising interrelated elements of land and water in a river basin, managed on an ecological and economic basis (SADC, et al. 2002). It is a system that favours integration of environmental policy across government, community, and industrial sectors through partnership and extensive stakeholders’ inclusion.”

The Objectives of Integrated Watershed Management can be categorized in to:

- Co-ordinate policies and actions of government, private sector and individuals in the use and conservation of land, vegetation and water;
- Maintain stability and enhance productivity of land, water and vegetation;
- Use land within its capability; and
- Increasing the awareness of communities regarding sustainable and balances in resource utilization (SADC, et al. 2002)

According IWM paradigm, (SADC, et al. 2002) the basic planning and management unit is the watershed. IWM recognizes that policies, plans and programmes of government agencies need to be co-ordinated and not based on a sectoral approach. Whereas previous approaches to watershed management were based on water as a single resource, this approach requires that government agencies adopt a multi-sectoral approach to management of resources. The utilization of one resource such as clearing of vegetation to make way for cultivation or livestock grazing will affect other resources such as water.
Solutions to problems of watershed degradation must be part of the broader developmental agenda of a country.

IWM is based on the establishment of partnerships (SADC, et al. 2002) between government agencies, the private sector, groups and individuals. Each of these parties, and especially local communities, have an important role in identifying and prioritizing problems and suggesting potential solutions. Previous approaches to watershed management tended to be too centralized without creating opportunities for local communities to become part of the solution to problems of watershed degradation. All groups of stakeholders are involved in the implementation of this approach (SADC, et al. 2002). The Central Government has the responsibility for providing guidelines on water resources management. A catchment management committee is formed for each watershed, with representatives of different groups of stakeholders with a mandate to implement integrated watershed management. This is the forerunner of a catchment management agency for the watershed.

A watershed can be subdivided into sub catchments for which a catchment forum is formed for each one of them. A catchment management agency as a corporate body is then assigned the primary aim of devolving responsibility to water resources management to local communities. Each catchment management agency has several catchment management forums which are non-statutory bodies formed to facilitate participation of local communities in watershed management (SADC, et al. 2002). Catchment management forums identify problems and prioritize them. The catchment management agency produces catchment/watershed management plan on this basis.

Watershed degradation in Africa is largely due to lack of a holistic approach to the utilization and management of land and water resources (SADC, et al. 2002). In addition, coordination of effort by various government agencies that have mandate over issues related to watershed management is rare. For example, soil erosion on arable lands may be a responsibility of a department dealing with natural resources conservation, and siltation of reservoirs may be under another department dealing with water affairs. IWM
creates opportunities for co-ordinating efforts of different government agencies and stakeholders. One of the major weaknesses of the approaches used in watershed management has been the lack of involvement of local communities in identifying and prioritizing problems emanating from watershed degradation. Top-down approaches towards the solution of watershed degradation that do not take account of local needs such as food security and fuel wood, for example, have been a norm in Africa (SADC, et al. 2002).

IWM provides a framework for the participation of local communities and other stakeholders, and one of its pillars is the need to have a balance in resource utilization, which can be achieved only through negotiation with resource users within a watershed.

2.12 Conceptual Framework

Integration in Watershed Management means different things to different people. Integration means managing benefits to diverse watershed-level components, including tree, water, livestock, and crop and soil components. This is required so that gains to one particular component do not have an overly negative impact on other components- or on users depending on the viability of other component for their livelihood. Integration also means integrating diverse solutions through a multi-disciplinary or multi-sectoral approach. This form of integration is required not only in a given “systems” thinking in a biophysical sense, but to support technical solutions with social, policy and market interventions. These relationships are represented diagrammatically in Figure 2.3.
Figure 2.3: Multi-Disciplinary and Multi-Sectoral Integration in Watershed Management

Adapted from Laura (2006), Evolution of Concepts and Models

Integration in Problem Definition

During problem definition, integration is achieved through a fully interdisciplinary exploration of watershed problems (including biophysical, social, policy and market dimensions) and through a systems analysis of component linkages. The second step, of a systems analysis of component linkages, is carried out once key watershed problems have been identified and prioritized. In each benchmark site, a list of biophysical issues are generated from the research questions through socially disaggregated problem diagnosis, grouping of like issues, and socially disaggregated ranking of issues. In addition to identifying issues of high importance to most social groups, discrete issues are regrouped according to the presence of strong functional interactions among them (German et al., 2003). The idea behind this is to identify clusters of issues that can be addressed
simultaneously, to foster positive synergies among them and multiple returns (i.e. water, food, fodder and fuel)

**Integration in planning**

![Diagram showing integrated solution for watershed management](image)

**Figure 2.4:** Articulate interactions of components in a watershed, *Source: Laura (2006), Evolution of Concepts and Models.*

Integration in planning is addressed from the standpoint of both component integration and disciplinary or sectoral integration. Higher-level system goals are specified for each cluster in order to avoid disintegration during planning. In order to achieve sectoral or disciplinary integration during planning, two considerations have to be known. First, unless 'other' dimensions of the problem are made explicit during planning, biophysical interventions will take precedence. For each major intervention, it is therefore critical to cross-check identified solutions by considering whether diverse dimensions (technical, social, policy, market) have been considered.

**Integration in Implementation**

There are strategies to ensure biophysical and multidisciplinary integration during early stages of implementation. To achieve integration of landscape-level components, there are several implementation options for any given problems. There are two clear possibilities for operationalizing this form of integration. First, teams of scientists and practitioners can work on individual components (spring development, Soil Water
conservation practices and niche-compatible afforestation) independently, to ensure the work addresses system goals, as defined in the overall cluster objective. The pitfall of taking this option is that existing interdisciplinary biases will tend to disintegrate the approach into component-specific approaches.

The second option to component integration is to implement each of the component activities through a single set of activities, for example by focusing activities on "Integrated Catchment Management" rather than individual components. This approach entails spring development to enhance enthusiasm about project activities, followed by integrated afforestation, soil, and water conservation activities in different landscape units (Ginchi, 2004).

**Problems in Implementation of IWM’s**

One of the major problems encountered in creating institutions for watershed management is that current planning by all agencies is based on administrative units that use political boundaries that may not be compatible with watersheds. In Zimbabwe, it was recommended that administrative units such as District councils should form sub-committees that deal with watersheds management issues for shared watersheds (Water Tech, 1999). Another issue in the implementation of IWM is that individual farmers are not likely to participate in initiatives with benefits that will be realized only in the distant future. It is therefore recommended that where possible, the initial watershed management activities should provide benefits within a reasonable time scale, so that the enthusiasms of local communities is maintained. At the local level, watershed management, initiatives should aim at providing tangible benefits to farmers that encourage them to participate in the implementation of their initiatives should be owned by the farmers and local communities. Government agencies should be facilitators in this process. Use should be made of Indigenous Knowledge Systems (IKS) in solving watershed management problems.
2.13 Principles of Watershed Development

Participatory
Watershed communities need to be involved in all stages of planning, implementation and management of watershed development activities. It is a continuous process and not a one time exercise. Different participatory techniques will be used based upon existing and innovative experience.

Gender sensitivity
Women are the most affected by environmental hardships; for example, they need to walk long hours to fetch increasingly scarce water, firewood and animal dung in addition to attending livestock, to name a few. Their involvement in watershed development planning, implementation and management is the key to ensure that they equally benefit from various measures.

Building upon local experience, strength and what works
Local knowledge is essential to improve existing technologies, to adapt new ones and to manage natural resources and other measures once they are introduced and established. Best practices should be identified and disseminated.

Realistic, integrated, productive and manageable
Watershed development planning should be realistic, based upon local capacity, locally available resources and other forms of government and partner support. Integrated conservation and development of the natural resources base is the guiding principle for watershed development together with the optimum use of social resources. To the extent possible watershed development activities should provide tangible and quick benefit to households. This is possible if measures are designed to accommodate both production and conservation requirements. Some measures, however, need some time before the full benefits can be achieved. In this case, combination of measures with short and longer term benefits is essential. This can be achieved if quality criteria and integration aspects of the interventions are met.
Watershed logic and potential respect

Adoption of ridge approach, of manageable size, and focused on interactions between land uses and their capability. Simple land uses and features descriptions would help to find suitable range of technical options to optimize existing land use or changing it for the better in respect of both biophysical and social requirements. Due emphasis is placed on production enhancement activities by optimizing productivity per unit area, per unit of water for both land owners and landless families. In this regard, the role of quality physical structures, vegetative cover and biological measures are emphasized. Reclamation and rehabilitation of degraded and marginal lands, including gullies, through alternative and productive land-use systems are promoted as a main activity in most areas. In semi-arid and arid areas, great attention is provided for water harvesting in situ and off site.

Flexibility at different levels

Flexibility is a key criteria required in PWDP to fit in local conditions. Flexibility is needed during the selection of community watershed, their size (slightly smaller or larger than the range indicted) and clustering and during the steps of the producers. Similarly, flexibility is essential when considering the choice and design of measures within the agreed criteria of quality and integration.

Cost-sharing and empowerment/ownership building

Cost-sharing by stakeholders contributes to the sustainability of a project for establishing the responsibility of various stakeholders in the management of the resources. Various forms of local contributions are possible based upon social networks and group formation mechanisms.
CHAPTER 3

3.0 The Study Area

3.1 Physical Set Up

3.1.1 Location and Extent

North Iveti Hills are situated between Kathiani and Central Divisions, Machakos District, which is one of thirteen Districts that form Eastern Province of Kenya. Machakos District is bordered by Nairobi City and Thika to the West, Makueni District to the South, Maragwa District to the North and Mbeere District to the Northeast. It stretches from 1° 21’ South and longitude 36° 45’ East to 1° 50’ South and 37° 53’ East. Iveti North comprises of Ngelani Location, Mitaboni Location, and Mutituni Location. It borders Mua Location to the West, Kathiani to the Northeast, and Kalama Division to the East. Location of the District and the study area is shown by map 3.1 and 3.2 respectively (GoK, 2002).

3.1.2 Topography

The topography of the District is varied and rises from 700m above sea level on the southern part of the District to 1700m above sea level in the West. The landscape is largely a plateau consisting of the Athi Kapiti and Konza plains, interrupted by Mua, Iveti, and Kiima Kimwe Hills. Central Division has a number of hills, notably Mua and Iveti Hills that are mainly of basement complex rocks. Other notable Hills include Mitaboni and Kiima Kimwe.

Iveti North Hills have a few perennial streams whose flow is extremely intermittent as they approach the lower altitudes. The Kalua, Kithima, and Ngelani springs and streams offer potential for piped water for gravity fed water schemes for domestic uses in low altitude areas. Kathiani and Machakos Central Division lies in the Athi River drainage basin where the general drainage direction is from West to East. Most of the water sources are seasonal in nature, usually with subsurface flow in sand filled riverbeds. The subsurface rivers are important sources of domestic and livestock water in many parts within the Divisions especially during dry seasons.
Map 3.1: Location of Machakos District in Kenya. Source: GoK, 2002
3.1.3 Drainage

Central Division is largely semi-arid and the amount and frequency of precipitation erratic. The area depends on rivers, streams, boreholes, springs, dams as water source for various uses. The hill masses are a source of permanent springs and streams whose flow is low, as shown in map 3.3. Ground water potential ranges from moderate to low, because of the massive nature of parent basement rock.
Due to the increase in population and economic activities, water resource is continuously becoming scarce. Consequently, conservation measures such as afforestation, and construction of sub-surface dams to capture and store surface run-off have not been explored. Permanent buildings that provide potential for roof catchments have also not been fully exploited (GoK, 2000).

3.1.4 Geology and Soils
Iveti is endowed with deeply weathered ultisols soils enriched with clay. They are often highly coloured by iron oxide occurring mainly on the hill masses, particularly in the densely populated, high potential areas. Vertisols are found in the lower areas of Iveti. These soils contain more than 30% clay, especially rich in swelling clays. Soil erosion particularly in the Hills is a major threat to agricultural potential. The dominant soils of the undulating topography of the uplands have low natural fertility. The area is underlain by a massive parent basement rock. Kathiani and Central Divisions are endowed with building stone that is used locally and in the urban areas for construction for construction purpose. The stone quarries are found in the lowlands while the streams are a source of large quantities of building sand.

3.2 Ecological Set Up

3.2.1 Climate
The District enjoys a pleasant climate, relatively warmer; varying from highland equatorial on Mua, Iveti, and Kiima Kimwe Hills summits, to semi arid on the Koma, Konza, Miumbuni, Kaviti, and Lukenya plains.

There are two distinct rain seasons, the long and short rain seasons. The long rain starts at the end of March and continues up to May, while short rain fall from end of October and lasts to December. The annul rainfall ranges between 500 mm - 1300 mm (GOK, 2000). A large part of Machakos District is semi arid- and receives very little and erratic precipitation. The rainfall varies from year to year making it difficult for farmers to plan their farming activities. This variation in rainfall affects both livestock and agricultural production. The high altitude areas receive slightly higher rainfall than the low land areas. Mean monthly temperature vary from 18°C - 25°C. The coldest month is July while October and March are the hottest (GOK, 2000). The area lies in Agro-ecological zones II, III, and IV. Land productivity varies from zone to zone with those in zone II having high crop yields, mainly because of reliable and higher rainfalls and soils that are better suited for crop farming. Land in zone II is used for crop cultivation and livestock rearing.
3.2.2 Vegetation

Vegetation varies with altitude. The plains, which receive less rainfall, are characterized by open grassland with scattered trees. In high altitude areas that receive high rainfall, dense vegetation is present. Eucalyptus and gravelleia are the most predominant vegetation in the high altitude areas. Forest resource in the Central and Kathiani Division, is limited to pockets of forests found on the hill masses in the high potential areas. The gazetted forest in the Divisions is Iveti Forest Block (3,476 ha) and the Forest Department Block (1,647 ha). There are no other natural forests in the Division. There is however, potential for the development of forests under the cultivated land through agro-forestry.

3.3 Socio -Economic Set-up

3.3.1 Economic-set up

Agriculture is the main source of income in the District. Food and cash crop production are the main sources of income. Crop production in the District is diverse. A variety of food and cash crops are cultivated using traditional cultivation tools with little or no manure application to heavy fertilizers application. Crops cultivated in North Iveti Hills include maize, beans coffee, French beans, horticultural crops (vegetables, fruits and flowers). Areas under different crops and yields per hectare vary from one place to another. Low yields is attributed to vagaries in weather, low use of farm inputs e.g. fertilizers and pesticides and other inappropriate crop husbandry practices, including use of inferior seeds (GOK, 2000). Other sources of income include business and livestock keeping.

Due to the high population and the ever-increasing demand for food, more land has been put under agriculture. As a result, erosion has and will continue unless measures are put in place to address the situation.
3.3.2 Population Growth

The 1999 census report indicated that Machakos had a population of 906,644 people, consisting of 442,891 males and 463,753 females. The majority of the population is the young with 510,507 being below twenty (20) years. The population in the District is expected to rise from 906,644 in 1999 to 954,082 and 1066,535 in 2002 and 2008 respectively. The majority of these people depend on agriculture for their livelihood. Already the agricultural activities have caused degradation of land due to high population density. Much soil has been lost through erosion, while encroachment on forests and water catchments has become a problem. The increase in population will exert more pressure on the available land thus leading to further reduction in agricultural production and depletion of water catchment areas (GoK, 2002).

Land use and settlement patterns are based on the agro-ecological zones and are influenced by soil fertility and rainfall. The high-density settlements in the District are along the hill masses of Matungulu, Kathiani, Central, and Mwala Division. These hill masses receive moderately high rainfall (700-1300mm per annual) and have great agricultural potential due to fertile soils. Sparse settlements are found in low plains where ranching and dairy farming is carried out.

Within the District, people have tended to migrate from densely populated, high potential areas with high population pressure to low potential areas where there is still adequate land for human settlement. The lowland areas that received less rainfall when compared to the Hills, were used for cattle rearing. Now, with the population growth in the District, they have become favorable for settlement. Despite the out migrations, population in the high potential areas continues to grow and still attract new residents.

Population density in the District is influenced by land productivity and availability of water. Population density is high around water sources and where soils are fertile. Divisions with fertile soils and high agriculture potential have higher population density than the rest of the Divisions. For instance Central and Kalama Division covering a total of 821.7km² with 184,227 persons, compared Ndithini and Masinga Divisions covering a
total of 1,410.9km², and a population of 106,836 persons (GoK, 2002). This includes the hill masses of Central, Kangundo, Kathiani and Matungulu Divisions. This population has, however put much pressure on land and will continue to increase over the years. There is, therefore, need to institute aggressive land management programmes that will ensure reduced degradation while increasing agricultural production.

A majority of the Division’s population is self-employed in the rural sector, mostly on small-scale farming, numbering approximately 332,300 in the District (GoK, 2002). From a general observation, average family income varies directly with higher potential agro-ecological zones. Data available at the District Social Development Office reveal that the number of adults and children who report to the office seeking relief is about 240,000 annually. Population distribution in the rural areas is influenced by a number of factors, among them, water and soils to sustain agriculture. The Division has the highest population compared to the other Divisions. It has 22,596 households.

Central Division has the highest population because it covers Machakos Town, and Iveti and Mua Hills that have fertile soils and high rainfall. Population density, especially in the high potential areas is high with an average of 539 people per sq km (GoK, 2002), as shown in Map 3.4. With the annual population growth standing at 1.7%, it is expected that these areas will continue to experience even more population growth.
3.3.3 Infrastructure

Roads are the mode of transport in the District. The road network is however poorly developed and mainly consists of gravel and earth roads. These are often rendered impassable during rainy seasons (GoK, 2002). There are sections of roads that are tarmacked in the District, for instance, the road to Machakos from Nairobi through to Kitui is tarmacked. Other roads that are tarmacked are the road to Kathiani from...
Machakos town, and the road to Kamuthanga from Machakos town. These roads are generally used for the transportation of both people and farm produce.

3.4 Major Development Challenges

Generally, the District has inadequate water for domestic, livestock, crop and industrial uses. The rainfall is inadequate and unreliable while water from the permanent rivers and dams have not been fully harnessed. The majority of population depends on surface and subsurface dams for water, which often do not hold sufficient water due to high evaporation rates during the dry seasons. The already existing water supplies systems are overstretched and cannot supply enough water for the increasing population.

The Majority of people depend on agriculture for their livelihood. In the high potential areas, land holding range from 0.5-2 acres. Over cultivation has left the land bare, exposing it to erosion. This has in turn greatly reduced the agricultural production in the District.
4.0 Research Methodology

This chapter examines various sources of data, methodologies of data acquisition and analysis, and the procedure for acquiring the sample from which generalization is made.

4.1 Nature of Data

Data comprised of two types, namely:

- Primary Data
- Secondary Data

Primary Data

Primary data collected was on the views and opinions of the residents on continued watershed degradation, various land uses, land sizes, sources of water, uses of water, conventional measures of watershed management, crops grown, household sizes and household water consumption, types and sources of energy. All these data sets were chosen because they give an indication of how the land resource is used, and on this basis, it was possible to argue whether their use has any link to watershed degradation in the area.

The local views and opinions were sought in the process of primary data collection. This was possible through use of household questionnaires (appendix I), surveys, direct observations and interviews with resource persons. Government Officers, Parastatals Heads and Private Developers were also interviewed based on the institutional questionnaire (appendix II). At the District level, the District Water Officer gave an analogy of water conservation in the area, the various measures so far adopted, their weaknesses, and suggested possible solutions. The District Agricultural Officer gave a description of the soil and water conservation measures in Iveti North, and a description of the problems, and policy conflicts in the management of catchments. The District Environment Officer provided crucial information on the management of riparian areas. The District Forest Officer gave information on suitable tree species for planting in the riverines and other measures for conservation of both soil and water. Athi Water Resource Management Authority staffs similarly were interviewed to provide information on how Iveti water catchments have previously been managed. They gave
problems in the management of the watersheds, and suggested the best options for the management of watersheds for sustainable water supply.

**Secondary Data**

The secondary data collected comprised of recorded and archived information. Policies on watershed management were evaluated. The Water Act, Agriculture Act, Forest Act, Physical Planning Act, Land Act and the Sessional Paper No 1 of 1999 on water resource development were all reviewed. Data on the causes and effects of watershed degradation, and other conventional measures in water conservation was also reviewed. In general, literature reviewed came from libraries, published information from Government Ministries, Maps and Physical Development Plans. Journals from websites on watershed degradation and conservation were also evaluated. The focus of the review was to get a global perspective on practice on watershed management, problems encountered in watershed management; theories explaining the management of watersheds, and any conflicts in Kenyan policy in watershed management.

4.2 Study Sample

In order to ensure that the sample was adequate, manageable and representative of all the aspects of the entire population, a sample of ninety households was selected from a entire population of 3345 households. The sample size was selected based on limitations of time and financial resources.

4.2.1 Sampling Frame

The sampling frame for the study comprised of all households in North Iveti Hills. All households within the catchments areas were targeted. Households in Iveti North water catchments and those downstream, all lying within Kithima, Kalua, and Ngelani river drainage basins, formed the sampling frame. Spatially, the sample collected was drawn from across three locations: Mitaboni, Ngelani and Mutituni locations.
4.3 Sample Survey Design.

In reaching the sample, both probability and non-probability sampling techniques were used. Specifically, simple random sampling, stratified random and purposive sampling techniques were used to draw the sample.

4.3.1 Stratified Random Sampling

The Stratified random sampling technique was used to achieve a sample that represented all the aspects of the population. Iveti North Hills was stratified in to three levels, based on altitude. The high altitude area, that serves as the source of several springs and streams. The middle altitude areas, where water from the streams is heavily tapped for irrigation, and lowland, the areas lying on the low altitude, which relies on the catchments for water supply.

The High Altitude Area

These are the Areas representing the highest ground in the study Iveti North Hills. They are rather cool, receiving higher rainfall than the surrounding, hence acting as important water sources both for the residents in the upper catchments and those downstream. Kisekini, Mutondoni, Ngelani and Thinu fall in this stratum. Indigenous vegetation in the area has almost been completely cut and replaced with exotic eucalyptus, or the land has been left bare for irrigation.

The Middle Altitude Areas

This zone represents the area that lies between the high altitude zone and the low land areas. This is the zone where streams have been heavily tapped for irrigation. It also represents the zone with the highest population densities. The area between Thinu and Muvaa falls in this zone. The land between Ngoleni and Thinu is also found in this zone.

The low-lying area

This is the lowest lying area, at the foot of North Iveti Hills. This area heavily relies on the Hills for water supply. Households in this zone are sparely populated as compared to the middle latitude area. The residents usually, are faced with water shortage, especially
during the dry periods of the year when stream flows are minimal. They walk for long distances in search of water.

4.3.2 Simple Random Sampling Technique

This technique was used to draw a sample of ninety households. Thirty households were drawn from each of the three established zones (the high altitude, middle altitude, and low altitude). In each of the three zones, the first household was picked randomly. In many cases, the first random household was decided based on closeness of households to a stream, and cultivation on riverines, cultivation on steep slopes, density of the settlement, intensity of irrigation activities in the farms, and on observed destruction of vegetation cover and degradation of soil resource.

4.3.3 Purposive Sampling

The existing institutions; Ministry of Water, Environment, Agriculture, Physical Planning, were all sampled through purposive sampling technique. The survey had already decided on the required data sets and singled out the various institutions as sources of data. At the District level, the District Water Officer gave the practice on water conservation; watershed measures so far adopted, their weaknesses, and suggested possible solutions. The District Agricultural Officer was to evaluate measures on soil and water conservation in Iveti North, a description of the problems, and policy conflicts in the management of catchments. The District Environment Officer was to provide information on the management of riparian areas. The District Forest Officer was to suggest suitable tree species for planting in the riverines, including other measures for soil and water conservation. Athi Water Resource Management Authority, similarly were supposed to provide information on how Iveti water catchments are managed, problems experienced in the management of the watersheds, and offer the best options for the management of watersheds for sustainable water supply.

4.4 Data Collection

In order to collect primary data in appropriate form and detail, household and institution questionnaires, observation guides and oral interviews guides were used. Before the main
study was undertaken, an initial pilot study was conducted. This was intended to refine
the research instrument, identify sampling units and make a general reconnaissance
survey of the study area to put in to context the issues of concern. Through the
reconnaissance survey, three zones were established: the high altitude area, middle-
altitude and the low altitude zone, each with a unique contribution to watershed
degradation.

During the main study, both primary and secondary data was collected. Questionnaire
schedules were used for the randomly selected households while interview schedules
were used for the governmental officers. To supplement information obtained through
questionnaires, a focused group discussion was held. In addition, field observations were
recorded using photographs.

4.5 Data Analysis
Data was analyzed using the SPSS statistical analysis package. Various data sets, such as
land size, use of watersheds, tree species planted in the riverines, method of irrigation and
other variables were fed in to the package. This generated percentages and averages.
The percentage and averages were then presented using tables, graphs, and charts, that
provided a picture upon which discussions, conclusion and recommendations were based.
The study established that there was a direct relation between destruction of riverines,
clearance of vegetation and increased irrigation activities in Iveti north area with
decreased stream flows and subsequent water shortages. The study did not however find
any direct link between livestock keeping and degradation of watersheds.

4.6 Constraints of data analysis
Data analysis had some problems at first. First, the data was analyzed using the SPSS.
The process of data input was rather a great challenge. It was also tedious and time
consuming to input the data, interpreting the tables and graphs generated. Getting specific
maps and images to show levels of watershed degradation was also difficult.
CHAPTER 5

5.0 Data Analysis and Discussion

5.1 Introduction

Iveti North Hills falls in the Athi water catchment, an area that is under the jurisdiction of the Athi Water Resource Management Authority.

5.2 The Athi River Catchments

Athi River Catchment cuts across five administrative provinces in Kenya: Central, Nairobi, Eastern, Rift Valley and Coast Provinces. It covers the following administrative Districts, as shown by map 5.1: The whole of Kiambu, Nairobi, Makueni, Taita taveta, Kilifi, Mombasa, Kwale, 44.8% of Thika, 77.7% of Kajiando, 60.2% of Machakos and 90.4% of Malindi (WRMA, 2006). Athi River Catchment Region is bounded by latitude $1^\circ$ South and $4.5^\circ$ South, longitude $37^\circ$ East and $40^\circ$ East. It extends from Ngong Hills and parts of Aberdares in the West, Southwards to the Tanzania border. It is bordered by Yatta Plateau to the East and drains to the Indian Ocean to the Southeast. The catchment area covers an area of $58,638.6 \text{ km}^2$, and has an estimated population of 8,500,127 people (WRMA, 2006).

The region has several protected water towers: Aberdares, Ngong Hills, Kyanzavi Hill, Kanzalu Hills, Iveti, Kilungu and Mbooni Hills (partly protected), Chulu Ranges and Shimba Hills. These protected areas are important for water recharge for the streams supplying water to the downstream areas and the aquifers in the area.

The Athi River Catchment region similarly has several protected and gazetted areas: The Ngong Forest, Karura Forest, Kyanzavi Forest, Parts of Iveti, Mbooni and Kilungu Forests, Chulu Forest and Arabuko Sokoke Forest. There are national parks and game reserves within the Athi catchment region. Nairobi National Park, Amboseli, Tsavo West, Shimba Hills, Malindi Marine Park, Watamu Marine Park and Mombasa National Park.
Based on these national resources, the water towers and protected areas, the catchments should be protected and conserved to enhance water supply, especially considering that the rivers provide water to the Athi basin, an area that is largely arid and semi arid.

Iveti Hills West is a micro-catchment within the larger Iveti Hills catchments, and drains into Athi River. Iveti North is a highly settled area and the majority of its people are engaged in agricultural activities on the hill slopes and along the riverines. Burning of papyrus reeds, charcoal and over-abstraction of water from the rivers for irrigation are other prevalent problems in the Hills. Land in Iveti North is privately owned, including the riverines. The clearance of land for agriculture has left the land bare and subsequently degraded the catchments and riverines as it is shown in map 5.2.

In spite of the heavy settlements, Iveti North remains an extremely important catchment for River Thwake, which later drains into Athi River. Conservation of the Iveti Hills is therefore necessary, for continued water flow in these rivers.

Map 5.2: Extend of Catchment Degradation in Iveti North Hills, Source: Google Earth, 2007
5.3 Policies and Legislations in Watershed Management in Kenya

Catchment management is dealt with under several acts and legislations in Kenya. The Agricultural Act, (Cap 318), the recently amended the land policy of 2005, the water act of 2005 Forests Act (Cap 385), all have several provisions on watershed management especially in relation to catchment conservation. Other legislation that have a bearing on the management of watersheds include the the Lakes and Rivers Act (Cap 409), and the River Basin Development Authorities Act (Cap 443).

5.3.1 Water Act, 2002

The water Act, 2002 is an act of Parliament that provide for the management, conservation, use and control of water resources in Kenya and for the acquisition and regulation of rights to water use. Section 14 of the Act provides that a Water Resource Management Authority (WRMA) shall be formed to manage the Catchment areas. The WRMA are mandated to formulate Catchment Area Management Strategy for each catchment that should be consistent with the national water resources management strategy. Section 10 of the Authority requires WRMA to establish regional offices in or near each catchment area. Section 16 mandates the Authority to appoint a committee of up to fifteen persons in respect of each catchment area to advise its officers at the appropriate regional office on matters concerning water resources management, including the grant and revocation of permits. The regulatory functions over water resources management currently performed by the District offices of the Ministry in charge of water affairs are supposed, under the new legal framework, to be transferred to the Catchment area offices of the Authority.

The Water Act 2002 imposes a permit requirement on any person wishing to acquire a right to use water from a water resource. Section 27 makes it an offence to construct or use works to abstract water without a permit. The act however, makes three exceptions on the permit requirement. These relate to minor uses of water resources for domestic purposes; uses of ground water in areas not considered to face groundwater stress and therefore not declared to be groundwater conservation areas; and to uses of water drawn from artificial dams or channels (GoK, 2005).
Though the water act has good intentions to control the use of water by requiring every person intending to use or abstract water from a water source to acquire a permit, it does not define the extend to which water should not be abstracted from streams. The regional offices set in Machakos town have also done almost nothing to manage the micro-catchments, let alone setting the catchments management committees and the micro-catchments offices as required by the law. It has also been difficult to implement and monitor the permit requirement, and as a consequent people continue to abstract water without the permits. The farmers upstream in Iveti North continue to abstract water from small streams despite the fact that this still impact on the residents downstream.

5.3.2 The Forest bill, 2005
The Forest Bill, 2005 defines a watershed as any land area drained by a river, stream, or fixed body of water and whose tributaries have a common source of surface run-off. It requires that forest plantations, indigenous forests and woodlands be managed on a sustainable basis for purposes of-

- Conservation of water, soil and biodiversity:
- Riverines and shoreline protection;
- Cultural use and heritage;
- Recreation and tourism;
- Sustainable production of wood and non-wood products;
- Carbon sequestration and other environmental services:
- Education and research purposes.
- Habitat for wildlife in terrestrial forests and fisheries in mangrove forests

The Forest Bill only recommends that forests should be protected for these values. It has not put in place a clear structure and measures to manage catchments. It deals much with the management of large forests. Nowhere does it mention the management of small watershed and individual plots that act as the source of the big rivers. This significantly complicates efforts for the management of privately owned farms in watersheds.

5.3.3 Agriculture Act (Cap.318) (1986).
Land and water resources are protected under the agricultural basic land usage rules. The Act sets out provisions for the management of hillsides and watercourses.
In its provisions to conserve hillsides and catchments, the act empowers an authorized agricultural officer to:

- Authorize a landowner to cultivate, depasture, cut-down or destroy vegetation on the land subject to such conditions as he may decide.
- By written order, prohibit cultivation, cutting down, or destruction of vegetation on any land whose slope exceeds 20%.
- Where the soil on any slope exceeding 12% is not in the opinion of an authorized officer, adequately protected against erosion, he may, by written order, require the owner to construct such works or to carry out such repairs, as he deems necessary within such reasonable period as specified in the order.

The agriculture act similarly list activities that it considers an offence and that if undertaken will destroy and degrade watershed, and lower their potential as water towers. They include:

- Cultivating, cutting down or destroying any vegetation, or depasturing any livestock on land whose slope exceeds 35%.
- Cultivating any land of which the slope exceeds 12% and does not exceed 35 percent, when the soil is not protected against erosion by conservation works to the satisfaction of an authorized officer.
- Cultivating by ploughing or other means on any land of whose slope exceeds 12% except along the contour or, except with the written permission of an authorized officer to dig or plough any boundary furrow, trenches or ditches on such land.

The act provides for a buffer zone of two (2) metres of a water course, or, in the case of a watercourse more than two (2) metres wide, within a distance equal to the width of that watercourse to a maximum of 30 meters. This measure is intended to protect streams and riverines from human encroachment that seriously degrades them, lowering their potential as water sources.

The Agriculture Act requires that the owner of any land to undertake steps that an authorized officer may specify to prevent water from flowing on to any adjoining land in such manner that may cause soil erosion. It also requires landowners to comply with orders given by an authorized officer to carry out the measures that prevent soil erosion.
In spite of the agriculture act being very clear on conservation of watersheds, hill sides and riverines, the residents in Iveti north Hills have indiscriminately cultivated in the riverines and on steep slopes, with some disregarding the requirement to undertake measures that conserve these fragile ecosystems, thus exposing them to degradation. Control by the agricultural officers has also been minimal and in other cases completely absent.

5.3.4 The Draft Land Policy (2005)

The overall objective of the National Land Policy is to provide for sustainable growth and investment and for reduction of poverty in line with Government's overall development objectives. Section 135 of the policy has provisions for watersheds and drainage basins protection. It states that protection of watersheds and drainage basins will be guided by the following principles:

- That settlement in the water catchment areas be discouraged and catchment instead protection be undertaken.
- That all watercourses and wetlands be identified, delineated and gazetted in line with the recommendations of International Conventions.
- Strict control of agricultural activities in catchment areas.

The land policy, if well implemented can play a role to protect the watersheds that have been degraded in Iveti North, and enhance stream water flows. The land policy has however came in place during a time when the catchments in Iveti North hills have densely been settled and almost all vegetation cut. The watersheds in this area have consequently been degraded. Implementation of the land policy in this area is therefore going to be a challenge, especially considering that the land in the watersheds is privately owned.

5.4 Causes of Watershed Degradation

The causes of watershed degradation in a locality are varied. In Iveti North Hills the causes can be understood by examining certain environmental variables that range from demographic characteristics, land use, and socioeconomic activities among others.
5.4.1 Household Composition

Iveti North Hills cuts across two Divisions, Central and Kathiani Division. The population density in the two Divisions has been rising for the last eight years as indicated by 5.1, with majority of the residents relying on agriculture for their livelihood. Watershed degradation has consequently occurred due to the intensive agricultural activities and high population density in the Hills. Encroachment into water catchments is a problem (GoK, 2002). With a District population growth rate of 1.7%, the population in Iveti North is expected to grow in future. It is noted that further increase in population will exert more pressure on land and water resources and probably result in a reduction in agricultural production and depletion of water catchment areas.

Table 5.1: Population Density in Central and Kathiani Divisions

<table>
<thead>
<tr>
<th>Division</th>
<th>Area (km²)</th>
<th>Population density per Annum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1999</td>
</tr>
<tr>
<td>Central</td>
<td>491.5</td>
<td>292</td>
</tr>
<tr>
<td>Kathiani</td>
<td>205.8</td>
<td>462</td>
</tr>
</tbody>
</table>


5.4.2 Levels of Education

Education levels differed in Iveti North with majority residents acquiring basic education. 22 persons out of the total ninety (90) respondents were illiterate, 29 had dropped from primary schools, while twenty (20) were primary school graduands. All these represented 79% of the sampled population. The low level of education of the residents is considered to be a factor in the degradation of catchments in Iveti North Hills. The residents may not understand the importance of watershed management and all other available options for effective catchment management owing to their low levels of education. This is evidenced by table 5.2.

The low levels of education coupled with the statistics obtained from Machakos District Development Plan, 2002-2008, on population growth, (table 3), and further bearing in mind that the majority of population in the District is rural, (614,525), it is expected that
pressure on land will increase, with consequent degradation of watersheds and depletion of water supplies.

Table 5.2: Education Levels

<table>
<thead>
<tr>
<th>Level of Education</th>
<th>Illiterate</th>
<th>Primary drop out</th>
<th>Primary graduands</th>
<th>Secondary drop out</th>
<th>Secondary graduands</th>
<th>Form six (6) graduands</th>
<th>Tertiary institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>8%</td>
<td>16%</td>
<td>35%</td>
<td>-</td>
<td>29%</td>
<td>4%</td>
<td>8%</td>
</tr>
<tr>
<td>Women</td>
<td>17%</td>
<td>25%</td>
<td>32%</td>
<td>-</td>
<td>21%</td>
<td>-</td>
<td>5%</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2006

Table 5.3: Population profiles

<table>
<thead>
<tr>
<th>Age</th>
<th>Population of primary school age (6-13)</th>
<th>Population of secondary school age (14-17)</th>
<th>Youthful population (15-25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size</td>
<td>225,630</td>
<td>103,843</td>
<td>223,708</td>
</tr>
</tbody>
</table>


5.4.3 Household sizes

The survey established that there were variations in household size in Iveti North as shown in Figure 5.1. According to the Figure, the modal household size in Iveti North Hills is 5 persons, i.e. 24% of those household surveyed had five members. The average household size in the Districts is 4.9 members per household (GoK, 2002). 19% of households had four members, those with six and seven members were 16% each. 12% had nine members. 4% of households had eight members, 4% had twelve members and 3% thirteen members and above. With large household sizes, and considering that a large percentage of the residents rely on farming for their livelihoods, demand for food and settlement is predicted to be on the increase. This is going to have negative implications on the watersheds, since more vegetated land is likely to be cleared to give room for food production.
The effect of high population pressure has already been experienced in the area where fragile ecosystems have been opened up for cultivation and in other cases for settlement. Population growth and its subsequent development of settlements and agricultural activities have destroyed the watersheds and riverines that serve as important water supplies.

Figure 5.1: Household sizes, Source: Field Survey, 2006.

Type of Occupation
Similarly, the occupation of the residents in Iveti North Hills varies considerably. It ranges from farming, business, and civil service to informal employment. 51% of both the residents are farmers while 9% are unemployed as indicated by figure 5.2. In order to earn a living, majority of the unemployed, engage in farming. With 51% of the residents engaged in farming activities, and noting their low academic levels, it is probable that degradation of both watersheds and riverines is likely to persist. The residents have in the recent past indiscriminately cleared vegetation for crop cultivation. The scenario will not be different from the past practice (watershed degradation) unless stringent measures are put in place to reduce the pressure on land.
5.4.4 Water Source

Machakos District lacks adequate water for domestic, livestock, and crop production. Rainfall is inadequate and unreliable while water from dams has not been harnessed. Majority of the population depends on surface and sub-surface dams for water, which often do not hold sufficient water due to high evaporation rates during the dry seasons (GoK, 2002). In an attempt to reduce distance covered in accessing streams to get water, the residents downstream and the urban dwellers have tended to use water obtained from boreholes and dams. Springs and streams represent 75% of the total water sources in Iveti North. The remaining 25% is water obtained from dams and boreholes. The use of dams and boreholes has increased over the past decade. Boreholes have been dug in individual’s farms. Their yields are however low.

5.4.5 Land use

Majority of residents in Machakos District depend on agriculture for their livelihood. The most productive areas are along the hilly terrain with land holdings ranging from 0.5-2 acres. Over cultivation in these lots has left the land bare, exposing it to erosion. This has in turn significantly reduced the agricultural production in the District (GoK, 2002).
The survey established various types of land uses in Iveti North. Generally, land in the area is used for farming, conservation, and grazing. Farming with grazing is practiced by 65% of the population in Iveti North area, (Figure 5.3). Grazing is usually undertaken in uncultivated lands along the riversides. It is undertaken through herding, tethering and zero grazing. Majority of the residents own small livestock numbers. 57% of the residents own two cows, 22% own 3 cows, and 15% of the residents do not own livestock at all. 6% of the residents own more than four cows. The survey establishes a weak linkage between livestock rearing with catchments destruction. This is because, the small numbers of livestock and considering the mode of grazing (either tethering or zero grazing), their impact is practically minimal.

23% of the residents in Iveti area practice arable farming. Only 3% of residents have set aside land planted with trees, whereas 9% of the residents do not undertake any form of land use (figure 5.3). These are the urban residents who do not undertake any agricultural activities.

![Figure 5.3: Land Use in Iveti, Source: Field Survey 2006.](image)

5.4.6 Irrigation Activities

Kenya has a total land area of 58.26 million hectares out of which only 11.65 million hectares (20%) receive medium to high rainfall. Out of the, 11.65 million hectares, 7
million (60%) hectares is used for agricultural production. Out of these, seven (7) million hectares, (60%) of agricultural land, irrigation accounts for about 105,800 hectares (1.5%) as of 2003 (UN, 2006).

In Kenya, agriculture is by far the largest consumer of water. It requires one thousand times more water than we use to drink and one hundred times more than we use to meet basic personal needs. Up to 70% of the water we take from rivers and groundwater goes in to irrigation. The amounts of water required by the different crops depend on the crop water requirements at the differing stages of growth. Most of this water is normally needed at the flowering and fruit formation stage. Irrigation therefore needs 900 Km$^3$ of water per year for food crops and additional for non-food crops (UN, 2006).

The role of irrigation in improving agricultural productivity in Kenya cannot be over-emphasized, despite its massive water consumption. Statistics indicate that large commercial farms account for 40% of irrigated land, while the smallholder farmers and government-managed schemes account for 42% and 18% of irrigated land, respectively (GoK, 2004).

Irrigation-based farming is still very limited in Kenya. It is mainly developed in form of irrigation schemes and large-scale irrigation of some crops such as rice and coffee. The scenario in Iveti North is however different. Individual small scale farmers have developed their own systems of irrigation, especially for export horticultural produce.

The development of irrigation in Kenya is hindered by a number of constraints such as low utilization of water efficient technologies, slow growth in the allocation of permits for the use of water, poor management of irrigation schemes under the government, weather changes and unpredictability that complicates irrigation planning (GoK, 2004). In addition, destruction of catchment areas, surface water degradation and uncontrolled exploitation of groundwater leads to a drop in the water table and an increase in extraction costs. In Iveti North, the most prevalent problem was destruction of catchment areas, lack of efficient irrigation technologies, lack of control in the abstraction of stream water, weather changes and unpredictability of rainfall events complicates irrigation planning.
Irrigation is heavily undertaken in Iveti North Hills. Majority of the farms where irrigation is undertaken are along riverbanks. 55% of residents use the riverbanks to grow vegetables. This is shown in Figure 5.4. In order to ensure that the vegetables planted during the dry season reach full production level, stream water is applied to the farms through furrows. Furrows however waste a lot of water, through seepage to the ground.

![Figure 5.4: Use of riverbanks, Source: Field survey.](image)

Riverbank cultivation is linked to the decline in stream flow that usually occurs downstream in Iveti North Hills, especially during the dry season. Residents draw water from the streams a number of times in a week to irrigate their farms, without any form of control. This happens despite the requirement by the Water Resource Management Authority (WRMA), through Water Act, (2002) that any person abstracting water from a stream, for purpose other than for domestic use, must obtain a permit from the water resources regulatory body. 43% of the residents irrigate their farms twice a week. 14% thrice week and 10% irrigate once a week, as it is shown in Figure 5.5.
The uncontrolled abstraction of water from the streams has reduced the quantities water available to the residents, especially those down-stream, that rely on the streams for their water supply.

Various methods are used to provide water to the farms. Some residents use furrows, others pipes, while others draw water manually from the streams. The number of water intake points has increased in the last one decade. It rose from 7 in 1992 to 37 in 2007, along Kithima River, in a stretch of 8 kilometers. Of the 37 water intake points, 8 have a piped system, while 29 are furrows. Water for Irrigation in Iveti North flows through gravity. The furrows conveying water to the farms vary considerably in length, with some estimated to be about 2.5 kilometers long.

There is no organized plan on how and when farmers using a certain furrow should draw water from the stream. As a consequence, almost all furrows in Iveti North Hills draw water from the streams simultaneously, a phenomenon that has reduced water in the streams and sometimes, even resulted in conflicts among the users. All other streams in the region have several furrows drawing water from them, to irrigate the farms. Ngelani stream has 17 water intake points. 15 of these are furrows while two are piped systems. Furrows have traditionally been used for a long period because they are easy to establish and cheap to construct and maintain. They have a low initial cost as they only require the
farmers to form groups and dig out the furrows. 45% of the farmers irrigate their farms by furrows. This is shown in Figure 5.6 and plate 5.1

Figure 5.6: Methods of irrigation, Source: Field survey, 2006

Plate 5.1: Irrigation Furrow on Terraced Land, Source: Field Survey 2006.

The current irrigation developments have varying efficiencies, mainly due to the losses incurred as water is conveyed to the farm. These losses take the form of leakages through canal embankments and pipe joints, overtopping of canal banks, seepage, evaporation and
transpiration. Within the irrigation farms, large volumes of water is lost through inefficient utilization such as over irrigation, which results in high salt levels when the excess water is not well drained. In piped systems, use of none standardized sprinklers leads to over extraction (UN, 2006).

There has been a low adoption of recent technologies for irrigation, for instance pipes, drip irrigation or sprinkler systems mainly because of the high cost of developing infrastructure. Drip and sprinkler irrigation technologies help increase water productivity. Smallholder drip irrigation systems reduce risks due to the unpredictability of rainfall. It is also an improved soil and water management practice. Drip irrigation, uses a network of perforated plastic tubes that deliver water directly to the roots of plants. It cuts water use by 30-70 percent and increase crop yields by 20-90 percent. Alternatively, sprinkler systems can be explored. The sprinkler is an efficient system with low energy precision application, and drop tubes extending vertically from the sprinkler arm. These tubes deliver water much closer to the plants, reducing evaporation losses. These systems can produce water savings by 25-37 percent compared with conventional furrow irrigation.

5.4.7 Water Conveyance to the Farm

There are problems experienced in conveyance of water to the farms. 22% of those that irrigate their farms cite excess seepage of water to the ground from canals to be a major draw back. Water is lost from the furrows because their base is not waterproof. Water seeping to the ground is usually unaccounted for and therefore reduces the amount of water reaching the farm. Consequently, farmers in Iveti North Hills are compelled to abstract more water from the stream in order to ensure water reaches the farm in adequate quantities. The continued use of ditches for irrigation results from the financial inability to purchase pipes that are more efficient in water deliveries to the farms. Pipes can last for several years without replacement since they are placed under the ground, and chances of braking are minimal. 8% of farmers doing irrigation cite the big number of people doing irrigation to be lowering the amount of water that reaches the farm. This is compounded by the fact that
the majority of farmers use furrow method of irrigation (45%), a method that loses a lot of water to the ground through seepage. With increase in number of water users for irrigation, reduction in stream volumes in Iveti North will continue to be experienced.

5.4.8 Riverbank Cultivation

The Kenya Forest Service, through a letter dated September 2004 called for zoning out of springs to act as a buffer. It also required all degraded catchment areas to be rehabilitated through planting of appropriate indigenous tree species. Natural regeneration of indigenous tree species was also encouraged to occur. The Forest Service clearly ruled that neither exotic tree species nor plantation blocks should be planted in these sensitive areas nor be established in areas conserved and managed as water catchments. Priority in planting of trees in the riverbanks should be given to indigenous trees. Past research has shown indigenous tree species to be good conservers of water than exotics. The Athi Regional Water Resource Management Authority is experimenting on the planting of bamboo tree species in the riverines as they consume less water.

Despite this requirement by the government, eucalyptus tree species (exotics) are predominantly planted in Iveti North. It is mostly planted on private plots and along the riverines. Eucalyptus was introduced because of its rapid growth and productivity. In one year, total biomass produced is greater than many of the slower growing native species. Prabhakar (1998), notes that in an eight year rotation, the mean annual growth of eucalyptus per hectare, is about 8 cubic metres (cu.m.), though it has been known to reach as much as 40 cu.m, while for indigenous trees, the average is 0.50 cu.m. This overall high productivity needs a greater overall water demand. According to statistics by Machakos District Forest Office, Eucalyptus is estimated to consist of 75% of all the vegetation in Iveti hills.

Research done in India for example show, that Eucalyptus tree species use large volumes of water thereby reducing water available for other species, Prabhakar (1998), effectively out-competing them. In arid areas, eucalyptus suppresses other plant life. This, coupled
with a high water demand, reduces soil moisture, reducing groundwater recharge and subsequently lowering local water tables.

Introduction of the high water consuming eucalyptus tree species destroys the hydrological balance of an area and contributes to increased aridity and soil erosion (Shiva, 1983). Eucalyptus has an ability to extract water from the soil, even when soil moisture tension is higher than that at which mesophytic plants extract water. Their transpiration rates remain high even when water supply from the soil is dwindling.

Going by experience from these regions, the eucalyptus tree species in Iveti hills are thought to reduce ground water levels. The reduction in ground water subsequently reduces spring and stream yields, therefore diminishing the local water supplies. 48% of the residents in Iveti North Hills were found to have planted eucalyptus trees in their farms, boundaries and in the riverines, as indicated in Figure 5.7.

![Figure 5.7: Tree Species, Source: Field survey, 2007.](image)

Though the decline in streams flow in Iveti Hills cannot singly be linked to the planting of eucalyptus, residents tend to believe that eucalyptus has, in addition to increased settlement and cultivation caused a reduction in stream flow. Mr. Jastus Muisyo for
instance was clear that in the year's before 1960, when the eucalyptus had been predominantly planted, the volume of water in the streams was high and streams were never seasonal.

Despite the scientific evidence that eucalyptus is a high consumer of water, both increased and indiscriminate planting of eucalyptus is expected to continue in future, unless awareness is undertaken among the public in Iveti on its consequences.

41% of the residents have however not planted any tree in their farms. They have utilized their farms for subsistence and cash crop farming. Land remains bare most of the time over the year when not planted with crops. Absence of trees indicates that, moisture is never retained in the ground. Almost all the moisture drains as run off and therefore ground recharge is usually minimal. This has subsequently affected streams and other water bodies.

5.4.9 Anthropogenic Activities
Watersheds are important ecosystems in the hydrological cycle. Anthropogenic activities have however lowered the value of these ecosystems. Watershed degradation in Iveti North can be attributed to various factors. 34% of the residents consider watershed degradation to be caused by a combination of factors that included sand harvesting, destruction of watersheds, population growth, poverty, and over abstraction of water for agriculture. Catchment degradation in Iveti can also be linked to the demand for firewood and wood resources. Trees in the riverines are often cut to provide firewood and charcoal for cooking. This view is held by 6% of residents. In Iveti North, firewood is used by over 83% of the residents. Charcoal burning accounts for 2%. Those that use a combination of charcoal, firewood and paraffin represent 15% of the total population. 57% of residents using firewood get it from private plots, 22% collect wood from natural bush, while 21% of residents either buys firewood or trees for firewood harvesting. Those who buy firewood do not own trees in their farms and therefore their land is usually bare, except for the crops grown during the rain season.
Indiscriminate clearance of vegetation for crop cultivation and settlement has left the land bare, exposing the soil to erosion especially due to heavy rainfall, and strong winds. Lack of knowledge on the values of watershed is attributed to the destruction and degradation of watersheds. To the majority of the residents, watersheds are potential agricultural areas that should be cleared for farming. People who own land adjacent to riversides consider themselves lucky and wealthier than their counterparts who do not own land in the riverbanks. Given these kind of perception, and the low levels of understanding on the values of watersheds (19% are not aware of their values), the fragile ecological areas are at a risk of destruction and disappearance all together. There has been an increased demand for land as a result of the increased population growth. With increase in the number of people, there is demand for land for cultivation to meet food demands for the large numbers of people.

Sand Harvesting

Sand harvesting is partly believed to be the cause of riverbank destruction in Iveti North Hills. In order to address the problems associated with sand harvesting, the National Environment Management Authority (NEMA) has established guidelines for sand harvesting. It has identified the factors that cause and contribute to environmental degradation. The factors identified range from uncoordinated sand harvesting activities, inadequate enforcement of existing legal provisions on resource use, inadequate environmental awareness and sensitization, policy conflicts in natural resource management, unsustainable resource exploitation, and lack of integration of sustainable use principles in management strategies to inequitable distribution of benefits accruing from resource exploitation. General illegal sand harvesting tendencies like cess evasion, sand harvesting at night, destruction of peoples’ farms and payment of wages below the recommended government minimum wage, are also blamed for the degradation of the area.

As a requirement, each District in Kenya is supposed to have a District Environment Committee. The Committee is charged with the responsibility of appointing a District Sand Harvesting Committee. The District Sand Harvesting Committee is mandated to
ensure that sand dams are constructed in designated sites, ensure that Lorries use designated access roads to sites, sand harvesting sites are re-filled and appropriate vegetation replanted. In addition, Sand Harvesting Committees should ensure social considerations are taken in to account in the management of harvesting areas. The committees should ensure that licensed dealers pay minimum government regulated wage to sand loaders and that proceeds of sand cess or revenue collected by the local authority are reinvested in to local community projects. The District sand harvesting committees are also required to establish local riparian resource management unit, charged with sustainable management of sand harvesting within its jurisdiction. In line with these guidelines, NEMA has also introduced an approval system to control sand harvesting. According to the guidelines, the owner of a parcel of land where sand is harvested is supposed to apply for a license to harvest sand, and a transporter to apply for a permit to transport the sand. NEMA is also mandated to suspend or cancel a permit to transport sand, suspend/cancel a license to harvest sand and also issues a certificate of compliance to environmental restoration, for those who comply. These regulations are however recent and have not yet been gazetted. Consequently sand harvesting continues to be undertaken illegally in Iveti North, and the degradation of river banks still continue. The effect of controls are yet to be realized as at the time of this study none had been put in place in Iveti. Sand harvesters carry their business without permits. In addition, no action has been taken to rehabilitate areas that have been degraded by sand harvesting.

Sand harvesting destroys riverbanks and lowers their role as water sources. Water is usually stored in pores between sand particles. Removal of sand through illegal harvesting exposes the water in the streams to evaporation especially during the dry season of the year. 4% of residents in Iveti North link the reduction in stream flow to sand harvesting. Sand harvesting in Iveti usually occurs where a bridge crosses a stream, or where a stream is accessible, using a road, as shown in plate 5.2. Sand is also packed into sacks and transported to the nearby road where it is loaded to trucks. The study established that land owners allow sand to be harvested is due to the financial incentive they get from the purchasers.
Sand is harvested for local use and also for use outside the region. Sand harvested from the streams is transported to Njiru and Ruai for temporary storage, particularly during rain season when sand is in abundant supplies. It is later transported to Nairobi where demand is high. Sand in Iveti North is harvested by groups called ‘bands’ with one band comprising of five to six men. Sand is purchased from the harvesters at a price of Ksh 1200 per 7 tonne lorry. A lorry loaded with sand is sold in Nairobi at a price 10 times the purchasing price. In order to make as much money as possible each day, sand harvesters dig as much sand as possible, further exposing the river banks and degrading the riverines, the sources of water. Though some residents are aware that scooping of sand exposes the streams to the sun which subsequently dries them up, they cannot stop the harvesting since the river banks are privately owned. Attempts to stop sand harvesting have been perceived as intrusion to private property. In other cases, attempts by the area chiefs (both for Mitaboni and Ngelani) to terminate sand harvesting were received with hostility by both landowners and the sand harvesters.

Perhaps the greatest reason why some farmers have not yet acted to improve the management of land next to streams in the waterway is the lack of understanding on the impact of farming activities and sand harvesting. Without that understanding landowners are neither motivated nor equipped to apply appropriate management techniques that are necessary to make a difference.

5.5 Effects of Watershed Degradation

Degradation of watersheds has various implications. It is believed that reduction in stream flow results in time wastage in search of water. Watershed degradation is also linked to minor water scarcity triggered conflict that usually hit Iveti North area, especially during the dry spell of the year (January- March and September-November). Residents attribute reduction in stream flow in the area to the destruction of catchments. 64% of the residents consider reduction in stream flow to be associated with destruction of watersheds. Residents up stream have for the past decade settled, cultivated and grazed in the water catchments.

There was a general view from the survey that land initially covered with vegetation has been cleared and instead used for cultivation of vegetables through irrigation. Residents accuse irrigation for its excessive use of water that has resulted in water shortage in the streams. This problem is highly experienced during dry periods when water is abstracted for irrigation. Residents downstream who spend extra time walking, covering long distance in search of water experience this problem most.

3% of residents attribute siltation of rivers to soil erosion in the catchment areas. Erosion has occurred in farms cultivated on steep slopes where conservation measures have been undertaken. It also occurs in the bare land, when farms are cultivated.

Minor conflicts often occur over water, especially in the dry periods, though the magnitude of the fights is minimal. The conflicts are associated with decline in water supply. In other cases, destruction of property was reported. Residents downstream feel that stream-water hardly reaches them as a result excessive abstraction by individuals using both furrows and pipes for irrigation. It is argued that some residents downstream gang-up at night and smash the pipes, since most of the pipes are made of plastic. They also dig up and destroy the furrows. This usually results in tension between up stream and down-stream residents. In other cases fights break up. 2% of residents believe the conflicts are linked to destruction of catchments.
5.6 Catchment Management Measures

5.6.1 Terraces

Various catchment management measures have been undertaken in Iveti North. They comprise of “fanya juu” terracing, cut off drains, planting of both trees and napier grass. These measures have been widely adopted in the area. This has been so, mainly because the Department of Agriculture has been very active, advocating for their adoption. Terraces have been constructed as ditches across the slope, therefore decreasing the length of the slope, by dividing the slope to shorter stretches. They are made by leveling the ground or through continuous use of grass strips and trash lines. The level pieces of land across the farm control soil erosion. Bench terraces are mostly preferred in Iveti. They have changed the degree of slope, thereby reducing the speed of runoff water, thus increasing the ability of water to percolate to the ground. Terracing (plate 5.3) is the most popular soil conservation measure in Iveti North. It is undertaken by 41% of the residents.

Plate 5.3: Terraces on the Hill slopes, Source: Field survey 2006.

In addition, some residents have dug cut-off drains to control watershed degradation. These are open trenches made at the upper part of the farm to collect water and direct it into an existing natural waterway. Cut-off drains have been dug at 2 feet width, and one
foot deep, along the upper boundary of the farms. In “fanya juu” terracing, the top terrace has been constructed as a cut off drain, with the soil being thrown down the slope so that the channel can carry as much water as possible. Cut off drains are used to control large volumes of water flow coming from outside the farm. Cut off drains are dug where there is evidence of large water flows that cannot be stopped through normal terracing. Usually only one cut of drain is required on a slope.

5.6.2 Agro-forestry

Trees have also been planted on the farms separately as wood lots or through agro-forestry. Technically, agro-forestry is promoted for the reason that it improves the production of land. Some trees add nutrients to the soil. Agro-forestry trees assist in soil conservation, where their roots hold soil together and for that reason, runoff water cannot easily carry away the top soil. Tree cover reduces the force by which raindrops hit the ground, hence reducing soil erosion. Moreover, leaves that fall on the ground from the trees provide soil cover, which prevents the run-off from taking away the top particles.

Various combinations of tree and crops and/or pasture when planted together, check the soil against erosion. Alternate rows of trees and crops are planted in widely spaced rows between which food crops are grown for instance rows of leucaenia spp., with maize. In boundary planting, as shown in plate 5.4, trees are planted along the farm boundaries. In addition to marking the boundaries; the trees act as hedge and windbreaks. Some trees are left on the cropland during land preparation. In other cases, trees are randomly planted in the cropland. Some of these trees could be fruit trees or fodder. Agro-forestry trees are also planted in the pasture either in rows or at random. These trees provide shade for animals. The animals also can eat some of these plants. When planted in rows, they act as life fences for example Kei-apple, croton spp., and leucaenia spp.
Plate 5.4: Trees planted on farm boundary lines, Source: Field survey, 2006.

According to the Ministry of Agriculture, all ecologically sensitive systems should be protected. Springs, riverines, hillsides, steep slopes and fragile water catchments should all be conserved. The ministry advocates for the planting of napier grass along riverbanks and other ecologically sensitive areas like springs. Napier grass is planted in the farms, especially along the terraces where it holds soil in place so that the terraces remain stable. Protected riverbanks ensure consistent flow of water in the river.

In order to protect a riverbank, vegetation should be left growing on both sides of the river. In an attempt to conserve both soil and water, residents have planted napier grass. 10% of the residents have planted napier grass. Not all terraces have been planted with Napier grass. 16% of the residents have not undertaken any conservation measures in their farms, as indicated in Figure 5.8. Consequently, both soil and water degradation has occurred in such lands. This has a subsequent impact on the watersheds. Lack of conservation measures reduces the infiltration of rain water, therefore reducing the recharge of ground water. This in effect has reduced stream water yields in Iveti north yields.
Furthermore, despite the requirement by the government to plant trees in the riverbanks as a check against soil erosion, and for sustainable water supply, 47% of residents have
not planted trees in their farms, (Figure 5.9). Riverbanks have therefore been exposed to erosion as it partly evidenced by sand deposited downstream.

![Diagram showing the percentage distribution of trees planted along boundary lines](attachment://image.png)

**Figure 5.9: Farms planted with trees, Source: Field Survey, 2006**

5.7 Watershed Management Approaches.

There is a range of catchment management approaches. They include catchment management at community level, planning at watershed level, planning in micro-catchment level, and planning at stakeholder level. These have all been undertaken by the African Highland Initiative (AHI) in an attempt to manage catchments in mountainous areas in East and Central Africa. The African Highland Initiative is a research organization that has undertaken a lot of studies on various measures of catchment management. This survey borrows heavily from these approaches in order to ensure rational watershed utilization in Iveti North area. These measures if adopted in Iveti will ensure sustainable management of the catchments.

**On-Site Planning**

Planning at this stage utilizes focused group discussions for diagnosis of watershed problems. Participatory ranking and prioritization of the problems follow in sequence. Spatial and historical analysis of the area is done to provide an indication of how diverse
landscape problems are linked. The site team then scrutinizes issues for structuring development interventions. This approach is of importance to Iveti area. It will determine all the problems and issues that together cause watershed degradation in the area. It will also rank the problems in accordance to perceived weight for their effective management and magnitude of the problems. Based on this ranking, stakeholders will be able to address an issue that is of greatest concern.

**Planning at Watershed Level**

This method identifies representatives of all villages in the watershed. This approach not only minimizes costs (i.e. time spent in planning) for both farmers and researchers, it also minimizes the number of participants who realistically participate. Close attention is given to those who participate, and to mechanisms through which the larger community contribute to this process. Planning at catchment level ensures that feedback information enable widespread participation and understanding of watershed problems and solutions. It also enables more detailed planning than what is possible from a single planning event. This approach is crucial in Iveti North area, considering that there are many stakeholders who have an interest in the area. The farmers for instance draw water from the streams, the urban dwellers depend on water from the stream for domestic use, the Ministry of Agriculture is concerned with use of similar water for increased food production, Ministry of Water Irrigation concerned with water conservation and development and NEMA , has responsibility to coordinate the activities of different actors in an area.

**Planning at Micro-Catchments level**

This approach advocates for integrated interventions within micro-catchments. It fosters positive synergies between system components (crops, trees, livestock, soil, water). For instance soil erosion on hillsides in Iveti (exacerbated through the use of metal roofing), coverage of fertile valley bottom soils with infertile soil from hillsides (with dramatic effects on yields of cash crops), and declining water discharge from springs. These efforts can jointly be addressed through water harvesting from rooftops for domestic use, soil conservation measures and negotiation of by-laws to govern the drainage of water from hillsides. All sources of streams are regarded as a micro-catchment for the sake of this
Residents are encouraged to undertake soil and riverbank conservation measures in their spatial areas. Conservation at micro-catchment level in Iveti will amount to the resolution of the root problems by emphasizing on certain conservation measures.

**Stakeholder-Based Planning**

This approach is based on the stakeholder concept, where actors with divergent interests or "stakes" come together to negotiate solutions for their mutual benefit. The approach involves an identification of watershed problems, identification of stakeholder groups (i.e. those perceived to be causing the problem, and those affected), and creation of an opportunity for the stakeholders to come together and negotiate more optimal solutions to the problem so that neither party is overly affected. This approach is fundamental for Iveti North for the reason that the stakeholder forums will provide important avenues where water rights of all stakeholders will be discussed. It is also in these stakeholder forums that actors will share on the various measures for sustainable catchment management.
6.0 Conclusion and Recommendations

6.1 Findings and Conclusion
The survey established that there was destruction of watershed in Iveti North. This degradation can be attributed to the reduction in stream water supplies in Iveti. The destruction of watersheds can partly be attributed to the shabby implementation of policies and legislations on watershed management. Destruction of catchments and reduction in stream water can also be linked to anthropogenic activities in Iveti North Hills. The riverines and steep slopes have been cleared for agricultural development with horticulture being the predominant farming activity. Irrigation is undertaken without any control and has often resulted in drying up of rivers and streams. Stream water is abstracted for irrigation without considering the right of downstream residents to use similar water or the requirements by Water Resource Management Authorities who have placed conditions for abstraction of water for purposes other than domestic.

Illegal sand harvesting is also prevalent in the streams in Iveti North that is blamed for the decline in stream flow. Removal of sand exposes the stream to excessive evaporation from the sun. This dries up the stream especially during the dry spells of the year. The survey further notes that degradation of watersheds will continue in Iveti, if unchecked. This is anticipated to complicate watershed degradation in Iveti North and probably result in severe economic difficulties.

6.2 Recommendations
Based on the issues identified in the survey, the study offers various strategies, that if adopted will address and/or reduce watershed degradation in Iveti North Hills.

Comprehensive implementation of the Water Act.
The clause that requires persons drawing water from streams to obtain permits from Water Resource Management Authorities should fully be implemented. Since the farmers abstract water from the streams without any control, the permit system will help regulate the amount of water abstracted. The permits should indicate the maximum amount of water that can be abstracted from the stream at any particular time. In order to avoid
wastage of water, a metering system should be adopted. People will have to pay for all the water they abstract from the stream.

- Immediate formation of catchment and micro-catchment management committees with, actual representation and participation of the local communities.

Provide advice on management of waterways

Develop an information system to provide advice to farmers about how they should manage their land. Information about the sources, causes and processes involved in deterioration of streams in farmed catchments and consequences of that deterioration should be well defined.

Education campaigns.

It is necessary to undertake additional education campaigns to educate the residents on new catchment management practices in Iveti North area. In addition, the public should also be educated on their water rights and other aspects related to water access. This will enable them seek court redress incase their rights are infringed, for instance if an individual abstracts all water in the stream at the expense of downstream residents.

Restore river and stream ecosystems.

- Riverbanks and streams should be restored and rehabilitated for their critical values. Particular focus on the restoration initiative should be to establish a native forest corridor along the streams. Planting of bamboo tree species should also encouraged because they consume less water, whereas the development of exotic plantation blocks should be discouraged, because of their high water consumption rates.

- The National Environment Management Authority (NEMA) should ensure that sand harvesting committees are formed to oversee and regulate sand harvesting in the area.

- Vigorous efforts should be made to protect the water catchments areas around the Hills through Reafforestation campaigns to restore tree cover on individual farms
Explore alternative sources of income
Alternative sources of income should be explored in order to reduce the current pressure on riverbank. Specifically, the Constituency Development Fund (CDF), the Youth Development Fund and the newly created Women Fund can provide loans to the residents for starting small businesses. This will reduce reliance on farming.

Irrigation efficiency
- Water deficit irrigation should be promoted. This can be achieved by providing less than full irrigation requirements, and supplemental irrigation, which uses limited irrigation at critical periods to supplement rainfall.
- Water efficient conveyance techniques should be developed and promoted. This can be achieved by the use water-saving technologies such as canal lining, gravitation through pipes and storage in overhead tanks to facilitate the use of drip irrigation.

Promote water-harvesting technology
Promote rainwater-harvesting technology on farms. This will reduce reliance on river resources, especially for the downstream residents who often lack water. These technologies will include roof catchments, water holes, dams, runoff diversion from roads, and a limited boreholes program (maintained and managed by the user associations or other groups).

Ensure water use efficiency
There is need to improve water efficiency in the catchments. Some pertinent measures include:
- Development of new crop varieties with higher yields per unit of water - for example, crops with comparable yields but shorter growth periods.
- Switch to crops that consume less water or use water more efficiently.
- Improve reliability of water supplies at critical crop periods, e.g. at flowering stage. This will encourage farmers to invest more in other inputs and lead to higher outputs per unit of water.
Explore Alternative Sources of Energy

- There is need to aggressively promote energy conservation technologies for households, as a way of reducing demand on wood and wood related resources. Energy saving stoves should be encouraged in Iveti in order to reduce the recent pressure on wood resources and for the conservation of forest and other forms of vegetation.

- There is need to replenish wood fuel resources through promotion of appropriate tree species and planting arrangements as a way of increasing available supply.

Other management practices include:

- Construct check dams across the streams to trap large amounts of run off. This can be channeled to fields or stored for later use. The small dams upstream stabilize river flows in addition to providing opportunities for irrigation.

- Developing new stakeholder- controlled scheme management that will run the affairs of the schemes for water supply and infrastructure maintenance.

- Changing modalities for irrigation from furrow systems to piped gravity-fed water intakes, which lend themselves to low levels of management.

- Review and implement the Irrigation and Drainage Policy. The public sector and stakeholders' roles in water management systems in existing and new irrigation schemes should be defined. Water-saving systems in new and existing irrigation schemes will be enforced to ensure sustainability.

6.3 Areas for further research

The survey established some areas that should be researched further. More studies should be undertaken to determine the effects of planting eucalyptus trees species in watersheds and riverines. The studies should adopt a comparative approach between eucalyptus, and other exotic trees against indigenous species. They should clearly identify the best species for planting in watersheds and catchments.
<table>
<thead>
<tr>
<th>Objective</th>
<th>Problem</th>
<th>Strategy</th>
<th>Activity</th>
<th>Time frame</th>
<th>Actor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causes and the effects of watershed degradation</td>
<td>Cultivation on riverines</td>
<td>• Enforce the various policies and legislations that deal with watersheds and hillsides. • Undertake soil and water conservation measures</td>
<td>• Formation catchment management committees. • More vigilance by the water officers. • Prohibit cultivation of riverines • Prohibit cultivation on steep slopes</td>
<td>Long-term</td>
<td>MOW, MOA, Forest Service, NEMA, Local NGOs, CBOs, Local residents, WRMA</td>
</tr>
<tr>
<td>Lack of soil and water conservation measures.</td>
<td></td>
<td>• Create Public Awareness</td>
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<td></td>
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<tr>
<td>Lack of awareness on</td>
<td></td>
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<tr>
<td>The values of watersheds.</td>
<td>Awareness on the importance of watersheds.</td>
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<td></td>
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</tr>
<tr>
<td>Felling of trees on riverines and hillsides for fuel wood</td>
<td>- Plant trees on riverines, watersheds and in the farms.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Indiscriminate planting exotic trees in the watersheds.</td>
<td>- Explore alternative sources of energy to reduce reliance on fuel wood.</td>
<td></td>
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<tr>
<td>Cultivation on</td>
<td>- Discourage planting of exotic trees on watersheds and riverines.</td>
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<tr>
<td></td>
<td>- Explore alternative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riverine degradation due to lack of alternative sources of income</td>
<td>Inefficient irrigation strategies.</td>
<td>Adopt water conserving irrigation systems.</td>
<td>Adopt the use of pipes for conveying water from the streams to the farms. Use the efficient sprinkler and drip irrigation systems.</td>
<td>Long-term</td>
<td>WRMA MOW Forest service Local communities</td>
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<tr>
<td>To determine the measures that the community is using to address watershed degradation.</td>
<td>The measures adopted by the community have not fully addressed watershed degradation.</td>
<td>Explore various soil conservation measures.</td>
<td>The residents to adopt various measures to address watershed degradation e.g. Planting of bamboo on riverines, conservation of riverines, etc.</td>
<td>Long-term</td>
<td>WRMA MOW Forest service Local communities</td>
</tr>
</tbody>
</table>
References


wwdrii.sr.unh.edu/; UN/WWAP 2006, UN World, Wikipedia, the free encyclopedia.
Appendix I
Household questionnaire

Kenyatta University
School of Environmental Studies and Human Sciences
Department of Environmental Planning, Management and Community Development

Integrated Watershed Management (IWM) for Improved Water Supply in Iveti North Hills, Machakos District.

Questionnaire no…………………………

Background information

1) Please answer the following questions

<table>
<thead>
<tr>
<th>Household member</th>
<th>Level of education</th>
<th>Occupation</th>
<th>House hold size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Father</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2) Form of land tenure

<table>
<thead>
<tr>
<th>Form of land tenure</th>
<th>Size of land</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Private</td>
<td></td>
</tr>
<tr>
<td>b. Communal</td>
<td></td>
</tr>
<tr>
<td>c. Leasehold</td>
<td></td>
</tr>
<tr>
<td>d. Government land</td>
<td></td>
</tr>
</tbody>
</table>

3) In order of preference, how do you utilize your land? , for

a. Farming
b. Grazing
c. Farrow
d. Conservation
e. Both grazing and Farming
f. None
4) How many of these animals do your rear

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>Number</th>
<th>Method of grazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Cattle</td>
<td>i. 1-2</td>
<td>i. Zero grazing</td>
</tr>
<tr>
<td></td>
<td>ii. 2-4</td>
<td>ii. Tethering</td>
</tr>
<tr>
<td></td>
<td>iii. 5&lt;</td>
<td>iii. Herding</td>
</tr>
<tr>
<td>ii. Sheep</td>
<td>i. 1-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii. 2-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii. 5&lt;</td>
<td></td>
</tr>
<tr>
<td>iii. Goats</td>
<td>i. 1-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii. 2-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii. 5&lt;</td>
<td></td>
</tr>
</tbody>
</table>

5) For what purpose do you utilize the riverbank?
   i. Vegetable farming
   ii. Farrow/uncultivated land
   iii. Grazing
   iv. No land adjoining a stream.
   v. Combination of grazing and farming

6) In your opinion what should be done to enhance the value of riverbanks?

7) Type of energy  | Source of firewood | Fuel wood problems | Solutions |
-------------------|--------------------|--------------------|-----------|
a. Firewood        | a. Natural bush    |                    |           |
b. Charcoal        | b. Trees in my lot |                    |           |
c. Both charcoal, paraffin and electricity | c. Buying           |                    |           |
d. Electricity     |                    |                    |           |
e. LPG gas f. Paraffin |                    |                    |           |
8) If having a wood lot in your farm, what is the size of the lot?
   a. 1/16
   b. 1/8-1/4
   c. ½
   d. >1/2
   e. Planted along boundary lines
   f. None

9) Which tree species have you planted in the lot?
   a. Eucalyptus
   b. Gravel lie
   c. Both gravelier and eucalyptus
   d. None

10) If doing irrigation which problems do you experience in the conveyance of water from the river to the farm?

<table>
<thead>
<tr>
<th>Source of water</th>
<th>Use</th>
<th>Domestic: Volume per day</th>
<th>Rate of irrigation</th>
<th>Method of irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Spring</td>
<td>b. Watering</td>
<td>b. 5-8</td>
<td>b. Twice</td>
<td>b. Furrow</td>
</tr>
<tr>
<td>c. Bore hole</td>
<td>b. Watering</td>
<td>b. 5-8</td>
<td>c. Thrice</td>
<td>c. Jerricans/manual</td>
</tr>
<tr>
<td>d. Water tank</td>
<td>c. Domestic use</td>
<td>c. 9-15</td>
<td>d. Quadruple</td>
<td>d. None</td>
</tr>
<tr>
<td>e. Dam</td>
<td>d. Combination</td>
<td>d. Over 15</td>
<td>e. Daily</td>
<td></td>
</tr>
<tr>
<td>f. A combination</td>
<td></td>
<td></td>
<td>f. When it is</td>
<td></td>
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<td></td>
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11) If doing irrigation which problems do you experience in the conveyance of water from the river to the farm?
   a. Seeping to the ground
   b. Conflict over water
   c. Decreasing water quantities
   d. Many people in need of water
12) How do you think the problems in (12) above can be addressed?

13) What is the trend in stream base flow annually for the last two decades?
   i. Increasing
   ii. Decreasing

14) If decreasing, what is causing the reduction?
   a. Over abstraction for agriculture
   b. Destruction of watersheds
   c. Destruction of river banks
   d. Increased domestic use
   e. Replacement of indigenous tree species with exotics.
   f. Sand harvesting
   g. Combination

15) In your opinion, how can the problem (decrease) above be addressed?

16) Which measures have you put in place to address soil degradation in the area?
   i. Strip cropping
   ii. Contour ploughing
   iii. Construction of gabions
   iv. Terracing
   v. Agro forestry
   vi. Planting of cover crops
   vii. Planting of trees
   viii. Planting Napier grass
   ix. Combination
   x. None
17) Are the measures in (17) above adequate?
   i. Yes
   ii. No
18) If no in (18) above, suggest reasons why you think the measures are not adequate?
19) What, in your opinion, can be done to effectively conserve the soil?
20) What are the causes of watershed degradation in this area?
   a. Population growth
   b. Uncontrolled destruction of vegetation cover
   c. Demand for more land for agriculture.
   d. More demand for firewood and other wood products
   e. Lack of knowledge on the values of watersheds
   f. Poverty
   g. Sand harvesting
   h. Combination of problems
21) What are the effects of watershed degradation in the area?
   a. Reduction in stream base flow
   b. Increased soil erosion
   c. Time wastage in search of water
   d. Longer distances to water resources
   e. Conflict over water resource.
   f. Combination of effects
22) In your opinion, what should be done to effectively control watershed degradation in this area?
23) Is there a catchment management committee in this area?
Appendix II

Interview schedule

Kenyatta University
School of Environmental Studies and Human Sciences
Department of Environmental Planning Management and Community Development

1) What is your role in watershed management?
2) What is the status of catchments and streams in the Division and location?
3) What causes watershed degradation?
4) Can you give a list of measures that have been adopted to address catchment degradation?
5) Why have policies as well as other conventional measures not effectively and adequately addressed catchment degradation?
6) What should be done to effectively conserve the catchments?
7) What has been the trend in water supply over the past decades?
8) What are the effects of catchment destruction in an area?
9) How can these effects, in (14) above be addressed/resolved?
10) In what ways is the public involved in the management of catchments?
11) To what extent have the catchment management committees been successful in the management of catchment?