EFFECTS OF DAMMING ON THE SOSIANI RIVER ECOSYSTEM: AN ENVIRONMENTAL IMPACT ASSESSMENT

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DECLARATION

This Thesis is my original work and has not been presented for a degree in any other University

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This Thesis has been submitted for examination with my approval as the University Supervisor

....
GEORGE S. ONGWENYI

DEDICATION

To my beloved wife ***Hellen*** and daughter ***Deckillah*** for their love and patience throughout the many days I was away from them.

ABSTRACT

The aim of this study was to analyze the changes in vegetation mosaic and patter arising from the construction of the Two River Dam found West of Eldoret Town. T accomplish this, it was necessary to study the behaviour of similar species (indicat species) both at the dam and below it. Since the two study areas were within the san agro-ecological zone, the major determining variable in the study was thus the wat quantity and quality.

The water quality aspect was determined by the quality of industrial effluents discharge into the river after treatment by the two treatment plants (Quarry sewage treatme works and the Eldoret west sewage treatment works) in the town, and the stipulate dilution water as set by the Kenya Bureau of Standards. Agro-chemicals were als considered as chemicals that can affect plants growth.

During the study it was found out that the stipulated dilution water from the dam of 5,75 M^3/day was not met . Also the two treatment works were inefficient such that the wat returned into the river was polluted above the set standards The riparian vegetatio below the dam was exposed to water stress qualitatively and quantitatively. At the da the vegetation was exposed to all year round high water levels that was relative unpolluted.

The indicator species (*Pennisetum clandestinum, Acacia nilotica* and *Carissa eduli* exhibited in the two study zones significant variations in certain aspects especial biomass and similar characteristics in other observable variables especially height plants, leaf area index, cover and composition. Explanations were thus adduced verify the observations and this tallied with other researches done previously (Oding 1979, Mwendwa 1984, Karr 1978) though in other areas. The plants were found to hav

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The work reported here would not have been achieved without the patience, love and encouragement from my wife *Hellen,* and my daughter *Deckillah.*

adapted to the prevailing conditions which it was concluded had not reached a level to cause extinction.

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CHAPTER 1: General Considerations

1.1 INTRODUCTION

This being an environmental study, it is important at the onset to define what we mean by the term environment. Dasman (1984) considers the environment to refer to the biosphere, the ecosystems of which it is composed, and the modifications of these brought about by human action. Dasman further defines the ecosystems as the sub-divisions of the biosphere consisting of communities of plants, animals and microorganisms along with the air, water, soil or other substrates that support them.

The maintenance of the environment in its unperturbed self acquired natural state and thus its quality, though it is clear, that the environmental state is not static but can be stable, is due to a combination of various unique and other mutually inter-related factors that nearly always provide a negative feed-back mechanism. Here feedback is the control of inputs as a function of output and in the case of negative feedback an increase (or decrease) in an initial value causes eventually a decrease (or increase) in another value. Positive feedback on the other hand, operates to emphasize the direction and the rate of change rather than to stop it. Both types of feedback mechanisms operate in natural ecosystems but it is the negative feedback mechanism, which attempts to remove disturbances (Pears, 1985). The feedback mechanism enables the system to maintain itself in a state of dynamic equilibrium, in spite of variations in the surrounding environment and hence of the inputs to the system. Provided the fluctuations are not so great as to exceed the limit of tolerance of the ecosystem, negative feedback mechanism operates to maintain the system in equilibrium. Environmental quality is therefore related to both biotic and abiotic factors.

From the above theory on feedback mechanism it becomes clear that the removal, reduction, and/or change of state etc of a unit or units or the change in physical factors (e.g. nuclear emission effects, acid rain) that help to sustain this steady-state concept is bound to affect the environment both quantitatively and qualitatively. Examples relevant to this study will be cited later. Any type of environmental deterioration is a concern of ecologists. Deterioration which results from selective exploitation affecting the equilibrium may end in a positive feedback mechanism which is nearly always destructive and is not only caused by rapid growth of human population (and the associated ever increasing demand for natural resources which are free to be exploited at will due to ecological dominance) and industrial activity but also by natural processes (e.g. earthquakes, floods, drought,). Widespread and systematic concern about environmental issues is relatively recent and it is therefore difficult to obtain reliable evidence on environmental trends extending back more than a few years. The question that is now being asked is whether environmental abuses can lead to local and planetary catastrophes and if it is possible to arrest or control these activities so that the global ecosystem can remain at a steady-state equilibrium. This concept will now be briefly developed from a historical point of view so, as not only to give a clear picture but also to pinpoint who and how all present efforts can be co-ordinated to reach a common goal. However, only important aspects will be highlighted at this juncture.

The basis of all environmental abuse assessment can be traced to the concept of the ecosystem. According to Tivy and O'hare (1987) the ecosystem is a set of interacting, interdependent living (organic or biotic) and non-living (inorganic or abiotic) components or sub-systems. It is a neat, concise term originally coined to convey the idea of a group of organisms and the place or habitat they occupy, and the way the two are linked together to form a working or a functioning unit. It is therefore clear that the indiscriminate interference of one or more units forces the system to adapt, strain or collapse. Munn, (1975) notes that predominant species tend to provide a larger number of checks and balances within an ecosystem.

However man's anatomical and mental characteristics have in totality enabled him to exert a greater effect on the environment than any other organism. Being numerically more abundant and occupying the highest trophic level, he exploits all other trophic levels for his needs and demands which are themselves quite diverse. Tivy and O'hare (1987), note that humans differ from other animals in that they exploit the ecosystem for that might be called non-consumptive uses, i.e. for uses other than nutrition and purely domestic purposes. The exploitative nature of man coupled with the speed of his technological advancement (technologies shape technological advancement (technologies shape societies and determine the impact of those societies on the environment that support them) has recycled or are not recycled rapidly enough by the ecosystem to maintain the environment in a steady state condition. This, in itself led to the idea of zero economic growth theory, which advocates for equilibrium between exploitation and replenishment of renewable resources. As seen from the fact that the mechanism of environmental deterioration is not so much a factor of economic advancement and industrialisation but is mainly due to our failure to build into the economic system proper safeguards against excessive levels of activities that degrade the environment. Sometimes however, the arguments are difficult and resolutions are hard to come by.

Environmental impact assessment (E.I.A.) came into being as it was noticed that some of the typical and irreplaceable components of the environment were gradually disappearing, imbalance on the other hand is on the upward trend between the quantity of products of nature and the quantity of products or man's brain and hand. The landscape is becoming altered and, in extreme cases devastated. The seriousness of the environmental impact assessment was highlighted by the club of Rome models which were attempts to predict mathematically the environmental future trends. Oates and Baumol (1979) report that the club of Rome model include equations in which implied path of the future of the world system.

Without going into details, good sense therefore dictated that we insure ourselves against environmental catastrophes like those of decimation of plant species, activities that might result in major climatological consequences or in general that might pose danger to our well being. This led to the emergence of various organizations both nationally and internationally to act as watchdogs to various abuses of the environment.

Environmental impact assessment is therefore an approach which attempts to estimate possible consequences which, should we not minimize or even eradicate environmental abuses would result in ecological disasters. Thus EIA has the task to prevent environmental abuses since the financial implications needed to restore the quality of the environment back to its original state (and that is, if it is reversible) are so enormous that many a poor nations (and these are in the majority) do not have that kind of capital.

The wealthy nations also have a duty to safeguard the environment for their own good since environmental abuses are not governed by political boundaries.

This present study considers man's influence and possible effects on a river system. Our concern is therefore focused on the effects of river damning on an existing natural river ecosystem of the Sosiani River catchment around Eldoret in Uasin Gishu District. The dam under consideration provides water for domestic and industrial use within Eldoret town. In retrospect it provides drinking water of acceptable quality and quantity and appearance, yet industrial and chemical discharges into the river system reduces the quality of the water for use to other forms of life forms. Our study aims at isolating salient factors involved and explaining their inter-relationships.

1.1.2THE BACKGROUND

The historical conglomeration of human beings into centers of commerce, and industry and the subsequent division of labour necessitated the provision of various amenities for domestic, agricultural and industrial uses. Water as an example, needed to be tamed river-wise so as to provide consistent supplies throughout the year. The availability of water in any catchment may be directly related to existing agricultural and industrial practices as well as the state of permanent settlement of people living in the affected area. Hence as a result of this stated needs, man learned to tame rivers by constructing embankments to create reservoirs which store water, only released as per demand. The FAO (1971) noted that any anthropogeneous changes to the biophysical environment, its deterioration and the contamination of the biospheric resources reduce the productivity of the ecosystem. Hence such embankments set on river channels and creating dams may have adverse effects on the river ecosystem. Four things are suggested and noted: -

a) Once dams are built, a new ecosystem is created around it due to an increase in the water level, introduction of turbulence, visibility changes, changes in speed and/or velocity of the water upstream etc. These changes lead to emergence of the new ecosystem alien to the prevailing one.

b) Below the dam we get also a new ecosystem different from the previously existing one due to water level reduction, absence or little deposition of silt .

c) Where industrialization is exhibited, a change in water quality is likely to be observed. The subsequent repercussion depends on the kinds of effluents; the matrix of effluent and the percentage and ratio of effluent types put back in the river. Of course the response of the biotic life is bound to differ from the originally uninterrupted state. The damming of rivers, though having already some clearly documented demerits will however continue for some time in the future since it has many advantages.

d) It is an obvious fact that the river does not exist as a single entity. Indeed, it is a complex ecosystem comprising first and foremost that entire region referred to as the watershed or catchment region. It is therefore logical to state that any interference on the river is bound to be felt along this zone. How different variables react is a matter of investigation (various examples are cited in the literature review). Some dams are multi-purpose (e.g. the Hoover Dam; the Aswan High Dam; the Kiambere Dam etc), while others serve mainly a unitary purpose. It should be mentioned here that some rivers have been dammed in more than one place along their courses. It should be expected that such rivers should exhibit certain peculiar characteristics unique to it.

1.1.3 LITERATURE REVIEW

The basis of reviewing literature will be based on what Dasman (1987) suggests in regard to technology and the environment. He writes that technologies shape societies and determine the impact of those societies on the environment that support them.

As indicated earlier, the goal for this study is to understand those dynamics of riparian vegetation as a result of damming. The question to be asked on the onset is whether there is any relationship between the vegetation and the river channel. If this is established and justified then the study can be undertaken without due uncertainty.

According to OAS (1978), the effect of a project on water quality may extend well beyond the immediate project area. Therefore, the total area under evaluation should be carefully considered in order to measure the cumulative environmental effects of all proposed actions. This statement in itself justifies a study of riparian vegetation. Further, since it does not include the scope of definition of how to delineate the affected area, the present study is confined within several meters of the riverbanks.

The OAS (1978) study, besides noting several negative impacts of dam construction on the human population also notes about "loss of biodiversity and stability". However this thesis does not indulge into details to explain what is meant by loss of diversity and stability. It is a well-documented fact (Barbour, et al 1987, Cole & Smith 1984, Baxter 1977, Goudie 1987, etc) that if one factor of the environment is changed, shifts in the quantity and quality of other environmental factors follow. The present study persues this line of approach to examining riparian vegetation. However, it should be grasped at the onset that because of the intricacy of the whole environment; anticipation of these innumerable actions is difficult and sometimes impossible to document.

Farvar and Milton (1973) relate the construction of the Kariba to agricultural productivity. They noted that the dam site is an excellent example of how man's engineering capacities can drastically reduce the productivity of an existing ecosystem.

The ZACPLAN (Daily Nation, May 27 1987), a study of the ecological and environmental issues concerning the Zambezi river, uncovered that the economic and social development of riparian countries has tended in the past to deplete resources and place stress on the environment. This statement by itself is alarmist since it indicates only the negative situation of "depletion". It only recognizes positive feedback mechanism. This study intends to look at the question of "adapting", "strain" and also "extinction". The question to be asked here is, whether the depletion of resources is a loss of diversity in plant species and probably an increase in abundance of a dominant species which can withstand the newly created environment. Odingo (1979) in their study of an African Dam, at Kamburu/Gitaru hydro-electric dam in Kenya record similar results to those of Farvar and Milton (1973) and the Zacplan study, but still remain silent on the above questions. This gap constitutes the path of investigation in the present study.

The issue of stress on the environment is adequately covered by the OAS (1975) where they report that greater species tend to provide a larger number of checks and balances within an ecosystem. Though this observation has lately come under a lot of scrutiny, one purpose of this study is to see how the various variables under investigation affect the environment singly or in unison. Little has been done in this area.

FAO (1971) delves a bit deeper and tries to pinpoint the shortcomings inherent once a dam has been constructed. It states that the construction of any river dam and/or reservoir is a distinct anthropogeneous interference with the natural environment and triggers off a number of primary and secondary, expected and unexpected consequences. In principle the effect of the reservoirs is shown (a) in the immediate vicinity and newly formed ecosystems, and (b) in systems situated downstream from the dam.

The presence of the reservoir affects the biophysical environment near the water level by: "Sunshine and thermal balance of accumulated water: an increase in albedo compared with the previous natural land surface may have an unfavourable effect on the former river plants (reduced adaptability) and in contrast, a positive effect on the new plants. Whatever FAO means by "an unfavourable" and "positive" effects is not clear, but such a generalization should be treated with a lot of caution since the response of plants in one particular area is bound to differ due to the prevailing circumstances. This style of explaining the changes exhibited in a uniform manner is common in the literature (e.g. see Goodman, 1975; Simmons, 1986; Tivy & O hare, 1987). The present study examines the behaviour of individual plants especially their response to those factors of the new environment that may influence these (plants) growth patterns. It is expected that such individual plant response will end up giving a detailed picture of ecological dynamics of the entire area under study

In retrospect does damming really bring about the anticipated changes? At Kariba dam, Attwell (1970) discovered numerous problems on the downstream floodplain Both vegetational patterns and wildlife activity had been disrupted. Petts (1985) gives a precise ecological cycle that evolved around the annual Zambezi floods, maintenance of riparian vegetation downstream and how this controlled and maintained animal movements and population in a harmonized way and how the building of the dam had disrupted this highly organized ecological set-up. If we have an idea of what brings about these changes then we can be able to predict to a reasonable extent the expected trends.

Baxter (1977) notes that, many of the effects produced by dams on the stream below them are the reverse of those produced by the lake above them. What is normally retained in the lake (heat, silt, inorganic or organic nutrients) is lost to the stream. Moreover the large annual variation of water level in the lake will almost certainly be associated with the decrease in the annual variation of water level in the stream, all these, in turn may have certain biological consequences, sometimes far away. This study investigates how some of these consequences manifest themselves. Further the physical conditions of a reservoir can result in a lot of changes to the surrounding area. Goldman and Horne (1983) note that, because water stores a lot of heat per unit volume, the presence of large volumes of water has the ability to alter the climate. FAO (1971) notes that the fluctuation in water level produced by the generating conditions of the reservoir system denudes a strip of land along the rim, encouraging the growth of waterweeds and marsh plants. When the slopes are steeper the banks are subjected to abrasion and, in flat country the adjacent land becomes waterlogged even at a long distance from the reservoir. The effects of such changes on the terrestrial vegetation with regard to the present study are investigated. On the other hand, the effects of dams on the aquatic life forms has been well documented as for example by, Carruthers (1973), Farvar and Milton (1972), FAO (1971), Moss (1982), Oates (1979), Talot (1985), Thorne and Goldman (1983) etc to mention but a few. However such studies tend to overlook the immediate river catchment area as a study region constituting part of the entire river ecosystem.

Gemmell, (1977) states that, stabilization of certain dominant species occurs after a disturbance has occurred. Two conclusions can be made from this straightforward statement. First, he acknowledges loss of diversity and, secondly he accepts the theory of extinction of those organisms that are unable to cope and withstand the resulting strain and disturbances. However, he overlooks (and this has been done by many authors), to explain what it takes the dominant species to adapt to the new environment.

This present study attempts to address this question. As Tivy (1982) notes, the relative resilience of an ecosystem will be dependent on:

a) Its amplitude, or how far it can deviate from the steady-state or equilibrium point, before complete disruption and replacement by another system and

b) Its elasticity or the rate at which it can recover from the disturbances.

The present study sites are located in areas which exhibit similar climatic, geological and physical attributes and should therefore show little or no fluctuation in species composition, biomass, productivity or any other quantitative or qualitative variables. It has been noted elsewhere (Hill, 1975) that once established savanna grasslands have revealed a high degree of stability even in the face of changing environmental conditions. Caution must be taken as Hills (1965) remarks in his review of savanna research by noting that confusion has arisen in interpretation of the origin and status of tropical grasslands because of the failure to distinguish clearly between pre-disposing, casual, resulting and maintaining factors.

Hollings (1973) notes that resilience, then is an expression of how much an ecosystem can be disturbed or how drastically its conditions can fluctuate in space or time before it is completely disrupted. It has been described as a measure of the probability of the extinction of an ecosystem. The present study, while acknowledging the concept of resilience it does not attempt to examine it. Instead, it looks at what stage the ecosystem "is at" due to the effects of the prevailing "disturbing factor". Of course the view of total extinction will be treated with caution but will be taken as a general overview expressing a change from the originally exhibited characteristics. The idea is clearly manifested when we appreciate that the weakest link in the ecosystem need not necessarily be at the base (e.g. the base of the food chain) and also at the multiplicity of linkages other than a simplistic linkage from the base to the top.

Tivy (1982), brings out this point clearly when he states that, "the relative resilience or fragility or an ecosystem will be related to that attribute, which is most susceptible disruption or to that environmental disturbance against which the ecosystem has the least resistance. Fragility will, therefore be dependent on the weakest component or link which will obviously vary from one ecosystem to another For example, if the system is a relatively stable one because of a constant environment with a small range of fluctuation, as in the case of tropical rainforest, its resilience will be low and it will be potentially fragile in the face of environmental change. On the other hand, an ecosystem such as the Arctic Tundra, where population may fluctuate dramatically in response to an intensely unstable environment, it will tend in some respects to be more resilient and less fragile.

To occur and thrive in a given situation, as Odum (1971) states, an organism must have essential materials, which are necessary for growth and reproduction. These basic requirements vary with the species and with the situation. Under steady-state conditions, the essential materials available in amounts most closely approaching the critical minimum needed will tend to be the limiting one. It is therefore necessary to identify the state in which the study area is and secondly to isolate those essential materials under question. In a situation like the one under study, we experience in one area a reduction in water level coupled with the introduction of new materials hitherto not present before. In such a situation how does the environment react assuming its state is already established? Shelford's "law" of tolerance comes into mind when such a statement arises. According to Odum (1971), Shelford noted that the presence and success of an organism depends upon the completeness of a complex of conditions. The absence or failure of an organism can be controlled by the quantitative and/or qualitative deficiency or excess with respect to any one of the several factors which may approach the limit of tolerance for that organism. It is important to note here that all physical requirements may be well within the limits of tolerance for an organism and the organism may still fall as a result of biological interrelations. It is therefore important (as Odum, 1971) notes, that studies conducted in intact ecosystems must be accompanied with experimental laboratory studies, which of necessity, isolate individuals from their population and communities. Thus it should be pinpointed here that the question of preferential adaptation should be considered since plants have mechanisms which can evolve to counteract the adverse circumstance. Only when such measures fail and no other alternative found does a plant species enter into extinction.

An appraisal of the water quality will now be considered and, the possible effects highlighted. The effect of both industrial, agricultural and domestic effluent as depleting agents in aquatic, life forms has been extensively covered by many researchers and documented, for instance, by Moss (1982), Oates (1979), FAO (1971), Home and Goldman (1973). In this study we envisage not to look at the changes in aquatic life forms per se but the physical and chemical characteristics of the river will be studied to establish whether any manifestation have taken place.

Tivy and O'hare (1987) and Mwanje et al (1989) record that effluent sewage drained into rivers and coastal waters if not treated result in becoming overloaded and oxygen used up in decomposition at a rate faster than it can be replenished. As a result natural water purification cannot take place. Water thus becomes polluted with partially decomposed sewage, anaerobic bacteria, excess carbon dioxide, ammonia, suspended solids and other such substances which make it inimical to other types of life and unsafe for human consumption. For instance marine life forms such as coral polyps suffocate under such conditions. The present study attempts to examine some of the above parameters, and others to documenting the extent of pollution in river Sosiani system.

Earlier on, Moss (1982), gave an in-depth analysis of the effects of effluent on the life forms when he noted that; "few pollutants are entirely new to living organisms, for with the exception of some synthetic chemicals, natural discharges of all of them occur somewhere in the world and, specialized communities of living organisms have evolved to tolerate them". It is not clear what he meant by the word "specialized" or in what context he applied it. Also, when talking about effluent several factors have to be considered in terms of their composition; concentration, persistence, etc. Surely if these factors are seriously looked into especially over a long time period, the alluded factors are bound to be wide and contrasting. Moss's statement need to be treated with a lot of caution since it is indeed a generalization. In fact Moss outrightly records that the communities which develop are generally not diverse, for the habitats created are, by the standards of most writers "extreme".

It is well known that manufacturing industries use vast quantities of water for processing, and are important sources of pollution No two areas globally have identical industries which are similar in all respects and therefore the mosaic of effluent discharge is different from one place to the other. The way organisms (which also differ from one place to the other) react to this problem so as to cope with, to adapt and to survive in a newly created environment is a unique element of that and only that particular area with its associated ecological strata. The ability to survive or adapt is a factor of the agent(s) of disturbance intertwined with the affected species, anatomical characteristic's response (to repulse or absorb) plus the effect of its neighbour's response – since all those are related.

In their publication, FAO (1971) suggest another possible avenue through which damage to resources can occur when they record that; "direct damage to resources can be inflicted on both agricultural (surface) and underground water by discharging wastes and effluent into streams or places where contamination of underground surface may occur. This slows down biological capacity for the stream – purification". Though the FAO study does not commit itself, this slow-down in biological capacity might provide optimum conditions for certain organisms and thus promote their dominance while others suffer.

The reaction of a multitude of "undesirable" variables on an area's resources is bound to be site specific, the study referred to above shows for example, how one factor can bring a significant change in an area's original resources. It notes that, "owing to lack of water the prairie is turned into barren land and the wood-covered areas into prairie. The natural restoring forces act over a long period of time (i.e. ecological succession) hence they cannot react to the intensity of anthropogeneous influence". Here, the factors which have led to the emergence of the prairie are important. It might be found that the quality of water has changed which in essence might be the overriding factor other than the quantity of water. An ecological study like the present one should be open ended to permit for possible solutions and try and quantify its magnitude, a path it envisages to pursue.

According to Best and Ross (1977) the effects of pollution depend upon the type of pollutant, its concentration in the water and the length of time for which the river community is exposed to. They add that different pollutants vary in their effects. Some directly affect the river community, others do so indirectly.

To give an insight on how what we consider a minor change can affect the environment, let us consider the example of toxic heavy metals which need not be in high concentration. Gemmell (1977), explains how this occurs and the extent to which it does so. He notes that, heavy metals affect plant growth in a number of ways. In solution culture it has been found that exceedingly low concentrations of metal ions, of the order of a few parts per million, causes inhibition of root growth. In soils, their toxicity induces similar roots-inhibiting effect, the root system of afflicted plants being coralloid or stumpy in appearance. Shoot and leaf growth is depressed, the leaf developing acute chlorosis and various types of interreinal necrosis. The degree of toxicity exerted by different heavy metals varies considerably. Copper for example, is more toxic than Zinc, thus 0.05 ppm Copper being more toxic in solution culture whereas the corresponding concentration for Zinc is 10 ppm. It is likely that toxicity is determined by the abilities or similar substance, thus destroying the ability of the chelate to transport ions in the plants. Some such analyses are made in the present study.

The construction of dams coupled with the introduction of wastes into the water downstream must therefore be viewed as a gross change on the microclimate and physical characteristics of the surrounding area and, therefore logically changes corresponding to these observations become inevitable. Simmons (1986), notes this when he writes that; "ecologically the effect of one shot 'weather conditions' is likely to cause shifts in species". Gross vegetation shifts are of course possible, but even more rapid growth would be those of rapid dissemination of species such as fungi and insects, some of which are bound to be pests. So even mesoscale changes which are artificially induced are likely to produce serious and unpredictable biological consequences; should the technology for larger scale changes become available then the prospect is full of hazards.

Though Simmons does not go into the details of how these changes occur, he nevertheless acknowledges the fact of change. This study examines how such changes occur basing itself on vegetation observation and related analysis. It is a well-known fact that vegetation is easily altered with changing ecological conditions. The basis of analysis in the present study. The Sosiani river basin is found in its own unique environment as it traverses the Uasin Gishu plateau and then the rapidly growing industrial town of Eldoret. Given its varied profile, the present study examines most of the observations isolated in the literature review and hopes to adequately document the resulting dynamics as per the stated objectives. In the next section, a justification for the choice of the study topic is presented.

1.1.4 JUSTIFICATION FOR CHOICE OF STUDY TOPIC

The literature reviewed has established that biogeographical characteristics of a river basin tend to form a cohesive hydrological and ecological system (and planning). Further, observation by OAS (1978) outlines the scope of importance of proper management and utilization of river basin as a resource base. The effect of the river water on the resources, that are affected both directly and indirectly should therefore be studied, documented and understood since it forms an important aspect of the very survival of the human race. Such a topic is bound to raise more questions and inquiries besides being quite challenging, intriguing and taxing and thus my choosing it.

It is obvious that we live in different ecological zones and, the multitude of factors that keep a particular ecosystem intact are unique to that zone. A similar study to this one done for example in the cool temperate zone can turn out quite different results than one done in the hot tropical zone. Thus this emphasizes the importance of actual field data collection.

Further from the reviewed literature, it is seen that no two regions in this world display in totality similar matrix of flora and faunal distribution and characteristics, since the climate and microclimates together with physical factors differ. The anthropogeneous changes that affect the already different ecosystems are of varying magnitudes and again this cannot be equal in magnitude to another area. The whole thing is intricate and complex and can only be understood by studying trophic levels and the interlinked food chains. A study thus done elsewhere on a river ecosystem can only apply to another as far as the methodology is concerned as results are bound to differ. Hence the need for the present study to be carried out.

In the process of this study the answers to the following questions are sorted:-

(i) Does the consistency of a river, in terms of water volume contribute to the growth and stability of the river ecosystem? Is a river a single entity such that it does not interact with the surrounding terrestrial ecosystem? In other words, can we demarcate the river ecosystem boundary effectively?

(ii) Is the water, its state i.e. quality and quantity a passive or active factor in the development of the surrounding terrestrial ecosystem especially the vegetation?

The present study aims at exploring avenues for minimizing environmental degradation as a result of economic actions such as building a dam. Indeed other studies can be done to show that such projects can be undertaken and environmental regulatory measures taken to avoid negative effects.

This study envisages to unearth the effects of a dam and the subsequent water quality and quantity on the surrounding environment and, enlighten on how these effects occur and are distributed besides trying to document the interrelationships exhibited. This constitutes a first step in introducing environmental regulatory measures, within the scope of E.I.A. However while sounding very optimistic, this study was carried out with cautionary measures which Simmons (1986) sounded when he wrote that "watershed management by vegetation control is not yet an exact science'.

As Eileen and Ludwik (in Goldman, et al 1973) noted once that, "the key to the ensuing study of water development and environmental" quality in history, therefore lies in awareness of the nature of water and systems; of their interdependence; and of their interrelationships with the other elements in the physical environment". The analyses in this thesis attempt to show the consequences of that awareness or lack of it. Hence the justification for the choice of the study topic.

1.1.6 STATEMENT OF THE RESEARCH PROBLEM

The purpose of this study is to document the impact of the Two rivers dam on the ecological parameters such as the riparian vegetation, especially its distribution, diversity, abundance and stability within the Sosiani River ecosystem, in Uasin Gishu District, Kenya Whereas the economic importance of dams need not be underplayed, little has been done to study their environmental impacts on the riparian ecosystems. In the present study, the following specific variables will be investigated: -

- The ecological basis of the Sosiani river catchment;
- The effects of water diversion on the riparian vegetation at quantitative and qualitative levels;
- The effects of discharged industrial, agricultural and domestic effluent on the ecosystem under study;
- The impact on the terrestrial ecosystem due to reduced water levels below the dam.

Thus the study is to be conducted on two broad areas namely: -

a) The area around the dam, characterised by high water availability due to the presence of the reservoir.

b) The area below the dam that is affected by low water availability and discharges of effluent from Eldoret town.

It is hoped that an examination of the above broad areas within the specified line of investigations should cast light on the effects of damming on the Sosiani river ecosystem.

1.1.5.1 Study Objectives:

The objectives of this study are as follows: -

a) To investigate the abundance, distribution quality and stability of riparian flora and its relation to the Sosiani River dam.

b) To document the trends on terrestrial life forms due to:-

- Increase in water level at the dam area.
- Fluctuation in levels below the dam.

c) To examine the response of the riparian life forms to the changes noted in (b) above and attempt to relate this to already documented evidence.

d) To evaluate water quality in the river system as a result of damming.

1.1.5.2 Study Hypotheses:

The null hypothesis tested in this study includes the following:-

H_{01}: The abundance, distribution and diversity of terrestrial flora are not significantly influenced by the damming of the Sosiani river system.

H_{11}: Alternative.

H_{02}: The changes in water quality and quantity in the Sosiani river system has not significantly influenced the abundance, distribution and diversity of terrestrial flora.

H_{12}: Alternative.

H_{03}: The damming of the Sosiani system river has had no significant effect on the observable physical conditions of the terrestrial flora.

H_{13}: Alternative.

H_{04}: The productivity and growth of the terrestrial flora is not as individual species or community level is not significantly different at the two study sites.

H_{14}: Alternative.

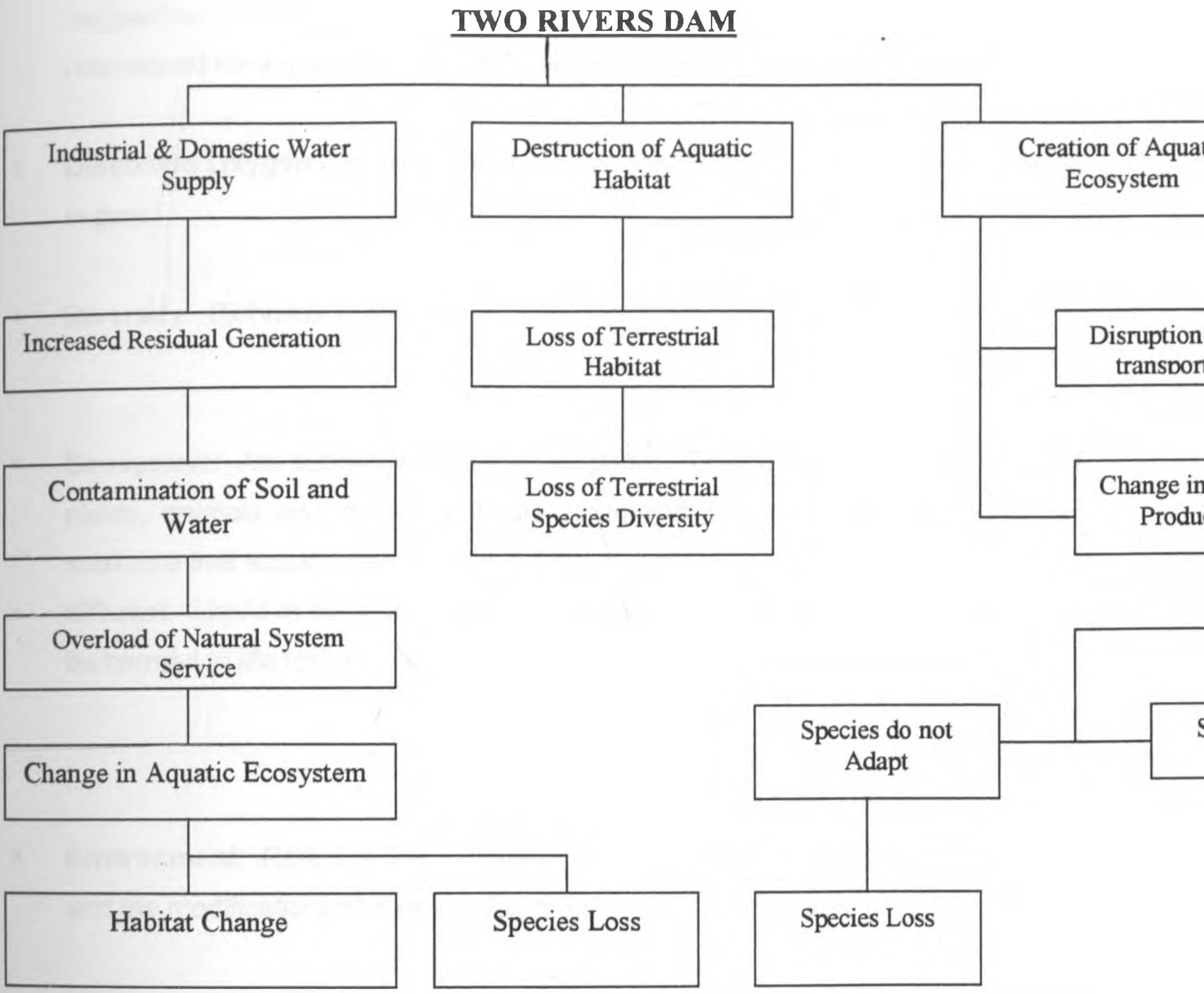
Hypotheses H01 and H02 are to investigate objectives a)and b) above while hypotheses H03 and H04 are to investigate objectives c) and d) above.

1.1.6 THE CONCEPTUAL FRAMEWORK

As was noted earlier, and anthropogeneous to the biophysical environment, its deterioration and the contamination of the biosphric resources reduce the productivity of the ecosystem in totality. The ecosystem through the system of feedback mechanism

tries to resist the "strain". The system is however eventually forced to adapt, lose part of it or even collapse. In formulating the theoretical framework (see fig 1.1) these factors of adaptability, change and loss were considered. The model is thus open-ended to permit a dynamic view of the study problem.

Fig1.1 The conceptual model of the effects of damming the Sosiani river system



1.1.7 OPERATIONAL DEFINITIONS AND CONCEPTS

Most of the technical terms and concepts used in this thesis are ecological. Hence the frequently applied ones are as follows:-

- **Biological Oxygen Demand (BOD)**: Is the amount of oxygen required to decompose wastes through biological activity.
- **Biotic Community**: The collection of species populations living together in a particular habitat.

- **Cover**: The proportion of the ground surface covered when the aerial parts of each plant are projected perpendicularly down on to it (expressed as a % of the total area of sampling unit).

- **Vegetation Density**: Exact number of individuals of species which is determined for a unit area (e.g. as quadrat of specified size).

- **Dissolved Oxygen**: is the amount of oxygen in a given volume of water, given in ppm.

- **Diversity**: Richness in species.

- **Ecosystem**: Are subdivisions of the biosphere. They consist of communities of plants, animals and microorganisms along with the air, water, soil or other substrate that support them.
- **effluent**: Liquid or semi-liquid waste that come from an establishment and may be harmful to life forms.

- **Environment**: Refers to the biosphere, the ecosystem of which it is composed, and the modifications of these brought about by human action.

- **Environmental Resistance**: The ability to continue to exist under conditions from which the species would flee.

- **Flora Quality**: Degree that the plant communities are in good conditions and tend to remain stable; diversity of species within a community: degree that the affected area is free from perstilence or nuisance species.

- **Flora Quantity**: Approximate population numbers and distribution of species that are rare or in danger of extinction, or that have a potential economic or other value; rates of spread of population increase or decline.

- **Grazing Capacity**: The maximum number of Wildlife which an area can support over a period of time without injury to the soil, forage resources, plant growth, watershed or unwarranted interference with other services or the land.

- **pH**: It is defined as the logarithm of the reciprocal of the hydrogen ion (H^+) concentration, expressed as moles per litre.

- **Quadrant**: A square marked on the ground for vegetation studies.
- **Resilience**: The ability of an ecosystem to persist and to maintain itself in the face of disturbances due to weather or climate.

- **Stability**: Is the ability of a system to maintain a relatively constant condition in terms of its species composition, biomass and productivity, with minor fluctuations around a mean value (the equilibrium point) and to return to this steady-state condition fairly rapidly after internal or external disturbances.
- **Standing Crop**: The weight of total living material. The amount present in any particular place will be related to:-
  a) The type of organism;
  b) The nature of surrounding environment;
  c) the season of the year;
  d) the stage of ecosystem development and, of course
  e) the nature of human activity.

- **Succession**: Is defined as an orderly predictable process of community changes that modify the physical environment and culminates in the most biological stable

ecosystem possible on a given site.

- **Water Quality**: Extent to which water quality impairs or enhances desired use.

- **Water Quantity**: Type and number of each waste water source, quantity of discharge from each source available, include data on BOD of discharge, suspend solids, temperature and other parameters.

- **Watershed (Synonymous with Catchment or Basin)**: Is made up of the natural resources in the basin, especially the water, soil and vegetable factors.

- **Watershed Management:** Is the comprehensive development of a basin so as to make productive use of all its resources and protect them. It includes land improvement; rehabilitation and other technical works as well as human consideration.

  (References from whyte (1987) UNESCO, MAB hand book.)

In the next chapter, the study area is described. Also various biophysical factors are considered.

CHAPTER 2

2.0 The Study Area

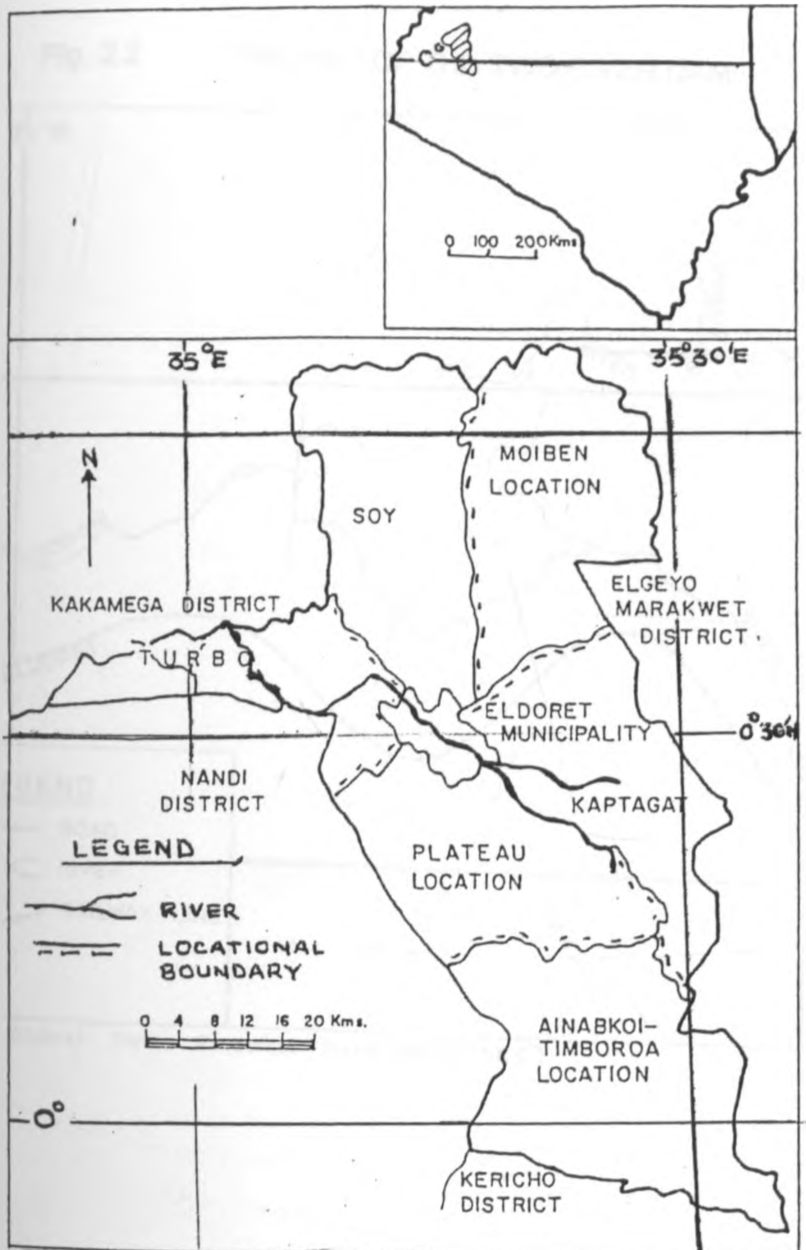
2.1 INTRODUCTION

The Uasin Gishu District covers an area of 3,784 sq.km. It is one of the eighteen districts in the Rift Valley Province and borders seven other districts, namely:- Trans Nzoia,Keiyo, Marakwet, Nakuru, Nandi, Koibatek and Kakamega (*Fig 2.1*).

The district is administratively divided into 2 divisions, 6 locations and 8 sub-locations. Eldoret Municipality (situated 00^0 31'N latitude 35^0 17' E longitude$_0$) is the fifth largest town in Kenya. Eldoret is situated 00 31' N latitude 35^0 17' E longitude. It is only 65 km north of the Equator, and has an altitude of 2,084 M above sea level. Besides being the district headquarters, Eldoret town, is also an important educational, commercial , industrial route centre. The town is linked by all-weather roads to Kisumu, Nairobi, Kabarnet, Kakamega, Busia and Kitale. The population of the District as per the 1979 census stood at 300,766 with 50,503 (16.8%) living in Eldoret town. Eldoret town gets a municipal water supply from the TWO RIVERS DAM situated at the confluence of the Endoroto and Ellengirini rivers both being the headwaters of the larger Sosiani river. Due to the present water demand of over 30,000m3, which the dam cannot sustain, the Ellengirini dam is to be commissioned soon (*Fig 2.2*).

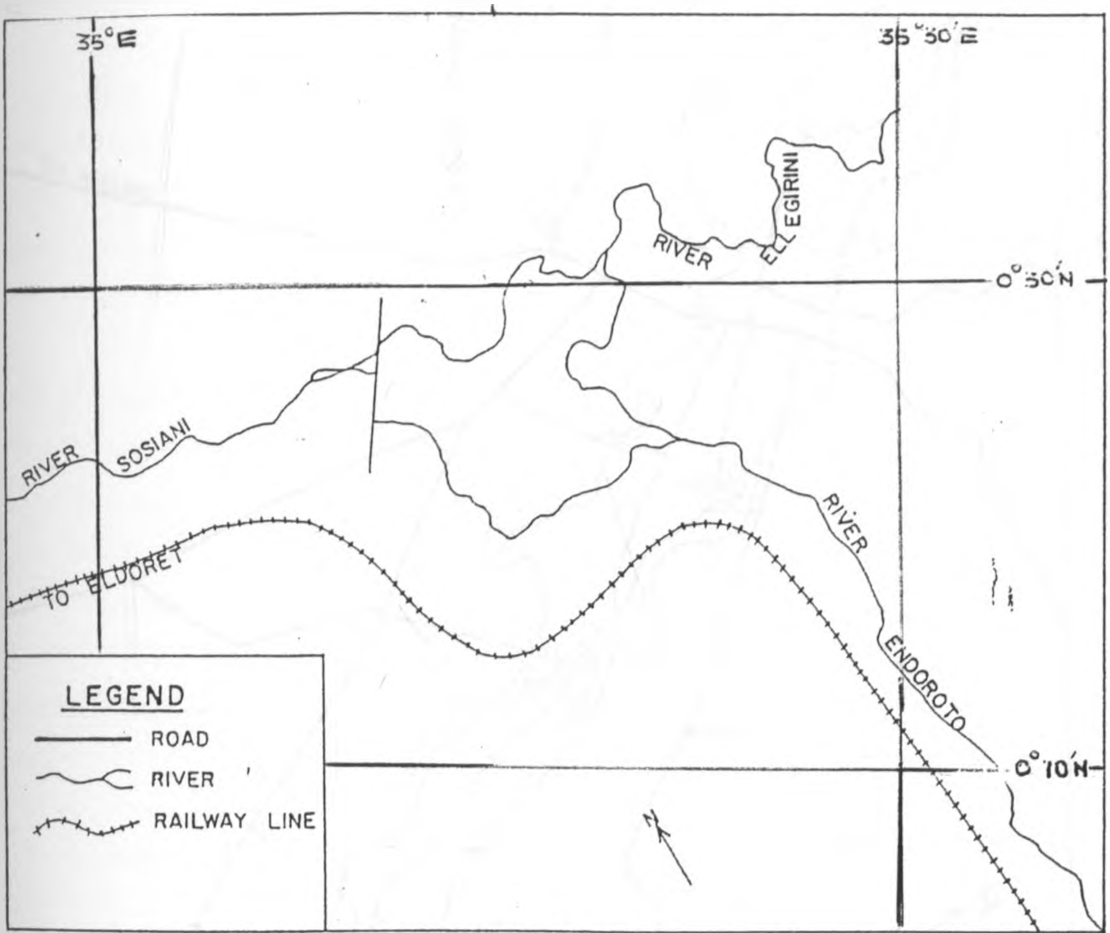
The data collection area is divided into two zones all along the river. The first area is represented by *Fig 2.2,* which represent the TWO RIVERS DAM and its environs. This area lies at an altitude of around 2155 M and the vegetated area of interest covers an area of $2km^2$. The second area lies below Eldoret town (*Fig 2.3*) between the two water and sewage treated plants. This area covers a total of 8 km^2

Fig. 2.1 **Uasin Gishu District (Political) map**



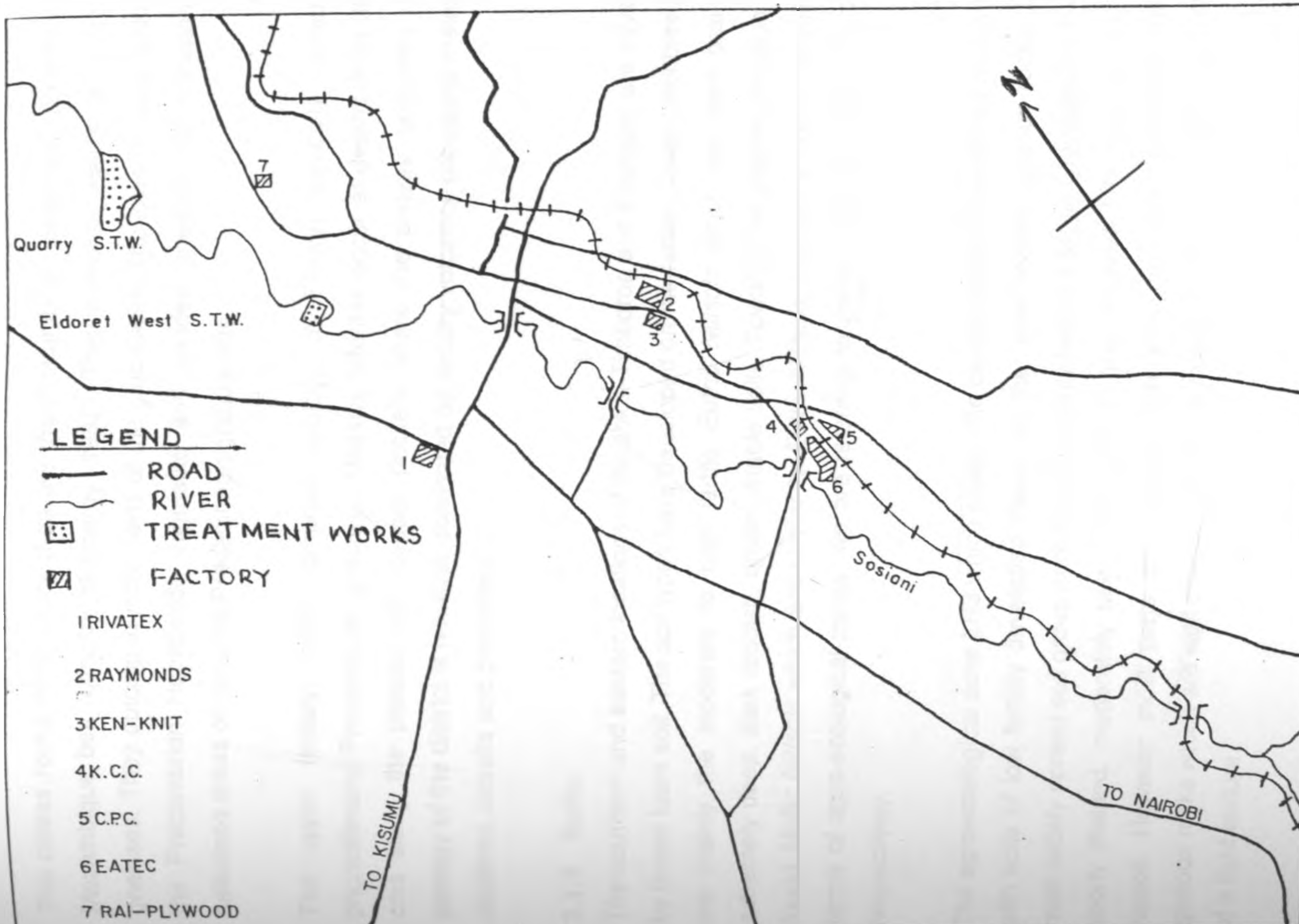
Source: Jaetzold and Schmidt (1982)

Fig. 2.2 **THE MAP OF THE TWO RIVER DAM**



Source: Eldoret Water Resources Investigation (1985)

Fig. 2.3 THE MAP OF ELDORET TOWN



SOURCE: OMUKOBA OUNA : NOT DRAWN TO SCALE.

2.1.2 GEOLOGY

The oldess rocks in the study area are the Precambrian metamorphic rocks of the Mozambique belt (Ministry of Energy, 1987). They comprise mainly of feldspathic gneisses. They outcrop in most parts of the study area. The lower tertiary rocks are the Precambrian Hornblende migmatite and banded gneisse with intrusions in selecteed areas of intrusive Precambrian granudiorite.

The upper tertiary rocks comprise geology of Eldoret basically comprises phonolitesand Precambrian gneisess. Massive laterites occur at depths from 30-90 cms along the plateau with deeper pockets where the plateau undulates. The geology of the district is however dominated by tertiary volcanics consisting mainly of alkalines, basalts and phonolites.

2.1.3 Soils:

The southern and eastern locations of Ainabkoi-Timboroa and Kaptagat are covered by brown loam soil. The soil types have developed on the tertiary lower phonolite and are mainly the moderate to high fertile *Eutric Nitisols* which are well drained, extremely deep, dark reddish, brown, friable soils. Towards the plateau location are found *Mollic Nitisols* which are similar to *Eutric Nitisols*, but with a humic topsoil. In terms of agro-ecological zones, we are referring to zones UH2 and UH1 (*Fig 2.7*) respectively.

The agro-ecological zone LH3 which covers the central parts of the district is covered with soils of low fertility developed mainly on the intermediate igneous rocks. The most widely spread soil group here are the heavily textured *Mollic Gleysols* which are poorly drained, moderately deep, dark grey to grey, mottled, firm clay and humic topsoil. However most parts are covered with soils developed on intermediate igneous rocks which are well drained, moderately deep to deep, dark red, friable clay of a light texture.

The agro-ecological zone LH4 found in the north and northwestern locations of Soy and Upper Moiben is covered by red clay soil type. This soil type is developed on upper tertiary phonolite formation and the precambrian banded gneisse respectively.

They are often not deep, with murram often close to the surface. The soils are however well drained, moderately deep, dark red, friable clay.

The brown clay soil type is centered mainly around Upper Lessos and plateau locations, and is mostly shallow with close to the surface. This soil type is poorly drained and supports livestock-rearing .

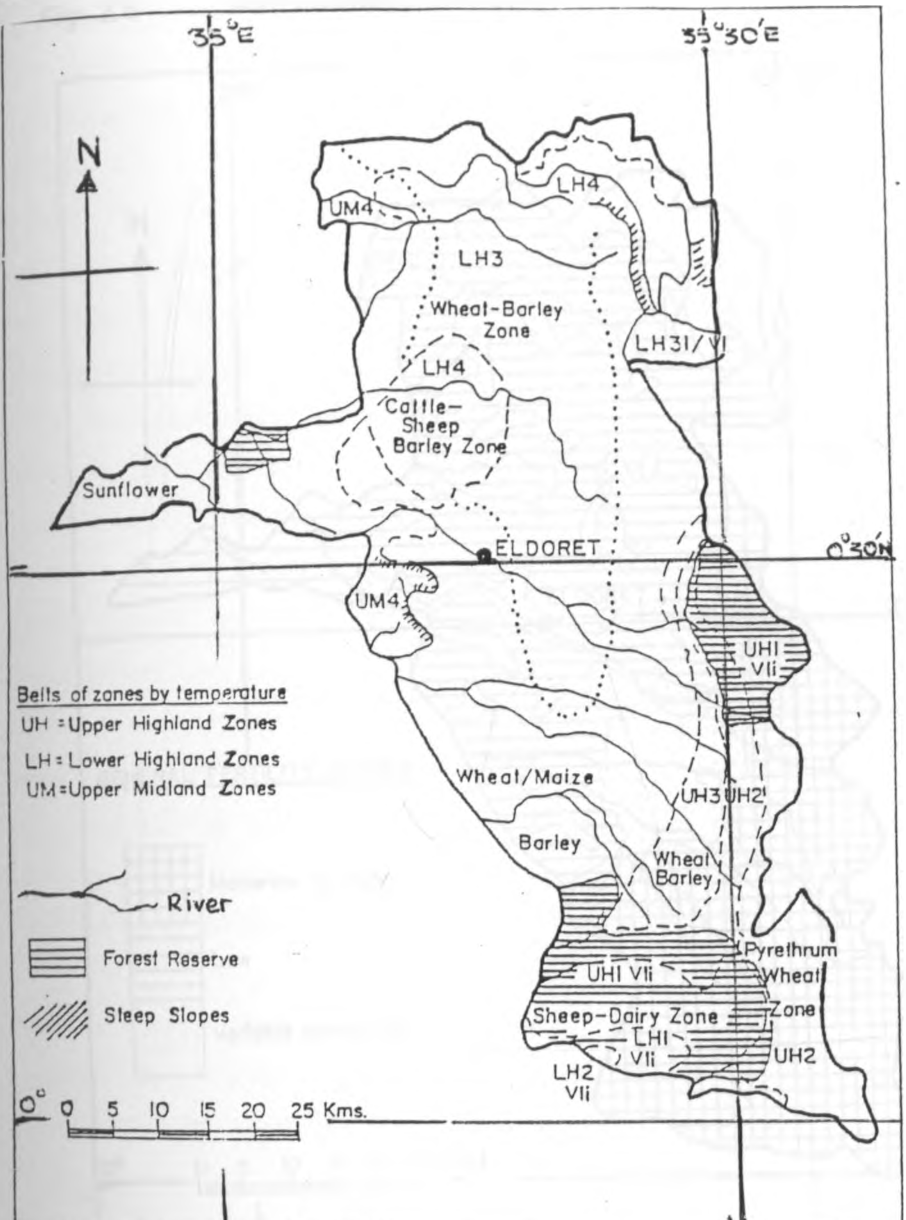
The mainly western agro-ecological zones UM4 consisting of Turbo location, Moi's Bridge and lower Moiben exhibits the red loam soil type. The soils are developed on the Precambrian Hornblende migmatite and banded gneisse with a small section having soil developed on intrusive Precambrian granudiorite. The soils are well drained, deep, red friable clay intertwined with *rhodic ferralsols*.

Our study area which is wholly located in the agro-ecological zone LH3 has soils of low fertility with riparian soils North of Eldoret town being mainly shallow. The soils are however well drained, moderately deep to deep, dark friable clay with inclusions of small bottomlands of *rhotic ferralsols* which are poorly drained, moderately deep, dark grey to grey, mottled, firm clay with humic topsoil. Below Eldoret town the soil texture is intermittently stony to bouldery (not well developed) and heavy where well developed. The fertility is thus variable mainly low (soil map – *Fig 2..5)*

2.1.4 TOPOGRAPHY

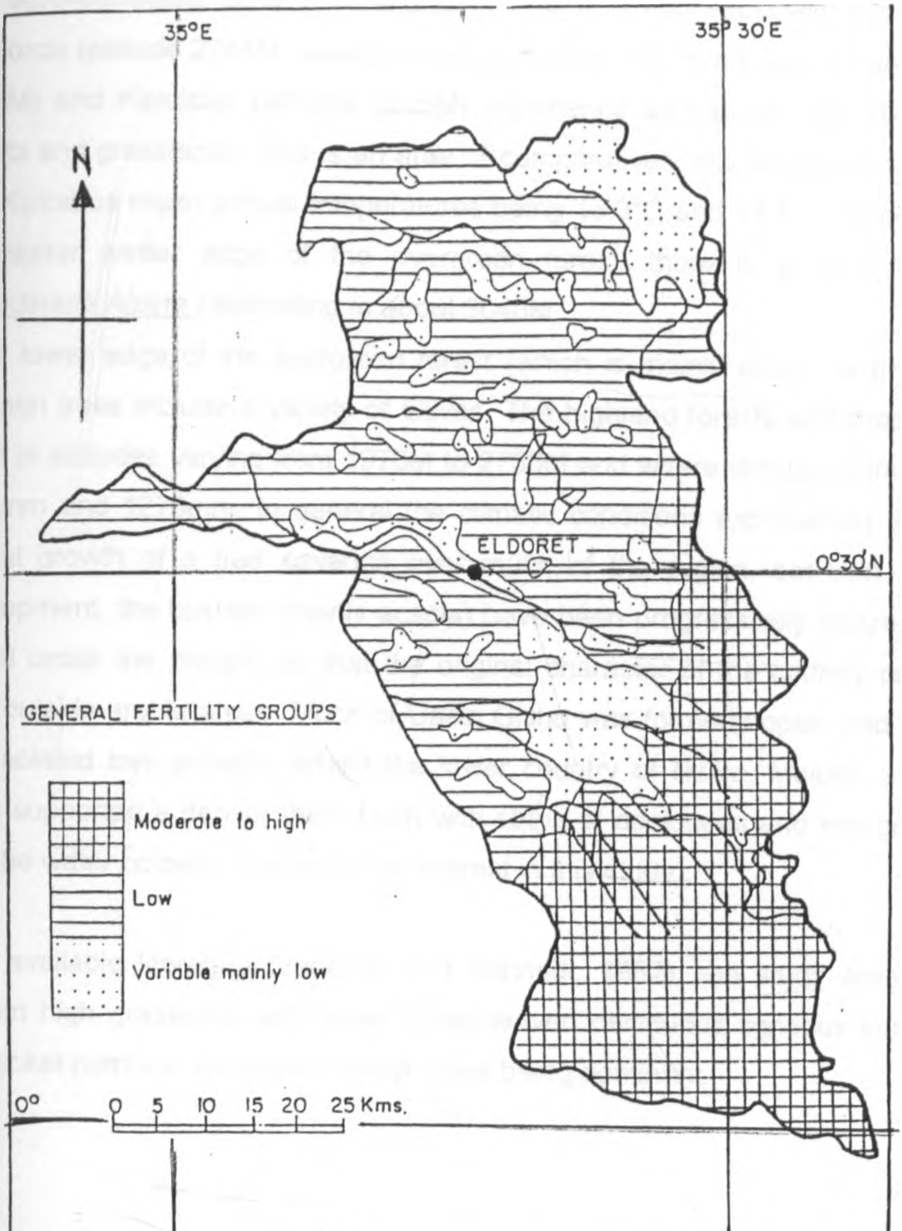
The district is a highland plateau with altitude varying between 2743M at Timboroa in the southeast and 1500M at Kipkarren in the west. Broadly the district can be divided into two physiographic regions with Eldoret municipality at an altitude of 2084M forming the boundary between the two regions. The central and northern parts of the district are characterized by level terrain plateau bordering undulating uplands. In the southern parts the topography becomes more dissected (the volcanic foot ridges). The plateau is dotted by numerous bottomlands. Basement system rocks outcrop in a few hills. The geology of the district is dominated by tertiary volcanic consisting mainly of alkalines, basalts, and phonolites.

Fig. 2.4 Map showing Agro-Ecological Zones (Uasin Gishu)



Source: Min. of Agriculture (1982)

Fig. 2.5 **Map showing soil types of Uasin Gishu Distirict**



Source: Joelzold and Schmidt (1982)

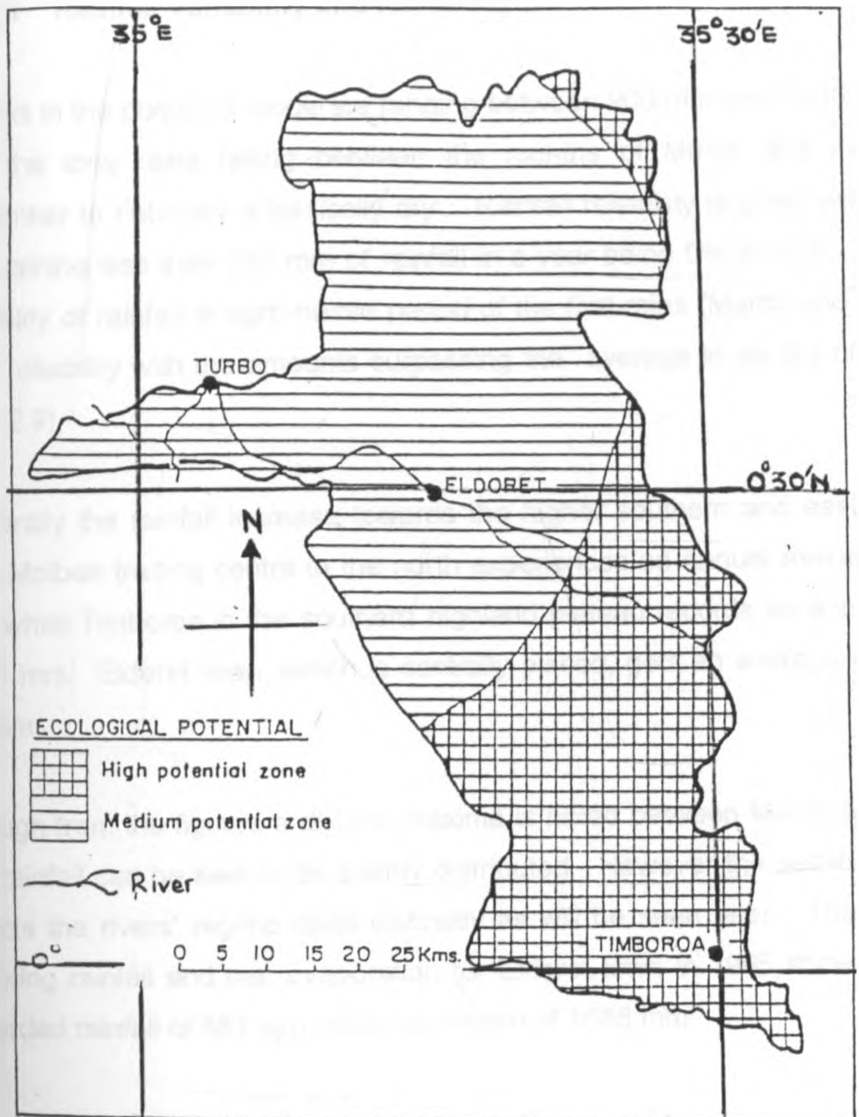
2.1.5 Vegetation

The agro-ecological zone UH2 and UH1 (*Fig 2.7*) and especially the environs of Timboroa (altitude 2743M, average annual rainfall 1171mm.) upto Ainabkoi (altitude 2660M) and Kipkabus (altitude 2525M) experience as natural vegetation highland forests and grasslands. This is an area of comparatively low temperatures (Ainabkoi and Kipkabus mean annual temperatures being 13.3°C and 13.8 °C respectively). At the higher wetter edge of the evergreen forest, there is a zone of bamboo (*Arundineria Alpina*) extending to about 3040M.

The lower edge of the evergreen forest (which is mainly exotic) is drier and the common trees include a variety of Olives. The highland forests and grasslands are found in altitudes varying from 1976M to 2736M and where annual rainfall averages 1000mm and 1270mm. In general the climatic conditions experienced induces the natural growth of a tree savanna over much of the region, but with agricultural development, the bushes (mainly acacia) have been progressively cleared and land placed under the plough, so that the original character of the country can only be seen outside arable areas. Much of Uasin Gishu was formerly open veld (grassland with isolated tree growth). Whilst the lower country of Nzoia, Moiben and Sosiani valley supported a denser thorn-bush with strips of deciduous and evergreen forest near the water courses (the region of interest in this study).

From available literature (Jaetzold and Schmidt, 1982), the study area exhibited medium high grassland, with small broad-leaved deciduous ligneous solitary trees and thicket patches, the hyparrehenia grass being dominant.

Fig. 2.6 **Map showing Ecological Zones of Uasin Gishu Distirct**



Source: Jaetzold and Schmidt (1983)

2.1.6 CLIMATE

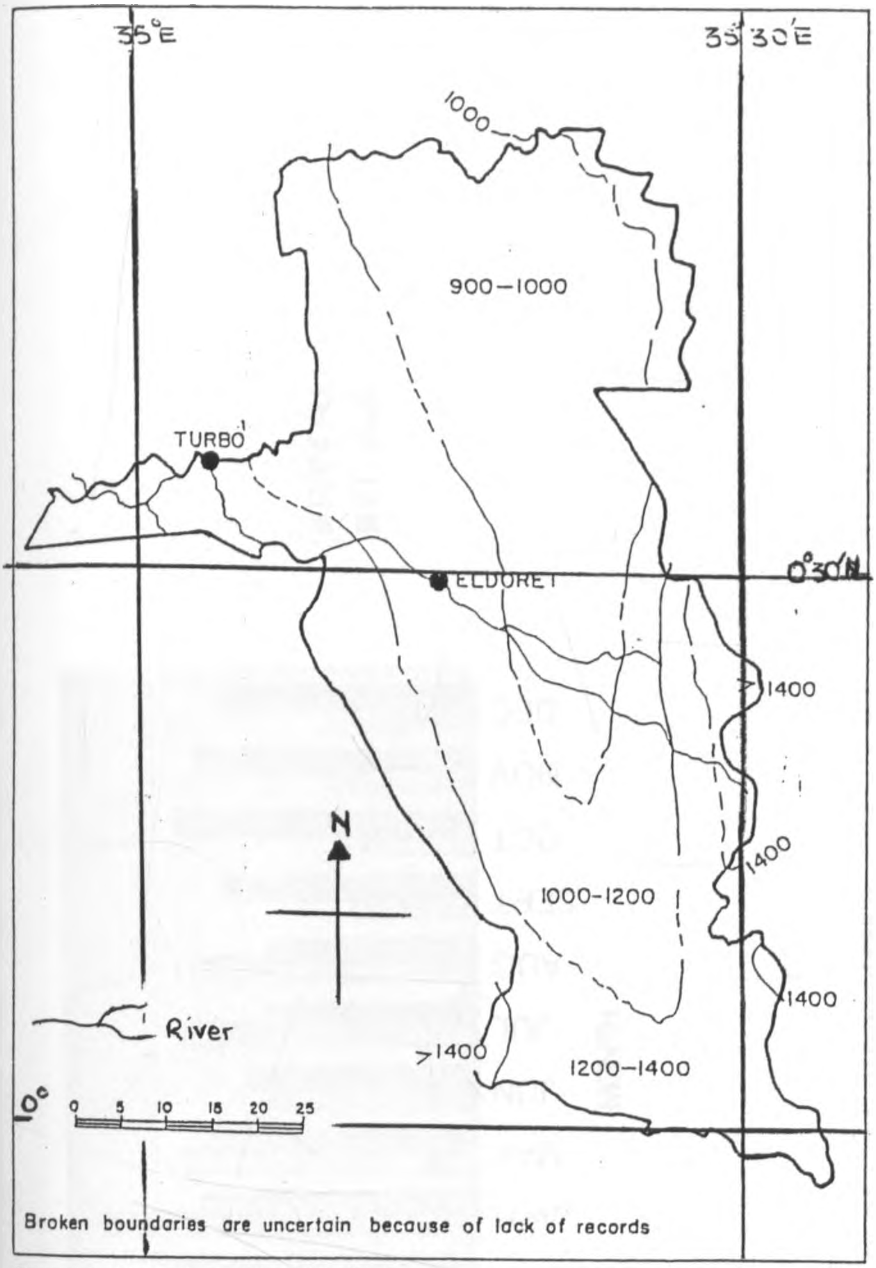
2.1.6.1 Rainfall Variability and Reliability:

Rainfall in the district is moderate ranging between 900 mm and 1400 mm (*Fig. 2.7*), with the long rains falling between the months of March and june (*Fig. 2.8*). November to February is basically dry . Rainfall reliability is good, with a probability of obtaining less than 750 mm of rainfall in a year being 0% to 10%. A study of the reliability of rainfall in agro-humid period of the first rains (March and June), gave a 60% reliability with the amounts surpassing the average in six out of the ten years (*Fig. 2.9*).

Generally the rainfall increase towards the higher southern and eastern highlands, thus Moiben trading centre in the north experiences an annual average of only 970 mm while Timboroa in the southern highland plateau records an annual average of 1171 mm. Eldoret town, which is centrally placed, gets an average of 986 mm per annum.

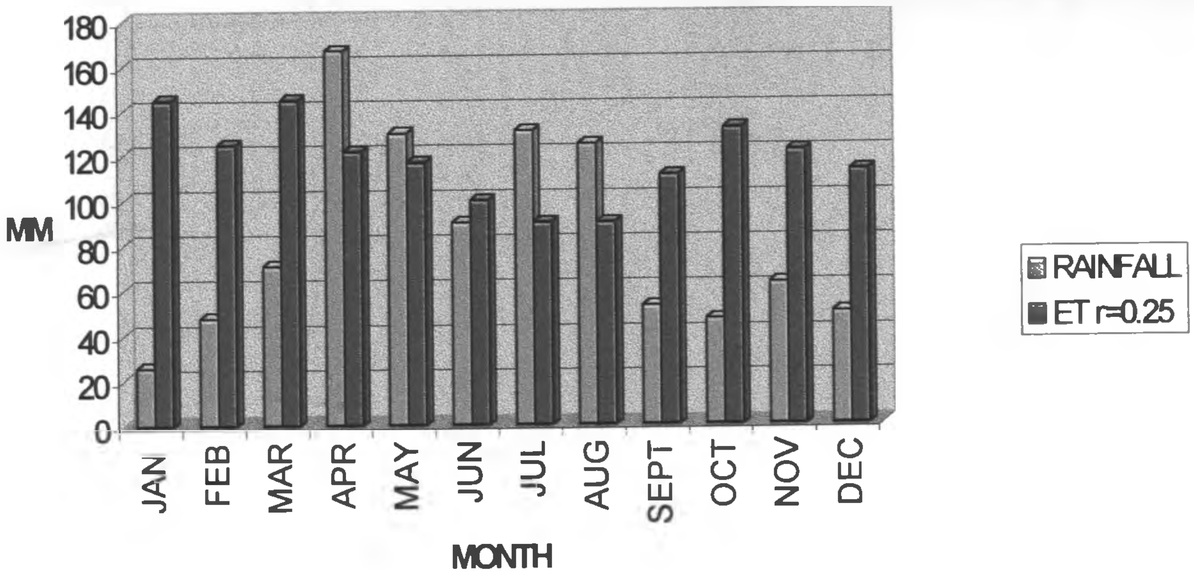
Though from the figures a distinct maxima is noted between March and September, the rainfall can be said to be evenly distributed. However the seasonality of rainfall affects the rivers' regime quite distinctly as will be seen later. The available data showing rainfall and pan evaporation for Eldoret town in 1965 shows that the town recorded rainfall of 881 mm and evaporation of 1688 mm.

Fig. 2.7 **Map showing Average annual rainfall of Uasin Gishu**



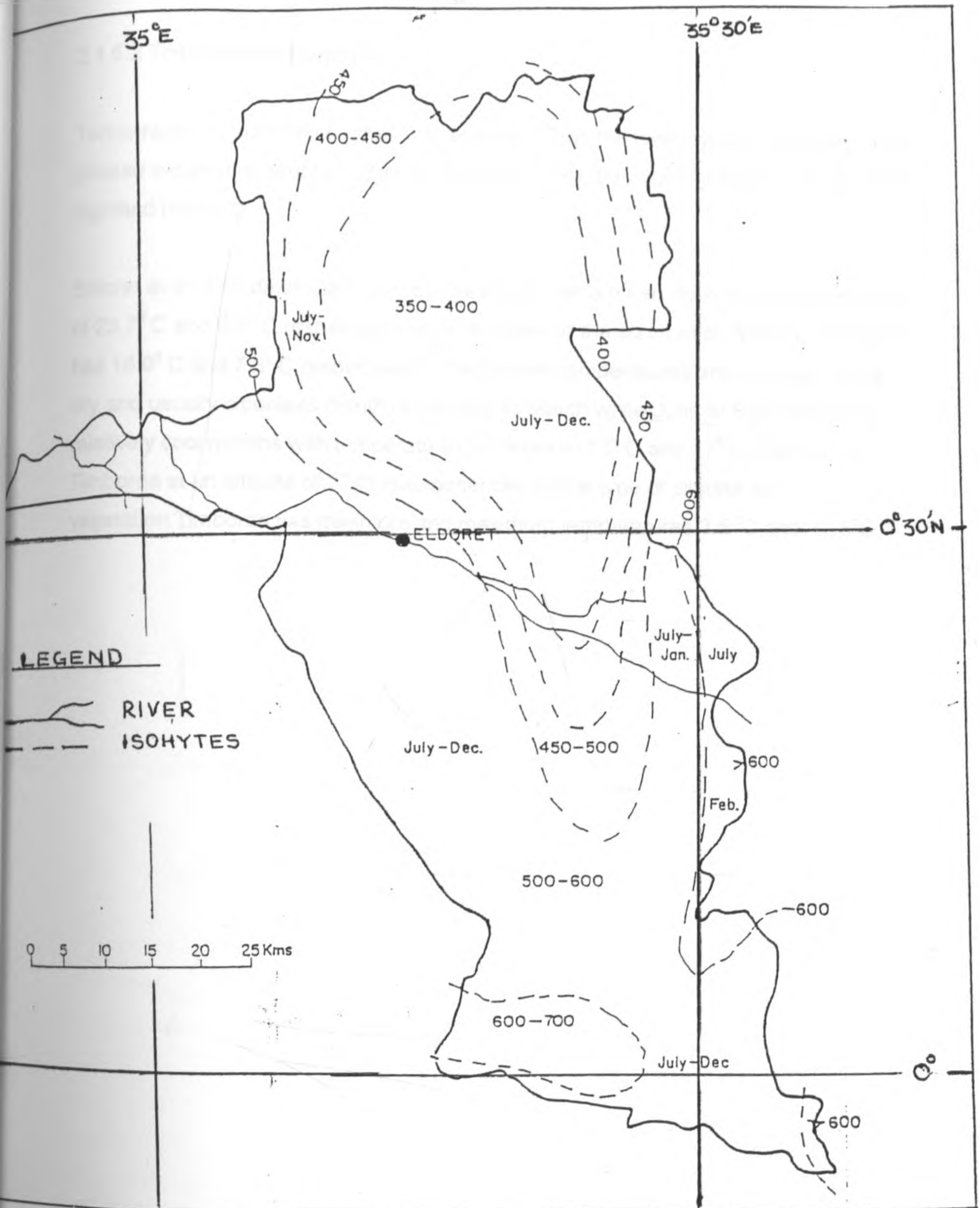
Source : Jaetzold and Schmidt 1982

Fig. 2.8: ELDORET:ET/RAINFALL RELATIONSHIP (1963-1966)



Source: Ministry of Agriculture (1982)

Fig. 2.9 **Map of Uasin Gishu district showing reliability of rainfall in Agro-humid period of second rains.**



Source: Jaetzold and Schmidt (1982)

2.1.6.2 Temperature Regimes:

Temperature in the district varies with altitude. Thus the lower western and northern plateau experience slightly higher temperatures than the higher eastern and southern highland plateaus.

Eldoret at an altitude of 2084 m above sea level has a mean maximum and minimum of 23.7^0 C and 9.5^0 C respectively while Ainabkoi in the south at an altitude of 2660 m has 18.9^0 C and 7.6^0 C respectively. The highest temperatures are recorded in the dry and usually cloudless month of January to March while June to September are relatively cool months with temperatures of between 12^0 C and 17^0 C (Table 2.1). Timboroa at an altitude of 2743 m experiences alpine type of climate and vegetation.Timboroa has minimum and maximum temparatures 3.5 °C and 17.5°C

TABLE 2.1. Temperature Data (Eldoret)

Name of station	AEZ	Kind of records	Jan	Feb	Mar	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.	Years of records
Eldoret D.C.	LH ii.1.1 lp	Mean max.	25.6	26.2	25.9	25.3	23.9	24.1	21.3	22.0	23.5	24.5	24.2	24.4	24.2	20
		Mean temp.	17.1	17.6	17.9	18.1	17.4	16.2	15.5	15.4	15.9	16.9	17.2	16.7	16.8	
		Mean min.	8.5	9.0	9.9	10.8	10.8	9.2	9.4	8.8	8.4	9.3	10.1	8.9	9.4	
		Abs. Min.	3.1	3.7	4.7	6.1	5.0	4.4	5.3	4.4	4.4	4.4	4.5	2.8	2.8	
Eldoret Met. Stat.	LH ii.1.2 lp	Mean max.	24.9	25.7	25.9	24.3	23.4	22.6	21.4	21.6	23.1	23.7	23.6	23.7	23.7	21
		Mean temp.	16.9	17.3	17.8	17.8	16.8	15.8	15.5	15.5	15.9	16.7	16.9	16.6	16.6	
		Mean min.	8.8	8.8	9.7	11.2	10.2	8.9	9.5	9.3	8.7	9.6	10.2	9.5	9.5	
		Abs. Min.	1.6	2.6	3.4	5.0	4.9	4.6	4.9	5.2	4.5	4.5	3.6	3.6	3.6	
Eldoret Experimental Farm	LH ii.1.3 lp	Mean max.	23.6	23.9	24.4	22.5	22.1	21.6	20.3	20.9	22.1	22.2	21.6	21.9	22.2	8
		Mean temp.	16.9	16.1	16.6	16.5	15.8	15.2	15.4	14.5	14.7	15.9	16.0	15.5	15.5	
		Mean min.	8.4	8.2	9.1	10.5	9.4	7.7	8.4	8.1	7.2	9.6	10.3	9.0	8.8	
		Abs. Min.	1.4	2.2	3.3	4.4	4.7	3.3	3.9	4.4	3.3	3.0	3.3	4.4	4.4	
Ainabkoi (operating to 1959)	UH ii.1.4 lp	Mean max.	19.2	20.2	19.9	19.1	18.7	18.6	18.2	18.1	18.6	19.2	18.5	18.8	18.9	14
		Mean temp.	13.4	13.9	13.8	13.5	13.3	13.0	12.9	12.8	13.1	13.6	13.1	13.2	13.3	
		Mean min.	7.6	7.6	7.6	7.8	7.8	7.3	7.3	7.5	7.9	7.9	7.6	7.6	7.6	
		Abs. Min.	2.8	3.3	5.0	5.0	4.4	5.0	4.4	4.4	5.0	5.0	4.4	5.0	2.8	
Kipkabus Downs Estate (operating to 1963)	UH ii.1.5 lp	Mean max.	19.9	21.0	20.8	19.8	19.8	19.1	18.3	18.1	19.1	19.1	18.3	18.4	19.3	7
		Mean temp.	14.9	14.3	14.8	14.4	14.3	13.1	12.8	12.8	13.2	14.0	13.7	13.9	13.8	
		Mean min.	7.9	7.5	8.7	8.9	9.1	7.1	7.3	7.4	7.2	8.8	9.1	9.3	8.2	
		Abs. Min.	3.2	4.4	3.3	0.6	5.0	4.4	4.4	3.9	4.4	4.4	5.0	4.4	0.6	

Temperatures in °C

Source :Ministry of Agriculture (1982)

2.1.7 RIVER DRAINAGE SYSTEMS

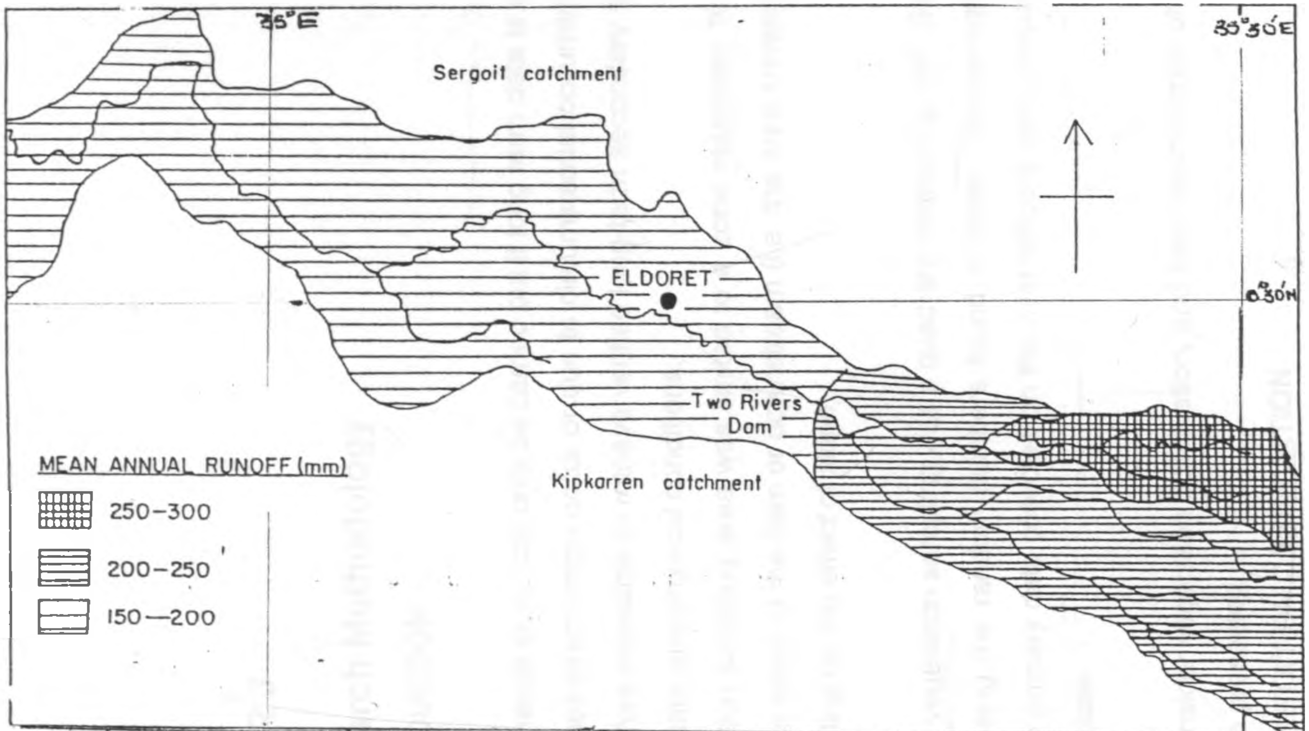
The district is endowed with numerous and well spread perennial streams and rivers of moderate lengths which draw their head waters from the well watered and forest regions in the south and east and especially Elgeyo escarpment in the north-east. In general the south and central parts of the district are drained by the Sosiani, Sergoit and Kipkarren. The river density is higher in the south and in the west and decrease northwards. The whole drainage system is part of the Lake Victoria drainage system. The Sosiani River which constitutes part of the study area, is approximately 60km. Long and passes in the middle of Eldoret town, has its headwaters near the crest of the well watered Elgeyo escarpment, where it starts as confluence where the TWO RIVERS DAM lies, which constitutes one of the study areas (*Fig.2.2*), the river takes on the name of Sosiani. The river which drops considerably in its descent flows westwards but centrally in the district cutting through tertiary phonolite formation in the lower highland zones, an area with a mean annual runoff of between 200 – 300mm. (*Fig.2.10*). The river then passes through Eldoret town dividing it into two, then proceeds to Selby Falls where it plunges from the western margin of the Uasin Gishu phonolite onto precambrian banded gneisse (metamorphic rocks and then flows the foot of the lava escarpment to Turbo eventually joining the Kipkarren river near the western margin of the district. The total catchment area of the river is 665km^2. The river experiences a high water volume between April and November, peaking off in April, and again between July and September. From December to March the river experiences relatively low water volume. This picture compares quite well with the rainfall pattern experienced in the district. The effect of damming the river at the confluence of the Endoroto and Ellengirini is the core of this study. The other major rivers in the district are the Sergoit (catchment area 692km^2) and the Kipkarren (catchment area 2641km^2).

2.1.8 LAND USE PATTERN

The land in the entire district is classified as arable, of which 2,354km^2 and 1,430km^2 of land are classified as high and medium potential agricultural land respectively (*Fig.2.9*). The district was easily settled by the white farmers more so due to its migratory population. The district in the past was exclusively farmed by large mixed farms. The relatively flat terrain of the district easily accommodated any type of machines.

According to Mwendwa (1985), the most dominant land-use type in Uasin Gishu is grazing which occupies about 50% (188,667ha) of the total land area. Maize, wheat and wattle (Acacia mearnsii) plantations occupied 19.4% (73,348 ha), 14.7% (55,470 ha) and 3.4% (13,139 ha) respectively, while natural forests, bush roads and trucks, forest, woodlots, swampy areas, fallow land, hedges, bare ground, structures, water bodies, bananas, sunflower, vegetables, napier grass and citrus fruits occupied: 3.3% (12,480 ha), 1.98% (7,286 ha), 1.6% (5,972 ha), 1.5% (5,606 ha), 1.48% (5,579 ha), 0.78% (2,960 ha), 0.4% (1,812 ha), 0.32% (1,212 ha), 0.29% (1,099 ha), 0.28% (1,042 ha), 0.23% (872 ha), 0.05% (196 ha), 0.04% (140 ha), 0.03% (113 ha),and 0.01% (26 ha) respectively. The next chapter examines the research methodologies used in the present study.

Fig. 2.10 **Map showing Mean annual run-off Sosiani River (1963-1966)**



Source: Eldoret Water Resources Investigation (1982)

CHAPTER 3

3.0 Research Methodology

3.1 INTRODUCTION

An environmental study can only be carried out if long term data is available so as to remove biases which might occur or due to circumstantial occurrences. In this study it was therefore inevitable to retrieve verified long-term secondary data especially as regards climatic and physical conditions.

The vegetation sampling area was limited to a zone maximum 10 metres from the water source either at the dam or downstream (i.e. the area known as the flood plain thus controlling on the effect of slope).

The unit for vegetation sampling was a quadrant measuring $1M^2$. Sampling was done randomly using the random numbers found in Neter, Wasserman and Whitemore (1988). The primary data collected on the river effluent was compared with available secondary data.

First we consider vegetation observation, and then the methods of chemical analysis of water are presented.

3.1.2 VEGETATION OBSERVATION

Various variables were to be observed in this phase. An overall surveillance established the indicator species which would make the basis of our study. These were mainly the major species. The variables thus noted were; (a) percent vegetation cover, (b) species abundance in terms of area covered, (c) percent greenness the various plant species.

To facilitate accurate observation the quadrant was divided into small squares of $0.25M^2$ and each division read separately before compiling the results of a single quadrant.

(i) Percent Greenness of the Vegetation:

This was based on the Munsell colour system. This system identifies a color in terms of three dimensions: hue, value, and chroma. Each dimension is divided into a sequence of steps arranged so that the steps are equally spaced from a perceptual point of view. Each step in each scale is assigned a designation, and the combination of these constitute a notation system that refer to the more than 1500 actual samples of the Munsell colours. Hues are equally spaced from one another in the sense of equal visual steps from one hue to the next. There are ten major hues. The order of hues corresponds to the order of the hues in the spectrum with the addition of purples. The ten major hues, consisting of five principals and five intermediates, may be referred to by their initials, for example, R for red or BG for blue green. More commonly, each of the spaces between the major hues is divided equally (visually) into four divisions, and designated by a numerical/letter combination e.g.. As 2.5 G or 10 YR, and so on.

Our field colour specification for greenness was based on that part of the visible spectrum lying between 540 nanometers (or 10.0G on the Munsell circuit) for green and 570 nanometers (or 10 GY on the Munsell circuit) for green yellow. The colour percentage notation thus gave 10 GY as a percent value of zero rising to 50% for 5 G and 100% for 10 G. Using the quadrant method each smaller quadrant was assigned a percent greenness value and the final percent greenness was the average of the total.

(ii) Biomass

Using a 1 meter squared quadrant, biomass was measured by clipping all above ground matter (which was then weighed to give us the field weight), then it was dried and weighed again (to give us dry weight). Woody vegetation was not cleared as this needed a permit from the local authorities. The biomass was expressed as grams per meter squared.

iii) Cover

The pin point method was used to calculate cover. In this case, metal pins with sharp tips served as the points, such that cover was equal to the fraction of total pins that touch any plant as the pin was lowered.

Eqn. 3.1:

$$\%\text{Cover} = \frac{\textbf{no. of pins which hit sp.A at least once}}{\textbf{total no. of pins}} \times 100$$

(iv) Height of plants

The heights of individual plants were measured and the average recorded such that the total recorded plant species height was:-

Eqn.3.2:

Ht = total plant height/no of species sampled in quadrant

3.3 CHEMICAL ANALYSIS OF WATER

Analysis of water into the conventional trickling filter plant and the stabilization ponds at the Municipal water works were undertaken. The discharged water after treatment into the river was also collected and analysed in the laboratory. Sampling down the river was done at an interval of 10m so as to confine ourselves within the study zone. At the laboratory the following variables were analysed; Biological Oxygen Demand (B.O.D), C.O.D, trace anions and cations. The pH was also monitored, while temperature in ^{0}C was measured. The results were tabulated in a table. These procedures were also repeated at the dam so as to compare the water quality in the two sample areas. Methods of water analysis were based on BEST and ROSS (1977), documented methods which are in universal usage..

(i) Biochemical Oxygen Demand (B.O.D)

The test involves measuring the dissolved oxygen in the sample initially and thereafter incubation for 5 days at 20^{0}C, the difference between the two values is the B.O.D. Since any substance which is likely to inhibit the activity of the microorganisms will interfere with this test, samples of high acidity or alkalinity outside the pH range 6.0 to 8.0 is buffered to approximately pH 7.0 with 0.5 M H_2S0_4 or 1M NaOH respectively.

In each case the required volumes of samples and dilution water at 20^{0}C were mixed in a one litre graduated cylinder. Two of the 250 ml were filled to overflowing with the mixture and the level brought to 750 ml. Two bottles were also filled with the plain dilution water and used as blanks. In each case the bottles were tapped with stoppers to remove air bubbles and the stoppers were then firmly inserted.

The dissolved oxygen is determined immediately in one bottle of each mixture of sample plus dilution water and also in one of the blank bottles. The remaining bottles were incubated for five days at 20^{0}C, after which time the dissolved oxygen was measured again. Equation 3.3 was used to determine B.O.D.

Eqn.3.3:

$$\text{B.O.D. (in p.p.m.)} = \frac{[(a-b) - z(x-y)]\,(z + 1)}{z + 1}$$

where:

a = initial dissolved oxygen in sample

b = final dissolved oxygen in the sample

x = initial dissolved oxygen in blank

y = final dissolved oxygen in the blank

z = volume of dilution water to 1 litre of sample

(ii) Dissolved Oxygen

In testing for DO 250 ml of sample was filled in a bottle till it overflew avoiding excessive babble formation. The sides of the bottle were tapped with a stopper to raise any trapped air bubbles to the surface. To the sample is added 2 ml manganous sulphate solution, followed by 2 ml alkali-iodide recipient through a pipette. After replacing the stopper, the solution was then carefully mixed.

The precipitate was then allowed to settle to a level that at least 100 ml of clear supernatant was produced, and then 4 ml of sulphuric acid was pipetted into the bottle below the liquid surface. The bottle was then stoppered again and thorough mixing done to ensure even distribution of liberated iodine.

Exactly 100 ml of the resultant mixture was titrated in conical flask, with M/80 sodiumthiosulphate to a yellowish colour, where upon 2 ml starch solution was added and titration continued until the blue colour just disappeared. The equation 3.4 was used to compute D.O. p.m.m.

Eqn.3.4:

D.O. p.m.m. = ml M/80 Thiosulphate used for titration

(iii) pH Value

The potentiometer was used to measure pH. In this method the pH values were determined by measuring the potential difference between two electrodes which are immersed in the test solutions. One of the electrodes, the reference electrode, the glass electrode, responds to the hydrogen ion in solution. The pH value was then easily read on the meter scale.

(iv) Suspended solids

Due to the faulty nature of the certificate at the laboratory, the filtration through a glass fibre filter pad was used. This method is however simple and does not require expensive equipment such as the centrifuge.

The glass fibre filter pad was dried in an oven at 1050C for two hours and then placed in a dessicator to cool It is then weighed and placed in a funnel above the perforated disk.

A predetermined volume (using 250 ml) of well mixed sample was measured in a measuring cylinder. The volume taken was dependant upon the suspended solids content of the sample as noted visually. The water pump was turned on to create a vacuum beneath the disk and the sample was poured into the funnel. When all samples had passed through into the filter flask, the pad was washed a few times with distilled water, taken from the funnel and placed in the oven at 105°C for at least two hours. After cooling in the dessicator, the filter pad was then re-weighed. Equation 3.5 was then used to compute suspended solids.

Eqn.3.5:

$$\text{Suspended solids (p.p.m.)} = \frac{(B - A) \times 10^6}{\text{Volume of sample}}$$

Where:

A = initial weight of GF pad in g

B = final weight of GF pad in g

Note that the weighing was done using the more sensitive and accurate analytical balance.

(v) Index of dominance C

This index of dominance © is defined:

Eqn.3.6:

$$C = \sum (n_1/N)^2$$

Where:

n_1 = importance value of each species,
N = total of importance values.

vi) **Index of similarity (s)**

This index expresses the distribution of species in an area. The index of similarity (s) between two samples is given by equation 3.7 below.

Eqn.3.7:

$$S = \frac{2C}{A + B}$$

Where:

A = number of species in sample A

B = number of species in sample B

C = number of species common to both samples

(vii) **Diversity and equitability indices**

The distribution of individuals among the species is drawn by species evenness, or species equitability. Evenness is maximum when all the species have the same number of individuals. Species diversity on the other hand is a combination of richness and evenness. To measure the diversity index (H), the Shannon-Weiner function was applied thus. The function is defined in equation 3.8.

Eqn.3.8:

$$H = -S\,(P_i)\,(\log 10\ P_i)$$

Where:

H = index of species diversity

S = frequency of species

P = proportion of total samples belonging to the ith species.

On the other hand equitability index is defined as follows:-

Eqn.3.9:

$$H_{max} = -S\,(I/S\ \log_{10} I/S) = \log_{10} S$$

Where:

H_{max} = species diversity under conditions of maximal equitability

S = number of species in the community.

3.4 Research and Methodology Limitations

The major limitation during the field study lay in water sampling analysis. Whereas the facilities to collect the water samples existed, an exhaustive analysis was hampered by the low number of samples collected, the number being directly dictated by capital resources. Water analysis sampling is quite an expensive undertaking. The total number of samples analyzed for B.O.D., C.O.D., suspended solids, pH and other trace elements was 40 downstream and 40 at the dam. This represented less than 50% of the originally planned sample of 150 in each area. This limitation was however drastically improved upon by the availability of secondary data from the German organization: *"Staatlich anerkanntes Laborder Deutschen Abwasser – Reinigungs – GmbH".* Their data was collected using the most modern techniques and analysis done in their German laboratories. My attempt to get the whole data set was however rejected and only selected data types were availed to me (app xiii). Data relating to river quality which was of much interest to this study was denied, and thus the analyses reported wholly on primary data downstream. The data from the German organization on the dam water quality tallied quite closely with our primary data *(app. xiii and table 5.1).*

Vegetation sampling was closely monitored by the Municipality such that vegetation sampling was again limited especially with regard to biomass observations. The reasons here were based on the recommendation of the Presidential Working Commission on Soil Conservation. While soil chemical status may be relatively constant through time, soil moisture and most atmospheric conditions vary constantly with time. With facet of this temporal variation to measure was a problem and this could only be solved through enlightened judgement based on extensive reading and field observations. The instruments and time to do field work were hampered by the costs involved. In choosing to undertake this study during the dry season the assumption was made that the environment variation was minimised as compared to the wet season.

How to measure correlation between plant populations and the environmental conditions posed on the onset a fundamental problem of interpretation. This is because a species performance normally increases along an environmental gradient and then decreases beyond the ecological optimum. In this regard linear correlation can yield a meaningless coefficient. Only when the data have been drawn from limited segments of environmental gradients, will the monotonic response of the species result in an interpretable correlation coefficient. The analyses in the present study attempted to avoid these complications by confining to graphical and other direct indices measure. This however makes it difficult to consider multiple environmental effects. Consequently, interpolation may be an option. This option was chosen due to the difficulty in pinpointing (or testing), which environmental effect caused what.

An even more vexing methodological problem concerned the interpretation of the plants themselves: environmental interrelationships in the field causing collinearities between variables may result in close correlation between a plant species distribution and several environmental conditions. It is normally impossible to specify which, if any, of these are truly casual without careful experimentation. Collinearities between measured and unmeasured variables would eventually present even more serious problems of interpretation as observed close correlation may be entirely spurious. An exhaustive description was thus preferred and then this closely related as much as possible to observed environmental effects. Synergistic effects between different environmental variables are widespread in field environments and, add further difficulties to the environmental interpretations. The next chapter examines the characteristics of vegetation patterns and distribution in the present study areas.

CHAPTER 4

4.0 Characteristics of Vegetation Patterns and Distribution

4.1 VEGETATION ANALYSIS

4.1.1 Introduction

The study area is broadly found in that zone referred to as: *Upland Evergreen and Semi-Deciduous Bushland* or more specifically the area under sub-zone L4 – defined as *Open Evergreen and Acacia* – Evergreen Bushland of Eldoret; undifferentiated plateau region; (survey of kenya 1966 : VEGETATION MAP OF KENYA)
The vegetation species found to "dominate" in the areas sampled and thus used indicator species for this study are outlined in the table 4.1 below.

Table 4.1: Species guide in the study area

SPECIES TYPE	DAM	DOWNSTREAM
sp_1	Present	present
sp_2	Present	present
sp_3	Present	absent
sp_4	Present	absent
sp_5	Present	present
sp_6	Present	present

sp_1 - *Pennisetum clandestinum*   **sp_6** *Caress edulis*

sp_2 - *Sida cuneifolia*

sp_3 - *Cissamperos pereira*

sp_4 - *Helichrysum pereira*

sp_5 - *Acacia nilotica*

Other vegetation species were also noticed but their frequency of occurrence was quite low, especially if each of those rare species were to be taken separately and, thus were not included in the analysis since their analysis would require far more complicated equipment than was available.

4.1.2 VEGETATION PATTERNS

Species association was observed and recorded as shown in the table below.

Table 4.2: Species Association and Frequencies

SPECIES TYPE ASSOCIATION	FREQUENCY	
	DAMSITE	DOWNSTREAM
sp_1 (pure stand)	36	32
sp_1/sp_2	17	5
sp_1/sp_3	7	0
sp_1/sp_4	2	0
sp_1/sp_5	24	7
sp_1/sp_6	2	22
sp_1/others	12	4
TOTAL	100	70

From the above table it is clear that species association in both sites of the study area is in favour of not more than any two species (considering the major species alone).

Further the average percentage cover and average height of *Pennisetum clandestinum* in association was tabulated and represented to highlight the spatial distribution of this species. The results are tabulated in the Table 4.3 below (*and field data see apps. xv(a), xv(b), xviii, and xx).*

Table 4.3: Percent cover and height by species and associations at study sites

Species Types & Association	Dam site		Downstream	
	% Cover	Ht (M)	% Cover	Ht (M)
sp_1 alone	91.8	0.154	92.9	0.158
sp_1/sp_2	87.1	0.118	78	0.084
sp_1/sp_3	85.4	0.142		
sp_1/sp_4				
sp_1/sp_5	76.5	0.922	67.1	0.207
sp_1/sp_6			82.1	0.55

From the above table it is immediately realized that the effect of other species growing in association with *Pennisetum clandestinum* (sp_1) is to reduce its total spatial distribution with the effect being more discerned downstream of the dam than at the dam site. Whereas the species *Sida cuneifolia* (sp_2) and *Helichrysum pereira* (sp_4) are herbaceous, *Acacia nilotica* (sp_5) and *Carissa edulis* (sp_4) are shrubs (woody plants). It will be demonstrated later that the decrease or increase in height is a factor of the particular plant that is growing in association with *Pennistum clandestinum*.

From the average area measurement of each species (*see apps.xviii* & *xx*), the index of dominance (C) was calculated to portray the study areas plant distribution.

The degree to which dominance is concentrated in one, several of many species can be expressed by the index of dominance (C) which sums up each species importance in relation to the community as a whole. Thus the relation; index of dominance (C) is defined by equation 3.6 in section 3.3 of chapter three. It's computations for the study area are given in the table 4.4 (a) and (b) below.

Table 4.4(a): **Index of Dominance (C) values at the Dam Site**

Species Types	Area of Species (n_1)	Total Area under Vegetation (N)	$C = \sum(n_1/N)^2$
sp_1	60.7 M^2	78.4 M^2	0.6
sp_2	2.09	78.4 M^2	0.00078
sp_3	1.75	78.4 M^2	0.0005
sp_4	0.04	78.4 M^2	0.00026
sp_5	8.5	78.4 M^2	0.01
sp_6	0.93	78.4 M^2	0.00014

Table 4.4(b): Index of Dominance (C) values at the downstream site

Species Types	Area of Species (n_1)	Total Area under Vegetation (N)	$C = \sum(n_1/N)^2$
sp_1	49.4	59.7 M^2	0.68
sp_2	0.89	59.7 M^2	0.0002
sp_3		59.7 M^2	
sp_4		59.7 M^2	
Sp_5	2.5	59.7 M^2	0.00175
sp_6	3.97	59.7 M^2	0.0044

Key:

sp_1 - *Pennisetum Clandestinum*
sp_2 - *Sida Cuneifolia*
sp_3 - *Cissamperos pereira*
sp_4 - *Helichrysum pereira*
sp_5 - *Acacia nilotica*
sp_6 - *Carissa edulis*

From the analysis shown in the Table 4.4 it is apparent that *Pennisetum clandestinum*is the dominant species in the two study areas. However in vertical stratification, the upper canopy was devoid *of Pennisetum clandestinum. Acacia nilotica* and *Carissa_edulis* constituted the major woody plants and upper canopy cover. The distribution of these two species was observed and the index of similarity (s) between the two species recorded (Table4.5)

Table 4.5: Index of similarity (S) and dissimilarity between the Acacia nilotica (sp_5) and Carissa edulis (sp_6) at both study sites

LOCATION OF SPECIES	NO. OF SPECIES SP_5 (A)	SP_6 (B)	NO. OF SPECIES COMMON TO BOTH SAMPLES (C)	INDEX OF SIMILARITY S = 2C/A+B	INDEX OF DISSIMILARITY 1-S
Dam	30	8	1	0.0526	0.947
Downstream	8	26	1	0.059	0.941

Using the same procedure as in the case of index of Dominance (C), the dissimilarity between *Pennisetum clandestinum* and species *Acacia nilotica* and *Carissa edulis* in the two study sites was calculated (Note that due to the nature of *Pennisetum clandestinum*, which does not allow for physical counting, frequency values were used).

Table 4.6: Index of similarity (S) and dissimilarity between Pennisetum clandestinum and Acacia nilotica and Carissa edulis in the two study zones

LOCATION	NO. OF OCCURRENCE OF P. CLANDESTINUM (A)	SP5 (B)	SP6(B)	C	S=2C/A+B	1-S
Dam	100	30		30	0.461	0.6
D/Stream	70		26	26	0.54	0.5

In order to consolidate the essence of the above analysis Diversity Index and Equitability index were computed and discussed.

4.1.2.1 Diversity Index and Equitability

The distribution of individuals among the species is known as species evenness, or species equitability. Evenness is maximum when all the species have the same number of individuals. Species diversity on the other hand is a combination of richness and evenness, it is thus species richness weighted by species evenness. To measure the diversity index (H) the Shannon-Weiner function was applied thus:-

Eqn.4.1

$$H = -\sum_{i=1}^{s} (P_1)(\log_{10} P_1)$$

Where:

H = index of species diversity

S = frequency of species

P = proportion of total sample belonging to the ith species

(a) Thus at the dam site for a sample of the five species (excluding Pennisetum clandestinum which could not be physically counted) with 76 individuals, the results are given in the table 4.7 below.

Table 4.7: Index of Species Diversity (Dam site)

SPECIES TYPE	FREQUENCY (f)	p_1	$(p_1)(\log_{10}p_1)$
sp_2	24	0.3157	0.1499
sp_3	7	0.0921	0.0964
sp_4	7	0.0921	0.0964
sp_5	30	0.3947	0.1596
sp_6	8	0.1052	0.1022
			H = 0.6045

Thus if all species were equitably distributed, then H_{max} is as defined by equation 4.2

Eqn.4.2:

$$H_{max} = \log_{10} 5 = 0.6989$$

Hence, equitability is determined by:-

$$E = H/H_{max}$$

$$= 0.6045/0.6989$$

$$= 0.864$$

(b) On the other hand at the Downstream site, for a sample of three species with 42

individuals (Pennisetum clandestinum excluded), the results are given in the Table 4.8 below.

Table 4.8: Diversity Index (H) at the Downstream Site

SPECIES TYPE	FREQUENCY (f)	P_1	H	E
sp_2	8	0.19047	0.0244	
sp_5	8	0.19047	0.0244	
sp_6	26	0.61905	0.1110	
			H = 0.1598	0.335
			$H_{max} = \log_{10} 3 = 0.477$	

The dominance of *Pennisetum clandestinum* in the two study sites is clearly exemplified by the index of dominance which in both cases is well above 0.5 and no other plant species approaches even a value of 0.1. As *for Acacia nilotica* and *Carissa edulis* which are the next most dominant species at the dam and downstream sites respectively, these appear to prefer to inhabit different habitat or at least prefer not to grow in association with one another. This is quite evident from the index of dissimilarity between the two species which nearly approaches unity, a value which expresses complete dissimilarity. On the other hand, *Pennisetum Clandestinum* seems to have a 50% chance in any of the two sites to inhabit the same habitat with the other two major species (index of similarity for *Pennisetum clandestinum* and *Accacia nilotica* at dam being 0.53 while the same value for *Pennisetum clandestinum,*and *Carissa edulis* is 0.54). The distribution of species at the dam is also more, even than at downstream as indicated by the index of equitability being 0.864 at the dam site and 0.335 downstream (these values do not include *Pennisetum clandestinum*). The question that arises is that: why this disparity given that the two site zones share the same climatic conditions? An analysis of the major species (*Pennisetum clandestinum*) was conducted in the hope of finding an answer to this question. The discussion is given in the next sub-section.

4.1.2.2 Characteristics of Pennisetum clandestinum

4.1.2.2.1 The Dam Site:

On the average, pure stand *Pennisetum clandestinum* covered an area of 0.65 M^2. The variance in area distribution was 0.044 and the standard deviation from the mean was 0.21. The total average area under vegetation at the dam averaged 0.748 M^2 *(app. xvii).*

The percent cover/total area relationship shows that there is a direct relationship between the total area covered by vegetation and the percent cover of *Pennisetum clandestinum (appendix I, II & III).*

On average, pure stand *Pennisetum clandestinum* registered an average height of 0.154 M with a standard deviation of 0.175 M from the mean. The average height of *Pennisetum clandestinum* either growing alone or in association was 0.29 M, with the least height of 0.02 M noted in association with *Sida cuneifolia* while the maximum of 1.2 M is also noted in association with *Acacia nilotica*.

4.1.2.2.2 Downstream Site

On the average, pure stand *Pennisetum clandestinum* covered an area 0.81 M^2 and the standard deviation from the mean was 0.146. The total average area under vegetation here was 0.84 M^2 (*see app. xx*). The total area under vegetation is a factor of *Pennisetum clandestinum* percent cover as compared to other plant species. The graphical representation of these relationships is carried in the appendices iv, v, vi and vii.

On the average, pure stand *Pennisetum clandestinum* registered an average height of 0.158 M with a standard deviation of 0.139 from the mean. The average height of *Pennisetum clandestinum* growing either in association or alone was 0.177 M, with the least height of 0.05 being a constant in either pure stands or when growing in association while, the maximum height of 1.2 M was recorded in association with Acaccia nilotica.Accacia are nitrogen fixing plants and may have improved the soil fertility.

4.1.2.3 Area – Cover Relationship

The area – cover relationship investigates the relationship between the total area covered by the vegetation and the percent cover of the plant species present.

4.1.2.3.1 Area-cover relationship at the Dam site:

For pure stand of *Pennisetum clandestinum* an $r^2 = 0.598$ was recorded. On the other hand the interaction of other species results in an $r^2 = 0.094$. The graphical representation of these interactions is carried in appendix viii.

4.1.2.3.2 Area-cover relationship at the Downstream site:

The absence of a large number of species association and the dominance of *Pennisetum clandestinum* and *Carissa edulis* (at the upper canopy) is quite evident from the graphical representation of the area-cover graphs as indicated in the appendix iv.

In both the study areas the relationship between the major plant species and the total area covered by vegetation is directly proportional. This allows us to concentrate our study of plant species behaviour on these species as they act as indicator species.

It is important to note that the above relation is maintained downstream only at the expense of other minor species which are virtually unrepresented unlike at the dam site where other minor species still occur. The mechanism which brings about this pattern of vegetation association are considered in chapter five.

4.1.2.4 Pennisetum Clandestinum in Association:

In both the study areas *Pennisetum clandestinum* was found in association with all other species. On the other hand, association between other species was minimal. The sample size for *Pennisetum clandestinum* association with other species other than *Acacia nilotica* at the dam and *Carissa edulis*, downstream was so low as to allow for any meaningful statistical tests. It is however, one thing to be able to document and quantify plant competition, association etc. and another thing altogether to determine the resources or causes for competition or association. The analysis below is intended to explain the present existing situation in a statistical manner with the hope that it will help in making certain deductions and inferences. The major upperstory canopy at the dam and downstream was composed of species *Acacia nilotica* and *Carissa edulis* respectively. For the 24 samples at the dam where Acacia nilotica occurred, it on average covered an area of 0.59 m^2. For the 22 samples of *Carissa edulis* sampled downstream, the upper canopy area averaged 0.67 m^2. *Acacia nilotica* and *Carissa edulis* in both the study areas were randomly distributed under the various canopies. An analysis was carried out to see what effect the canopies have on the characteristics of *Pennisetum Clandestinum*. Investigation was done using the Spearman's rank correlation method which can be represented as shown in equation 4.3 below.

Eqn.4.3

$$r_s = 1 - \left[\frac{6 \sum d^2}{n^3 - 1} \right]$$

Where:

r_s = Spearman's rank correlation coefficient

$\sum d^2$ = Sum of the squared difference

n^3 = number of parts of observations

In investigating the effect of the canopy on the area covered by *Pennisetum clandestinum* the r_s value for the dam and downstream were found to be 0.07 and 0.109 respectively.

Using the same methods and with the same assumptions the relationship between the canopy area and height of *Pennisetum clandestinum* was investigated. The r_s values for the dam and downstream were 0.474 and –0.232. For these values the students "t" test was conducted to test for significance. The "t" test can be represented as given in equation **4.3**:

$$t = r_s \sqrt{\frac{n-2}{1-r_s^2}}$$

4.2.4.1 Effect of canopy on vegetation distribution:

Investigation of the dominant shrub species on the *Pennisetum clandestinum* was carried out in the two areas, a factor that could have a bearing on the biomass productivity. At the dam site samples of *Pennisetum clandestinum* covered by *Acacia nilotica* were considered while at the downstream site samples of *Pennisetum clandestinum* under *Carissa edulis* canopy were more important and were considered. Twenty-four such samples were identified at the dam site while correspondingly, twenty-two samples were identified at the downstream site.

In both cases above, the area under *Pennisetum clandestinum* is the total area in the quadrant since it is practically impossible to demarcate the direct area under vegetation canopy of the two dominant shrub species.

The results indicate that on the average the canopy area of *Acacia nilotica* was found to be 0.5887 M^2 while the area under *Pennisetum clandestinum* on the average was 0.5966 M^2 this being at the dam site. Further on average, at the downstream site the canopy area of *Carissa edulis* was found to be 0.671 M^2 while the average area under *Pennisetum clandestinum* was 0.49 M^2.

The total average understory vegetation cover in the two samples areas worked out to be 0.8645 M^2 and 0.8631 M^2 at the dam and downstream site respectively

Hence on testing the Hypothesis H_{04}, the following results were adduced:-

Though the samples size was small (24 at the dam and 22 downstream) a test was conducted (using Spearman's rank correlation coefficient) to try and establish if any correlation exists between the canopy area of dominant species and *Pennisetum clandestinum*. At the dam an rs =0.0723 was established while downstream an rs =0.109 was recorded. It could be said that the canopy area was not large enough to have a significant effect on the understorey vegetation both at the dam and downstream site.

4.1.2.4.2 Effect of canopy on Pennisetum clandestinum spatial growth:

Basing our argument on the results analysed in section 4.2.1 above, investigations were carried out to determine effects (if any), of the dominant shrub species canopy on the spatial growth of the dominant understorey vegetation, in this case *Pennisetum clandestinum*. In retrospect, it was that:

- On the average, the canopy area of *Acacia nilotica* for the 24 samples was 0.588 M^2,
- On the average, the canopy area of *Carissa edulis* for the 22 samples was 0.671 M^2, the average height of Pennisetum clandestinum growing under canopy *of Acacia nilotica* at the dam was 0.52 M,
- The average height of *Pennisetum clandestinum* growing under canopy of *Carissa edulis* downstream was 0.221M.

The result of testing H_{05} shows that, an increase of *Pennisetum clandestinum* height growing in association with *Acacia nilotica* at the dam and *Carissa edulis* downstream with pure stands of *Pennisetum clandestinum* in both locations is explained as follows:

At the dam site the computed value F (.0.01, df: 23, 31) gave a value of 2.55. Given a table value of F = 14.4, the H_{04} could not be rejected.

At the downstream site computed F (0.01; df 21, 31) gave a value of 1.8. Given a table value of F = 3.686, we similarly could not reject H_{04}. Since in both cases the critical F- value is larger than computed we conclude that there is no significant increase in height of *Pennisetum clandestinum* growing under *Acacia nilotica* at the dam site and *Carissa edulis* at the downstream site than as when growing as pure stands. It is known that vegetation cover will strongly modify the diurnal temperature fluctuations in the soils and the extent will depend on the various characteristics such as height, colour and density (Barbour, et al 1978). The possible reasons as to the above noted observation will be linked to other factors noted below. In general however, solar radiation penetration into the canopy is depleted exponentially by successive leaf layers according to Bouguer – Lambert law (Barbour, et al 1987). The present study did not examine spectral reflectance of the vegetation in the two areas nor did it look into the spatial temperature profiles.

4.1.3 GREENNESS OF PENNISETUM CLANDESTINUM

The average percent(%) greenness of *Pennisetum_clandestinum* growing under *Acacia nilotica* at the dam site was 56.45%. On the average the sampled area (i.e. 36 quadrants) where *Pennisetum clandestinum*_grew as a pure stand, the greenness stood at 45%. For the 22 samples of *Pennisetum clandestinum* downstream growing under canopy of *Carissa edulis*, the average greenness was 53.8%. For the 32 samples of pure stands of *Pennisetum clandestinum* at the same site, the average greeness stood at 48.28%. The relationship between total plant respiration and gross photosynthesis is difficult to establish with the results that field investigations of canopy photosynthesis and plant growth rate usually give ambiguous results. It is therefore difficult to find a significant correlation between daily crop growth and canopy net photosynthesis in various stands of grasses. However it is generally accepted that, as a result of canopy development there arises adaptation and a change in spectral quality as light penetrates the canopy (Seehy and Peacock, 1975). Consequently, the larger the range of light saturated photosynthetic rates amongst the leaves and species of the canopy, the greater the number of photosynthetic niches available. This has the tendency of allowing the development of deep, species rich and efficient light harvesting canopies. This perhaps explains the reason for the deeper pigmentation (i.e. percent greenness) of the *Pennisetum clandestinum*_growing under *Acacia nilotica*. The low light adaptations of deep shade species make them more quantum efficient. Indeed long-term consequences of the photosynthetic process are weight gain by the whole plant. Blackman (1919), showed that plant growth is a phenomenon in which the rate of increase of size or weight is often governed by existing size and as such may be expressed in the form of the Kelvin's compound interest law as given in equation 4.5.

Eqn.4.5

$$W_1 = WO^{eR}\,(T1 - T0)$$

Where:

W_1 and WO = the dry weights at the beginning and end of growth periods

e = the base of the natural log (2.718)

(T1 – T0) = the growth period, and

R = the relative growth rate.

These modifications will obviously be a factor of the canopy leaf area index (L), which is the ratio of leaf area to ground area, and leaf area duration (D) which is the integrated value of the relationship between leaf area index and time. Leaf area duration represents the leafiness of the vegetation cover throughout the growing period and can be represented as given in equation 4.6 below.

Eqn.4.6

$$D = \frac{(L_1 + L_2)\,(T_1 + T_2)}{2}$$

Where:

L_1 and L_2 = leaf area indices at

T_1 and T_2 = beginning and end of growing season.

From the observation explained above, we expect the modifications alluded as represented at the dam site where canopy is closed and leafiness is quite significant as compared to the downstream site where *Carissa edulis* represents a relatively open canopy and leafiness is low. The percent increase of *Pennisetum clandestinum* growing under canopy at the dam and downstream is 11.45% and 5.25% respectively.

4.1.4 GRAZING DENSITY

In the study areas, grazing by cows, sheep and goats was observed. Around the dam site, rabbits and smaller species of antelopes were sited. Due to their infrequent visits the latter two species were excluded from the grazing density calculations. Plant predation was considered here due to three impacts associated with plant predation namely;

(i) Uniform and non-lethal removal of organs or metabolites which change the physiological status of the plant in relation to the environment, competition and entry of pathogens;

(ii) Death or competitive elimination of the individual and,

(iii) Production of regeneration niches, often bare soil and modification of the soil by inputs of faeces or urine, creating new niches of modifying competitive status.

The grazing density (i.e. number of animals per km^2 per hour) in the two zones was relatively high being twenty animals/km^2/hr at the dam site and 18 animals/km^2/hr at the downstream site. With grazing being selective we expected dramatic effects on the species association (e.g. a reduction on the species or *Pennisetum clandestinum* to minor representation, promotion of a greater plant species diversity, the creation of grazing niches permitting otherwise physiologically similar plant species to co-exist without exclusion competition).

The interaction between grazing and other environmental factors is multifactoral and difficult to characterise but it appears that heavy grazing either leads to selection or discrimination to ascertain whether the absence of *Cissamperos pereira* and *Helichrysum pereira* and the low occurrence of *Sida cuneifolia* and *Acacia nilotica* had anything to do with grazing downstream. However species *Helichrysum pereira* is both rare at the two sites. The only notable observation at the downstream site was that grazing was more predominant in the areas where *Pennisetum clandestinum* grew as pure stand than where in association with *Carissa edulis.* At the dam site however, due to the high plant association grazing was mainly on *Pennisetum cla*ndestinum but the animals had to graze even in the areas where it grew in association. Areas where the average height of *Pennisetum clandestinum* was lowest is characterised by pure stands. However the observed selectivity of grazing animals at both sites is not well understood. Thus, it may be necessary to examine other factors such as biomass, in order to decipher the underlying structure on the interaction of several factors.

4.1.5 BIOMASS PRODUCTION

The main interest here was placed on the behaviour of *Pennisetum clandestinum* growing either as pure stand or in association with the major species. A summary of biomass productivity is given in table 4.9 below (app ix, xvi, xvii, xix)

Table 4.9: Biomass Productivity at Dam and Downstream Sites, Sosiani River

Location	Pure Stand Pennisetum Clandestinum		Pennisetum clandestinum under canopy	
	Average Field weight (g/m^2)	Average Dry weight g/m^2)	Average Field weight (g/m^2)	Average Dry weight g/m^2)
Dam	53.46	50.76	41.208	36.25
Downstream	55.7	51.73	51.26	47.25

As previously considered in section 4.1.3 and 4.1.4 certain aspects have a direct bearing on biomass. These include:-

- The average area under vegetation downstream and at the dam site was found to be $0.8415M^2$ and $0.784M^2$ respectively.

- In the areas where *Pennisetum clandestinum* grows as the predominant plant species, the average area under vegetation both downstream and at the dam site was found to be $0.879M^2$ and $0.784M^2$ respectively.

- The average cover of *Pennisetum clandestinum*_growing under canopy of *Carissa edulis* downstream and *Acacia nilotica* at the dam site is given in the table 4.10 below, and includes other characteristics likely to have a bearing on the biomass. Only *Acacia nilotica* at the dam site and *Carissa edulis* downstream are considered.

Table 4.10: Pennisetum clandestinum cover characteristics. Dam and Downstream Sites, Sosiani River System

Location	% Composition of Pennisetum clandestinum under canopy	% Cover of Pennisetum under canopy	Average area below canopy under vegetation	Average height of Pennisetum under canopy
Dam Site	76.5	59.5	0.864	0.58
Downstream	82.1	67.1	0.863	0.221

Further the other vegetation aspects which may influence the productivity of biomass in the study area are summarized below:-

There is a threefold increase (2.59 times) in height of *Pennisetum_clandestinum* growing under canopy of *Acacia nilotica* as compared to *Carissa edulis thus* average height of *Pennisetum clandestinum* under *Accacia nilotica* is 0.596M, while average height of *Pennisetum clandestinum* under *Carissa edulis* canopy is 0.22M. Further the average height of *Pennisetum clandestinum* at the dam site and downstream are 0.2998M and 0.1775M, respectively.

An F-test conducted to determine if there was any difference in the canopy structure in the two areas gave values of F- computed (d.f; 21, 23; 0.01) was determined to be 2.85 compared to the critical F-value of 1.04438. This led to the conclusion that there is a significant difference in the canopy characteristics at the two sites.
Ecologically it is necessary that biomass production studies must also account for loss of leaves, branches etc. during the period between harvests. The narrow range in standard deviation on both the field and dry weights (at the dam site) and the standard deviation for pure stand of *Pennisetum clandestinum* being 29.79 gm/m^2 field weight and 28.90 gm/m^2 dry weight while downstream it was 12.47 gm/m^2 and 10.52 gm/m^2. In areas where there was association the standard deviation for field and dry weights were, dam site 24.3 gm/m^2 field weight and 23.37 gm/m^2 dry weight, and at downstream, 19.14 gm/m^2 – field weight and 19.16 gm/m^2 dry weight downstream is noted as compared to the large standard deviation in field and dry weights at the dam site (where water is not a limiting factor and thus the canopy is fairly closed).

The addition of sludge downstream increases fertility and therefore productivity is expected to be high. The environmental constraints of sludge are considered in chapter five. In the next chapter the effects of water quality and quantity are examined at the study sites.

CHAPTER 5

5.0 Factors Influencing Water Quantity and Quality

5.1 INTRODUCTION

The vegetation characteristics of the Two Rivers Dam study sites have been considered in the previous chapter. As a result certain pertinent questions arose. Flaws in the management and control of the Two Rivers dam ecosystem are appraised in this chapter so as to understand and explain the existing scenario. Whereas specific and exhaustive analysis on various pollutants (both hazardous and toxic) effects lack in the present study, a few suggestions are highlighted in subsequent sub-sections. Specifically, issues concerning the approach to improve the water quality situation downstream are addressed.

5.1.2 ASPECTS OF WATER QUANTITY

The aim here is to look into the water supply situation in the study area and at what rate the available water is consumed now. Further, future demand for water is considered.

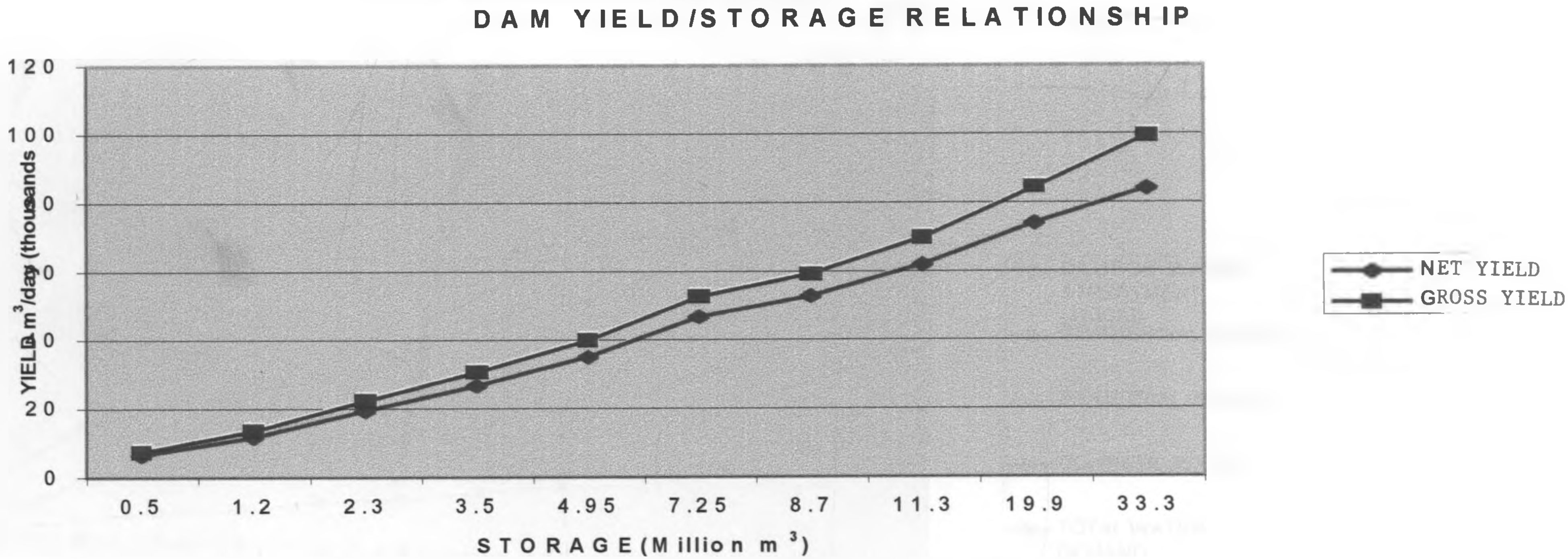
5.1.2.1 Rainfall Characteristics

The rainfall situation between September and February (*Fig 2.3*) around Eldoret is generally characterized by low levels.

For instance, the average for 1963 – 1966 being 288 mm, while for the same time evapotranspiration was 752 mm thus giving a water deficit of 464 mm.

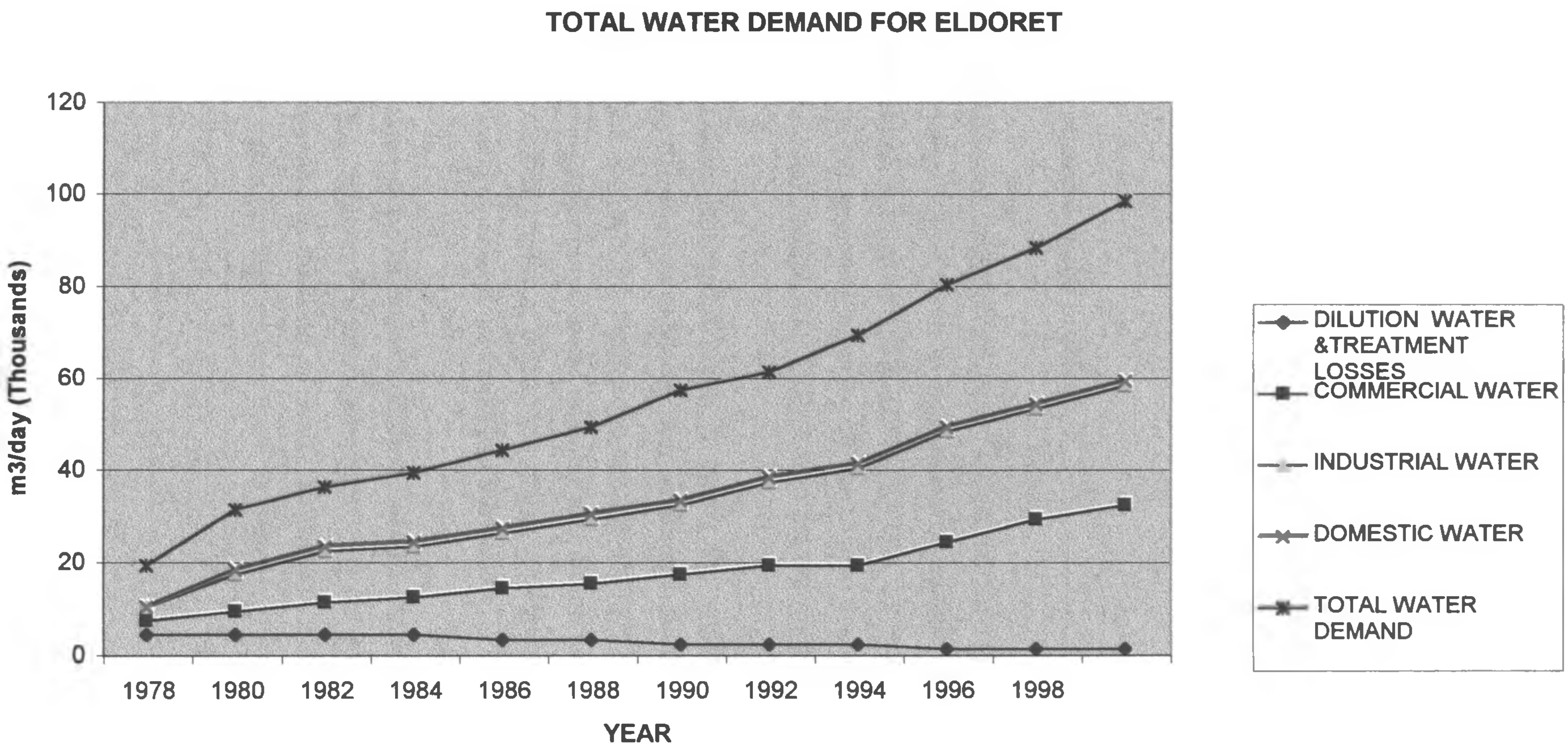
The theoretical dam yield/storage relationship (Fig. 5.1) ignores the rainfall situation on an annual basis which if considered would reveal the critical situation of water supply from the dam. Figure 5.2 (Total water demand for Eldoret) addresses this issue. However the picture can only be made clear if the seasonal fluctuations are superimposed over the graphs. The eventual results is that the stipulated bypass for the Municipal water supply dam on the Sosiani River which is supposed to be 2.5 cusecs (5.750M^3) is not met for most of the time in the year.

Fig.5.1



Source: Municipal Council of Eldoret (1985)

Fig.5.2



Source: Municipal Council of Eldoret (1985)

5.1.2.2 Water storage characteristics of the Two-River Dam

The existing daily capacity (assuming no situation, loss by seepage, evapotranspiration etc) is $9.5 \times 10^3 M^3$, whereas the daily total demand by 1990 was expected to exceed $20.0 \times 10^3 M^3$. For the same period of time, the town treatment plants are expected to treat 30,770 M^3 of sewage effluent. For the dam to provide a net yield of over $20 \times 10^3 M^3$ day then the storage of the dam has to be maintained at over 2 million cubic meters. From Figure 5.1 it is clear that if evapotranspiration, siltation, seepage etc are included, then the months of September to February (app. xxi), the total intake by the Endoroto and Ellengirini fall far short or maintaining the balance of over 2 million m^3 so as to give a daily abstraction of over 30×10^3/day. It should be noted that when the dam was constructed in 1962/63 it was to provide a daily abstraction of about 7.0×10^3/day.

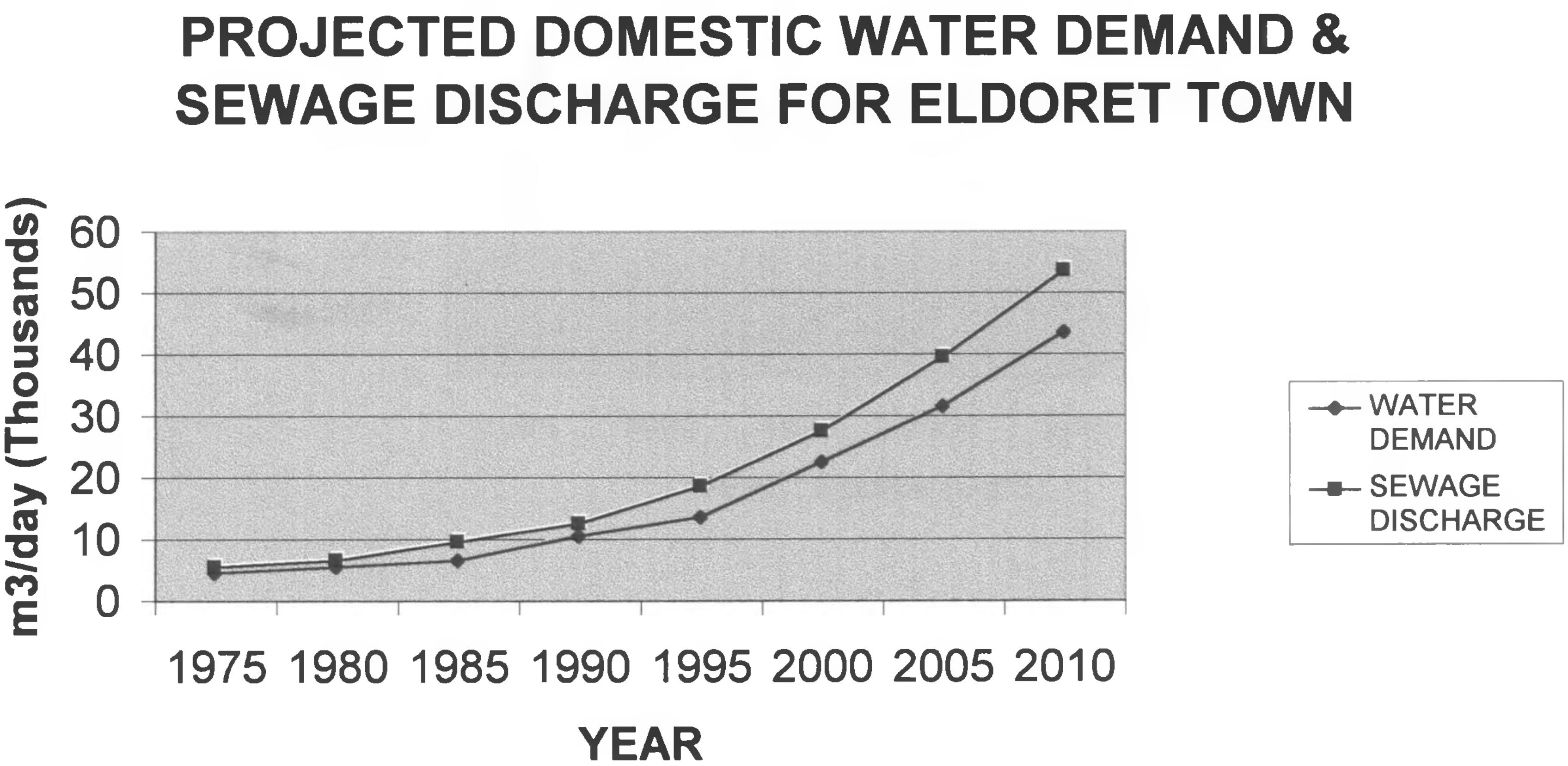
5.1.2.3 Water demand and sewage profiles:

The projected water demand for Eldoret covering the period 1978 up to and including 2000 AD is given in *Fig. 5.2.* Due to a rapid human population growth rate, the demand for water shows a commensurate increase. This demand is compared to other aspects such as industrial and domestic demand. Also the projected domestic water demand and sewage discharge for Eldoret town are shown in *Fig. 5.3.*

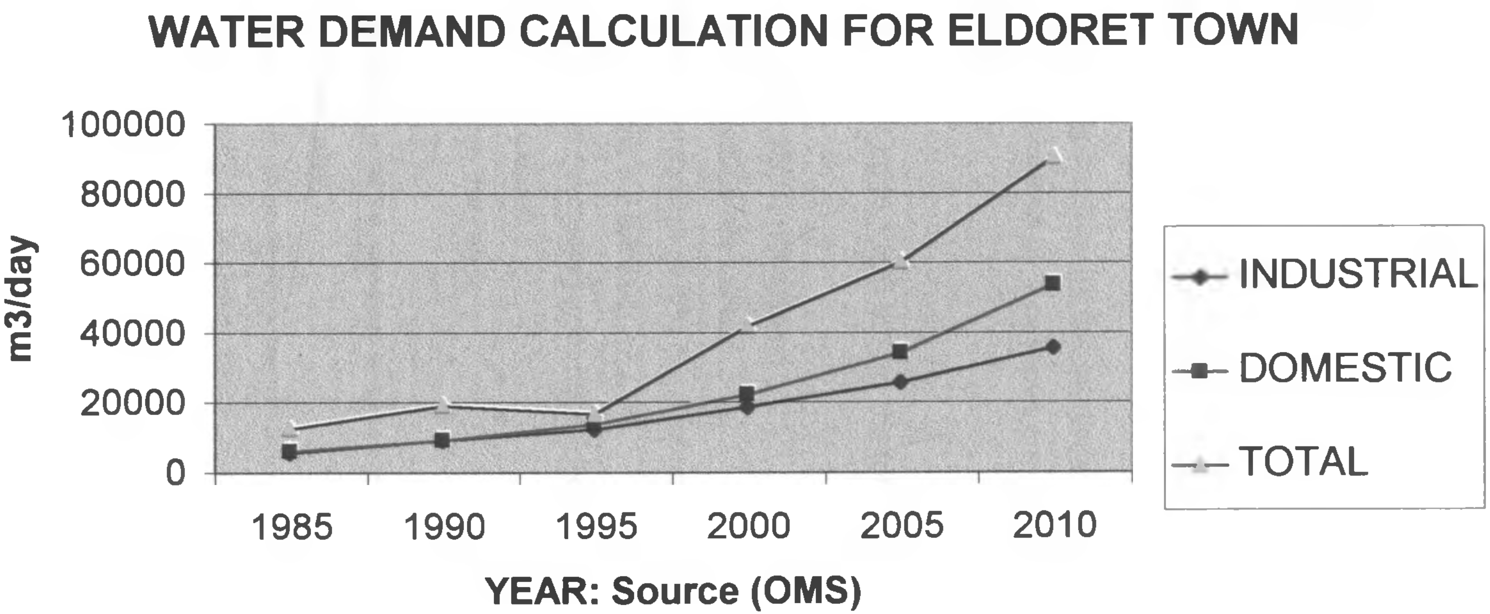
As expected the sewage discharge curve is below the water demand curve. However, both curves demonstrate similar growth patterns, indicating the similarities as at the present. The impact of the increase in sewage discharge will be discussed below. However an increase in the water demand and an increase in the sewage disposal has the ecological impact of putting the plants under water stress while at the same time introducing other external inputs into the system.

The effects of the external inputs depend on their nature. *Fig 5.4* gives a specific distribution of the water demand in subsequent years. It is not known at what level the plants start experiencing the kind of water stress (coupled with the above mentioned external influence) that causes them to change (distribution, extinction etc). An interpolated analysis due to the prevailing circumstances is attempted in the next section.

Fig. 5.3



Source: Municipal Council of Eldoret (1985)



Source: Municipal Council of Eldoret (1985)

5.1.3 WATER QUALITY

The aim of water quality analysis in this study was to document the extent to which the water impairs or enhances the environment under which the plants are exposed. Specifically aspects of water standards and water sample analysis are considered.

5.1.3.1 Water standards:

An appraisal and analysis of the sewage system set by the Kenya bureau of standards,(1985), constitute the baseline data for this study. The standards are:-

(i) The stipulated bypass flow for the Municipal water supply dam on the Sosiani River shall be increased by 1 cusecs from 1.5 to 2.5 cusecs (3,450 M^3/day to 5,750 M^3/day).

(ii) For discharges of up to 1,820 M^3/day the following must be met:-

▪ BOD (5 day, 20^{0}C) not exceed	20 mg/l
▪ Suspended solids not exceed	30 mg/l
▪ Permanganate value (4 hrs) not exceed	15 mg/l
▪ Free ammonia not exceed	1.0 mg/l
▪ Heavy metals (excluding iron) not exceed	1.0 mg/l
▪ Phenols not exceed	0.1 mg/l
▪ pH to be within the range	5.5 – 6.5
▪ oil	no trace

- the effluent must be aerated to at least 90% dissolved oxygen saturation prior to discharge
- the effluent must be disinfected prior to discharge into the river
- Flow-measuring devices must be installed at the final outlet into the river.

5.1.3.2 Water Sample Analysis

To examine the quality of water just above the Two-Rivers Dam, the following variables were studied as they are representative of the water quality in the study areas. They are:-

- Biochemical Oxygen Demand (BOD5)
- Chemical Oxygen Demand (COD)
- Hydrogen ion concentration (pH)
- Dissolved oxygen (DO)
- Suspended solids (ss)
- Presence or absence of cations and anions

The results of these analysis based on 42 samples (primary data) both at the dam site and downstream and also some secondary data are given below *(Table 5.1)*.

Table 5.1: Analysis of water samples at the dam and the downstream

DAM SITE				DOWNSTREAM SITE					
BOD	COD	pH	SS	BOD	COD	pH	SS	Cu^{2+}	Cr^{3+}
14	12	7.9	0.1	102	173	8.5	1.8		
12	18.5	7.2	0.5	105	170	6.8	0.1		
5	12	9	0.1	130	168	7.6	0.6		
12	19	7.3	0.5	150	228	8.3	1.0		
10	12	7.4	0.5	40	394	8.4	6.0	1.31	0.159
7	12	9.2	0.1	60	381	7.8	1.0	1.21	0.171
6	14	7.1	1.2	40	306	7.3	1.0	1.2	0.166
5	12	7.9	1.3	40	156	7.6	1.0	1.701	0.169
15	19.5	7.8	0.5	50	290	7.8	1.5	1.19	0.17
13	20.1	7.3	0.1	35	370	7.9	1.5	1.482	0.158
14	17	7.1	1.2	50	400	7.6	1.8		
8	19.5	7.5	0.4	40	396	6.6	0.1		
9	20.1	7.2	0.3	60	400	7.6	0.6		
6	17	7.3	0.7	105	386	7.8	1.0		
5	14	7.4	1.2	102	365	7.3	1.0		
15	12	8.2	2.1	105	400	7.5	1.5		
12	13	8.1	0.8	160	397	8.3	6.5		
10	12	7.3	0.7	103	300	7.6	1.1		
7	10	7.1	0.1	105	399	7.9	0.1		
10	17	7.5	0.4	180	400	9.0	2.1		
12	10	7.9	0.1	103	403	8.3	0.1		
14	12	7.2	1.2	40	505	7.9	1.1		
18	20	7.3	0.7	102	718	7.5	1.8		
12	20	9.0	0.5	50	400	7.3	1.0		
9	18	7.5	0.3	105	725	7.4	1.5		
5	14	7.4	0.7	103	729	7.6	6.0		
12	16	7.8	0.7	160	605	7.9	2.1		
14	12	7.9	1.3	105	401	7.4	2.2		
10	18.5	7.2	0.7	130	602	7.6	1.1		
9	18	8.0	1.3	105	597	8.3	1.2		
5	15	8.1	1.3	80	103	7.5	1.3		
7	16	7.6	1.4	140	336	8.3	1.2		
2	12	7.6	0.3	80	317	7.4	1.5		
6	14	7.5	0.5	100	323	0.6	10	1.411	0.095
12	10	7.1	1.6	70	340	8.4	2.0	1.661	0.01
14	12	7.2	0.7	80	413	7.6	1.5	1.545	0.097
15	18	8.2	0.5	120	319	7.6	1.0	0.013	0.009
7	18.5	7.3	1.2	280	537	6.2	2.0	0.901	0.2
9	19	7.9	1.5	50	718	6.2	7.0		
12	18.5	8.1	0.4	130	377	7.4	1.5		
10	14	7.4	0.3	80	624	7.2	10		
5	12	7.2	0.7	80	301	7.0	1.0		

Tests conducted to determine if there was any significant difference between the water quality at the dam site and at the downstream site shows (app xi(b), xiii, xiv) that indeed there is a significant difference in the water quality in the two zones.

5.1.4 WATER TREATMENT PLANT

The main aim of treating the water is to get rid of toxic and hazardous substances that can impair the proper functioning of the river as an ecosystem. The water quality expected after treatment, is governed by the standards set in section 5.1.3.1 (item a and b).

The conventional treatment plants such as the one in Eldoret is expected to upgrade effluent quality from the existing preliminary treatment facilities (which are totally lacking or have been neglected in most firms). However no major success has been recorded as discussed below.

5.1.4.1 **The Present Treatment Works (Ponds) .**

***PRIMARY PONDS (ANAEROBIC)*:**

Surface loading (BOD, 20^{0}C) of the primary anaerobic ponds has been found to be 2340 Kg/ha/d (Ministry of Local Government, 1985). This should be 200 kg BOD/ha/d or less in which case no smell nuisance will arise. Hence depth of the secondary facultative ponds in Eldoret should be increased.

5.1.4.2. Retention Time

In Eldoret conventional treatment plants, water losses have been noticed through seepage. Sludge accumulation has resulted in the reduction in pond capacity for maximum retention.

5.1.4.3 Effluent Quality

Soluble Chemical Oxygen Demand (COD) was utilized as test for characterization of pond effluent quality. This test measures both the biodegradable and refractory soluble organic compounds.

BOD_5 – Biochemical Oxygen demand is a measure of the degree of stabilization achieved by pond treatment. Effluent having a soluble BOD5 level of 20 mg/1 or less would be considered as stable. The waters at the dam exhibited on average a BOD_5 level of 9.97 mg/1 (with a standard deviation of 3.487 mg/1 and never recorded more than 18 mg/1). The average BOD_5 downstream on the other hand was 96.547 mg/1 (the Municipal Council average is 37.7 mg/1).

Due to he high industrial wastes received by the conventional works there is a high disinfection chlorine demand. The dye wastes, for example from RIVATEX, Raymonds, KEN-KNIT all being Textile factories have been found to have a 20 minute chlorine demand in excess of 70 mg/1 (ordinarily, a chlorine dosage of 5 mg/1 in a contact basin having a real retention time of 30 minutes will destroy almost all faecal coliform bacteria source – Eldoret Municipal Council, 1985). Chlorinating of pond effluent reduces the suspended solids by a large percentage if the retention time is increased. No cleaning measures were evident in the conventional works in Eldoret.

5.1.4.4 Sludges

In the treatment process metals present in the influent become concentrated in the sludge.Anaerobic sludges contain greater metal *(app. xiv)* concentrations than those of aerobic treatment processes. Detailed cation identification analysis was lacking in the two study areas but downstream copper and chromium were positively identified (*Table 5.1*). It was not possible to identify what metal ions if any, were released by factories such as EATEC, (chemical Plant for tanning) RAIPLYWOOD (pulp plant).

Metals tend to accumulate near the surface of the ground (*Acacia nilotica* are not deep rooters like *Carissa edulis*) except in coarse, sandy soils. It was found by de Haan (1978: in Dinges 1985) that penetration of lead, zinc, copper and cadium in sludges placed on a test site was restricted to the upper 30-40 cm of the soil profile with the highest concentration being in the uppermost 5 cm of the soil.

Metals present on a sludge treatment site may leave by soil erosion, leaching, plant growth-harvest, by insects and animal transport, and by volatilization. Intensive land sludge deposits receiving industrial residue with elevated metal or organic content would require an extensive programme of monitoring of the soils, plants and groundwater to assure that irreparable damage is not inflicted upon the land.

The check calculation for the sludge drying beds in Eldoret show that the present area of sludge drying beds has to be increased from the present 1080 M^2 to at least 1370 M^2 to achieve a satisfactory metal ions extraction. Representation of *Carissa edulis* at the dam (an area relatively free of pollutants) appears to be a water related issue. It is less competitive in such a water abundant environment and it is replaced preferentially with other species that do well in such environment. Since it grows quite well in association with *Pennisetum clandestinum* at the downstream site, it is therefore less likely that *Pennisetum clandestinum* is in competition with it or in any way inhibits its growth.

On the other hand, the low species association at the downstream site as compared to the dam site, the virtual absence of *Cissamperos pereira* and *Helichrysum pereira* and the relative low representation of *Acacia nilotica* is a reflection of factors acting in association with the low water quantity experienced downstream. It would be of paramount interest to find out at what level the above mentioned species would go into extinction when exposed in the laboratory to similar conditions as those experienced at the downstream site that is, diminishing water quantity (that is highly loaded) and exposure to pollutants found in the water. The water theory is ample in explaining the reversal in representation of the two major shrub species in the two zones but falls short in detailing the other observations (low species association at the downstream site, extinction or rather absence of the minor species etc). Observation made at the downstream area but outside the study zone (the flood plain) revealed the presence of *Cissamperos pereira* and *Helichrysum pereira* (this is an important observation since it rules out the dam acting as a barrier to seed transmission from the dam site. If the water causes seed mortality then still the two species should still be represented at the study site since not far away they appear though in an area outside our study zone).

The other reason which strongly supports the effects of pollutants as a factor in the vegetation distribution at the downstream area, is the fact that the area of study at the downstream location was much closer to the river. It was never 15M from the banks of the river than at the dam site. where the study zone was always about 20 to 30 meters from the water, a buffer zone created by reeds extended from the water to a range of 20 to 30 meters at the dam site while at the downstream site this rarely exceeded 15M.

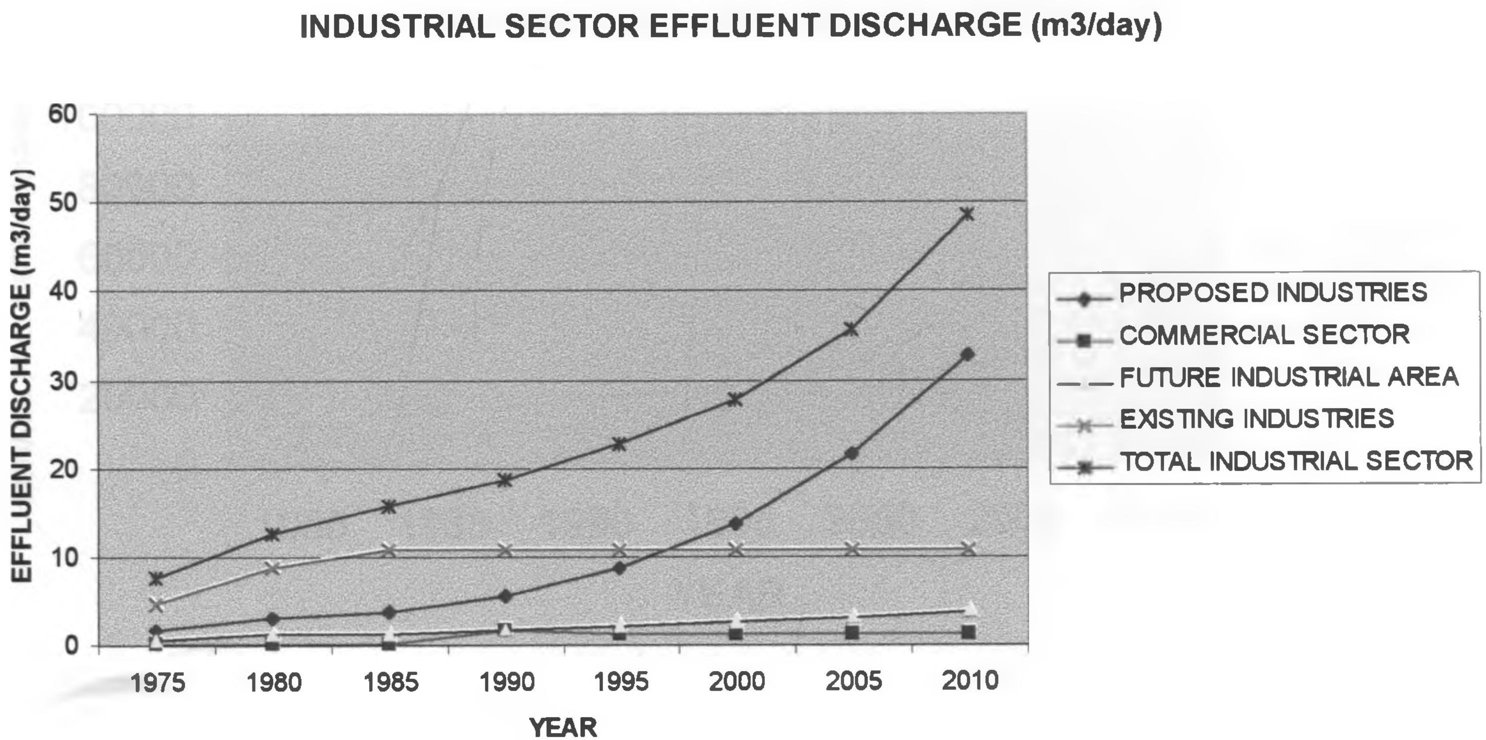
It is known that, populations can develop a tolerance to pollutants which enable them to survive in highly polluted environments. They may achieve this by functioning normally at high toxic loading or by metabolizing and detoxifying pollutants. The mechanisms of tolerance to pollution are extremely complex, involving several metabolic systems and species have solved the problem of tolerance to a particular pollutant in different ways.

Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn) and Molibidinum (Mo) are required by plants. Silver (Ag), Cadmium (Cd), and Lead (Pb) may be toxic in very small quantities. All these latter metals were positively identified *(app. xiv)* in the sludge at varying degrees. The association of the plant species exhibited at the downstream site is either due to their ability to evolve metal-tolerant species or purely due to water deficiency or a combination of the two. The former explanation in relied on to a great extent since it was observed that farther away from the downstream site towards the upper sides of the valley a reversal to species association seen at the dam site is exhibited.

5.1.4.5 General Aspects Of Pollutants And Effluent Impact Assessment

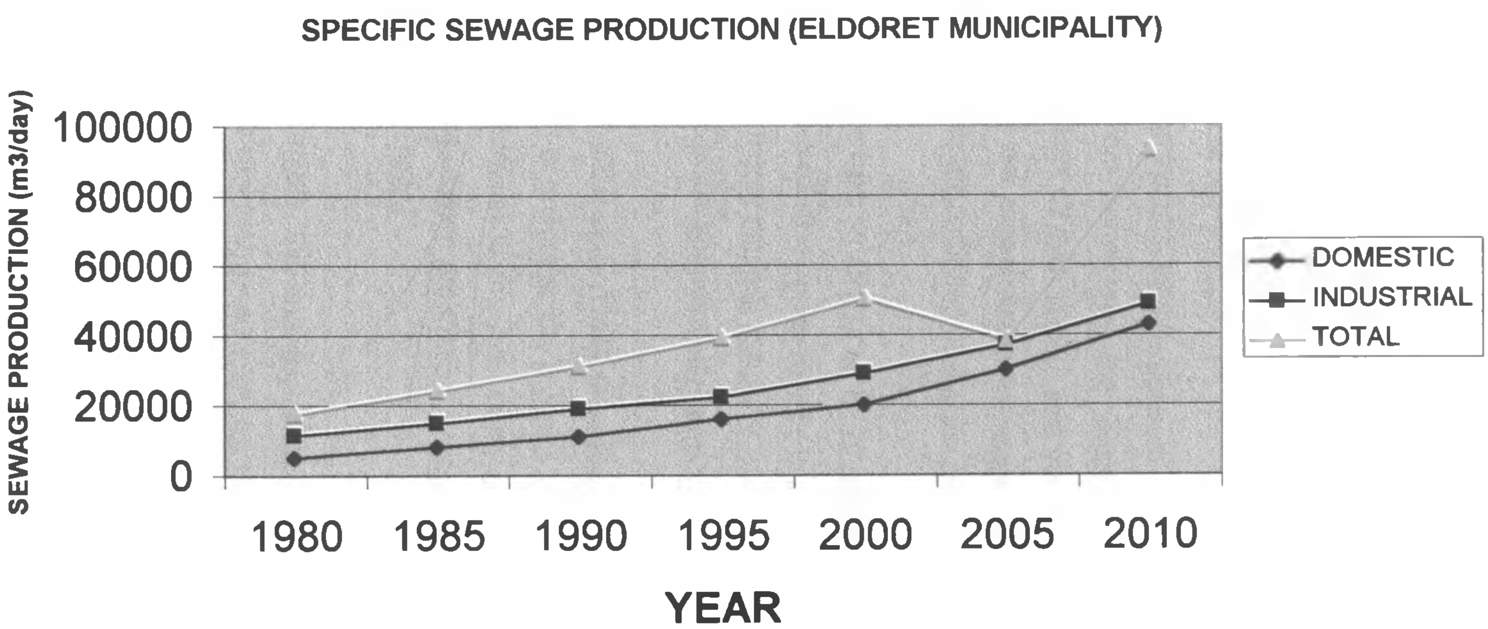
The sewage treatment plants receive large quantities of industrial wastewaters in excess of 2,674 M^3/d in addition to the town's domestic sewage in excess of 3,000M^3/d. *(Fig 5.5 and 5.6)*

Fig. 5.5



Source: Municipal Council of Eldoret (1985)

Fig.5.6



Source: Municipal Council of Eldoret (1985)

The industries discharge very alkaline wastes so much so that pH values of more than 9 *(Table 5.1)* and 12 (*app. Xii(b)*) have been recorded in the influent sewage to the lagoon.

The pH of all ponds effluent is also very high (primary data averages 7.638).

A large quantity of dyes are discharged from the RIVATEX, Raymond and KEN-KNIT textile plants and they pass largely through the treatment system.

Industries such as the C.P.C., EATEC discharge effluent with extremely high organic content which has undoubtedly given rise to overloading of the pond system. The stink experienced at the treatment works and its environs is due to the high surface loading (2340 Kg BOD_5/ha/d which is more than 10 times the acceptable load of 200 kg/ha/d which should produce no or little smell).

A high pH value results in slow growth of the bacteria while presence of dyes prevents light from penetrating the waters thus preventing algae growth. This furthermore reduces oxygen supply and the ponds turn septic. The ponds also turn septic since they are organically overloaded while due to hydraulic overloading has resulted to inadequate retention of wastes thus reduced removal of pollutants.

The pH of effluent from RIVATEX is 12.55 (***OMS Wiesbaden***) and it is too high to be accepted into the oxidation ponds as this is likely to interfere with microbial reactions in the pond. The highly alkaline nature of the effluent is also reflected by an alkalinity of 1.84 mg/1 (as CaC03 phenolpthalin carbonate) and 1636 hydroxide alkalinity.

The high COD of 1020 ppm ***(OMS Wiesbaden)*** and sulphides content of 500 ppm (OMS Wiesbaden) is unacceptable organic load as this leads to anaerobic condition in the pond. In addition to the dye stuffs of unknown characteristics but certainly capable of reducing oxygen production by algae in the pond by up to 80% (*Ministry of Local Government 1985).*

Considering for example, the quantity of discharge into the sewers by RIVATEX of 1.920 M^3/d (app XIIb) which is 40% of the hydraulic design capacity of the Eldoret sewage ponds and the above analysis, it could be said that untreated effluent from RIVATEX is killing the pond (the pretreatment plant at the RIVATEX factory is no longer functioning).

The sewage treatment plants are facing severe problems indicated by poor industrial effluent, which are not, or only partially and insufficiently treated. This reduces the efficiency of unacceptability polluted effluent into water courses, that is, extreme pit, various organic matters and even toxic chemicals.

This is made worse in the dry season (November-March) by the fact that little or no water at all flows (dilution water) over the Two-Rivers Dam to dilute the effluent discharged. The system has become overloaded, such that oxygen is used up at a rate greater than it can be replenished. Hence natural water purification is not operational (dilution water from the dam was not being received). The water downstream is thus polluted with partially decomposed sewage, anaerobic bacteria, excess carbon dioxide, ammonia, suspended solids and other substances.It is this water that drains the riparian vegetation under study below the dam.

The situation at the Two-River Dam is nearly opposite that experienced at the downstream site as exhibited by the primary data and the secondary data furnished by *"Staatlich anerkanntes labor der Deutschen Abwasser Reinigungs GmbH" (Ministry of Local Government1985).* The BOD level averaged 9.97 mg/l, COD 14.919 mg/l, pH 7.647, no traces of metal ions were recorded. It is this water that drains the riparian vegetation at the dam.

The movement of persistent toxic and hazardous pollutants through an ecosystem is obviously complex and, a study of the whole system is usually impracticable. Effluents are often complex mixtures of poisons. If two or more effluent poisons are present in an effluent (*Table 5.1)* they may exert, depending on their composition, a combined effect on a plant species, They may interfere with one another or their overall effect on an organism may be greater than when acting alone.

Pollutants occurring together may act completely independently on a target and, the one exerting the greatest effect would then be the most important one. The effects of pollutants might be additive, or antagonistic, that is, in which the combined effect on the target organism is less than expected by each pollutants effect when alone, or synergistic, that is, when the combined effect is greater than the predicted from this effect when alone. The behaviour of the pollutants downstream and how they behave need to be examined much more.

CHAPTER 6

6.0 Conclusions and Recommendations for Further Research

6.1 INTRODUCTION

The results of this study, whose main goal was to study vegetation distribution, association and adaptability to various factors that interact with it, indicate that vegetation is a good indicator of the aforementioned interaction if rigorous and exhaustive observations are made. A number of highlights are given in this section to indicate these relationships.

6.1.2 CONCLUSIONS

6.1.2.1 Conclusions on Vegetation Studies

The two study areas in actual essence exhibited similar types of vegetation. Due to various anthropological activities our interest was centered on trying to find out if these factors have had any significant effect on the vegetation characteristics. The following was noticed

- The most predominant plant species in the two zones was *Pennisetum clandestinum* and this was equally distributed in the two zones especially when growing as pure stands. No major deviations were noticed of this species when it grew as pure stand in terms of percent cover, abundance, height and percent greenness in the two zones of our study areas.

- At the dam site the major shrub species was *Acacia nilotica* while at the downstream site the major shrub species was *Carissa edulis*. These two plant species exhibited quite similar characteristics in their zones of dominance in terms of abundance; association with *Pennisetum clandestinum*, percent covers characteristics and their ability to dominate the upper canopy.

- The behaviour of *Pennisetum Clandestinum* under canopy of *Acacia nilotica* at the dam and *Carissa edulis* at the downstream site again showed a lot of similarity in the two zones. This again being in terms of height, percent cover characteristics and biomass productivity. Where a few changes were notice that were significant available explanations were deduced and theories advanced.

- The vegetation analysis done in chapter four, thus had to be explained bearing in mind that already there had been a reversal in the major shrub species matrix in the study zones.

6.1.2.2 Conclusion on Water Quantity Analysis

The two areas that comprised our study zones receive equal rainfall amounts. They are also drained by the same river (River Sosiani). During the dry season (November to March) the region below the Two Rivers Dam is poorly drained since virtually all the water is channeled to Eldoret town for human and industrial use. The only water that flows along the river at this time is the water from the treatment plants and some that comes from the factories and flow to the river directly. The area below the dam experiences a water stress during the dry season.

6.1.2.3 Conclusion on Water Quality Analysis

The water quality analysis as done in section 5.1.3 and 5.1.4 aimed at establishing the nature of the water so as to help in explaining some of the observations made especially in vegetation analysis.

- The dam waters showed that it met the standards as set up by the Kenya Bureau Standards in nearly all the aspects (section 5.1.3.1 a and b).

- The waters in the river at the downstream site on the other hand, based on the analysis done in section 5.5 rarely met the standards as set out in section 5.1.3.1 (a) and (b). The water downstream was thus not only overloaded but highly polluted with effluent sewage.

6.1.2.4 Conclusion on impact assessment of the dam construction

The effect of the Two River Dam is two-fold: -

- It retains the water and silt at the dam site thus denying the lower zones of not only water but also constant soil nourishment. Of special importance is the dilution water, more critical during the dry season.

- It does not act as a mechanical barrier to the seeds that are dispersed by water especially during the dry season.

6.1.3 RECOMMENDATIONS FOR AREAS FOR FURTHER RESEARCH

A study of this nature needs quite a bit of time, equipment and money. The above work can only be said to have covered the major aspects of the vegetation but lacks the in-depth necessary to give authoritative conclusions. A few areas that can be vital for research of this nature will be highlighted and areas of further research suggested.

- There is no significant difference on average on Pennisetum clandestinum characteristics at both the study zones, but we note a significant decrease in *Acacia nilotica* downstream where *Carissa edulis* increases (and yet it decreases at the dam site). It is imperative to introduce other elements to explain the discrepancy other than water alone. The mechanism that leaves *Pennisetum clandestinum* unaffected downstream while suppressing *Acacia nilotica* and encouraging the growth of *Carissa edulis* has to be looked into the *Acacia nilotica* thrives in areas of high water table.
- The utilization of the environment by organisms is governed by space, resources and time. If *Acacia nilotica* and *Carissa edulis* are utilizing the same combination of these components, then they are in exclusive competition. The greatest problem in studying nutritional competition (assuming lack of toxic or hazardous effluent) is the complexity of the interaction for so many major, minor and trace elements coupled with the range of competing species, some of which may also

show strong differentiation of nutritional ecotypes. A plant's success in gaining a greater share of the limiting nutrient may be suppressed secondarily by shading.

- Since rooting depth and the extent is related to drought tolerance and *Acacia nilotica* dominates at the dam site, this can be a reflection of the rooting characteristics in the water abundant areas as compared to *Carissa edulis* in a water deficient area downstream. The root niches have to be investigated.

- The question of biomass will remain inadequately tackled until total biomass is investigated. It is *established (Barbour, 1985)* that a perennial plant growing in a nutrient or water limiting environment might have a greater below ground productivity and root biomass, because uptake of water and limiting nutrients is increased by having a large and rapidly growing root system. This is an adaptation ability of *carissa edulis* in a water deficient area

- The extent to which the pollution source is the major cause of the variation must be established and whether or not the source may be tipping the balance in a situation caused by long term changes, which result from other human activities or natural environmental changes.

- At some point in the study, it will be imperative to calibrate the biological changes detected with actual measurements of the amount of pollutant(s) involved in order to be able to comment reliably.

- Attempts will have to be made to measure site water balance so as to establish a correlation between water balance and plant distribution. If this correlation is known (e.g. by having a model regression equation) then effects of other variables can be added.

6.1.4 RECOMMENDATIONS FOR POLICY PLANNERS

The U.S. Resource Conservation and Recovery Act of 1976 (RCRA) considers wastes toxic and/or hazardous if they cause or significantly contribute to an increase in the mortality or an increase in serious irreversible or incapacitating reversible illness. Also if pose a substantial present of potential hazard to human health of the environment when improperly treated, stored, transported, disposed or otherwise managed.

In attempting to regulate toxic and hazardous wastes countries draw up lists of specific substances for which there is sufficient scientific evidence linking them to adverse effects.

- Regulators of toxic and hazardous wastes must look not only at the effects massive doses of a substance (acute toxicity), but also at the effects of exposure to small doses over longer periods (chronic toxicity). The latter may be lethal even though a single massive dose is not.

- Another significant problem for regulators is defining the quantities or concentration at which wastes becomes hazardous. Nearly all substances are toxic in sufficient high doses. Some chemicals are deadly in microgram doses. Others induce a toxic response only at doses measured in grams. However, most chemical wastes fall somewhere between, making it difficult to draw the line between safe and toxic especially when dealing with plants.

- It is thus of vital interest to see if installation of specified primary, secondary and tertiary treatment plants by the Eldoret Municipality and the industries will account for any change in the vegetation and characteristics. The fact that has to be borne in mind is that the present day cost of providing sewage treatment works capable of producing satisfactory effluent is enormous. In Britain (1981), was somewhere in the region of ten million pounds for a population of 100,000 (MASON 1981).

6.1.5 SUMMARY

In the two areas of the study, the major vegetation types (i.e. the indicator species) are the same (grasses and shrubs).

The way in which they manifest themselves is also similar especially the spatial distribution. In both areas *Pennisetum clandestinum* predominates the understorey while *Acacia nilotica* (at the dam) and *Carissa edulis* (downstream) dominate the upper canopy.

The dam site is an area of silt accumulation, has relatively unpolluted water and is an area with sufficient water throughout the year. On the other hand, the area downstream is an area of water deficiency, has relatively polluted water and the soil is not replenished with silt from upstream. The absence of runners such as *Cissamperos Pereira* (which is exhibited at the dam site) is due to the fact that it's shallow roots; branches and leaves would come into direct contact with the polluted water.
Acacia nilotica virtually a xerophytic species is relatively common in areas which have climatic conditions as those found in *Chapter Two* but thrive much better in areas with slightly more water (they usually have a high leaf area index). *Carissa edulis* is short in height and has hairy and thorny leaves (factors common in dry areas).*Pennisetum clandestinum* seem to be the most resilient of the species studied and it is common for such grasses to exhibit a wide range of ecological niches.

It was not easy to quantify the part played by the effluents but it became evident that they are involved in creating the ecological niche experienced at the downstream site whose effect is the manifestation of the plants as already explained. The fact that the plant exhibit different though marginally distribution patterns both horizontally and spatially is an indication of how plants can adapt to various conditions. These enhances the species survival and the community as a whole and this if conditions are such that extremes are not such as to cause extinction.

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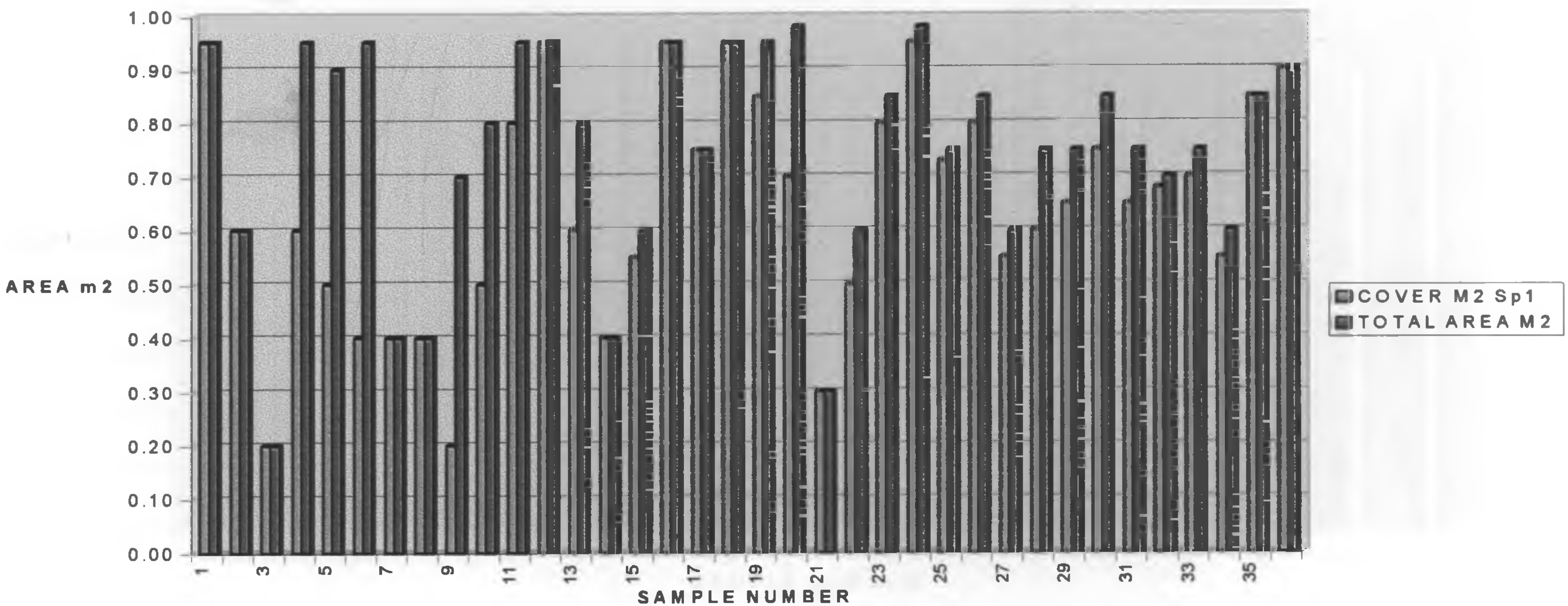
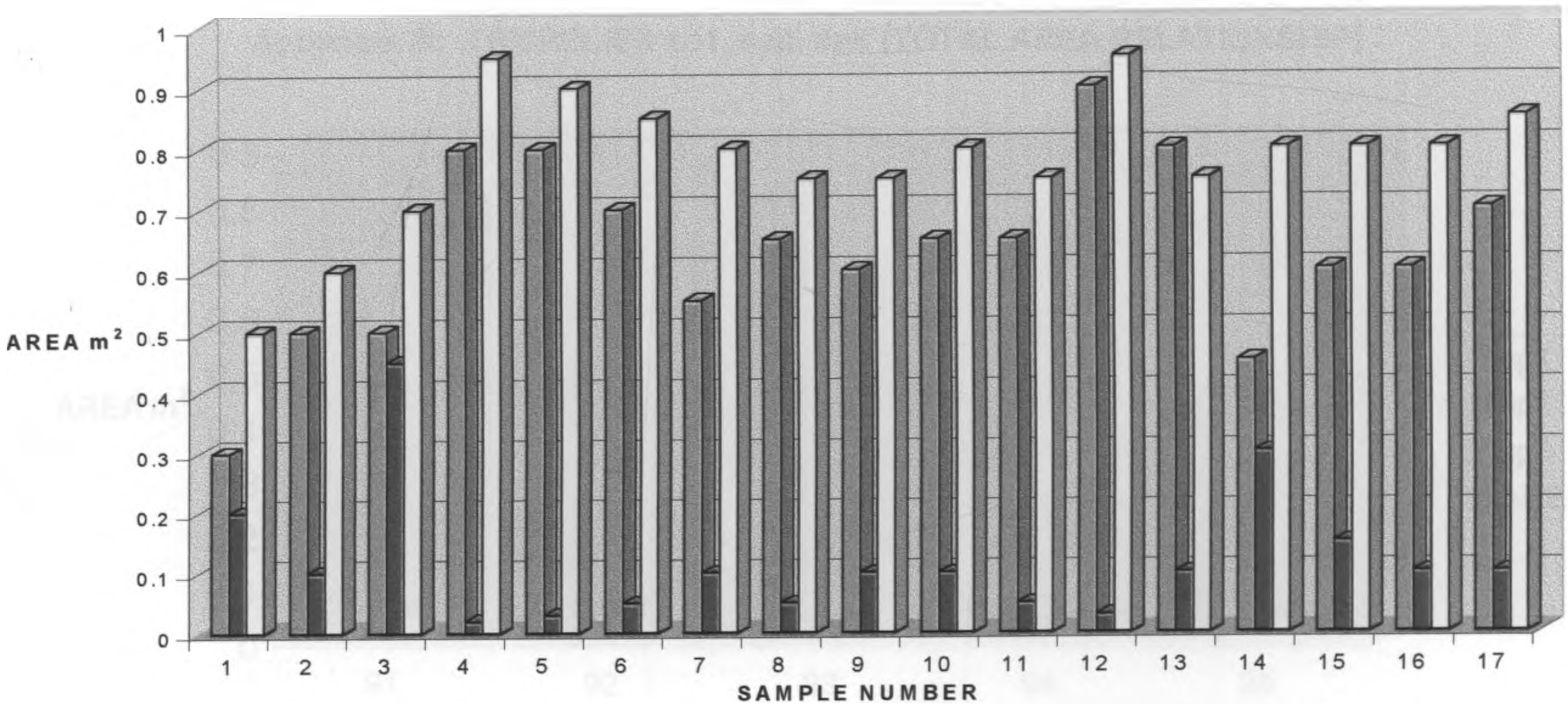
Appendix 1: sp1 COVER/TOTAL AREA RELATIONSHIP (DAMSITE)



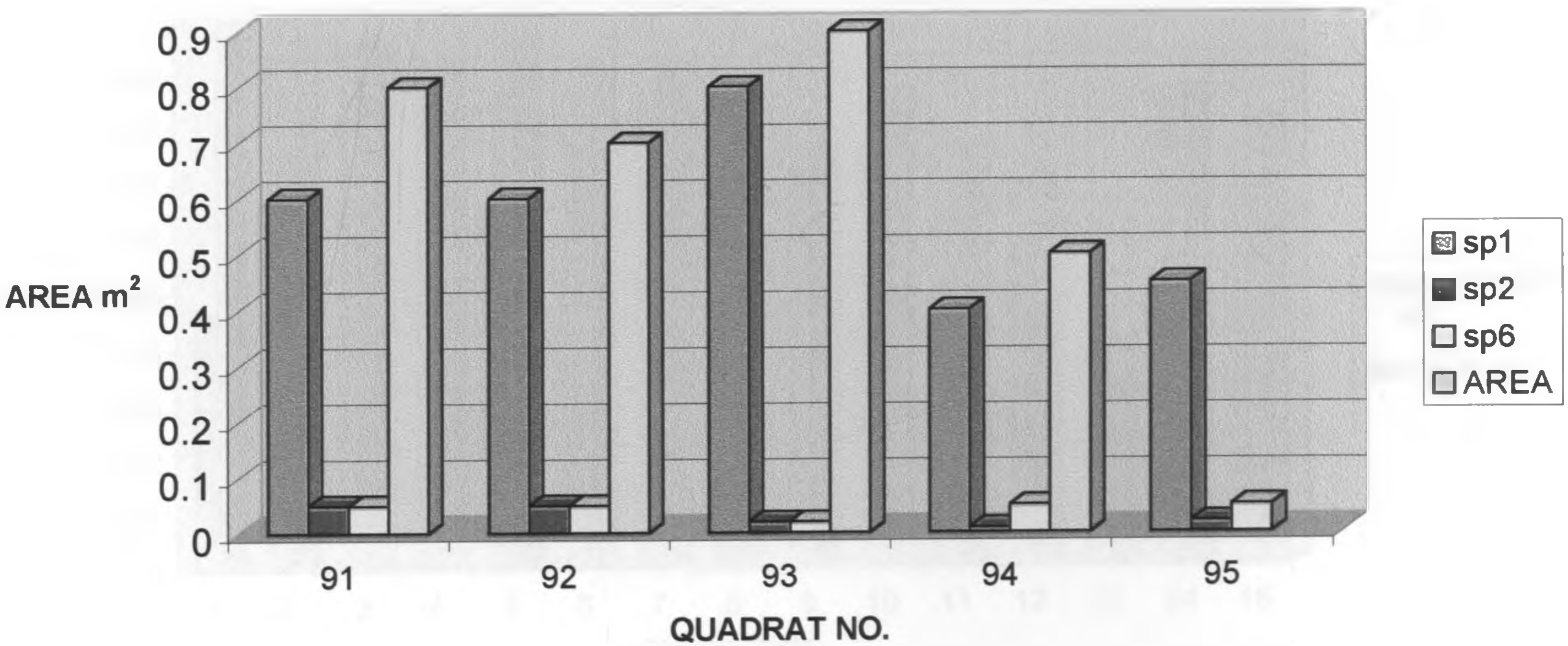
Source: Omukoba Ouna (1988)

Appendix II: COVER sp_1/sp_2, TOTAL AREA RELATIONSHIP



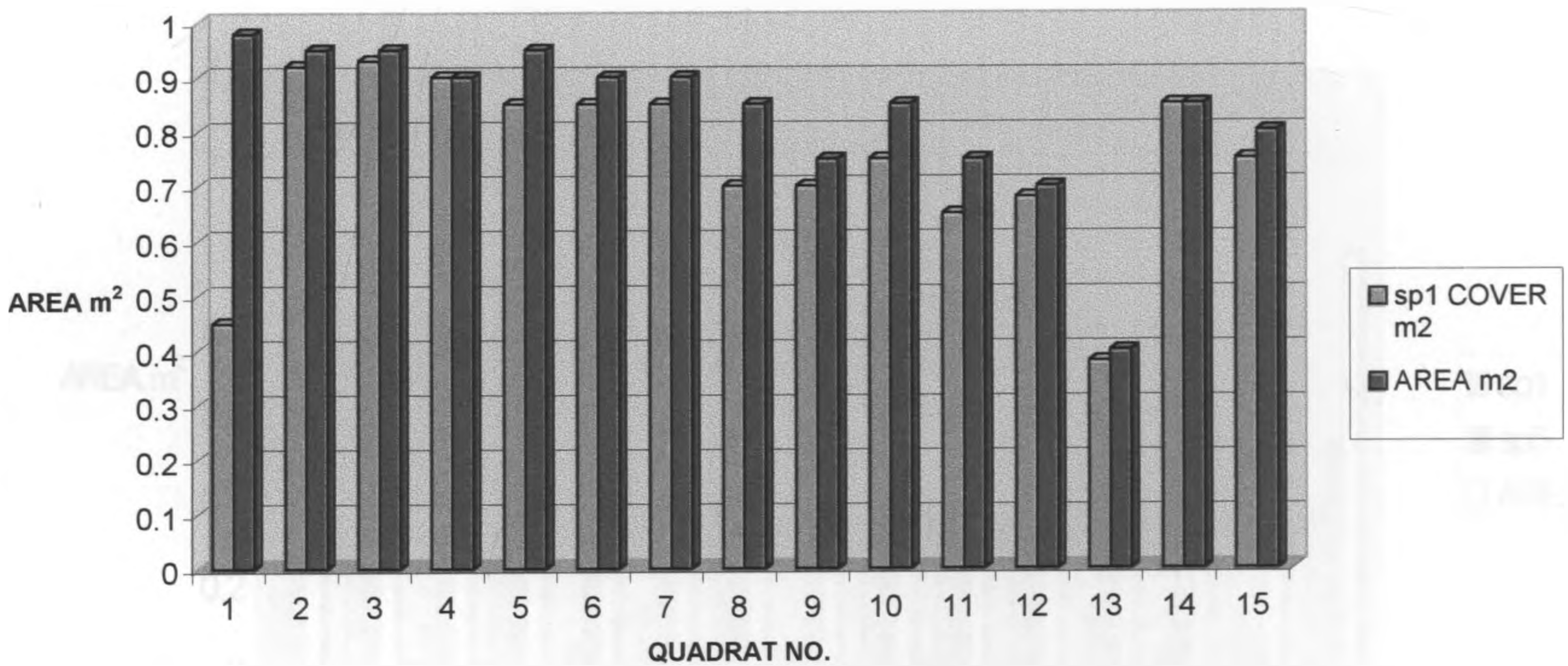
Source: Omukoba Ouna (1988)

Appendix III: TRISPECIES sp1, sp2, sp6 (TOTAL AREA RELATIONSHIP)



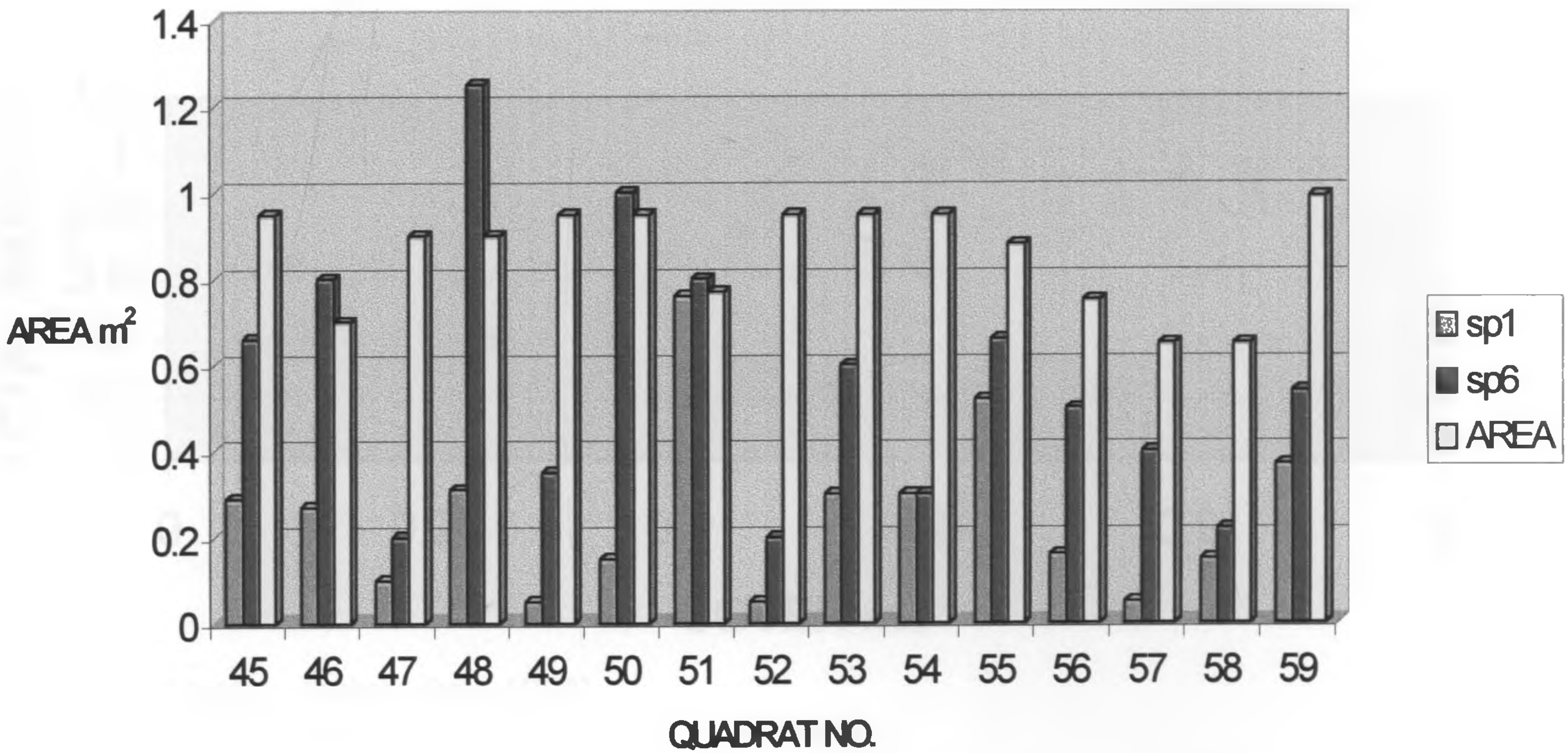
Source: Omukoba Ouna (1988)

Appendix IV: sp_1 COVER TOTAL AREA RELATIONSHIP (DOWNSTREAM)



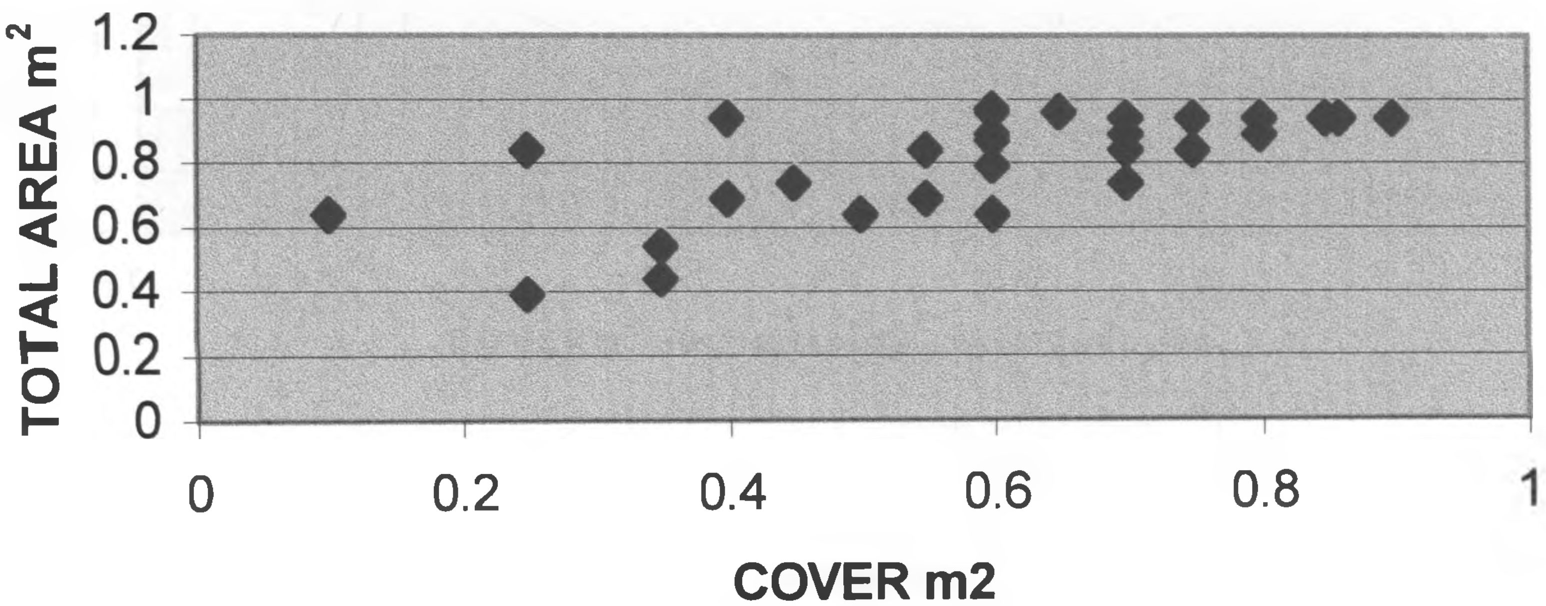
Source: Omukoba Ouna (1988)

Appendix V: sp_1,sp_6 TOTAL AREA RELATIONSHIP (DOWNSTREAM)



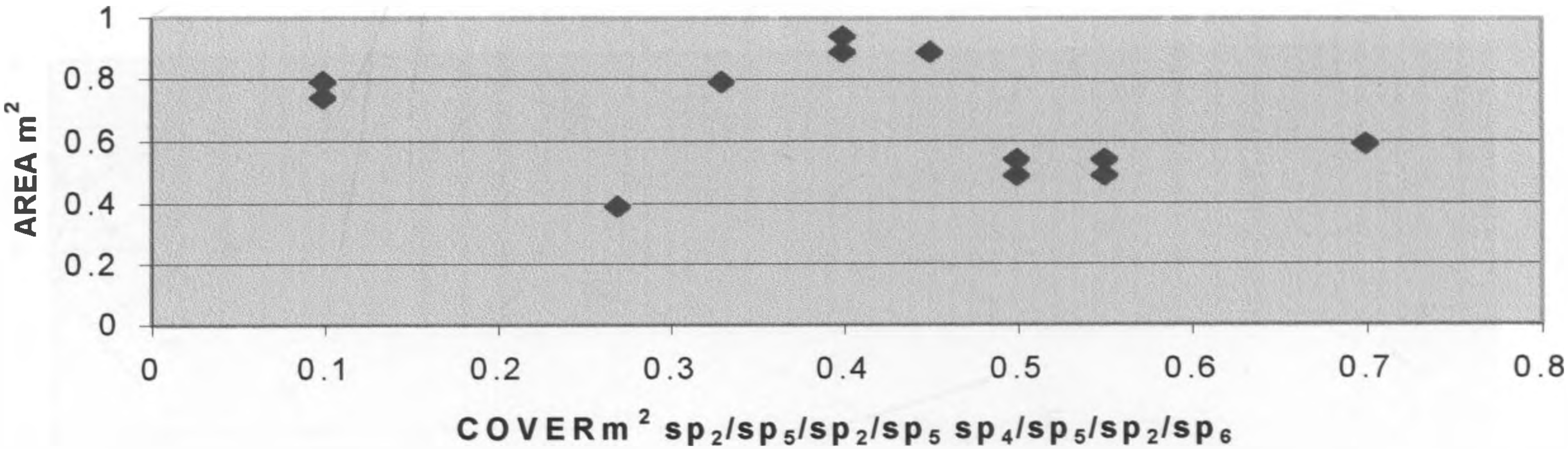
Source: Omukoba Ouna (1988)

Appendix VI: SCATTERGRAM:COVER sp1/ TOTAL AREA (DOWNSTREAM)



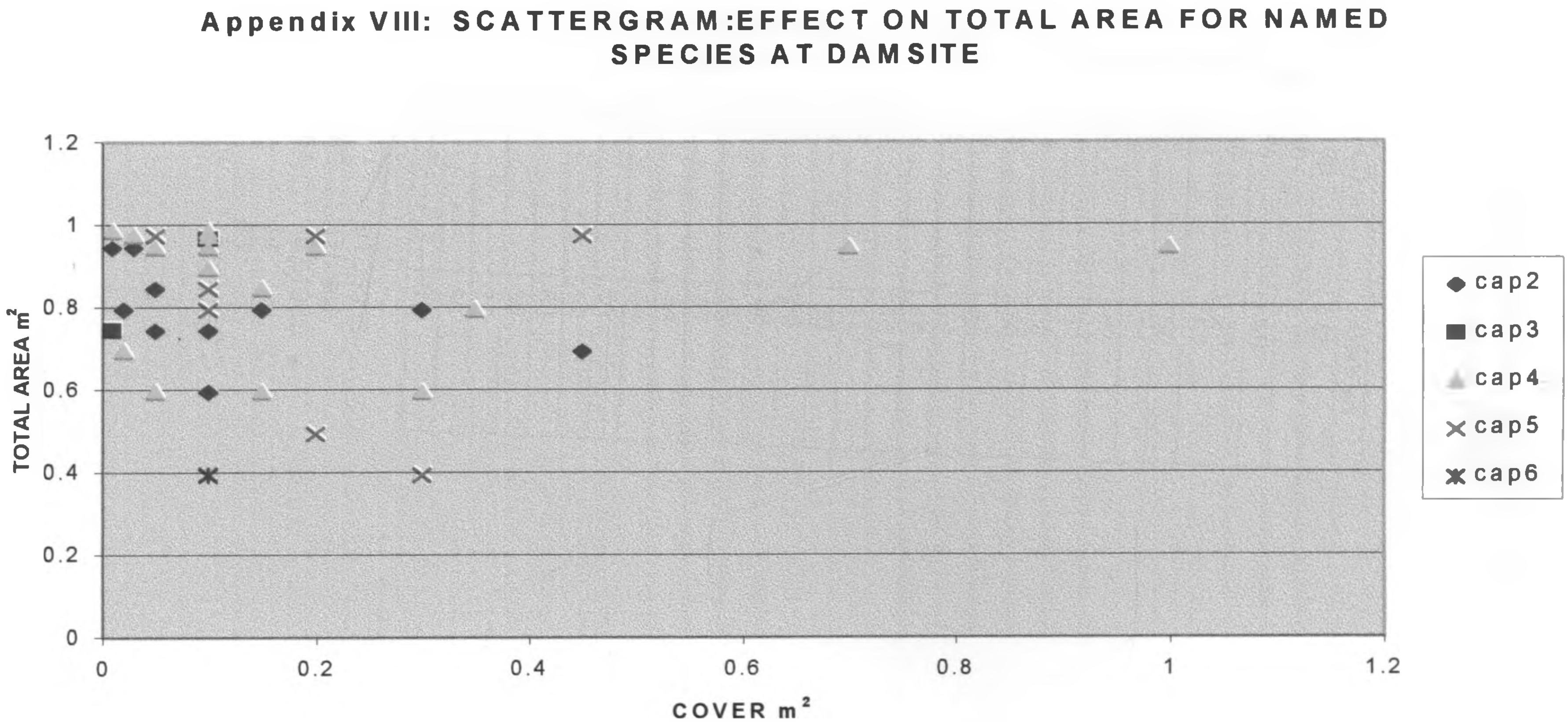
Source: Omukoba Ouna (1988)

Appendix VII: SCATTERGRAM:TRISPECIES/TOTAL AREA



Source: Omukoba Ouna (1988)

Appendix VIII



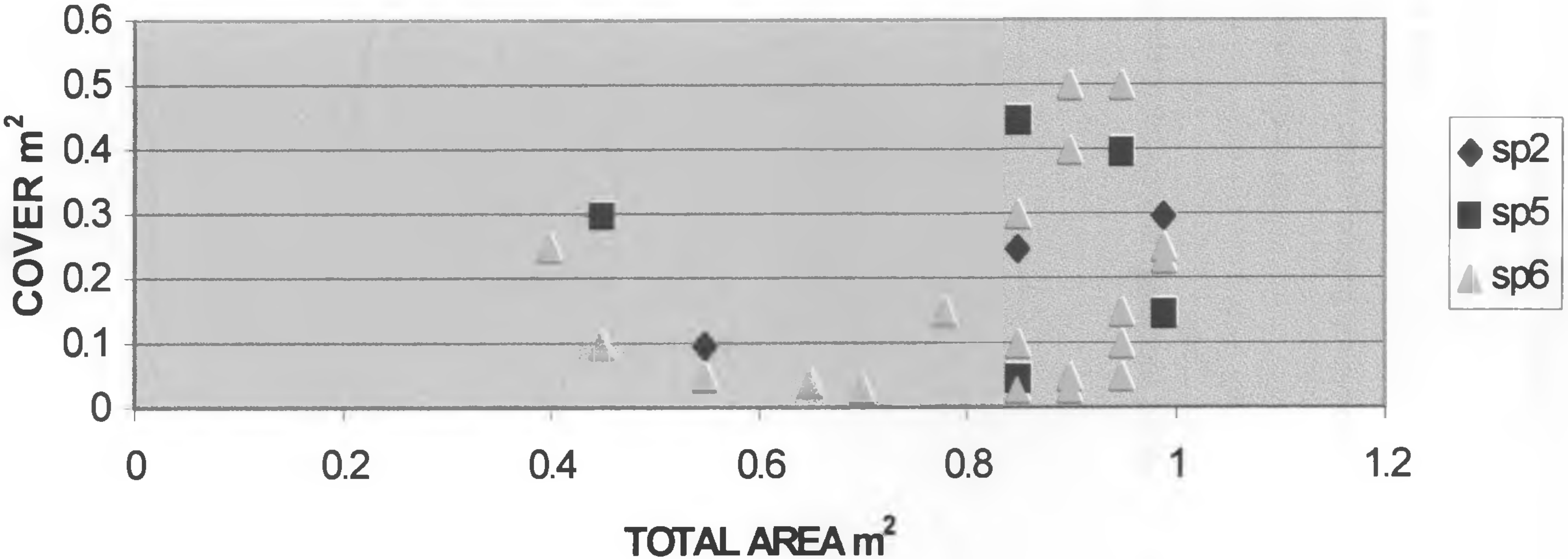
Source: Omukoba Ouna (1988)

Appendix IX: FIELD AND DRY WEIGHTS – PURE STAND P. CLANDESTINA (DOWNSTREAM SITE)

Sample No.	FLD.wt	DRY.wt
1	100	85
2	60	57
3	60	56
4	56	53
5	63	57
6	55	50
7	58	51
8	55	53
9	55	51
10	53	52
11	52	50
12	49	47
13	15	14
14	50	48
15	45	43
16	54	41
17	58	56
18	60	56
19	58	56
20	70	65
21	51	47
22	45	44
23	60	54
24	55	51
25	56	52
26	61	53
27	63	59
28	40	37
29	60	56
30	54	51

Average:	55.7	51.73333
Variance	155.6766	110.662
Std. Dev.:	12.47704	10.51961
Minimum:	15	14
Maximum:	100	85
Total:	1671	1552

Appendix X: SCATTERGRAM: BISPECIES/TOTAL AREA DOWNSTREAM (EXC sp1)



Source: Omukoba OUna (1988)

Appendix XI: DESCRIPTION OF THE EXISTING SEWAGE TREATMENT WORKS

At present Eldoret is being served by two sewage works. One is situated in Eldoret west and the other is about 3 km downstream from the Eldoret west one.

The details of the works are as follows:-

1.	**Eldoret west S.T.W.**	**Design Capacity**
	Conventional treatment plant Providing grit removal	
	Sedimentation, Biofiltration, etc	1,575 m^3/d
2.	Quarry S.T.W.	
	Anaerobic, secondary, tertiary and maturation ponds	4,800 m^3/d

Appendix XII (a): **ELDORET WEST SEWAGE TREATMENT WORKS – CONVENTIONAL WORKS**

Constructed in 1959/60 they are situated on the south bank of the Sosiani River towards the west of the town. The whole of the sewered area North of the Sosiani River drains to this sewage works. The sewage treatment works is a conventional plant, consisting of trickling filters, sedimentation tank and humus tank.

Appendix XII (b): **QUARRY SEWAGE TREATMENT WORKS - PONDS**

This sewage works was designed and constructed in order to meet immediate requirements of the town in respect of treatment of effluent from existing and proposed factories. Quarry sewage treatment works have basically been designed to cater for existing industries in Eldoret which were not connected to the sewerage system and also because of the grossly overloading of the Eldoret West sewage treatment plants. The works were designed to treat a flow of 4,800m3/d. Details of the flows to be treated and the loading of the works were as follows:-

DESCRIPTION	FLOW (DWF) M^3/D	B.O.D.		SS	
		MG/1	KG	MG/1	KG
Rivatex	1,920	400	768	297	570
CPC	450	400	180	300	135
EATEC	458	2,090	957	927	424
Doinyo Lessos	130	62	8	8	1
By-pass from	12	1,647	19.8	4,921	59
existing sewage works	1,830	390	714	355	650
Total load	4,800		2,646.8		1,839

B.O.D. = 551,5 mg/1

SS = 383,1 mg/1

Appendix XIII: STAATLICH ANERKANNTES LABOR DEUTSCHEN ABWASSER-REINIGUNGS – GESELLSCHAFT M.b.H.

Test Results

PARAMETER	UNIT	SAMPLE NO.1	SAMPLE NO.2	SAMPLE NO.3	SAMPLE NO.4
Place of sample taking		1	2	3	4
Settleable Solids		<0.1	< 0.1	<0.1	<0.1
PH	Ml/l	7.2	7.2	6.9	7.1
Chemical Oxygen demand	Mg/l	5.9	9.3	5.7	58.0
Biological oxygen demand	Mg/l	1.7	9.2	7.3	24.5
Ammonium	Mg/l	<0.750	<0.75	<0.75	2.1
Nitrate	Mg/l	<0.500	0.5	0.53	0.53
Phosphates	Mg/l	<0.100	<0.1	<0.1	0.12

No.1 Two River dam intake
No.2 Above Eldoret bridge to Nairobi
No.3 Above outlet Conv. Works
No.4 100m below outlet Conv. Works

Appendix XIV: TEST RESULTS OF SLUDGE (Source: OMS-Wiesbaden W. Germany)

HEAVY METALS	CONV. WORKS DRYING BEDS	PONDS ANAEROBIC PONDS	CONV. WORKS DRYING BEDS	PONDS ANAEROBIC PONDS
Cd	31.9	29.5	2.56	0.39
Pb	165	18	108	87.9
Ni	25	188	19.7	27.3
Cu	77	228	94.3	57.7
Hg			0.47	0.76
Zn	956	467	1027	317.7
Cr	<40	<40	31.3	58.9
Fe			12867	42167
Ag			24.8	1.8

Appendix XV(a): DAM DATA SHOWING VEGETATION'S HEIGHT (H), PERCENT COVER (C)

NO.	Hsp1	Hsp2	Hsp3	Hsp4	Hsp5	Hsp6	Csp1	Csp2	Csp3	Csp4	Csp5	Csp6	%C0 sp1	%C0 sp2	%C0 sp3	%C 0sp 4	%C0sp 5	%C0 sp6	Area	%Gre
1	0.1						0.95						98						0.95	70
2	0.04						0.6						98						0.6	40
3	0.07						0.2						97						0.2	10
4	0.15						0.8						97						0.95	60
5	0.2						0.5						90						0.9	60
6	0.03						0.4						90						0.95	60
7	0.06						0.4						97						0.4	10
8	0.07						0.4						98						0.4	30
9	0.08						0.2						97						0.7	40
10	0.03						0.5						60						0.8	60
11	0.1						0.8						80						0.95	75
12	0.15						0.95						80						0.95	70
13	0.1						0.6						80						0.8	60
14	0.1						0.4						97						0.4	50
15	0.1						0.55						97						0.6	40
16	0.1						0.95						97						0.95	90
17	0.06						0.75						50						0.75	60
18	0.08						0.95						97						0.95	60
19	0.7						0.85						95						0.95	30
20	0.85						0.7						80						0.98	60
21	0.36						0.3						95						0.3	30
22	0.15						0.5						95						0.6	40
23	0.15						0.8						95						0.85	70
24	0.18						0.95						98						0.98	70
25	0.1						0.73						98						0.75	20
26	0.1						0.8						98						0.65	30
27	0.05						0.55						98						0.6	20
28	0.08						0.6						98						0.75	10
29	0.1						0.65						98						0.75	5
30	0.07						0.75						98						0.85	10
31	0.08						0.65						98						0.75	5
32	0.06						0.68						98						0.7	45
33	0.5						0.7						98						0.75	40
34	0.17						0.55						95						0.6	60
35	0.15						0.85						98						0.65	70
36	0.06						0.9						75						0.9	60

37	0.05	0.1					0.3	0.2					80	20					0.5	50
38	0.03	0.05					0.5	0.1					85	10					0.6	5
39	0.06	0.12					0.5	0.45					97	2					0.7	35
40	0.1	0.09					0.8	0.01					90	1					0.95	50
41	0.75	0.05					0.8	0.02					95	1					0.9	40
42	0.1	0.1					0.7	0.05					90	5					0.85	70
43	0.07	0.05					0.55	0.1					90	5					0.8	40
44	0.09	0.04					0.65	0.05					95	1					0.75	40
45	0.05	0.1					0.6	0.1					85	10					0.75	60
46	0.05	0.1					0.65	0.1					80	15					0.8	40
47	0.1	0.09					0.65	0.05					90	5					0.75	15
48	0.02	0.05					0.9	0.03					95	2					0.95	5
49	0.09	0.1					0.6	0.1					95	3					0.75	15
50	0.1	0.1					0.45	0.3					50	45					0.8	40
51	0.05	0.1					0.6	0.15					90	5					0.8	10
52	0.05	0.1					0.6	0.1					90	5					0.8	10
53	0.25	0.05					0.7	0.1					85	10					0.85	40
54	0.06		1				0.8		0.35				90		10				0.98	80
55	0.05		0.3				0.9		0.45				98		2				0.97	90
56	0.15		0.9				0.93		0.05				90		5				0.98	70
57	0.15		0.25				0.6		0.1				80		15				0.75	60
58	0.2		0.55				0.65		0.3				70		25				1	98
59	0.24		0.47				0.6		0.35				85		10				0.98	95
60	0.15		0.13				0.65		0.15				85		10				0.85	60
61	0.35			0.7			0.4			0.03			80			3			0.5	35
62	0.68			0.8			0.78			0.01			95			2			0.8	40
63	0.8				1.15		0.8				0.15		90				5		0.95	60
64	0.5				1.1		0.95				0.6		95				60		0.99	35
65	1.1				1.3		0.85				0.1		90				5		0.98	40
66	0.75				1.3		0.97				0.8		97				99		0.99	60
67	1.15				1.3		0.55				0.5		55				50		0.7	45
68	0.35				0.2		0.6				0.35		85				10		0.98	80
69	0.15				10		0.6				0.25		70				20		0.9	70
70	0.55				0.65		0.45				0.1		85				10		0.6	50
71	0.55				1		0.65				0.3		85				10		0.95	50
72	0.2				0.5		0.85				0.05		90				7		0.95	60
73	0.85				0.9		0.6				0.3		60				35		0.95	60
74	0.78				1.13		0.6				0.35		65				30		0.98	80
75	0.55				0.58		0.7				0.05		85				10		0.85	60
76	0.25				1.13		0.3				0.1		85				10		0.4	30
77	0.52				0.68		0.6				0.2		80				1		0.85	70
78	1.2				0.8		0.55				0.25		75				20		0.85	60
79	0.95				1.37		0.6				0.3		70				25		0.98	85
80	0.2				1.1		0.5				0.4		50				30		0.95	70

81	0.9				0.24		0.6				0.3		70				25		0.95	60
82	0.6				1		0.4				0.45		45				50		0.95	40
83	0.45				1		0.4				0.4		90				5		0.95	50
84	0.15				1		0.4				0.15		90				5		0.6	40
85	0.4				0.7		0.4				0.45		40				55		0.9	60
86	0.15				1		0.4				0.15		90				5		0.6	40
87	0.9					1.3	0.3					0.6	20					70	0.98	60
88	0.28					0.17	0.35					0.01	95					2	0.4	70
89	0.07	0.1			0.4		0.1	0.02			0.25		10							
90	0.1	0.08			?		0.3	0.01			0.05		60							
91	0.15	0.1				0.6	0.6	0.05				0.05	80							
92	0.45	0.25				0.4	0.6	0.05				0.05	85							
93	0.32	0.08				0.15	0.8	0.02				0.02	90							
94	0.36	0.04				0.55	0.4	0.01				0.05	90							
95	0.15	0.57				0.3	0.45	0.02				0.05	85							
96	0.73			1.75	1.73		0.4			0.2	0.35		90							
97	0.76			0.84	0.95		0.45			0.35	0.2		95							
98	0.56			1.3	1.02		0.4			0.15	0.3		65							
99	0.73			1.33	1.4		0.4			0.03	0.3		45							
100	0.8			1.4		1.45	0.55			0.3		0.1	70							

Key: H – Height: C – Cover: Co – Composition: Gre. - Greenness

Appendix XV (b)
RIVER DATA SHOWING VEGETATION'S HEIGHT (H), COVER (C) PERCENT COMPOSITION (%COM), AREA AND PERCENT GREENNESS

NO	Hsp1	Hsp2	Hsp5	Hsp6	COsp1	COsp2	COsp5	COsp6	%COM sp1	%COM sp2	%COM sp5	%COM SP6	Area	% GRE
1	0.57				0.45				40				0.98	75
2	0.1				0.92				98				0.95	60
3	0.1				0.93				98				0.95	70
4	0.1				0.9				100				0.9	60
5	0.12				0.85				90				0.95	50
6	0.08				0.85				98				0.9	60
7	0.1				0.85				85				0.9	60
8	0.07				0.7				90				0.85	50
9	0.08				0.7				98				0.75	50
10	0.1				0.75				90				0.85	50
11	0.1				0.65				98				0.75	40
12	0.05				0.68				99				0.7	20
13	0.1				0.38				98				0.4	10
14	0.07				0.85				98				0.85	50
15	0.13				0.75				98				0.8	20
16	0.06				0.95				99				0.95	20
17	0.06				0.9				98				0.95	50
18	0.5				0.9				90				0.98	50
19	0.07				0.95				98				0.98	50
20	0.20				0.95				98				0.99	40
21	0.10				0.85				98				0.9	40
22	0.50				0.95				98				0.98	60
23	0.08				0.88				98				0.9	5
24	0.18				0.95				99				0.95	50
25	0.05				0.9				99				0.9	50
26	0.33				0.9				99				0.9	50
27	0.40				0.99				99				0.99	50
28	0.08				0.7				99				0.7	55
29	0.20				0.9				95				0.95	40
30	0.11				0.8				85				0.95	80
31	0.12				0.6				65				0.9	60
32	0.15				0.65				80				0.8	60
33	0.13	0.25			0.8	0.05			80	5			0.95	60
34	0.07	0.24			0.55	0.25			75	20			0.85	70
35	0.05	0.15			0.35	0.1			75	20			0.55	40
36	0.10	0.2			0.65	0.3			75	20			0.98	20
37	0.07	0.7			0.7	0.1			84	10			0.85	25
38	0.10		1.3		0.35		0.4		95		100		0.45	50
39	0.40		1.2		0.25		0.45		90		95		0.4	40
40	0.30		0.6		0.25		0.6		15		80		0.85	35
41	0.05		0.15		0.7		0.15		90		8		0.9	80
42	0.10		0.5		0.8		0.05		85		10		0.9	10
43	0.30		0.3		0.6		0.3		75		20		0.98	70
44	0.20		0.45		0.1		0.45		20		75		0.65	65
45	0.29			0.66	0.4			0.5	45			50	0.95	50
46	0.22			0.8	0.4			0.3	60			35	0.7	50
47	0.10			0.2	0.8			0.05	90			3	0.9	50
48	0.31			1.25	0.6			0.25	80			15	0.9	60
49	0.05			0.35	0.84			0.1	90			8	0.95	50
50	0.15			1	0.75			0.1	80			15	0.95	30
51	0.76			0.8	0.43			0.25	45			43	0.77	40
52	0.05			0.2	0.7			0.02	95			3	0.95	75
53	0.30			0.6	0.8			0.05	95			5	0.95	30
54	0.30			0.3	0.9			0.02	95			1	0.95	60
55	0.52			0.66	0.6			0.23	75			23	0.88	65
56	0.16			0.5	0.7			0.03	90			5	0.75	55
57	0.05			0.4	0.5			0.1	85			5	0.65	40

58	0.15			0.22	0.6			0.02	95			2	0.65	40
59	0.37			0.54	0.6			0.4	60			40	0.99	50
60	0.30			0.56	0.8			0.5	95			5	0.9	90
61	0.20			0.26	0.55			0.15	90			8	0.7	80
62	0.15			0.7	0.8			0.15	95			1	0.95	50
63	0.14			0.7	0.6			0.15	75			20	0.8	50
64	0.07			0.55	0.75			0.05	90			5	0.85	50
65	0.10			0.5	0.8			0.1	95			3	0.95	40
66	0.13			0.35	0.85			0.05	90			3	0.95	50
67	0.05	0.08		0.55	0.55	0.05		0.2	80	5		15	0.8	50
68	0.28	0.1		0.35	0.85	0.02		0.05	90	1		5	0.95	20
69	0.20	0.08		0.7	0.5	0.02		0.1	85	1		10	0.65	50
70	0.10		1.05	1.5	0.7		0.1	0.05	75		5	2	0.9	

where
Hsp - Height of species (m)
CO - Cover (m^2)
% COM = % composition
% Gre - Percent Greeness

Appendix XVI: FIELD AND DRY WEIGHTS – PURE STAND P. CLANDESTINA AT THE DAMSITE

Sample No.	FLD.wt	DRY.wt
1	100	96
2	70	68
3	15	14
4	100	97
5	100	97
6	100	97
7	15	14
8	16	15
9	40	38
10	60	55
11	100	95
12	70	68
13	50	59
14	20	18
15	30	26
16	80	72
17	40	36
18	85	82
19	50	47
20	85	80
21	15	14
22	30	26
23	60	54
24	85	79
25	35	33
26	35	33
27	25	23
28	30	27
29	28	27
30	35	33

Average:	53.46666	50.76666
Variance	887.6488	835.3788
Std. Dev.:	29.79343	28.90292
Minimum:	15	14
Maximum:	100	97
Total:	1604	1523

Appendix XVII: **FIELD AND DRY WEIGHT P. CLANDESTINA UNDER CANOPY AT THE DAM SITE**

Sample No.	FLD.w t	DRY.wt
1	65	60
2	105	100
3	65	62
4	110	100
5	35	33
6	35	28
7	40	35
8	35	33
9	45	40
10	65	58
11	35	27
12	35	25
13	35	28
14	5	4
15	30	26
16	30	26
17	40	34
18	35	31
19	30	24
20	23	20
21	25	21
22	23	20
23	20	16
24	23	19

Average:	41.20833	36.25
Variance	590.9149	546.4375
Std. Dev.:	24.30874	23.37600
Minimum:	5	100
Maximum:	989	870
Total:	24	24

Appendix XVIII: TABULATION OF DAM DATA

VALUE	Hsp1 1-36	Hsp1 37-88	Hsp1 89-100	Hsp1 1-100
Average	0.153611	0.370576	0.431666	0.2998
Variance	0.030750	0.113620	0.071280	0.091091
Std. Dev.	0.175359	0.337076	0.266984	0.301814
Minimum	0.03	0.02	0.07	0.02
Maximum	0.85	1.2	0.8	1.2
Total	5.53	19.27	5.18	29.98
Number	36	52	12	100
VALUE	Csp1 1-36	Csp1 37-88	Csp1 89-100	Csp1 1-100
Average	0.650277	0.612115	0.454166	0.6069
Variance	0.44369	0.029962	0.02769	0.038367
Std. Dev.	0.210640	0.173097	0.166406	0.195875
Minimum	0.2	0.3	0.1	0.1
Maximum	0.95	0.97	0.8	0.97
Total	23.41	31.83	5.45	60.69
Number	36	52	12	100
VALUE	%COsp1 1-36	%COsp1 37-88	%COsp1 89-100	%C0sp1 1-100
Average	91.88888	80.90384	72.08333	83.8
Variance	122.4876	268.9330	556.0763	295.06
Std. Dev.	11.06741	16.39917	23.58127	17.17731
Minimum	50	20	10	10
Maximum	98	98	95	98
Total	3308	4207	865	8380
Number	36	52	12	100
VALUE	AREA 1-36	AREA 37-88	AREA 89-100	AREA 1-100
Average	0.748888	0.831538	0.683333	0.784
Variance	0.041826	0.25213	0.032222	0.03487
Std. Dev.	0.204515	0.158786	0.179505	0.186735
Minimum	0.2	0.4	0.4	0.2
Maximum	0.98	1	0.95	1
Total	26.96	43.24	8.2	19725.47
Number	36	52	12	100
VALUE	%GRE 1-36	%GRE 37-88	%GRE 89-100	%GRE 1-100
Average	45	51.5	54.58333	49.53
Variance	519.4444	485.3269	172.743	472.5691
Std. Dev.	22.79132	22.03013	13.14317	21.73865
Minimum	5	5	30	5
Maximum	90	98	80	98
Total	1620	2678	655	4953
Number	36	52	12	100

Appendix XIX: FIELD AND DRY WEIGHTS – PENNISETUM CLANDESTINA UNDER CANOPY (DOWNSTREAM)

Sample No.	FLD.wt	DRY.wt
1	10	8
2	15	9
3	65	63
4	60	58
5	66	63
6	63	57
7	12	9
8	63	60
9	65	60
10	70	65
11	60	67
12	60	57
13	30	26
14	60	57
15	60	58
16	45	38
17	65	60
18	45	41
19	60	55
20	60	56

Average:	51.26315	47.31578
Variance	36.1939	36.70581
Std. Dev.:	19.13619	19.15876
Minimum:	10	8
Maximum:	70	65
Total:	974	899

Appendix XX: TABULATION OF RIVER DATA RESULTS

	Hsp1	Hsp1(1)	Hsp1(2)	Hsp1	Hsp1(2)	Hsp1(5)	Hsp1(6)
VALUE	**1-32**	**33-66**	**67-70**	**1-70**	**33-37**	**38-44**	**45-66**
Average	0.158125	0.198235	0.1575	0.177571	0..084	0.2071420.01	0.221363
Variance	0.019340	0.023235	0.007918	0.020998	0.000784	0.014591	0.027611
Std. Dev.	0.139069	0.152586	0.088987	0.144908	0.028	0.120796	0.166167
Minimum	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Maximum	0.57	0.76	0.28	0.76	0.13	0.4	0.76
Total	5.06	11.8	0.63	12.43	855.51	1.45	4.87
Number	32	34	4	70	5	7	22
	C0sp1	**C0sp1(1)**	**C0sp1(2)**	**C0sp1**	**C0sp1(2)**	**C0sp1(5)**	**C0sp1(6)**
Value	**1-32**	**33-66**	**67-70**	**1-70**	**33-37**	**38-44**	**45-66**
Average	81.03125	61.38235	65	70.57142	61	43.57142	67.13636
Variance	215.2177	386.7655	187.5	389.7591	234	597.9591	220.2086
Std. Dev.	14.67030	19.66635	13.69306	19.74231	15.29705	24.45320	14.83942
Minimum	38	10	50	10	35	10	40
Maximum	99	90	85	99	80	80	90
Total	2593	2087	260	4940	305	305	1477
Number	32	34	4	70	5	7	22
	%COMsp1	**%COsp1(1)**	**%COsp1(2)**	**%Cosp1**	**%Cosp1(2)**	**%Cosp1(5)**	**%Cosp1(6)**
VALUE	**1-32**	**33-66**	**67-70**	**1-70**	**33-37**	**38-44**	**45-66**
Average	92.96875	78.47058	82.5	85.32857	78	67.14285	82.18181
Variance	143.1552	407.1903	31.25	314.9920	16	1020.408	246.3305
Std. Dev.	11.96475	20.17895	5.590169	17.74801	4	31.94382	15.69492
Minimum	40	15	75	15	75	15	45
Maximum	100	95	90	100	65	95	95
Total	2975	2668	330	5973	390	470	1808
Number	32	34	4	70	5	7	22
	AREA	**AREA**	**AREA**	**AREA**	**AREA(1/2)**	**AREA(1/5)**	**AREA(1/6)**
VALUE	**1-32**	**33-66**	**67-70**	**1-70**	**33-37**	**38-44**	**45-66**
Average	0.879678	0.832352	0.825	0.841549	0.836	0.732857	0.863181
Variance	0.014096	0.023312	0.013125	0.019094	0.023184	0.046906	0.011730
Std. Dev.	0.118729	0.152683	0.114564	0.138182	0.152262	0.216578	0.108308
Minimum	0.4	0.4	0.65	0.4	0.55	0.4	0.65
Maximum	0.99	0.99	0.95	0.00	0.98	0.98	0.00
Total	28.15	28.3	3.3	59.75	4.18	5.13	18.99
Number	32	34	4	70	5	7	22
	%GRE	**%GRE**	**%GRE**	**%GRE**	**%GRE(1/2)**	**%GRE(1/5)**	**%GRE(1/6)**
VALUE	**1-32**	**33-66**	**67-70**	**1-70**	**33-37**	**-38-44**	**45-66**
Average	48.28125	51.32352	37.5	49.14285	41	50.625	53.8636
Variance	293.1396	323.9835	168.75	311.4081	324	481.6326	243.0268
Std. Dev.	17.12132	17.99954	12.99038	17.64676	18	21.94613	15.58931
Minimum	5	10	20	5	20	10	30
Maximum	80	90	50	90	70	80	90
Total	1545	1745	150	3440	205	355	1185
Number	32	34	4	70	5	7	22

Where:

sp1 represents	Pure stand of Pennisetum clandestina (i.e. sample 1-32)
sp1(2) represents	Pennisetum clandestina in association with SIDA cuneifolia (i.e. sample 33-37)
sp1(5) represents	Pennisetum clandestina in association with Acacia nilotica (i.e. sample (38-44)
sp1(6) represents	Pennisetum clandestina in association with Cariss edulis (i.e. sample (45-66)

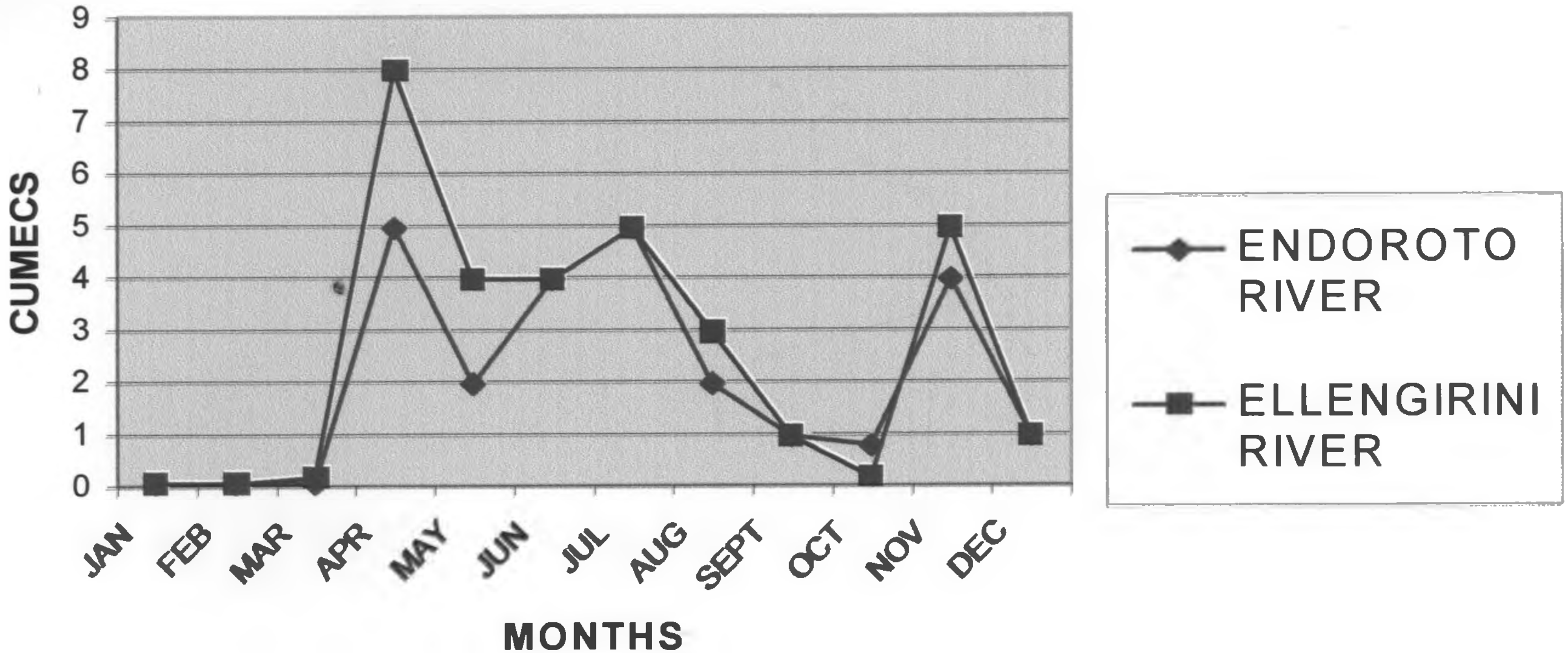
Appendix XX (cont...)

REGERSSION (AREA/% COMPOSTION)

Between sp1(1-32) **% com = y variable**

Regression Output:		**Regression Output:**	
Constant	1.029061	Constant	107.3221
Std. Err of Y Est.	0.121005	Std. Err of Y Est.	0.026215
R squared	0.026215	R squared	0.026215
No. of Observations	32	No. of Observations	32
Degrees of Freedom	30	Degrees of Freedom	30
X Coefficient	-0.00160	X Coefficient(s)	-16.3164
Std. Err of Coef.	0.001787	Std Err of Coef.	18.15576

Appendix XXI: DAILY RECORDED DISCHARGE (CUMECS) 1967: ENDOROTO & ELLENGIRINI RIVERS



Source: Municipal Council of Eldoret (1985)