THE USE OF REMOTE SENSING IN RESOURCE (FUELWOOD) PLANNING IN TETU DIVISION, NYERI DISTRICT, KENYA.

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A THESIS PRESENTED IN PART FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS (PLANNING), IN THE DEPARTMENT OF URBAN AND REGIONAL PLANNING, UNIVERSITY OF NAIROBI, KENYA.

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DECLARATION

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

Signed

(Candidate)

This Thesis has been submitted for examination with my approval.

Signed

(Supervisor)
DEDICATION

This thesis is humbly dedicated to

Maitu, Miriam Nyathogora and
Awa, Joshua Ichang’i

For giving me access to knowledge,
encouragement to acquire knowledge
and vision of the possibilities
created by knowledge.
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Lastly, convention requires that I acknowledge that none of these, nor any of my colleagues who undertook to read portions of this dissertation can be held responsible for the contents.
Remote Sensing has been used to document resources systematically since the turn of the century using tools such as air-borne cameras. The techniques when used provide a synoptic view of a region and also can be used to guide and facilitate fieldwork. Remote sensing technology has advanced and hence enabled the documentation process to proceed.

It is imperative to show how land-use changes that have occurred in the study area can be monitored using remotely sensed data sources such as aerial photographs; also that planning of resources such as fuelwood (vegetation cover) and the resultant decision-making can be effectively carried out using the same data.

Aerial photography has been in use for a long time in cartographic and engineering works but has been used less by planners, land-use analysts and geographers due to the technology involved. Like planning, the analysis and application of remotely sensed data involves the joint efforts of resource technologists, planners and decision-makers at all levels of policy-making and project implementation.
The study sets out to test the efficacy of the aerial photography technique in providing information on land-use changes due to primarily fuelwood demands, in the study area. It also proposes a method of resource planning and decision-making with emphasis on vegetation cover (fuelwood) using aerial photography as a source of remotely sensed data. It is assumed that remote sensing technology will be used increasingly as an efficient data gathering tool in the country. Vegetation cover in rural areas such as Tetu Division will also be depleted in terms of woody biomass while population will increase and result in land-use changes and greater demands on the land for fuelwood and also food.

The study found out that aerial photographs can enable the planner to plan land-use for a resource such as fuelwood by depicting clearly, large areas suitable and available for such a land-use. The areas that have been cleared of vegetation over the years can also be shown using such photographs and the land-use that has replaced them thus enabling a planner to know whether any replacement of trees or other vegetation or agricultural land-use has occurred. Also, the physical characteristics of the land such as the steepness and ruggedness can be picked out from the stereo-plot maps. These maps are plotted using the aerial photographs.
The study concludes that aerial photography can be used effectively for monitoring purposes which is a management aspect of planning. They also provide a reliable data base which is essential for planning and decision-making although the use of these photographs is constrained due to their high costs and also need for skilled man-power in data analysis. Recommendations are made for the drawing up of policies that cater for the demand of fuelwood, protect the environment while remaining cost effective. Also, that other types of remotely sensed data be adapted to the planning process due to their added advantage of being quick data producers, reliable and accurate. Application of remote-sensing should go beyond data collection and analysis, to the actual use in planning and decision-making processes which result in policy formulation and implementation.
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CHAPTER ONE

INTRODUCTION:

Remote Sensing can be referred to as the science and art of acquiring information about material objects without coming into physical contact with them. (Johannson & Saunders, 1982). It has been used to document resources systematically since the turn of the century using various tools such as air-borne cameras.

One of the areas where remote sensing aids is in providing a synoptic view of a region; and also in guiding and facilitating field work which allows for the extrapolation from and a mapping framework for, field observation. (King, 1984).

Developing nations need data on land-use in the form of inventories in order to be able to keep pace with change. (NAS, 1977). This enables them to keep tabs on the changes that are occurring and also to monitor these changes and to analyse the relationship between these changes and the people in the areas. Population growth as well as the spreading human settlements often lead to significant change in the MAN-LAND relationship (NAS, 1977).

Remote sensing as a technology requires a numerous and diversified user-field as well as an inter-displinary team-work approach and for this...
reason, it has been found to generate incentives for new operational and organizational arrangements for the handling of resource data. This is necessary in developing nations just now beginning to acquire land-use and resource data.

**STATEMENT OF RESEARCH PROBLEM:**

Man has had a long-standing cognition of the significance of terrain permeating his activities, but formal attempts to document land resources in a manner that would permit scientific predictions of their capabilities under various imposed duties is a relatively recent phenomenon. (Townshend, 1981). Remote sensing technology has however advanced, and in so doing enabled this documentation process to proceed.

It is imperative to show how landuse changes that have occurred in an area, can be monitored using remotely sensed data sources such as aerial photographs; also to show how planning of resources such as vegetation cover and the resultant decision-making can be effectively carried out using the same data.

Available resources in an area can be determined using remote sensing. Natural resources should be
evaluated, planned and managed for current as well as future use; and this can only be carried out effectively if monitoring of past trends is also carried out. Although remote sensing as a tool has been used extensively for data collection purposes in developing nations, its potential as an effective planning and decision-making tool has not been fully exploited. When data has been collected analyzed and inferential interpretation carried out, policy-making takes place. Often-times, there exists a gap between the user's requirements be he the decision-maker or planner, and the data that has been collected due to inadequate specification on the data requirements from the user.

The decisions that are made usually have an impact on society in general and the opportunity and financial costs of BAD DECISIONS can be high. In contrast, the cost of improving decision-making through the provision of better information to the decision-makers is much lower. Efforts should thus be placed in areas of information gathering and analysis. While remote sensing has helped in the former, it is now required to help in the analysis so as to lead to BETTER DECISIONS being made.
Other tools that are used by planners to facilitate decision-making include various sorts of surveys as well as other data collecting tools.

Planners may be interested in the frequent up-dating of broader-scale changes or monitoring and these enable the patterns of land-use change to be clearly seen and analysed over the years. Remotely sensed information has been used for this purpose because of the possibility of re-photographing or re-imaging areas with ease.

**LITERATURE REVIEW:**

Remote sensing using aerial photography has been in existence since the turn of the century, (Muret, 1972) but it is only during the last forty years or so that large scale aerial photographs have come into general use in all areas affected by man.

Aerial photographs were first taken in order to establish economically and with the aid of photographic surveying techniques, the basic plans required for civil engineering and city planning studies, (Muret, 1972). Aerial photography as a
technique progressed and peaked in use in the seventies and it has been applied to numerous fields among them phytogeography and geology.

Acceptance and utilization of the 'newer' remote sensing techniques using satellites and other space or high altitude captors mushroomed during the 1960's towards whose end, many articles had began to be published on the tools and their application. Despite the new sensors, the interpretation of conventional airphotos continues to be an important part of remote sensing and many techniques used in photo interpretation are now employed in image interpretations (Rudd, 1971).

Aerial photography has also been used for long for cartographic and engineering purposes although with the evolution of technology, the trend has been rapidly changing. Topographical map preparation in Kenya has been on going using aerial photogrammetric techniques although due to the technology involved, planners, land-use analysts and geographers have not been able to use these, leaving them to surveyors and photogrammetrists. (King'orjah, 1984).

Some institutions in Kenya have however been using these techniques as well as the more recent satellite imagery techniques, for data collection purposes.
Remote sensing tools have evolved due to their advantages. They provide wide coverage of the regions under study and also pick details that could otherwise easily pass unnoticed. They also allow for repeated coverage which is advantageous for monitoring trends.

The analysis and application of remotely sensed data involves the joint efforts of resource technologists, planners and decision makers at all levels of policy making and project implementation. Planners now have a land-use data acquisition system which can be continually re-used with reasonable accuracy. However, this information should be used for planning purposes within the resources available. King, (1984) says that the physical planners are concerned with the occurrence, location, magnitude and quality or suitability of a resource (such as vegetation cover specifically fuel wood), for exploitation. A general lack of awareness concerning the applicability of remote sensing to planning and decision making exists among planners and as a result planners have remained seemingly unaware that remote sensing can enhance resource exploitation as well as provide information
that would affect decision-making with respect to the resource.

Remote sensing has been utilized by a few government agencies in Kenya such as Kenya Rangeland Ecological Monitoring Unit (KREMU) and the National Environment Secretariat (NES) as well as the Survey of Kenya department for cartographic purposes. Land-use mapping for Kenya has been completed at a reconnaissance level at a scale of 1:1 million using Landsat colour composites augmented by strip photography and field-checks (Agatsiva & Mwendwa, 1982). While conducting a forestry inventory of Kenya, Ochanda et al. (1981) says that "it is vital that existing forest cover in the country be assessed and monitored" so as to assist resource planners and decision-makers at large. He concludes from his study that remote-sensing has made possible an estimate of Kenya's actual forest cover rapidly but he does not show how planners or decision makers can use this data for long and short term planning of resource utilization.

Western et al. (1981), using data collected
using a Systematic Reconnaissance Flight Survey method (SRF) on natural wood supplies in Kenya's rangelands managed to provide an estimate of natural wood biomass within the range-lands in well-defined ecological regions. He also estimates wood available for fuelwood and charcoal and also wood fuel available within each ecological region annually. He however does not propose remedial measures for halting depletion nor does he suggest methods of planning the resource area and its management or even how to influence decision-making using his collected information.

Agatsiva, (1982) discusses detailed land-use mapping at district level, of the high potential agricultural areas of Kenya using this technology especially aerial photography. Here again, the concern lies in gathering information on problems and constraints facing farming systems but there is no discussion on the application of this information at a higher level such as decision-making and planning.

The use of remote-sensing for monitoring of various processes which effect change has been advocated by Kishk, (1982) in his report on desertification in Egypt where he gives recommend-
ations on how to arrest the eminent desertification process. He says that land evaluation using modern application methods should serve as the base for land-use planning and that remote sensing techniques will play a vital role in data acquisition necessary for the monitoring process. Ottichillo, (1981), concludes and recommends in his study on Tsavo, that "the SRF method is a simple, cheap, and reliable method for monitoring (at all levels of planning) while Kanani, (1982), in his study on land degradation mapping using remote sensing subscribes to the theory that land degradation is manifested in a general reduction in vegetation type and quantity leading to exposure of soils to erosion agents. He did not use the data so analysed any further for planning purposes nor to make a case for decision-making and policy formulation with regard to land degradation.

There has been a great increase in surveys executed for the sole purpose of initiating and promoting development yet all this data rarely if ever contributes to the envisaged development, (Van der Brock, 1982). This further strengthens the case for bridging the gap between data collection
using remote-sensing techniques and information usage in decision-making, of this data so collected. This calls for the analysis of such data collected in the surveying process since the analysis will lead to the synthesized information that can enable better decision-making and hence planning of resources or land-use.

The administrator and the planner must have comprehensive and current information if they are to have any hope of promoting orderly use of land. Planners have made use of one form of remotely sensed data namely aerial photographs from early days and re-photographing has often been undertaken. The task of learning how to use the remotely sensed data especially with the advancement in technology is a big one (Rudd, 1974).

The problem of non-contribution to the effectiveness of planning and decision-making lies not in the technology itself, but in the way it can be adapted to processes that involve human society. "The provision of data ...... necessary for effective planning and implementation depends on efficiency of the data collection process" (Rudd,
1974) and in this context remote sensing has great potential for enhancing the decision-making process since as a technology, it will provide the economist/planner with data which describes natural resources on a continuous basis at relatively low cost and with enhanced accuracy.

In Kenya, development planning techniques have been powerful tools in decision-making for influencing economic growth and national development. Despite this, many people do not clearly understand the planning process so that they can appreciate its strengths and weaknesses. Ideally, the process of planning for natural resources conservation and exploitation should begin with stock-taking, which would provide the statistical data upon which the plan is built (Otieno, 1982). Remote sensing has not been used fully to provide the data necessary for this kind of planning in Kenya although the greater problem lies in the analyses of such data for purposes of planning. There is inadequate trained man-power in the use of technology within Kenya as well as inadequate funds to purchase all the required equipment that facilitates such analyses. Otieno, (1982) says that the technology has great potential for making data and information available to the decision-makers on planning matters but more so for the planning of
development and management of natural resources.

Planners are called upon to use such data for their purposes because it reveals dynamic changes which may be constantly occurring and also to convince the decision-makers on the usefulness of the technology to development planning.

Aerial photography has been extensively used in forestry surveys as well as in vegetation and land-use surveys. (FAO 1982). Rapid population increases have raised the demand for food which has in turn resulted in an expansion of cropped areas as well as an intensification of land-use. The former has resulted in a change in land-use often resulting in loss of woody vegetation cover.

Within the central highlands of Kenya, cash cropping of coffee and tea (in high altitudes) was introduced during the colonial era. Large coffee and tea estates were planted and these have largely remained unchanged in terms of their aerial extent. Within the small scale farm sector however, a lot of change has been seen especially after land consolidation. Coffee was introduced and planted and its acreage has tended to increase gradually. Cash cropping has been in competition with food crops in parts of these central highlands. As a result, areas
planted with cash crops have tended to remain constant or to increase and hence loss of vegetation cover can be said to be due to meeting other wood demands such as fuel or to making room for food crop agriculture.

In most rural areas, loss of vegetation cover can be attributed either to the change in landuse favouring agriculture or to demand for the wood products. Such demand would usually go to meet building needs or fuelwood needs. When it is continuous, it is more likely as a result of meeting fuel wood demand especially where no other crop can be seen to have replaced the former land-use.

In rural areas, the primary use that cut vegetation is put to is as a source of fuel. Thus, rather than the wanton destruction of vegetation in such an area, there is need to control it's use so that any increase in population does not adversely affect the environment. Population increase results in greater pressure on existing resources and the extraction of vegetation may result in soil erosion and loss of fertility among other environmental effects. (Strahler 1973).

A case is therefore made for the planning of the utilization of vegetation cover for fuel or fuelwood.

It becomes economically feasible for a nation to sustain a national analysis capability for remote
sensing if it has numerous and diverse users. The technology demands inter-disciplinary work as well as the need to make the most of scarce specialized facilities, (NASA, 1977). Remote sensing as a tool for data collection has revolutionized data collection. Traditional methods advocated for ground truth mapping of physical factors and landuses which required extensive coverage on the ground. Often such data yielded an oblique picture of the terrain surveyed and there was no possibility of rechecking from a birds eye view. Aerial photography provides this option of wide coverage from a vertical view-point and this is in turn supported by ground-truth surveys that confirm certain minute details that are not clear on the aerial photograph. Aerial photography thus cuts down costs in terms of time, accuracy and even money.

It is thus necessary to apply such a tool to the process of planning and decision-making of the land and it's use which is usually depicted by loss in vegetation cover. Planning requires the identification of a problem, formulation of goals and objectives, analyses of alternative courses of action and the selection of the preferred course of action. All these in turn require analysis of relationships between various physical, social and economic variables. This may in turn require the use of statistical tools especially if relationships between variables are to be studied. In terms of vegetation cover, relationships to be studied may include
that between tree volumes and height, tree breast-height diameters and volumes, tree species consumption and household sizes and tree volume consumed and tree species. For such studies, regression analysis is a useful tool to employ because it measures the degree of association between two sets of paired variates although the way in which such pairs are related cannot be known (Frees, F. 1976). One variable is set as the dependent variable and the other as the independent variable using common sense (Yamane, 1978). A rapid forage inventory of Kenyan rangelands by double sampling methods utilized regression analysis to relate percent vegetation greenness to the provision of acceptable predictions of range forage using an airborne digital radiometer (Mwanje, 1981).

Regression analysis has also been used to test the relationship between yields of coffee and fungicide spraying as well as yields of coffee and fertilizer applications. The essence of the method is to test the hypothesis that a set of independent variables $x_1, x_2, \ldots, x_n$ have a 1-way casual linear influence on the value of a dependent variable $Y$, (Snedecor & Cochran, 1980). It thus becomes a useful tool for relating dependent and independent variables and for making predictions. Graphical representations on the other hand help to depict trends for various variables such as population,
demand and supply, proposed hectarages or land amounts that may be required for a particular land-use.

Planning therefore makes use of both spatial and quantified representations and decision-makers require both in order to effectively make their decisions. Aerial photography could make both possible and should therefore be used more effectively in the planning process especially that of natural resources such as vegetation cover.

JUSTIFICATION OF THE STUDY:

While recognizing that remote sensing technology rather than being a panacea, is a tool that provides information necessary for arriving at solutions, (Rudd, 1974), it is also clear that adequate appraisal of trends and changes in the patterns of resource availability will make a sounder basis on which to plan for the more ordered use of resources. Land-use is dynamic and has been more so in Kenya, since independence and the reasons for these changes, the scale of changes, regulation of these land-use changes e.t.c. must be sought. In Kenya, most work using remote sensing has been for resource assessment and for cartographic purposes as well as monitoring changes. The gap between data-collection and the use of data for decision-making so as to make the technology
fully utilized, must be bridged. Applying remote sensing to planning of resources and vegetation in particular, calls for resource-use modelling, planning, monitoring and management using the systems approach of planning. It also calls for the coordination of the decision-making process at all levels vertically and horizontally. The formulation of data requirements by decision-makers is basic to information collection requirements and calls on the decision-makers to be relatively familiar with the new and useful technologies at their disposal. Remote sensing as a technique needs to be adapted to the processes that involve human society in order for it to contribute to the effectiveness of planning and decision making.

OBJECTIVES OF THE STUDY:

There are two objectives namely:

1. To test the efficacy of the aerial photography technique in providing information on land-use changes due to primarily fuelwood demands in the study area.

2. To propose a method of resource planning and decision-making with emphasis on vegetation cover (fuelwood), using aerial photography as
a source of remotely sensed data.

Loss of vegetation in rural areas such as Tetu, is primarily attributed to meeting the demand for energy hence, the provision of woodfuel was the case study that was analysed. Energy plays an intimate role in meeting basic human needs.

THE SCOPE OF THE STUDY:

The study focuses on parts of Tetu Division and it was not possible to cover a larger area due to numerous constraints. The resource to be considered is mainly wood or wooded areas (namely vegetation) because, only by clearing the original vegetation has land been made available for other users. It is therefore important to monitor change in relation to planning as well as to gauge wood depletion.

ASSUMPTIONS:

The study assumes the following:

1. That remote sensing technology will be increasingly used as a quick and reliable data gathering tool in the country.

2. That vegetation cover in the rural areas and hence in Tetu Division will continue to be depleted in terms of woody biomass.
3. That population in the division will continue to grow resulting in land-use changes and greater demands on the land for fuelwood.
CHAPTER TWO

THE STUDY AREA:

The study area comprises various parts of Tetu Division in Nyeri District, Central Province, Kenya. Tetu Division is one of the district's 6 divisions and is centrally located within the district. It extends between $0^\circ 30'$ and $0^\circ 27'\ S$ longitude while $37^\circ E$ latitude passes through the southern part of it.

The division has four locations namely Aguthi, Tetu, Muhoya's and Thigingi and these occupy 382 $\text{Km}^2$ out of the district's 3284 $\text{Km}^2$. (Map 1) and (Map 2).

TOPOGRAPHY AND SOILS:

The district varies in elevation and is dominated by Mt. Kenya to the East, which rises up to 5199 m above mean sea level, and by the Nyandarua Range to the West, which rises 3999 m above mean sea level. In between these two is lower land that is in turn interspersed with higher ground such as Karima Hill and Tumutumu Hills which rise up to 3000 m. This central portion varies in elevation, between 1600 and 3000 m above mean sea level.

Tetu Division is characterized by the undulating to rolling topography with volcanic rocks forming the
District boundaries
Provincial boundaries
International boundaries
Nyeri district

LOCATION OF NYERI DISTRICT WITHIN KENYA

G. N. Ichangi
M.A. (Planning) 1987

Map No 1
LOCATION OF TETU DIVISION IN NYERI DISTRICT.

G. N. Ichangi
M.A. (Planning) 1987

Map No. 2
bedrock, in this central part of the district.

The soils in the district vary from moderate to high fertility with small pockets of low and variable fertility soils. Tetu Division is covered by soils of moderate to high fertility referred to as andohumic nitosols with humic andosols (heavy texture) and humic nitosols (heavy texture) in the Farm Management Handbook of Kenya. These soils are derived from volcanic ridges which bear soils with variable top soil. Andohumic nitosols with humic andosols are well drained, extremely deep, dark reddish brown to dark brown, friable and slightly smeary clay (of the kaolinitic type) with humic top soil. Humic nitosols are in turn, well-drained, extremely deep, dusky-red to dark reddish brown, friable clay with acid humic top soil.

Such soils are extremely suitable for agriculture and tend to support vegetation cover well. Indigenous tree species such as Albizia gummifera, Croton macrostachys and Cordia abyssinica have done extremely well despite their being slow-growing. These soils in the division require such trees which play a major role in ecological and environmental maintenance. The soils are easily erodable especially when exposed on steep slopes. A lot of the division
has ridge and valley topography and with the increasing exposure due to vegetation cover removal, ecological balance has been disturbed resulting in erosion of the top soil. Aerial photographs depict the effects of erosion on the landscape especially on the steeper slopes. (Map 3.)

**CLIMATE AND DRAINAGE:**

The climate varies over the district with rainfall averaging 2200 mm p.a. on high ground to 700 mm in the lower plateau areas. The amount of rainfall relieved in different parts of the district varies from 1200 mm. to 160 mm. during the long rains season and 600 to 150 mm. during the short rains.

The study area receives between 800 mm. and 1400 mm. p.a. and the rainfall occurs as a double maxima rainfall pattern. Map 4(i).

The temperatures vary in the district with Mt. Kenya sporting a permanent snow cap all year round, to relatively high temperatures in the North of the district at about 26°C. The average in the study area is about 24°C.

The District is well watered and most of the rivers flowing in it have their source regions in the two massifs. Water is discharged from these
SOILS IN TETU DIVISION
NYERI DISTRICT.

KEY
- Andohumic nitosol with humic andosol (heavy texture)
- Humic nitosols (heavy texture)
- Study area

TITLE

SOURCE
G.N. ICHANGI
M.A.(PLANNING) 1987

Map No. 3
two source regions all year round and the streams and rivers are thus perennial.

Although the water quality of these rivers is excellent at their sources, it deteriorates downstream mainly due to siltation resulting from soil erosion of the area. This is again pegged to the reduction of vegetation cover because of the agriculture and also to meet wood demands. Tetu Division has a very good network of rivers flowing through it and these form tributaries to the major rivers such as Chania and Sagana. Map 4(ii).

The rainfall amounts and pattern as well as the temperature are the major determinants of land-use with respect to vegetation cover. The crops planted as well as any other vegetation is dependent on these two parameters. In the study area, the agricultural land-use is closely determined by the seasons while temperatures determine the crops especially cash crops with tea being cropped at higher altitudes beyond Ihururu area in the North West of the division. Aerial photography enables a planner to compare vegetation cover land-uses in different seasons as well as different altitudes in different years and may be required. Calculations of areas under different vegetation cover can be done with ease and all these related to the
DRAINAGE PATTERN IN TETU DIVISION, NYERI DISTRICT
climate and drainage.

AGRO-ECOLOGICAL ZONES:

On the basis of soils and climate (rainfall and temperature) and their integration, agro-ecological zones are determined which determine areas better suited to the various crops and agricultural land-use. The zones classified are as follows:

Upper Highland and Lower Highland which enable permanent cropping possibilities during the drier months because of their higher altitude which enhances the retention of moisture. Parts of Tetu comprise these zones. On the windward sides of the massifs especially Mt. Kenya, the zones become upper midlands suitable to tea and coffee crops as well as to dairying and associated fodder crops. Tetu division lies in three agro-ecological zones namely upper highlands, lower highlands and upper midlands. The first zone includes forests and parks, while the second allows for pyrethrum, horticultural crops, tea and maize. The last zone is mainly the coffee zone or tea-coffee zone and dairying is practised in all these zones. (Map 5).
AGRO-ECOLOGICAL ZONES:
TETU DIVISION, NYERI DISTRICT

SOURCE
G. N. ICHANGI
M.A (PLANNING) 1987
Map No. 5
In relation to the agro-ecological zones, certain tree species may be suited especially in terms of meeting multiple needs such as browse or fodder, soil conservation, fencing and fruit or horticultural needs. Some trees such as *Cordia abyssinica* have good potential in vegetation cover systems. This tree for instance, has extensive shade and loses its leaves during the rainy season providing excellent organic fertilizer and reducing crop/tea competition for light if planted along with other food crops. It would be suitable in pasture lands as well as on areas liable to erosion. Aerial photography depicts areas falling under the different agro-ecological zones clearly and suitable areas for different tree types for example, can be picked out. Monitoring of changes in vegetation cover in the different zones can also be done over the years using this tool.

**LAND-USE TYPES:**

The land-use types in the district are varied but can be broadly categorized as land-use related to agricultural activities, forests and national park, ranching, as well as built-up areas and settlements which form the 'urban' areas either as markets or rural, local or urban centres or principal towns as in the growth centre hierarchy and infra-structure.
Tetu Division takes from these and has a variety of agricultural land-uses mainly in balls. Coffee dominates in the warmer south of the division while tea is grown dominantly in the higher north-west bordering the Nyandarua Range. Dairying is practised extensively. Maize and Beans as well as other crops such as potatoes (sweet and Irish) and a variety of vegetables and fruits are grown. The division also has forests which belong to the state and also part of the Nyandarua Range National Park. The town of Nyeri is also found within Tetu Division as are Ihururu, Tetu, Mununga-ini and Kamakwa, Giakanja, Gatitu and other smaller 'urban' areas. There are various roads tarmaced, gravelled or rural access roads as well as other infra-structure and public purpose land-uses such as schools and health facilities and offices. The settlement pattern varies over the division. There are dispersed settlements in the small-scale farms as well as the 'traditional' or registered villages used during land 'consolidation' and never demolished. These are concentrated settlements. In the 'towns' there are other settlement types for the urban population which include formal and informal housing types. (Map 5).

Aerial photographs help in monitoring the changes in settlements as well as other land-uses. The use of
multi-date photography clearly is an asset in this respect. Actual areas devoted to the different settlement types can be calculated and deductions can be made about the direction of growth of centres of population concentration. The number of structures and their sizes can also be calculated yielding different implications. Actual lengths of certain infrastructure such as roads and power lines can also be picked from aerial photographs and the ease with which this is done reduces many man hours for the planner and decision-maker. The difficult terrain can be picked out and thus enable the decision-maker to avoid making costly decisions on the basis of inadequate information. Land-use patterns can therefore be analysed using remotely sensed data.

POPULATION:

According to the 1969 population census, Nyeri District had a total population of 360,845 persons on a total rural area of 201,000 hectares. Of this area, there are 158,900 hectares (79%) suitable for either agriculture or livestock herding. The last census in 1979 indicated that the population had swelled to 486,477 persons on the same area. The census indicated that between 1980 and 1990, the growth rate is estimated to be approximately 3.65% p.a.
Population projection based on a growth rate of 1.65% per annum (Central Bureau of Statistics).

The formula used to project population in the study area is as follows:-

\[ P_t = P_o (1 + r)^n \]

where

- \( P_t \) = Future population i.e. projected population
- \( P_o \) = Present population
- \( r \) = Rate = \( \frac{3.65}{100} = 0.0365 \)
- \( n \) = The intercensal period
- \((1 + r) = 2\)

The area spanned by Tetu is 382 Km\(^2\) and the density in 1979 was therefore 360 people per Km\(^2\). In the same year, the district density was 148 people per Km\(^2\).

Statistics from the Central Bureau of Statistics (CBS) reveal that the average farm holding available to a household was about 1.80 ha. The average household was 4.90 persons. In 1979, 8.4% of the total population lived in the urban areas of Nyeri and Karatina (18,713 persons) and Othaya (2,159 persons). The holdings are
larger in the drier agro-ecological zone areas where ranching is most suited to. Most of the population is engaged in agricultural activities while the 8.4% resident in the urban areas is primarily engaged in trade, administration, health working and teaching. Although agriculture is the mainstay of the people in the study area, commercial activities are gaining momentum as are informal activities and trade especially in the urban areas.

The greatest percentage of people in the division is found outside the urban areas and is therefore rural. The land-use activities engaged in therefore include food and cash crop farming as well as dairying. Due to the increase in population that is envisaged, there will be greater demand for food and for other land related activities. Consequently, vegetation cover is bound to decrease even more as it is replaced by other land-uses. The encroachment of the less steep slopes of Nyeri Hill by agriculture as depicted clearly in the aerial and oblique photographs bears this out. Remotely sensed data can aid in providing the necessary information on time and subsequently enable planners and ultimately decision-makers preclude environmental degradation which results from loss of vegetation cover due to increased population pressure on the land. Conventional methods used to aid decision making take extremely long and often provide information several years later than would have been necessary to effect
corrective measures. They also may be less accurate since they do not provide a birds eye view of a region, which is necessary for effecting decisions related to broad scale changes in land cover.

It is clear that land-use is dominated by vegetation cover of different sorts be it agricultural or wood based vegetation. The soils and topography of an area influence the vegetation cover of an area while climatic variables play a major role in determining the cover and this is also tied to the agro-ecological zones which are derived from these factors combined. Land-use changes occur and need to be monitored so as to be evaluated and if need be corrective measures to be taken on time. Aerial photography is an important tool which can be used for these purposes as well as for showing areal extents of different land-use types. They provide relatively cost-effective information which requires only ground-truthing for verification of minute details. Little manpower is required although it must be of necessity, trained in the technical aspects of the tool. The amount of money required is to collect the same data using traditional methods. The relationship of the variables to land-use changes and vegetation cover depletion can therefore be evaluated using aerial photographs.
RESEARCH METHODS:

The study required both primary and secondary data in order to be successfully carried out. The primary data was collected out in the field while secondary data was found in various publications as well as maps and aerial photographs that were purchased.

SECONDARY DATA COLLECTION:

A lot of the data collected from secondary sources was found in various publications in numerous agencies that are concerned with the subject of the study. The Kenya-Rangeland Ecological Monitoring Unit (KREMU) and ICRAF libraries had available a lot of secondary data. Secondary sources are usually diverse and rich and this called for thorough exploration and critical evaluation of these materials.

Aerial photographs covering the study area were also purchased as were topo maps which aided in the multi-data land-use mapping of the area. The necessary field surveys were set up and carried out and this led to the collection of primary data in the field. This methodology enabled the researcher to avoid repetition or the collection of unnecessary
data in the field.

**PRIMARY DATA COLLECTION:**

Two types of primary data were collected namely the fuel-wood/energy requirements survey and the field mapping survey. The letter was done so as to verify certain aspects found to be occurring (with respect to land-use), on the aerial photographs. It was also done in order to give the situation in 1986 as it was and this would enable comparison of the situations in the 1960's, 1970's and 1980's.

The method applied in the survey was adapted after the Jones and Finch Mapping Method. In this method, the land to be surveyed is sub-divided into units and viewed as a mosaic of spaces. The fractional complex code was used to map the details required in terms of the natural environment and the land-use. The denominator is descriptive of the land (land-use). Two field maps were used on which land utilization was mapped on one and the natural environment, on the other, for each of the mosaics that were mapped.

The use of two maps was preferred because of the simplicity of use. Areas essentially uniform throughout in utilization were identified while those processing essential uniformity in their combination of slope,
soil, drainage and natural vegetation were identified and mapped out separately. A description of each area type was written out while the map record was made out using fractional notation where each number connotes a specific item of land-use or land condition.

The Numerator table included the major land-use type, the specific use type and the condition of use/cover while the Denominator table included the slope of the land, the soil type and the drainage.

**NUMERATOR**

<table>
<thead>
<tr>
<th>Left Hand Digit</th>
<th>Major Landuse Type</th>
<th>2nd Digit</th>
<th>Specific Use-Type</th>
<th>3rd Digit</th>
<th>Condition of Use/Crop</th>
</tr>
</thead>
</table>

**DEMOMINATOR**

<table>
<thead>
<tr>
<th>Left Hand Digit</th>
<th>2nd Digit</th>
<th>3rd Digit</th>
<th>Slope of Land</th>
<th>Soil Type</th>
<th>Drainage</th>
</tr>
</thead>
</table>

The following data variables were mapped:

1. Cover types
   i) Tilled land (1) Good
   ii) Fallow land (2) Medium
   iii) Woodland/Forest (3) Poor

2. Settlements
   i) Towns/Shopping Centres
   ii) Villages
   iii) Individual Homesteads

3. Transportation lines and communication channels.

4. Agro-forestry
   i) Trees and animal feed.
   ii) Trees/shrubs and food crops.
5. Fuelwood.

The denominator variables included.

1. Slope
   i) Level 0° - 3°
   ii) Rolling 3° - 9°
   iii) Rough 9° - 15°
   iv) Steep 15°

2. Soil Type
   1) 7.6R Andohumic nitosols with andosols.
   ii) 7.7R Humic nitosols.

3. Drainage
   i) Poor
   ii) Very Poor
   iii) Good

This data was used to review the historical change of vegetation cover using remotely sensed data as well as to assess the current vegetation cover and land-use in the area. The land-uses were categorized broadly into vegetation, agriculture, built-up area and Infra-structural use. A comparison of the state of land-use past and present as well as of vegetation cover and an evaluation of the usefulness of remotely sensed data in assessing and monitoring change for planning purposes is now possible.

The data found in the aerial photographs was plotted using a stereoplotter to give a land use map.
As has been mentioned, land-use changes are often depicted by loss in the original vegetation cover of an area. Hence the analysis of land-use changes is naturally related to the analysis of vegetation cover over a number of years and it become necessary to evaluate the vegetation cover of a rural area in order to evaluate land-use patterns and change. The vegetation type in the study area is montane rain forest but tree cover has been found to diminish with distance from Mount Kenya and the Nyandarua Range (University of Stockholm, 1981). The decrease in tree cover over the area can be attributed to expansion of agricultural land-use and also to a demand for wood products. This demand has been found to be high in the district and is expected to rise with time due to the increasing population (Christiansson, et al (eds), 1981). They also found that woodfuel is an essential commodity in the area both in homes and in public institutions and called for an increase in tree planting to meet the demand.

Since loss of vegetation cover is due to the two factors mentioned above, and in light of the need for wood as a source of wood products for building and primarily, fuelwood, it becomes necessary to plan for the ordered use of vegetation (tree) cover and also for its maintenance and management. Aerial photography is used along with field surveys and one such survey was conducted for energy/fuelwood requirements in home.
The fuelwood/energy requirements survey was conducted so as to enhance the case being made in applying remotely sensed data to planning and decision-making, for resources. It is important to carry out fuelwood surveys related to the consumption because there is lack of information on which solutions to the problems facing the fuelwood users can be based. The surveys data provided a firm information base for analyzing energy/fuelwood decisions and ultimately for improving those decisions. Although energy is an urgent issue and the tendency is for the researcher to focus on the immediate project and planning needs, due consideration should be given to long term policy making and planning needs which are often served by more general information gathering efforts that combine energy with other needs. Thus, the linking of the ground truth mapping exercise with the survey facilitated this general information gathering. Energy decisions like other decisions are often assisted by an analysis of the data gathered.

The fuelwood survey was flexible in design and operation. It allowed for the gathering of more information along the way which gave more substantial conclusions.

The fuelwood survey included a set of questions on fuel consumption and supply which was issued to
households within the study area. This was necessary because it enabled the people to participate. A set of trees were also measured so as to be able to calculate the volume and rates of growth of certain tree species suitable for fuelwood among other uses. These were a pure stand of Pinus, a set of Grevillea robusta and Casuarina sp., a set of Cupressus sp., and a few indigenous trees of Muhugu type. Their ages differed as did the management of these tree lots.

Thus both primary and secondary data sources have been used in order to fulfill the objectives of the study. The data collected for the trees included volume, height, and breast-height diameter, and also the preference for the different tree types by the households and the consumption of the tree types as well. There was need to see how these variables related to each other and the data was therefore subject to regression analysis which is a statistical tool which tests whether paired variates are related.

The multiple regression model used was of the form:

$$y_{xi} = B_0 + B_1x_{i1} + B_2x_{i2} + E_i \ldots \ldots \ldots \ldots \ldots (1)$$
Where \( B_0 \) = Regression coefficient

\( B_i's: \forall i = 1, 2 \) are regression coefficients

\( E_i \) = Random disturbance; \( E_i \sim N(0, \sigma^2) \)

\( y_{yi} \) = the \( i \)th observation of the dependent variable

\( x_{1i} \) = The \( i \)th observation of the first independent variable and so on.

The assumptions of the technique include:-

i) Error terms (E) in observations are normally distributed and independent of \( Y \) as shown.

ii) Successive error terms are mutually independent. If strong relationships exist between 2 or more of the independent variables, serious rounding errors can accumulate in the calculations.

The simple linear regression model was also used and was of the form:-

\[
y_{yi} = B_0 + B_1 x_{1i} + E_i \quad \text{...............(2)}
\]

Where:

\( y_{yi} \) = the \( i \)th observation of the dependent variable

\( B_i's: \forall i = 0, 1 \) are regression coefficients

\( x_i \) = the \( i \)th observation of the independent
variable.

\[ E_i = \text{random disturbance or error} \]
\[ E_i \sim N(0, \theta^2) \]

The assumptions are as for multiple regression.
The study deals with two issues that are pertinent to development. Firstly, it seeks to bring out the opportunity that remote sensing technology (special reference to aerial photographs) provides to a resource planner for planning purposes and secondly, to plan for a resource (namely fuelwood) using the remotely sensed data. Fuelwood is important because it is a basic necessity in life and also because it's availability or otherwise seriously affects the environment.

Over the years, remote sensing as a tool has been used mainly for data collection related to land-use and/or resources in a manner that enabled the inventorying of the resources. Analysis of data provided by aerial photographs should be carried out in a manner that allows/leads to better decision-making. These photographs provide data on numerous variables such as the physical aspects of the area and this information if well analysed should help the planner in guiding the making of decisions on resource utilization and the planning of the utilization per se. In the past the effectiveness of planning and decision-making has not been aided much by the tool of remote sensing because of the manner in which it has been (or not been) adapted to the processes that involve human needs.

Planning is assumed to be a rational process of human beings and generally, the following hold:-
any plan should be directed toward well-defined goals and objectives.

planning requires coordination between specialists in different fields.

planning is a prerequisite to management.

planning requires continual re-drafting of plans which enables the planner to seize new opportunities as they come.

planning should retain flexibility and provide alternative courses of action.

Planning is carried out because of people and the needs they express whether felt or perceived and it is an iterative process that requires careful examination of available courses of action. It is carried out by planners whose main role is to guide policy-making by creating an environment of knowledge and data within which the policy maker can make the most rational and logical decisions. Because the planner is not accountable for decisions made, he does not make them whereas the policy-maker is held accountable. It is important therefore that the best available information be used for decision-making. The planners role is thus two fold. He helps the community achieve particular goals they may set for themselves and he also speaks on behalf of the client.
He also aids in decision-making by guiding the policy makers in making decisions that meet the clients needs.

For a long time, planning has not been taken beyond the data analysis stage (for resource data) and most data collected has not been subjected to the planning process in full and knowledge is usually required about many sets of factors. Increasing pressure on resources requires that planning be done to conserve and also improve their utilization levels. Such planning requires in depth knowledge of the resources which in turn demands the development of Information systems that provide efficient classification, compilation, mapping, storage retrieval and usage of resource information. Monitoring is needed to enable assessment of land-use changes to be done. Management can also be enforced which would in turn allow for better resource utilization. For this, models capable of estimating the response of the land to the imposition of new duties are designed and the results are integrated with other factors which helps in the creation and implementation of planning procedures. (Townshend, 1981).

Most of the land-use planning that has been done in Kenya has been done on the basis of sample surveys and questionnaire data collected in the area
of interest. Remote sensing has been used mainly as a tool for data collection. That such data can be subjected to the planning process in demonstrated using "fuelwood requirements" in the study area as a felt need which must be met and in so doing requires planning. The planner must have sufficient data of factors pertaining to fuelwood with which he can plan and also present to the policy maker so as to enable him make a good decision on fuelwood procurement and provision.

**FUELWOOD AS A SOURCE OF ENERGY:**

Within the study area, the field survey data indicated that fuelwood accounted for about 61.4% of the total energy/fuel consumed (Table 1). Household consumption averaged 19.3 head loads (117.75 Kg.) per month. Each head load cost an average of KSh.4.60 which implies that about KSh.88.80 is spent on fuelwood per month per household (Table 2). The Beijer Institute has estimated an accessibility parameter which measures various specific relationships such as distance away from the fuelwood source and privatization of land. The data collected in the study area reveals that the average distance travelled to fetch fuelwood is 3 Km. and the average time taken to fetch a days supply is 92 minutes (1 hr. 32 mins.). This gives a total of 2760 minutes (46 hours) per month or about 1.92
<table>
<thead>
<tr>
<th>FUEL TYPE</th>
<th>PERCENTAGE USING FUEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUELWOOD</td>
<td>63.38</td>
</tr>
<tr>
<td>CHARCOAL</td>
<td>34.93</td>
</tr>
<tr>
<td>PARAFFIN</td>
<td>34.93</td>
</tr>
<tr>
<td>SAWDUST</td>
<td>10.71</td>
</tr>
<tr>
<td>GAS</td>
<td>5.36</td>
</tr>
<tr>
<td>ELECTRICITY</td>
<td>0.89</td>
</tr>
<tr>
<td>OTHER (Ex Maize cobs)</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Table 1 FUEL TYPES USED IN THE STUDY AREA

<table>
<thead>
<tr>
<th>Average number of fuelwood headloads per month</th>
<th>Average number of charcoal sacks per month</th>
<th>Average Price/headload</th>
<th>Average Price/Sack</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.3</td>
<td>3</td>
<td>4.60</td>
<td>47/15</td>
</tr>
</tbody>
</table>

Table 2 QUANTITY USED AND PRICE PAID FOR CHARCOAL AND FUELWOOD
days per month dedicated to this activity. (Table 3).

Most of the people within the study area owned an average of 2.07 ha. of land while the rest lived in the urban areas and village sites such as Kamuyu (Table 4). Fuelwood demands are met by local wood resources either on farms, existing wood-lots and bush or saw mills. Field data further indicated that about 52% of the fuelwood was collected in the forest/bush lots while about 36% was purchased at sawmills. Only 11% was collected from the farms. (Table 5). 70.5% of those people claimed that they preferred Eucalyptus trees for fuelwood. These trees were available either on farms or in the bush. A lot of the vegetation in the study area is dominated by this species (Plate 1). 13.6% said that they preferred cypress trees which were mainly found on farms, the bush and sawmills while Grevillea robusta ranked third with about 9% respondents liking it and getting it on their farms. (Table 6).
PLATE i Dominant
Tree in the area is Eucalyptus
<table>
<thead>
<tr>
<th>Distance Travelled to fetch fuelwood (Km)</th>
<th>Distance travelled to fetch charcoal</th>
<th>Average time taken to fetch fuelwood/day</th>
<th>Average time taken to fetch charcoal</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>46 Minutes each way</td>
<td>102 minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>92 minutes</td>
<td>1 hour 42 Mins.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 hr. 32 Mins.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 AVERAGE MAXIMUM DISTANCE TRAVELLED AND TIME TAKEN TO FETCH FUEL

<table>
<thead>
<tr>
<th>Average Household Size</th>
<th>Average Size of land unit (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.74</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Table 4 HOUSEHOLD SIZE AND LAND UNIT SIZE (HA.) IN THE STUDY AREA
### Table 5 Sources of Fuelwood in the Study Area

<table>
<thead>
<tr>
<th>Species</th>
<th>Source</th>
<th>% Age Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus Species</td>
<td>Home or Bush/Forest</td>
<td>70.5</td>
</tr>
<tr>
<td>Cypressus Species</td>
<td>Home or Bush/Forest or Sawmill</td>
<td>13.6</td>
</tr>
<tr>
<td>Wattle</td>
<td>Home/Bush/Forest</td>
<td>2.3</td>
</tr>
<tr>
<td>Mutarakwa</td>
<td>Home/Bush/Forest</td>
<td>4.5</td>
</tr>
<tr>
<td>Grevillea robusta</td>
<td>Home</td>
<td>9.1</td>
</tr>
</tbody>
</table>

### Table 6 Woodfuel Species Preferred and Their Source Areas
The data collected on the tree species preferences and consumption from respondents was subjected to regression analysis to test whether there was any significant relationship. The results indicated that only a weak correlation existed:

From the aerial photographs, Eucalyptus trees show up as the dominant tree species followed by Cupressus species. The Eucalyptus trees occur in large numbers along the river courses as well as in stands in open spaces while cypress trees dominate on the areas towards Nyeri Hill and the Muringato Forest Station. These trees also appear to be planted on farms once the original vegetation was cleared while cypress trees are found along farm boundaries as well as within farms. The tree canopies appear to be more dense in the 1960 photographs than the 1970's and this indicates that their consumption has been on the increase. The 1970's photographs also indicate thick crown cover which shows that the trees are mature and old in the area.

From this, it can be inferred that the apparent preference for Eucalyptus and cypress trees is based on their availability and abundance rather than on actual beneficial considerations that may be derived from their use. These trees were introduced into the area in great numbers and have as a result replaced
indigenous tree species as the dominant trees. The aerial photographs do not indicate large stands of indigenous species in the study area except on Nyeri Hill on the upper parts.

Demands for wood may be met through either (i) the harvesting of sustainable yield from existing wood stocks or (ii) from the cutting of standing stock. Data on national wood supply and demand indicate that Central Province, within which the study area lies and which is a high population density province had by 1984 began to cut wood stocks as a wood source. This supplied over half the wood rather than such a supply coming from sustainable yield. Shortfalls exist in unmet demand but not in wood stocks. There has prevailed a situation of insufficient wood supply available on sustainable yield basis and it has not been possible to meet all the demand for fuelwood. Cutting of woodstocks has been at a rate which "can only exacerbate the future wood shortage and lead to further environmental degradation". The cutting of woodstocks signifies the beginning of a process which leads to a more serious set of social and environmental problems.

Aerial photographs indicate that the cutting down of woodstocks has been on-going in the study
area. Nyeri Hill forest line has receded over the last two decades as people encroach on the area. Part of the forest area is very steep and not suitable for agriculture and it can therefore be said that the loss in vegetation cover was in response, to meeting the demand for wood. The less steep slopes to the west of the hill, opposite Mathari Hospital has been due to agricultural expansion, and human settlements mainly while the steeper slopes may have been cleared for wood needs.

To be able to halt this process and to provide fuelwood, proper planning is required which will allow for the provision of sustainable yields of wood. Planning of this type requires population data. From the calculations, using an average household size of 6.74 people as found in the field, Tetu division will have 292,033 people by year 2000 which is equivalent to 43,477 households. (Table 7).

If the number of fuelwood headloads are projected to the same year, there will be a demand for 839106.1 headload or 14,684 tonnes. (Average weight per headload is 17.5 Kg.). (Table 8).

Field data tree measurements revealed cypress trees averaging 14.6 m. tall and a stand of pine averaging 8.23 m. tall. The aerial photographs on the other hand depict dense tree canopies over tree lots which can give an indica-
tion of the tree heights or the maturity of the trees.

Using simulated stand volume tables for cypress and pine from the Ministry of Natural Resources, the following is deduced:-

For Cypress trees, 14m. tall with basal area of $14m^2$ per ha., the maximum overbark stand volume in $m^3$ per hectare that can be achieved is $281m^3$ per hectare.

For pine trees, 8m. tall and with a maximum basal area of between 18 and $22m^2$/ha., the maximum overbark stand volume that can be achieved is between 77 and $79m^3$/ha.

The population projections for Tetu Division are based on the growth rate of 3.65% per annum. 1979 is used as the base year. Table 7 and Graph ai and aii.
Graph: Population Projection, Tetti Division.
Source: G.N. ICHANG'I
M.A. (PLAN.) 2
1987.
Graph aii: Household Projections, Tetu Division.

(average household size = 6.74)

source: G. N. ICHIANG'I
M.A. (PLAN)
1987
Table 7: POPULATION PROJECTIONS FOR TETU DIVISION

- The field survey data indicates that the average household size within the study area is 6.74 persons.

- The density is calculated for Tetu Division which extends over 382 Km².
FUELWOOD DEMAND:

The average fuelwood requirements are 19.3 headloads per month per household. Thus, the fuelwood demand is projected on the basis of increasing households as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Size</td>
<td>171,149</td>
<td>204,749</td>
<td>244,945</td>
<td>293,033</td>
</tr>
<tr>
<td>Number of Households</td>
<td>25,393</td>
<td>30,378</td>
<td>36,342</td>
<td>43,477</td>
</tr>
<tr>
<td>No. of Headloads of Fuelwood</td>
<td>490,084.9</td>
<td>586,295.4</td>
<td>701,400.6</td>
<td>839,106.1</td>
</tr>
<tr>
<td>No. of Kg. equivalent</td>
<td>8576485.75</td>
<td>10260169.5</td>
<td>12274510.5</td>
<td>14684356.75</td>
</tr>
<tr>
<td>No. of tonnes equivalent</td>
<td>8576.5</td>
<td>10260.2</td>
<td>12274.5</td>
<td>14684.4</td>
</tr>
<tr>
<td>Volume equivalent (m³)</td>
<td>1981.5</td>
<td>20315.2</td>
<td>24303.5</td>
<td>29075.1</td>
</tr>
</tbody>
</table>

Table 8 FUELWOOD PROJECTION FOR TETU DIVISION

1 headload of fuelwood averaged 17.5 Kg. while for cypress and pine, 1 tonne yielded 1.98 m³ of woody biomass resulting in the above volumes.
If the fuelwood tonnage is converted into cubic metres, by year 2000, 29075.1 m³ will be required by the households. If Cypress trees of 14m height and an average basal area of 162.4 m²/ha. are to be available for fuelwood in a stand, 179 ha. will be required by year 2000 while if pine trees, 8m tall with an average basal area of 47.2 m²/ha. are expected to supply fuelwood as required, 616 ha. of pine will be required. This is equivalent to 1.79 and 6.16 Km² for cypress and pine respectively. The age required for trees to reach these specifications is also important.

Since the hectarage is projected over 5 year blocks of time, a fuelwood planting plan is required to enable provision of the required annual amounts as well as planting of the required annual hectarage so that there is sufficient woodfuel on sustainable yield basis to be able to meet all the demand for it in the community.
PLANTATION PLANNING FOR FUELWOOD

Planning for fuelwood plantations can be done at several different levels with each level bearing a specific objective. It can, for example, be done at the following levels:

<table>
<thead>
<tr>
<th>Level</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. National Forest Policy/Objective</td>
<td>To make the nation self-sufficient in wood by year X.</td>
</tr>
<tr>
<td>2. National Quantitative Forestry Target</td>
<td>To produce Y million m³ of fuelwood per annum in year 2000 and an additional 5% annually thereafter.</td>
</tr>
<tr>
<td>3. Project Aim</td>
<td>To plant Z ha. of <em>P. Patula</em> and W ha. of <em>Eucalyptus grandis</em> annually in District. A for production of f m³ fuelwood and d m³ poles in rotation of 10 and 20 years respectively.</td>
</tr>
<tr>
<td>4. Operational Planning</td>
<td>To arrange beforehand HOW and WHEN to obtain seed, prepare nurseries, carry</td>
</tr>
</tbody>
</table>
out site preparation e.t.c. in order to achieve the project aim as efficiently as possible.

5. Execution or Management

To convert operational plans into effective action.

There is a close relationship between the different levels or phases of planning and often, the methods worked out to achieve an objective at one level become the objective at the next lower level with a subsequent interaction occurring between the several planning levels. (After Chapman, et. al. 1978)

Forestry planning needs to be expressed in written form as a wood lot/plantation management plan because of it's nature as a long-term programme.

The Plantation Management Plan (PMP)

Data requirements include the following:-

1. Resources Data which includes land, planting stock, materials and equipment, human and financial resources and the information that is required is on availability, productivity
and cost. For land resources, sufficient land that can accommodate the projects planting programme must be found and the determination and clarification of tribal and/or other legal rights affecting the long term use or availability of land must be considered. The suitability of particular tree species within the area must be determined and this requires soil surveys and preparation of soil and vegetation maps. Human resources are also important since they provide the man-power required.

2. Operational Data which includes data on unit of measurement such as ha., Km. or '000 plants.

- Input such as man-days, machine operating time and materials.
- Output such as units per hour, per day.
- Cost such as for each resource per unit.

These form a basis for appraisal and budgeting and also for estimating resource requirements. Operational data is fundamental to the planning process.

3. Institutional Data which normally refers to the political environment and includes the projects legal framework and the commitment of the
supervising agency. Other data required is on the inter-relationship of the local community and the project facilities for multiple land-use and information on plantation research.

The legal framework should provide for appropriate and effective legislation and regulations and the means to enforce them. An adequate management and administrative structure should be available to run and service the project. The plan should be simple and flexible so as to allow for effective management and should be tailored according to local conditions and requirements.

**Plantation Layout**

This includes the design and delineation of compartments, blocks, main and secondary roads, rides and fire traces. It is a major aspect of planning requiring careful study for each project. The layout should be adapted to the pattern of plantable soils, topography and natural features and the design is also influenced by fire protection requirements and anticipated methods of logging and extraction.

Remotely sensed data using aerial photography provides the broad scale comprehensive picture of an area such as the study area. The pattern of suitable
soils and topography as well as land available for use can be estimated from aerial photographs. It is thus much simpler to design the layout since there is a comprehensive view of the area from above. Maps drawn using stereo-plotting bring out the steep slopes and when used in conjunction with the soil maps, areas prone to degradation due to loss of cover can be mapped and incorporated in the plan's layout design. Most compartments may be 20 to 40 ha. but size is relative so long as each is confined to 1 years planting. Road densities vary from 1 to 4 Km. per Km² depending on the terrain. The selection of plantation species should be evaluated during the collection of the data base and map records should be included in the plan.

Network Analysis in Plantation Projects

Such a project is composed of many activities spread over a large tract of land and involving many people. Correct timing is important and thus scheduling and controlling of all the activities so that the work programme needed to complete the project is carried out within the time and financial limits set needs to be done and can be achieved through the use of network analysis.
AERIAL PHOTOGRAPHY AND PLANNING

Aerial photographs can be used for many purposes and in planning they may help in quick data gathering on land-use especially where future monitoring is required. Techniques of aerial photography and remote sensing have been used widely in surveying and geological projects but have remained high technology areas for planners, land-use analysts and geographers (King'oriah, 1984). He further argues that *ad hoc* land-use in Kenya's rural areas has been due to the lack of a systematic and coordinated methodology for land-use and planning studies and lack of unconstrained, centralized decision making on land-use. Land-use conflict and environmental degradation can be avoided through careful planning. In keeping with trying to make planning of resources such as fuel-wood easier and readily carried out, the collected data ought to be subjected to analysis and decision-making processes. Data gathered from aerial photographs can be analysed and yield sufficient data for planning purposes. It gives a large expansive coverage that can be repeated as often as required and this is important because planning is an iterative process and the planner must constantly review and evaluate his plan and also because planners need to give their work a spatial dimension.
The photographs analysed in this study have yielded the following results:

The study area is hilly and covered with ridge and valley topography. It is quite deeply incised and dissected by rivers such as the Chania and Muringato rivers and their numerous tributaries. Their source region is in the Nyandarua Range. The river valleys and steeper slopes were covered by brush and trees and grasses (riverine vegetation) in the 1960's but with time as confirmed by the later photographs and ground truth survey, they have been deforested and cultivated or left devoid of vegetation cover. This has resulted in soil and the subsequent pollution of rivers with silt. The aerial photographs show coffee plantations as static with no change at all over the last two decades although the road network has improved planting in the areas. In small scale holdings, coffee has been on the increase over the two decades and this can be seen clearly.

Most of the loss of trees and vegetation has been due to an increase in agricultural activities and also to the demand for wood for fuel and other uses.
The built-up areas are very clearly depicted and when plotted, the actual buildings and their sizes can be seen and are measurable. This helps in showing the direction of growth for built-up areas within the study area as well as the exact locations of individual buildings, their concentrations and their relationship to the lie of the land. The structures are found on ground that is flattish with about 15% slopes i.e. on the ridge tops. (Map 6).

The extent of trust-land, government land and privately owned land can also be seen in a spatial way which further enables the planner to locate and measure the available land for other public purposes. Such land is found to exist in villages, along the river channels, forest reserve areas and steep slope areas.

Nyeri Hill Forest has been shrinking and the forest line shows recession over the two decades with agriculture replacing it and/or succession vegetation or exotic tree species planted in the recent past. PLATE 11
LAND USE AND SETTLEMENT TYPES IN TETU DIVISION
NYERI TOWN

KEY
- Village Settlement
- Dispersed Settlement on small scale farms
- Large scale farming coffee estates
- Nyeri town
- Centre of urban concentration

Small scale farming - coffee-dairying-food crops
Small scale farming - tea-dairying-coffee-food crops

SOURCE
G.N. Ichangi
M.A. (Planning) 1987

Map No. 6
PLATE ii Replacement of indigenous trees with exotic species.
AERIAL PHOTOGRAPHY DATA AND FUELWOOD PLANNING

Aerial photographs provide data on the land resources needed in fuelwood planning. Such woodlots or plantations require sufficient land with suitable terrain and soils and where the peoples legal patterns governing land are considered as agreeable or can be amended to make them suitable. Fuelwood can be provided by individuals on their plots or by an agency using government land and the people. Rates of depletion can also be calculated using aerial photographs.

To be able to decide on the species for such woodlots, it is essential that certain variables be examined for the different tree species. The study took into consideration the volume, DBH, Height, Household size, consumption and the species consumed.

Using the simple linear regression model (Equation 2, Chapter Three), data collected on Pine and Cypress trees was analysed. The variables of interest being Volume, Breast-Height - Diameter (DBH) and Height. The same model was also used to analyse woodfuel consumption, household size and woodfuel consumption, household size and woodfuel preference data. The results of these analyses are given in Tables 9 i & ii.
TABLE 91 A Summary of the linear regression equations characterizing the relationship between consumption of woodfuel (C) and Household Size (HS); Wood-type preferred (WP) and Household Size (HS); and Wood-type preferred (WP) and Consumption (C) for households in Tetu Division.

<table>
<thead>
<tr>
<th>EQUATION NUMBER</th>
<th>REGRESSION EQUATION</th>
<th>ESTIMATED PARAMETERS</th>
</tr>
</thead>
</table>
| 4.7             | $\hat{C} = -0.1737 + 2.3056 HS$ | $r = 0.52, S=10.57365511, P<0.01$  
                  | $(3.4266)$           | $S.e. (B_1) = 0.6729,$  
                  |                    | $F - Ratio = 11.7414$ with 1 & 32 d.f. |
| 4.8             | $\hat{WP} = -2.1247 + 1.8309 HS$ | $r = 0.32, S=9.9779, P<0.01$  
                  | $(2.7334)$           | $S.e. (B_1) = 0.6698,$  
                  |                    | $F - Ratio = 9.0649$ with 1 & 32 d.f. |
| 4.9             | $\hat{WP} = -2.1247 + 4.3040 C$ | $r = 0.47, S= 9.9779, P<0.01$  
                  | $(2.2231)$           | $S.e. (B_1) = 1.9361,$  
                  |                    | $F - Ratio = 9.0649$ with 1 & 32 d.f |
TABLE 91: A summary of the linear regression equations characterizing the relationship between Wood Volume (V) and Breast-Height Diameter (DBH); Wood Volume (V) and Tree Height (HI); and Breast-Height Diameter (DBH) and tree Height (HI) for Cypress and Pine Trees in Wood lots in Tetu Division.

<table>
<thead>
<tr>
<th>EQUATION NUMBER</th>
<th>REGRESSION EQUATION</th>
<th>TREE TYPE</th>
<th>ESTIMATED PARAMETERS (VARYING SAMPLE SIZE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>( V = -2.6096 + 0.0056 \text{ DBH} )</td>
<td>CYPRESS</td>
<td>( r = 0.77 \quad S = 1.658610352 ), ( P &lt; 0.01 )</td>
</tr>
<tr>
<td></td>
<td>(4.2288)</td>
<td></td>
<td>( S.e.(B_1) = 0.0132 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( F - \text{Ratio} = 17.8830 ) with 1 &amp; 12 d.f.</td>
</tr>
<tr>
<td>4.2</td>
<td>( V = -2.1788 + 0.4853 \text{ HT} )</td>
<td>CYPRESS</td>
<td>( r = 0.75 ), ( S = 1.739591647 ), ( P &lt; 0.01 )</td>
</tr>
<tr>
<td></td>
<td>(3.8943)</td>
<td></td>
<td>( S.e.(B_1) = 0.1246 ).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( F - \text{Ratio} = 15.1655 ) with 1 &amp; 12 d.f.</td>
</tr>
<tr>
<td>4.3</td>
<td>( \text{DBH} = -7.2240 + 0.0046 \text{HT} )</td>
<td>CYPRESS</td>
<td>( r = 0.24 ), ( S = 0.6989030691 ), ( P &lt; 0.01 )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( S.e.(B_1) = 0.0006 ),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( F - \text{Ratio} = 78.64914 ) with 1 &amp; 12 d.f.</td>
</tr>
<tr>
<td>4.4</td>
<td>( V = 0.7077 - 0.0024 \text{ DBH} )</td>
<td>PINE</td>
<td>( r = 0.61 ), ( S = 0.3290296339 ), ( P &lt; 0.01 )</td>
</tr>
<tr>
<td></td>
<td>(4.0458)</td>
<td></td>
<td>( S.e.(B_1) = 0.0006 ),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( F - \text{Ratio} = 16.3686 ) with 1 &amp; 28 d.f.</td>
</tr>
</tbody>
</table>
\[ \hat{V} = 0.3248 + 0.1167\text{ HT} \]
\[ (19.7074) \]

**PINE**

<table>
<thead>
<tr>
<th>4.5</th>
<th>[ \hat{V} = 0.3248 + 0.1167\text{ HT} ] (19.7074)</th>
<th>[ r = 0.97, S = 0.037345491, P&lt;0.01 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ \text{S.E. (B₁)} = 0.0006, ]</td>
<td>[ F - \text{Ratio} = 388.3829 \text{ with 1 &amp; 28 d.f.} ]</td>
</tr>
</tbody>
</table>

\[ \text{DBH} = 46.4004 - 1.05518\text{ HT} \]
\[ (0.6572) \]

**PINE**

<table>
<thead>
<tr>
<th>4.6</th>
<th>[ \text{DBH} = 46.4004 - 1.05518\text{ HT} ] (0.6572)</th>
<th>[ r = 0.58, S = 8.300199853, P&lt;0.01 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ \text{S.E. (B₁)} = 1.9000, ]</td>
<td>[ F - \text{Ratio} = 9.2947 \text{ with 1 &amp; 28 d.f.} ]</td>
</tr>
</tbody>
</table>

*The figures in brackets are the "t" values for B₁ at 28 degrees of freedom and 12 degrees of freedom.*
People in the study area consume fuelwood in amounts related to the household size although the household size does not determine the tree species consumed. Also, consumption is not based on preference and from this, it can be inferred that consumption is based on the availability. (Table 9).

Hence, although 70.5% of the people claimed that they preferred Eucalyptus and 13.6% Cypress, the regression analysis proves this null. The aerial photographs show Eucalyptus and Cypress as 1st and 2nd most prevalent vegetation species after coffee bushes. (PLATE iii).

For Cypress trees, the volume yielded is dependent on the DBH and also the height while for Pine trees, volume yielded is dependent very strongly on height. Cypress trees take very long to acquire sufficient volume of wood unlike the Pine species. (Table 10).

People in the area indicated a preference for *Grevillea robusta* after Eucalyptus and Cypress despite this tree having the greatest diameter and height in the shortest length to time. The mixed stand data reveals that the average height for a tree averaging 14.7 years was 22.75 m with an average diameter of 184 cm.
PLATE iii Encroachment of Nyeri Hill Forest Line
Using the multiple linear regression model (Equation 1, Chapter 3), data collected on wood volume, \((V)\), Tree height \((HT)\) and Breast-Height Diameter \((DBH)\) for Pine and Cypress trees in a stand in Tetu Division were analysed. The results are summarized in the table below:

Table 10i The multiple linear relationship between wood volume \((V)\), Tree height \((HT)\) and Breast-Height Diameter \((DBH)\) for Cypress Trees in a stand in Tetu Division.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficients ((B_i's))</th>
<th>(s.e(B_i's))</th>
<th>(t(B_i))</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-7.2240</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HT</td>
<td>0.3877</td>
<td>0.0052</td>
<td>7.5221</td>
<td>(P &lt; 0.01)</td>
</tr>
<tr>
<td>DBH</td>
<td>0.0046</td>
<td>0.0006</td>
<td>7.9589</td>
<td>(P &lt; 0.01)</td>
</tr>
</tbody>
</table>

\(n = 14\) 
\(R = \sqrt{76.834784} / \sqrt{82.2079174} = 0.9346\) 
\(S = \sqrt{0.4884655} = 0.6989\) 
\(= 0.9667\)

Regression Model: 
\(\hat{V} = B_1(HT) + B_2(DBH) + B_0 + \epsilon_i\)
Table 10ii The multiple linear relationship between wood volume ($V$), Tree Height ($HT$) and Breast-Height-Diameter (DBH) for Pine trees in a stand in Tetu Division.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient ($B_i$)</th>
<th>$s.e(B_i)$</th>
<th>t($B_i$)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>44.5782</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HT</td>
<td>-0.0072</td>
<td>1.6353</td>
<td>0.0044</td>
<td>$P &lt; 0.01$</td>
</tr>
<tr>
<td>$V$</td>
<td>16.1668</td>
<td>14.8760</td>
<td>1.0878</td>
<td>$P &lt; 0.01$</td>
</tr>
</tbody>
</table>

$n = 30$

\[
\begin{align*}
R &= \sqrt{\frac{1158.8568480}{3140.7999999}} = 0.6074 \\
S &= \sqrt{73.4053019} = 8.5677
\end{align*}
\]

Regression Model: $\hat{DBH} = B_0 - B_1(HT) + B_2(V) + \varepsilon_1$
It is thus a fast-growing high yielding tree species. It was introduced relatively recently and this may be the reason why people do not yet know of its full benefits. It is also advantageous because it is a multi-purpose tree species. Data from Wambugu Agroforestry/Energy Centre indicates that it is gaining in popularity with time. High demand species from this centre are *Cypressus lusitania*, *Grevillea robusta* and the Eucalyptus species (Table 11).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EUCALYPTUS SP.</th>
<th>C. LUSITANICA</th>
<th>G. ROBUSTA</th>
<th>L. LEUCOCEPHAL A</th>
</tr>
</thead>
<tbody>
<tr>
<td>APRIL 1983</td>
<td>46,939</td>
<td>6559</td>
<td>4150</td>
<td>3976</td>
</tr>
<tr>
<td>SEPT. 1983</td>
<td>784</td>
<td>3672</td>
<td>2739</td>
<td>642</td>
</tr>
<tr>
<td>1985</td>
<td>971</td>
<td>4680</td>
<td>1945</td>
<td>1282</td>
</tr>
</tbody>
</table>

Table 11 TREE SEEDLINGS PURCHASED AT WAMBUGU A.F. CENTRE

The demand for Eucalyptus species declined in two years while that of cypress and *G. robusta* rose. The decline in the Eucalyptus tree seedlings planted may have arisen as a result of failure to grow well in dry conditions. In 1983 - 84, the area was subjected to a dry year with little rainfall and the 46,000 odd seedlings that may have been planted that year probably did not survive due to the rain failure. Eucalyptus trees have a high affinity for water. The failure may
have served to discourage the people from purchasing and planting this specie which in turn meant an upsurge in the demand for other tree species.

Cypress is mainly planted as a hedge and rarely for fuelwood. *Grevillea robusta* is a multi-purpose species and is used for fuelwood, browse/fodder and soil conservation purposes. *Eucalyptus* spp. are used mainly for fuelwood, poles and soil conservation purposes. One disadvantage is that despite the fast growing nature of these trees and their being high yielding in terms of fuelwood, they have a high demand for water and can affect water availability in an area. *Grevillea robusta* has moderate to fast growth and less environmentally harmful affects. Of the *Eucalyptus* species,* E. Saligna* is said to produce more fuelwood at a faster rate than any other tree in Kenya. Data from Muguga Research Station indicates that plantations can yield 178 m$^3$ per ha. after six years and 277 m$^3$ per ha. after another 6 years from coppices.

On the basis of such data, the fuelwood planner can be able to select the better tree species which will be able to yield the volume of fuelwood required to meet the demand. In this case, the planner may opt for some stands of *Eucalyptus* and some of *G. robusta* hedged in by *Cypressus* and interspersed with *L. Leucocephala* which is also a multi-purpose
tree. Some of the indigenous species whose demand is low because of their slow growing characteristics are of great importance ecologically and environmentally in terms of maintaining such balance. These include *Cordia abyssinica*, *Albizia gummifera* and *Croton macrostachyus*.

The supply side

This must also be considered. Provincial data indicates the following for Central/Nairobi Province.

<table>
<thead>
<tr>
<th>Supply Source</th>
<th>Million tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable supply</td>
<td>0.99</td>
</tr>
<tr>
<td>Supply from stocks</td>
<td>1.63</td>
</tr>
<tr>
<td>Total Supply</td>
<td>2.62</td>
</tr>
<tr>
<td>Total Demand</td>
<td>2.64</td>
</tr>
<tr>
<td>Shortfall</td>
<td>0.02</td>
</tr>
</tbody>
</table>

TABLE 12 SUPPLY OF FUELWOOD IN CENTRAL/NAIROBI PROVINCE.

(After Beijer Institute Publication 1984)

If this data is generalized so as to apply to the whole of Central Province equally, than there exists a shortfall in woodfuel supply. This infers that the people are digging into the woodstocks to meet their
demand for fuelwood because there is inadequate fuelwood from sustainable supply/yield (Graph ). The national figure indicates the same.

It is thus, of paramount importance that ways and means of planning for woodfuel resources be considered. Wood resource enhancement policies must be given priority attention if environmental degradation is to be avoided by providing a source of fuelwood elsewhere.

Within the study area, the demand is found to be rising up to about 14,684 tonnes in the year 2000. (Graph b). Supply in Central Province is 2,620,000 tonnes and the shortfall is 20000 tonnes. This is

\[
\frac{20000}{2620000} \times 100 = 0.76\%
\]

Demand is 2,640,000 t. Thus the shortfall is

\[
\frac{20000}{2640000} \times 100 = 0.75\%
\]

If demand is 14684t in AD 2000, then Supply expected will be 0.75 x 14684 = 11013t and shortfall will be 3671t in that year. Consumption will exceed supply by 3671t by year 2000. (Graph b).

This negative disparity must be filled and the decision making process comes in to help create policies and a plan that can meet this demand.
Graph b  Fuelwood Demand & Supply Projection for the Study.

source: G. N. ICI-IANG'I MA (Plan) 2
1987.
This should be in keeping with environmental protection and conservation of soil and rivers. Remotely sensed data provides the basis on which the land-use may be planned.

THE DECISION-MAKING PROCESS

Decision-making is affected by policy makers and this should be done on the basis of data submitted to them by planners whose role it is to guide the policy-making process. The policy makers could in turn demand from the planner the data that they know the planner can supply in order to enable him to make certain decisions. The planner also helps the community to achieve certain set goals and to reach decisions on what they as a client want or require. Both the planner and the policy maker do not have monopoly of knowledge and thus they must consider what and listen to, the people's wants. Also, they must leave other specialists to do their jobs and simply perform the planning routine i.e. the implementation of any project will involve a multi-disciplinarian team of specialists each of who know exactly what aspect of a project they are trained to deal in.

To be able to make good use of collected and analysed data, decision-making must be affected but only on the basis of the best information. Such information is from the analysed data. Decisions
should also be made on the basis of peoples needs and requirements which they may have expressed. Decision-making has several steps which include:

. Identification of the objective.

. Data collection regarding various alternatives in terms of resources, constraints, costs, consequences, socio-political variables e.t.c.

. Data evaluation set against standards or aims.

. Selection of the strategy which must be flexible and able to accommodate changes within the environment which is dynamic.

. Plan of action to be used.

. Monitoring of the project within a given time frame.

Decision making is not a one point process and achievement must always be evaluated within the time set out. Using this information, the decision-making process for fuelwood Provision within the study area can be effected. The information required is as discussed in the fore.

The objective is to supply the people with 14684 tonnes of fuelwood by the year 2000 so as to halt the process of wood stocks depletion.

The physical data is available from the aerial
photographs. Other data shows that the area is covered by well-drained extremely deep, dusky red to dark reddish brown friable clay with acid humic top soils that are heavy. The rainfall averages 2200 mm to 1200 mm with temperatures averaging 24°C. The area is well watered. The spatial extent, vegetation coverage and direction of growth are clearly displayed by the aerial photographs.

Constraints may include the inavailability of large free areas of land that can be used due to land ownership patterns and also the topography and concentrations of people in public land such as villages which exist on public land which is trust land.

The constraints to protecting the bio-physical system such as soil erosion limits include the steep slopes as well as the cost of protection and the lack of enforcement of sound environmental policies.

Data analysis also reveal that the people would use fuelwood as available though the popularity for multi-purpose trees is on the increase. This is in keeping with the environment conservation and soil conservation programme aims and objectives as well as those of the agro-forestry programme.

Selection for various alternatives can be carried out such as the following proposals made by this
researcher.

* The setting aside of land on trust land for public wood lots/plantations extension service centres.

The labour and costs would be shared by the agency and the beneficiaries as happens for most public purpose facilities. This can be done on sites such as Kamuyu - Kamakwa - Gitathi-ini areas.

* Highly geared campaign for agro-forestry practises on all small holder plots whose average size was found to be 2.07 ha.

These can yield quite a lot of fuelwood if well managed alongside agriculture and if the proper choice of tree species is effectively done through proper guidance and advice by technical experts.

* Near areas of population concentrations, wood lots may be set up and this would lessen the inconvenience of fetching fuelwood in peri-urban areas.

Such woodlots would reduce transportation costs in these areas. Data indicates that Eucalyptus, Wattle, Prosopsis juliflora and Leuceana leucocephala and Grevillea robusta if managed well would give wood production characteristics comparable to those of planted forests. Policies need to be set out regarding land-use around towns with the aim of making wood production a prequisite to having large concentrations of people.
+ Encourage people and interested agencies to invest in tree farming. Trees would be farmed just like any other cash crop and disposed of through selling.

+ Consider making use of the otherwise 'useless' (in terms of agriculture and buildings or industrial activity) land.

This includes steep areas which the aerial photograph map plots clearly bring out such as along the river courses such as Chania and Muringato rivers. Their valleys are steep and have been cleared of previous vegetation with no replanting having taken place. The area is useless for agriculture because of the steepness 30° slopes and any attempts have resulted in severe soil erosion as depicted by the oblique photographs. Such a proposal would be multi-purpose because it would result in the following benefits.

+ Utilization of available government land that is not suitable for any other use unless very great cost is incurred.

+ Creation of green belts along the rivers which act as corridors through which the urban areas breathe, for instance Nyeri Town.

+ Creation of a riverine recreation belt for public consumption. It could be made multi-purpose.
+ Enhancement of the aesthetic quality of such steep areas as well as the surrounding environs.

+ Provision of fuelwood to the people from an otherwise uneconomic area since it was not productive at low costs.

+ Reduction of soil erosion and the subsequent environmental degradation such as gulleys, land slides e.t.c.

+ Protection of the rivers and their waters from pollution due to soil from steep areas as is currently a major problem in the area.

+ Creation of labour required to manage the project.

+ Retention of remaining wood stocks.

From the study carried out, it is proposed that the steep river valleys and the foot slopes of Nyeri Hill be re-planted with trees. From the data analysis, it was found out that the maximum hectarage required to fully supply people with fuel wood by the year 2000 using 8 metre tall pine trees averaging 52.8 cm. in diameter was 616 hectares. While the least area required would be with 6 year old eucalyptus trees which would require about 120 hectares. *Grevillea robusta* and cypress species require hectarages in
between these two extremes. (Graph C).

Within this range therefore, in the next 14 years, if planted, the study area would be able to have its fuelwood demand met without using the existing wood-stocks.

The areas which would supply the required land areas are the areas that are useless for other land uses unless high costs are incurred. The river valleys and steep slopes are thus proposed. These include the river valleys of Chania River and its nearby tributaries, Muringato River Valley slopes and the valley of one other river with its source in the Nyandarua Range referred to in this study as Lower River. The lowest steep foot slopes of Nyeri Hill are also proposed so as to re-forest the encrouched area and to also use the trees planted to both conserve the area and to provide fuelwood for the areas people. The areas proposed total 416 hectares. Existing canopied area along these areas is 217 hectares. Thus when implemented, a total of 687 hectares will be covered with trees. (Table 13) and Map

There is need to plant the trees in different phases as well as in lot of different tree species. Since the projected demand is known and the yield of different species then the tree species can be be planted according to the following table schedule. (Table 14)
Graph c: Projected Hectarages required for different species in the study area.
<table>
<thead>
<tr>
<th>AREA</th>
<th>Existing Canopied Area (HA)</th>
<th>Proposed Area to be planted (HA)</th>
<th>Total Area To be covered (HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHANIA RIVER AND TRIBUTARIES</td>
<td>91</td>
<td>229</td>
<td>320</td>
</tr>
<tr>
<td>NYERI HILL FOOT-SLOPES</td>
<td>34</td>
<td>42</td>
<td>126</td>
</tr>
<tr>
<td>LOWER RIVER</td>
<td>21</td>
<td>87</td>
<td>108</td>
</tr>
<tr>
<td>MURINGATO RIVER</td>
<td>75</td>
<td>58</td>
<td>133</td>
</tr>
<tr>
<td>TOTAL AREA</td>
<td>271</td>
<td>416</td>
<td>687</td>
</tr>
</tbody>
</table>

**TABLE 13 AREAS PROPOSED FOR PLANTING TREES IN THE STUDY AREA**
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tonnes of Fuelwood</strong></td>
<td>8576.5</td>
<td>10260.2</td>
<td>12274.5</td>
<td>14684.4</td>
</tr>
<tr>
<td><strong>Cubic Metres of Fuelwood</strong></td>
<td>16981.5</td>
<td>20315.2</td>
<td>24303.5</td>
<td>29075.1</td>
</tr>
<tr>
<td><strong>Cubic metres increased over 5 years</strong></td>
<td>3333.7</td>
<td>3988.3</td>
<td>4771.6</td>
<td></td>
</tr>
</tbody>
</table>

**Table 14** FUELWOOD DEMAND PROJECTION AND PROJECTED INCREASES OVER THE 5 YEAR BLOCKS OF TIME
The actual phasing and details of tree species lies in the field of the forester. Suffice it to say that highest yielding species may be planted in the initial stages with the other species filling and coming in at later dates to supplement. However, if 416 hectares are needed to supply fuel then at least 104 hectares must be planted in every five years. Since trees are long term crops, the demand will continue to be met from the peoples personal holdings and sawmills in the meantime as well as bush areas although this latter will be discouraged with an aim of ultimately doing away with it. This is because these are wood stocks which need to be preserved for environmental and ecological reasons among others.

A proposal is thus made of intensifying the extension service for agro-forestry practises and this could be done in conjunction with the Wambugu Agro-Forestry Centre Programme. If it is successful, it will help in meeting part of the demand for fuelwood, in the plan period. The proposed area to be planted assumes full responsibility for meeting the demand but the problem needs to be tackled using a multi-prong approach. Hence agro-forestry must be intensified and this has the added benefits of ensuring that households have some basic fuelwood security on their holdings. (Map 7).
The land found in the villages is suitable for solving part of the problem and this is in way of having extension sub-centres and offices as well as the proposed Green Belt supervisors, housed at these headquarters. With time, sheds may be constructed for storing harvested wood and people can purchase it from these centres. The land is suitable since such offices are public purpose use for which trust land is often set aside. Nurseries may however be set up at these centres from which the tree seedlings are dispatched for both the Wood Belts and the agro-forestry extension.

Labour could be provided on a harambee basis for some time until the project begins to pay back whereby some labour could be hired periodically to man the belts. Since the project would primarily benefit the people, they should be made aware of the benefits accruing to them if it succeeds and public participation should be encouraged from the initial stages.

Using the river valleys is beneficial in many ways but one major advantage is that water is available and free for use. This is an aspect that could lead to the success of the project because tree seedlings require plenty of water in their early stages. Thus the cost of water would be at a minimum which is advantageous to all.
Plan of action that is to be used can be selected when all the factors have been considered. The researcher proposes use of all the strategies to ensure adequate or better still, surplus production of fuelwood and this will result in the halting of using wood stocks by the year 2000 and the increased use of sustainable yield/supply. As with any other activity, the most economic species which consume the minimum resources should be planted i.e. those that yield much and are relatively fast-growing.

The Project would need to be monitored over the given time frame using remote sensing techniques which would indicate the areal coverage and success of the replanting.
CONCLUSIONS AND RECOMMENDATIONS:

The study set out to investigate the use of remotely sensed data (special reference to aerial photographs) in planning. A resource namely fuelwood was used as a case study since it had resulted in vegetation cover depletion. The main objective was to propose a method of resource planning and decision-making using remotely sensed data, by evaluating land-use changes that have occurred in the area especially with respect to vegetation cover. That this type of data can be used for resource planning has been shown and it can hence contribute to policy-making for fuelwood or other resources.

CONCLUSION:

The question of fuelwood as a source of energy has not been tackled fully although a national policy on energy is available. Vegetation cover depletion has been on-going yet the problem of provision of the cover has not been yet tackled especially in the rural areas. It has often been assumed that there are still plenty of forests and woodland areas in these zones and as such, still plenty of fuelwood in these areas.

Hence the situation does not warrant much attention. The study reveals that attention is
indeed required desperately because already, a shortfall exists in woodfuel supply which has resulted in the use of wood stocks to meet the demand which is still not satisfied. This is evidenced by the depiction for instance in aerial photographs, of the receding Nyeri Hill Forest line. It is said that by the year 2000, Kenya might have a shortage of 30 million tonnes of fuelwood which would cause a serious crisis. (Daily Nation March, 1982).

Aerial photographs yield data on vegetation loss in a spatial context. Accurate areas of specific land-uses can be obtained as can vegetation differentiation be easily done. The lie of the land and direction of change can also be assessed from this data. The planner can thus utilize this information for making recommendations and guiding the policy-maker. The nature of built up areas, infrastructure and roads can be accurately picked out which are also essential in planning.

A lot of the area which has lost vegetation/trees has been converted to agriculture which indicates some degree of competition between food-supply and fuelwood supply if it is assumed that wood cut down is consumed as fuelwood of some sort. People in the area will require fuelwood increasingly as the population increases and they will also require
food. A balance must be sought between the two in a manner that enhances the environment and also protects it.

In studying rural space, aerial photographs have advantages over the human eye in that they give a complete view of the landscape, furnish documents which may be studied in three dimensions and record details which would pass unnoticed by an observer (Muret (ed) 1972). Certain documents necessary for the management of rural spaces and for planning projects can be produced by analysing photographs. Physiographic studies are necessary before making a decision that could alter surroundings and these include data on climatic variations, topography, hydrology, geology, soils and biogeography.

The major purpose of development plans in rural areas is partly to judge the use of the area in the past and possibly propose a change of space utilization. (Muret (ed) 1972). The current study has attempted to do that in terms of vegetation cover reduction in the study area in general and has proposed a change of the space utilization especially along river valleys and steep slopes. Extensive clearing of brush land results in a change in the micro climate of the area and increases in water flow and erosion evidenced by the silt in the rivers as well as the gullies that have been formed on some
of the slopes.

Aerial photographs have further helped the researcher to draw up a map document for work purposes of the fuelwood project showing vegetation cover changes, terrain, drainage and other such variables useful to the planner. (Map 8i-ix).

Aerial photographs enable this to be done with minimum loss of time and such a document is useful to other experts who may carry out work in the area.

While it is known that deductions from photo-interpretation alone do not suffice for resource planning studies and related research, they do act as valuable aid for analysis and also contribute savings in terms of effort and time. Thus, rather than replace traditional investigation and research methods, photo-interpretation supplements it by simplifying and shortening the work.

The research carried out in this study bears this out because it has used aerial photographs to study historical data and to note the trends in land-use and in the synthesis has used traditional method of stereo-plotting to map the area in conjunction with photo-interpretation methods. The result has been a proposal map for meeting fuel-wood demand.
MAP DOCUMENT

Map 81 - ix
VEGETATION (1970'S)
It has been found that most of the material presented to the political and administrative decision-makers for action normally consists of work prepared by the economist/planner prepared from the information and data available to him, (Otieno, 1982) and thus, a reliable data base is necessary for effective decision-making and this in turn depends on the efficiency of the data collection system.

Aerial photography has the following characteristics:

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>AERIAL PHOTOGRAPHY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Traditional Use</td>
<td>Technique</td>
</tr>
<tr>
<td>(Historical use)</td>
<td>Long use in the past</td>
</tr>
<tr>
<td>2. Cost</td>
<td>High</td>
</tr>
<tr>
<td>3. Resolution</td>
<td>Large</td>
</tr>
<tr>
<td>4. Coverage</td>
<td>Small</td>
</tr>
<tr>
<td>5. Cycle</td>
<td>Irregular</td>
</tr>
<tr>
<td>6. Identity</td>
<td>Ground Surface</td>
</tr>
<tr>
<td>7. Differentiation</td>
<td>High</td>
</tr>
<tr>
<td>8. Penetration</td>
<td>Nil</td>
</tr>
</tbody>
</table>

The major constraints of using aerial photography rests mainly in the high cost, need of highly trained and skilled manpower, and problems cloud cover effects as well as the tool not being weather proof.
The collection of data or information must be related to the development policy and objectives that affect a particular area or resource such as fuelwood.

Development Policy

Development Objectives

Information Requirement

Information requirement in relation to development policy and objective.

Mwanje et al, (1982) identify information types that specify the data needs for decision-making at the broad or national scale and for energy, of which fuelwood is one type, the following matrix is derived:

(See next page)
<table>
<thead>
<tr>
<th>DEVELOPMENT OBJECTIVE</th>
<th>TYPE OF INFORMATION</th>
<th>ENERGY (FUELWOOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+ SELF SUFFICIENCY IN FOOD NUTRITION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ CONSERVATION OF NATURAL RESOURCES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ OPTIONAL USE OF NATURAL RESOURCES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ DEVELOPMENT OF APPROPRIATE TECHNOLOGY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ IMPROVEMENT OF INFRASTRUCTURE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ PROVISION OF BASIC NEEDS-HEALTH, EDUCATION, HOUSING E.T.C.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ PARTICIPATION IN DEVELOPMENT PROCESS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ MINIMIZATION OF UNEMPLOYMENT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ ENVIRONMENT PROTECTION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ RURAL DEVELOPMENT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>† NATIONAL SECURITY</td>
<td></td>
</tr>
</tbody>
</table>

**KEY:** ++ = Highly necessary; + = Necessary; − = Not necessary
In the national development process, intersectoral information requirements are necessary and these vary from low to high level coordination. The application of remote sensing techniques in data gathering, enhances the quality of decision-making so as to arrive at the desired development strategies (Mwanje et al. 1982). At the local level of planning, detailed information must be collected as was done in this study. The clearing of vegetation or the re-planting of it is indicated by the extent, quantity and quality of vegetation and the aerial photos indicate a decrease to date, in the thick vegetation type of the 1960's which appears as a thick canopy on the photographs. Buildings and coffee on small scale holdings or agricultural practice have however increased with time. Use of such data (multi-date) affects monitoring which deals with the dynamism of our environment (Hempenius, 1982), and with processes of human activities as opposed to mapping which deals with the static objectives of the environment. Though good, data collection should not be considered a goal in itself. The data collection and preparation of maps and documents should be adapted to the planning and decision-making purpose which is itself a management function. Limitations occur in the analysis capacity for which requires trained man-power. The time has come for energy and resources to be directed at data analysis rather than more data collection. The study attempts to do this by analysing the photographs and subjecting the information to planning and decision-making with respect to the fuel-wood. Remotely sensed
data can be used at the local level and this helps reduce the gap between the central government and the local levels.

**RECOMMENDATIONS:**

The policy-making body must address itself to the real problem of vegetation cover depletion mainly due to fuelwood shortage in rural and peri-urban and in some cases, urban area. It must come up with policies that will cater for the demand, protect the environment and be cost effective. A legal framework must be worked out and training of people in the field of energy/fuelwood planning is also essential. The body must also readily accept new innovations in terms of planning tools, which are quicker and more accurate and yield better results more efficiently than those currently used if any. The application of remote sensing must now go beyond the data collection and analysis stage to the actual planning and decision-making processes which result in policy formulation and implementation.

The study sought to apply such data as remotely sensed information, to planning. There exists a wide scope for research in the field of usage of other types of data such as satellite imagery and also in the use of such data for other forms of planning such as urban and transportation planning.
As a tool, remote sensing gives quick and reliable data in a spatial context which land-use planners require in carrying out their tasks.

During the investigation carried out in the field, it was clear that a lot of trees went to other fuel uses notably charcoal making. Research on this aspect could throw further light on the extent of charcoal usage as well as on the intensity of charcoal burning in the study area and how it has contributed to loss of vegetation and perhaps environmental degradation.

The tree species *Eucalyptus saligna* has been said to produce fuelwood at the fastest rates in Kenya yet these trees are said to affect the water table levels in an area. Research into an adapted eucalyptus tree species would be able to alter the water-loving tendency of the tree species while maintaining its other good qualities. Foresters may help in the breeding of such a tree.

Fuelwood has been decreasing in the country and currently, wood stocks are being depleted. The situation must be arrested in this includes having a policy document to guide provision of fuelwood. 75% of Kenya's fuel comes from wood and this calls for immediate appraisal of the current situation as well as proposals to solve the problem. Aerial photography acts as a viable tool for quick and accurate appraisal as has been attempted in this study. It must be increasing
used as must other newer and more economic tools such as satellite imagery for monitoring which is geared to be the main concern of future decision-making. Training of adequate man-power to effectively use analysed data for planning and decision-making is a great need so that the already accumulated data can be used further in development planning.
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