THE USE OF REMOTE SENSING IN RESOURCE

(FUELWOOD) PLANNING IN TETU DIVISION,

NYERI DISTRICT, KENYA.

By GRACE NYAMBURA ICHANG'I

A THESIS PRESENTED IN PART FULFILMENT OF THE

REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS

(PLANNING), IN THE DEPARTMENT OF URBAN AND

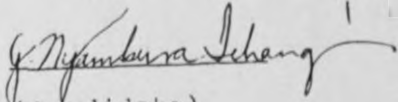REGIONAL PLANNING, UNIVERSITY OF NAIROBI, KENYA.

MAY 1987
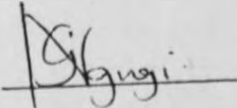
DECLARATION

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

Signed *J. Njambura Icheng*
(Candidate)

This Thesis has been submitted for examination with my approval.

Signed _____
(Supervisor)

D E D I C A T I O N

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.

ACKNOWLEDGEMENTS

have been of assistance.

Karitu Nguyo has been especially encouraging
throughout the course of this work as has been
Kagure Mugo and I am most grateful of all to them.

Miss Nancy M. Gachau has so willingly typed
this work and to her I am most thankful.

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.

ABSTRACT

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 shoud 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 systema-
tically 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 signifi-
cant 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 arrange-
ments 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 attemps 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, it's 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 require-
ments 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-photo-
graphing 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 inter-
pretation 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, 1974).
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'oriah, 1984).
Some institutions in Kenya have however been using
these techniques as well as the more recent sattelite
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 effect decision-making with respect
to the resource.

Remote sensing has been utilized by a few
government agencies in Kenya such as Kenya
Rangeland Ecological Monotoring 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 reconnaisance 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 invent-
ory 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 it's
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 subscribers 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 develop-
ment. Despite this, many people do not clearly
understand the planning process so that they can
appreciate it's strengths and weaknesses.
Ideally, the process of planning for natural
resources conservation and exploitation should begin
with stock-taking, which would provide the statisti-
cal 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 consolida-tion. Coffee was introduced and planted and it's acreage has tended to increase gradually. Cash cropping has been in competion 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 environ-
ment. 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 consump-
tion 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, ..., 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 techno-
logy 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 assess-
ment 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 require-
ments 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 Divison 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 quage 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 rual areas and
   hence in Tetu Divison 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° 30' and 0° 27' S longitude while 37^oE latitude passes through the southern part of it.

The division has four locations namely Aguthi, Tetu, Muhoya's and Thigingi and these occupy 382 Km^2 out of the district's 3284 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	**TITLE**		**SOURCE**
Provincial boundaries	**LOCATION OF NYERI**		G. N ICHANGI
International boundaries	**DISTRICT WITHIN KENYA**		M A (PLANNING) 1987
Nyeri district			1
			Map No 1

Map labels: SUDAN, 36°E, 4°E, ETHIOPIA, Lake Turkana, UGANDA, RIFT VALLEY, SOMALI REPUBLIC, WESTERN, Uasin Gishu, Baringo, Laikipia, EASTERN, NORTH EASTERN, 0°, Nakuru, NYERI, Kericho, CENTRAL, NYANZA, Narok, Kiambu, RIFT VALLEY, NAIROBI, Nyandarua, EASTERN, TANZANIA, Kajiado, COAST, INDIAN OCEAN, 4°S

36°45'E	37°E	37°15'E

NANYUKI

KIENI EAST

MT. KENYA

0°

0°15S

KIENI WEST

NYERI

MATHIRA

ABERDARE
FOREST

TETU

KARATINA

0°30S

OTHAYA

MUKURWEINI

	TITLE	SOURCE
District boundary	**LOCATION OF TETU DIVISION**	G. N. ICHANGI
Divisional boundary		M.A.(PLANNING)1987
Divisional name	**IN NYERI DISTRICT.**	

5   10   15   20

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 <u>Albizia gummifera,</u> <u>Croton macrostachys</u> and <u>Cordia abyssinica</u> 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 rain
fall 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

KEY		TITLE	SOURCE
▨ – Andohumic nitosol with humic andosok (heavy texture)		SOILS IN TETU DIVION NYERI DISTRICT.	G.N. ICHANGI
▨ – Humic nitosols (heavy texture)			M.A (PLANNING) 1987
◇ – Study area			Map No. 3
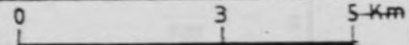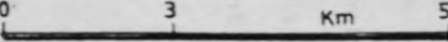
0   3   5 Km

0°25'S

25

0°30'S

900 mm

800 mm

0°25 S

1000 mm

1200 mm

900 mm

1000 mm

- 26 -

0°30 S

1200 mm

1000 mm

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 down-
stream 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
an may be required. Calculations of areas under different
vegetation cover can be done with ease and all these
                                        related to the

Anuringato river

KEY

	Divisional boundary
	Nyeri hill
	River
	Study area

TITLE

DRAINAGE PATTERN IN TETU DIVISION. NYERI DISTRICT

0°25'S

0°30'S

Chania river

Thuta river

Kagumo river

Sagana river

Gura river

- 28 -
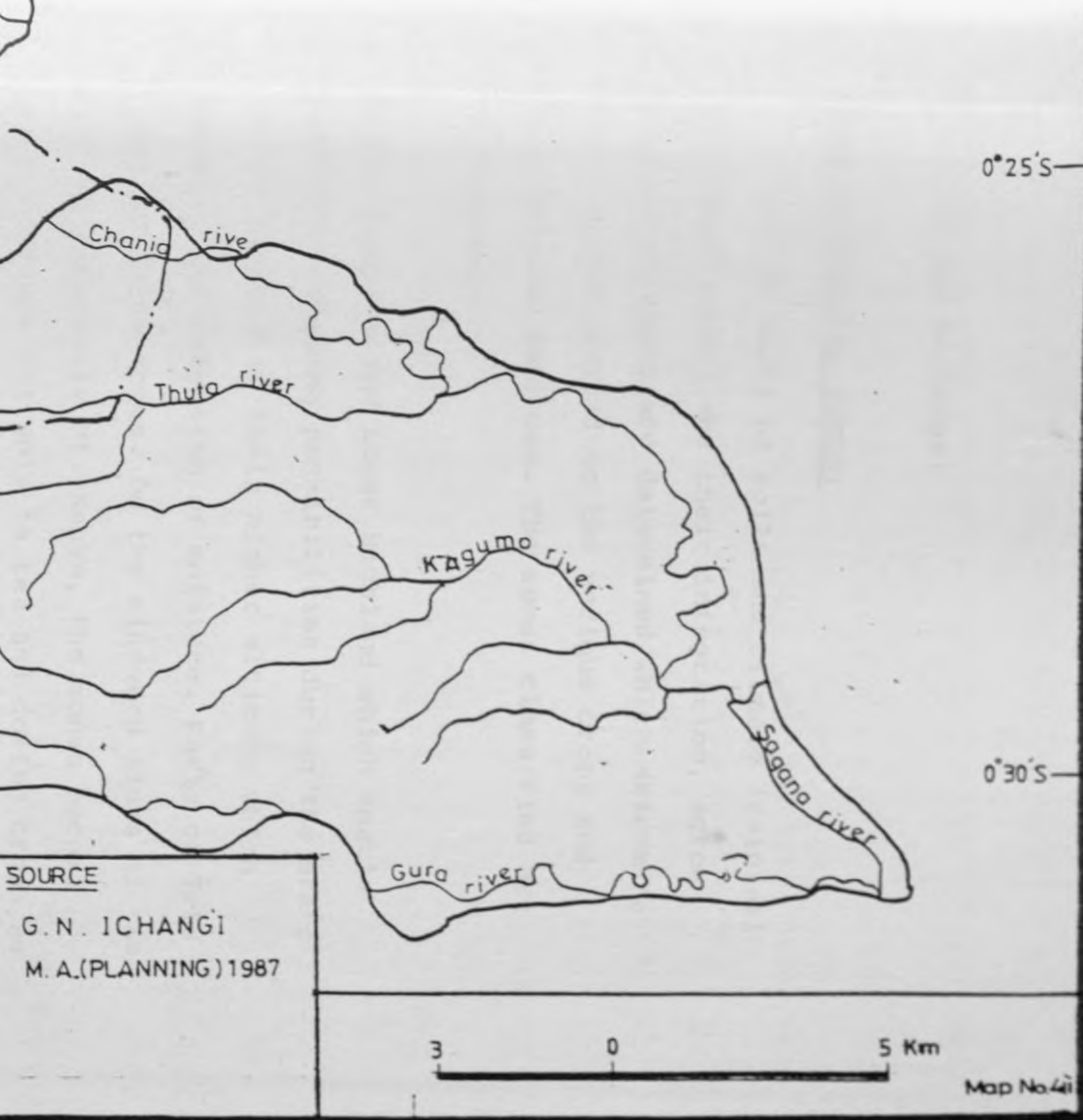
SOURCE

G. N. ICHANGI

M. A. (PLANNING) 1987

3   0   5 Km

Map No. 4i

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, horticultrual 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).

SHEEP
BARLEY

CATTLE
SHEEP,
BARLEY WHEAT,
PYRETHRUM
MAIZE

NYANDARUA RANGE

PYRETHRUM

MARGINAL COFFEE

FOREST
RESERVE

SHEEP
AND
DAIRY
ZONE

TEA AND DAIRY

MAIN COFFEE

COFEE
AND
TEA

0°25'S

— 30 —

0°30'S
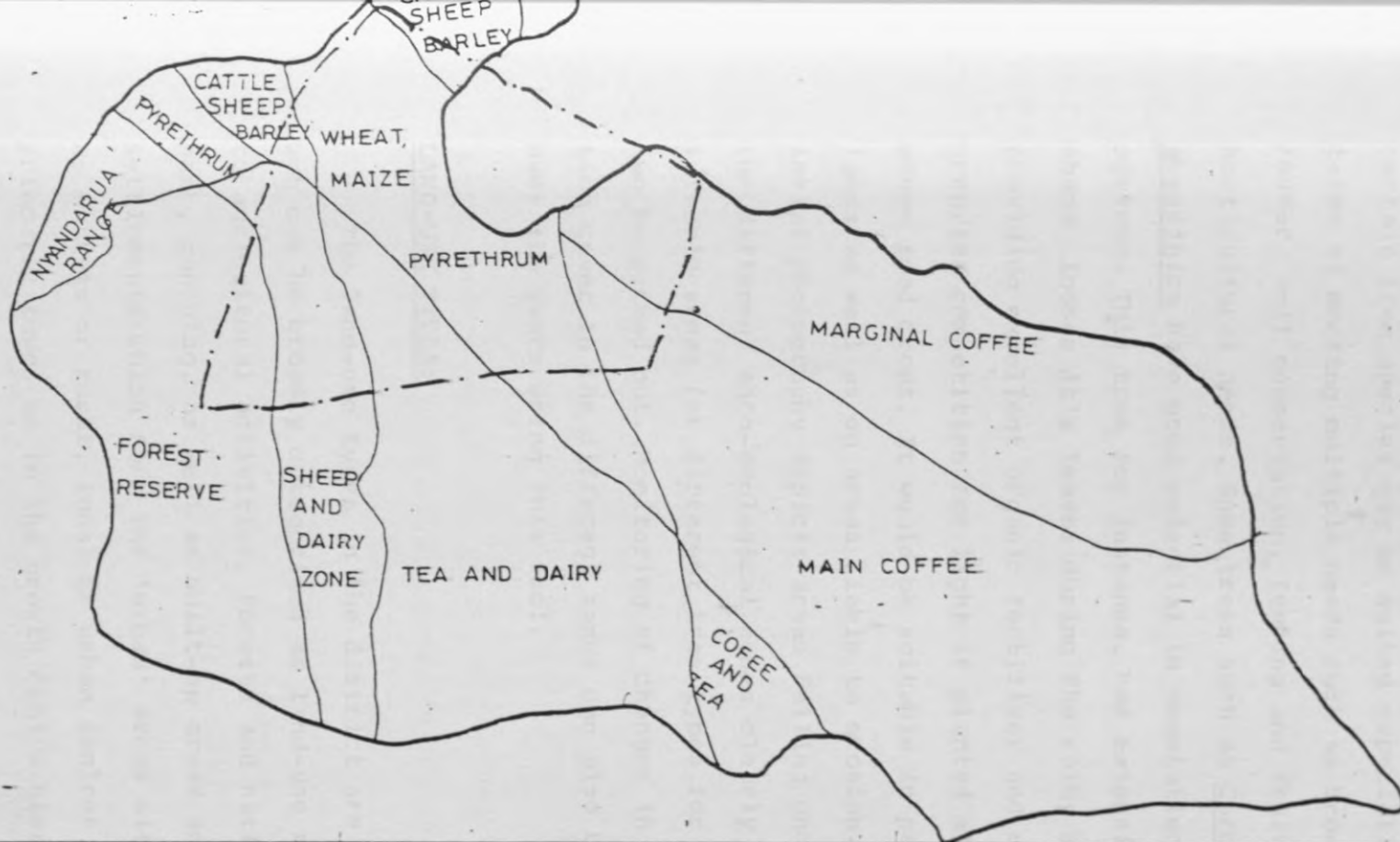
KEY		TITLE	SOURCE
▭	Divisional boundary	**AGRO-ECOLOGICAL ZONES:**	G. N. ICHANGI
∿	Agro - ecological zone boundary	**TETU DIVISION, NYERI DISTRICT**	M. A (PLANNING) 1987 Map No. 5
▭ ▭ ▭	Study area		3 0 5 Km

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 looses it's 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 vegeta-
tion 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 hierachy
and infra-structure.

Tetu Division takes from these and has a
variety of agricultural land-uses mainly in
hills. 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 termaced,
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 there-
fore 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.

	1979	1985	1990	1995	2000
TETU DIVISION	138,026	171,149	204,749	244,915	293,033
NYERI DISTRICT	486,477	581,981	696,234	832,917	996,434

Population projection based on a growth rate of 3.65%
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 = $\dfrac{3.65}{100}$ = 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 (38,733
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 in lude
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.

CHAPTER THREE

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 purch-
ased.

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 evalua-
tion 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

Left Hand Digit	2nd Digit	3rd Digit
Major Landuse Type	Specific Use-Type	Condition of Use/Crop

DEMOMINATOR

Left Hand Digit	2nd Digit	3rd Digit
Slope of Land	Soil Type	Drainage

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 $0^o - 3^o$

            ii) Rolling $3^o - 9^o$

            iii) Rough $9^o - 15^o$

            iv) Steep 15°

2. Soil Type   1) 7_h6R Andohumic nitosols with andosols.

            ii) 7_h7R 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 fuel-
wood 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 fulfil 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:-

$$Y_{xi} = B_o + B_1 X_{1i} + B_2 X_{2i} + E_i \ldots\ldots\ldots\ldots (1)$$

Where B_o = Regression coefficient

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

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

Y_{xi} = the ith observation of the dependent variable

X_{1i} = The ith 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:-

$$Y_{xi} = B_o + B_1 X_i + E_i \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:-

Y_{xi} = the ith observation of the dependent variable

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

X_i = the ith observation of the independent

variable.

E_i = random distrubance or error

$E_i \sim N(0, \theta_i^2)$

The assumptions are as for multiple regression.

CHAPTER FOUR

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 utili-zation _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 prequisite to management.

. planning requires continual re-drafting of plans
  which enables the planner to seize new opportuni-
  ties 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
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 imposi-
tion 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   the basis of sample
surveys and questionaire 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 63.4%
of the total energy/fuel consumed (Table   1).
Household consumption averaged 19.3 head loads
(337.75 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

FUEL TYPE	PERCENTAGE USING FUEL
FUELWOOD	63.38
CHARCOAL	34.93
PARAFFIN	34.93
SAWDUST	10.71
GAS	5.36
ELECTRICITY	0.89
OTHER (Ex Maize cobs)	0.89

Table   1   FUEL TYPES USED IN THE STUDY AREA

Average number of fuelwood headloads per month	Average number of charcoal sacks per month	Average Price/head-load	Average Price/Sack
19.3	3	4.60	47/15

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   i). 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).
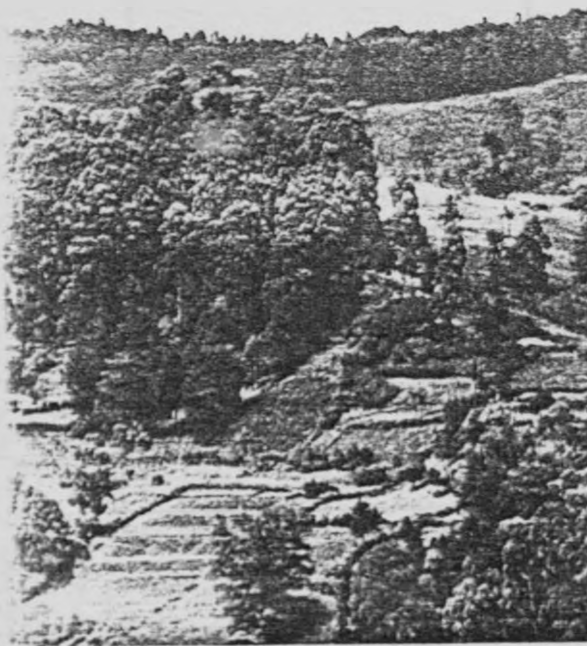
PLATE i Dominant

Tree in the area is Eucalyptus.

Distance Travelled to fetch fuelwood (Km)	Distance travelled to fetch charcoal	Average time taken to fetch fuelwood/ day	Average time taken to fetch charcoal
3	2	46 Minutes each way = 92 minutes = 1 hr. 32 Mins.	102 minutes 1 hour 42 Mins.

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

Average Household Size	Average Size of land unit(ha)
6.74 7	2.07

Table 4 HOUSEHOLD SIZE AND LAND UNIT SIZE (HA.) IN THE STUDY AREA

Table 5   SOURCES OF FUELWOOD IN THE STUDY AREA

SPECIES	SOURCE	%AGE PREFERENCE
Eucalyptus Species	Home or Bush/Forest	70.5
Cypressus Species	Home or Bush/Forest or Sawmill	13.6
Wattle	Home/Bush/Forest	2.3
Mutarakwa	Home/Bush/Forest	4.5
Grevillea robusta	Home	9.1

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 situa-
tion of insufficient wood supply available on
sustainable yield basis and it has not been possible
to meet all the demand for fuelwood. Cutting of wood-
stocks has been at a rate which "can only exacerbate
the future wood shortage and lead to further environ-
mental 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.
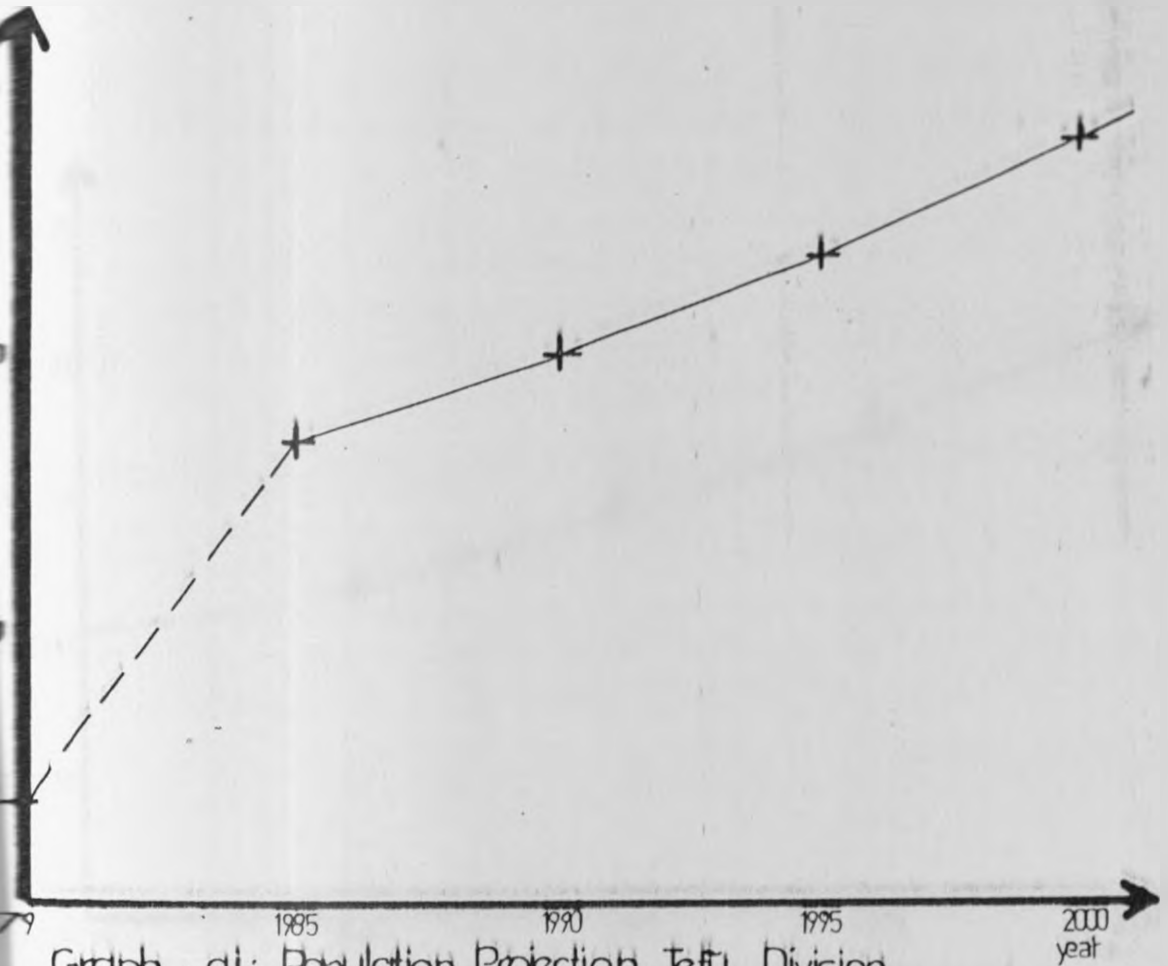
Graph a1: Population Projection, Tetu Division.
source: G.N. ICHANG'I
M.A. (PLAN.) 2
1987.
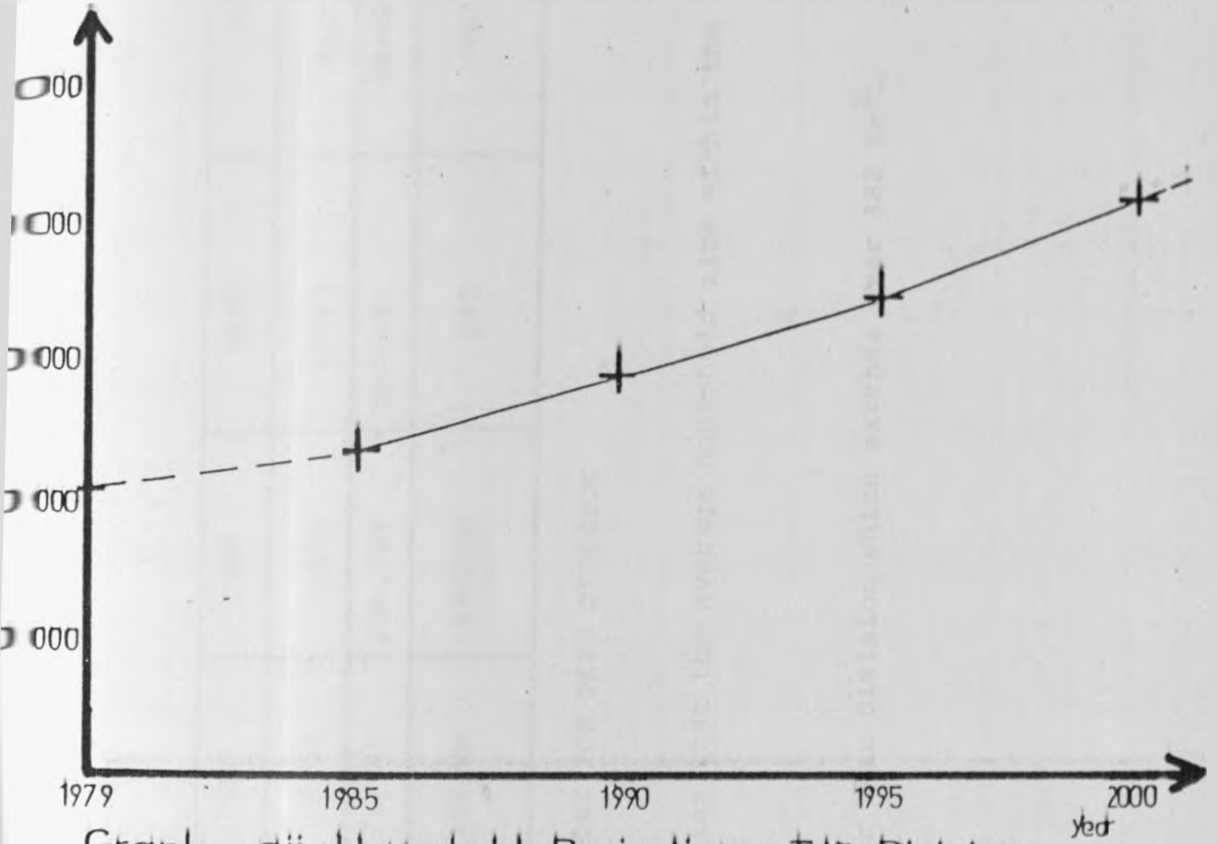
Graph dii : Household Projections, Tetū Division.
(average household size = 6.74 ,

source : G . N . ICHANG'I
M.A. (PLAN)
1987.

	1979	1985	1990	1995	2000
•No. of Households	20,479	25393	30378	36342	43477
Population Size	138026	171,149	204,749	244,945	293033
••Population density	$361/Km^2$	448/Km	536/Km	641	767

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 Km^2.

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:-

	1985	1990	1995	2000
Population Size	171,149	204,749	244,945	293,033
Number of Households	25,393	30,378	36,342	43,477
No. of Headloads of Fuelwood	490,084.9	586,295.4	701,400.6	839,106.1
No. of Kg. equivalent	8576485.75	10260169.5	12274510.5	14684356.75
No. of tonnes equivalent	8576.5	10260.2	12274.5	14684.4
Volume equivalent (m^3)	1981.5	20315.2	24303.5	29075.1

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 m^3 of woody biomass resulting in the above volumes.

If the fuelwood tonnage is converted into cubic metres, by year 2000, 29075.1m^3 will be required by the households. If Cypress trees of 14m height and an average basal area of 162.4m^2/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 47.2m^2/ha. are expected to supply fuelwood as required, 616 ha. of pine will be required. This is equivalent to 1.79 and 6.16 Km^2 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:-

1. National Forest Policy/ Objective	To make the nation self-sufficient in wood by year X.
2. National Quantitative Forestry Target	To produce Y million m^3. of fuelwood per annum in year 2000 and an additional 5% annually thereafter.
3. Project Aim	To plant Z ha. of P. Patula and W ha. of Eucalyptus grandis annually in District. A for production of f m^3 fuelwood and d m^3 poles in rotation of 10 and 20 years respectively.
4. Operational Planning	To arrange beforehand HOW and WHEN to obtain seed, prepare nurseries, carry

	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 occuring 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 clarifica-
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 appro-
priate 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 conjuction 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 Km^2 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   ii

0° 25 S

72

0° 30 S

Bhururu
*NYERI HILL

Kamuyu
Kamakwa

Tetu

Giakanja

NYERI TOWN

Gatitu

Marua
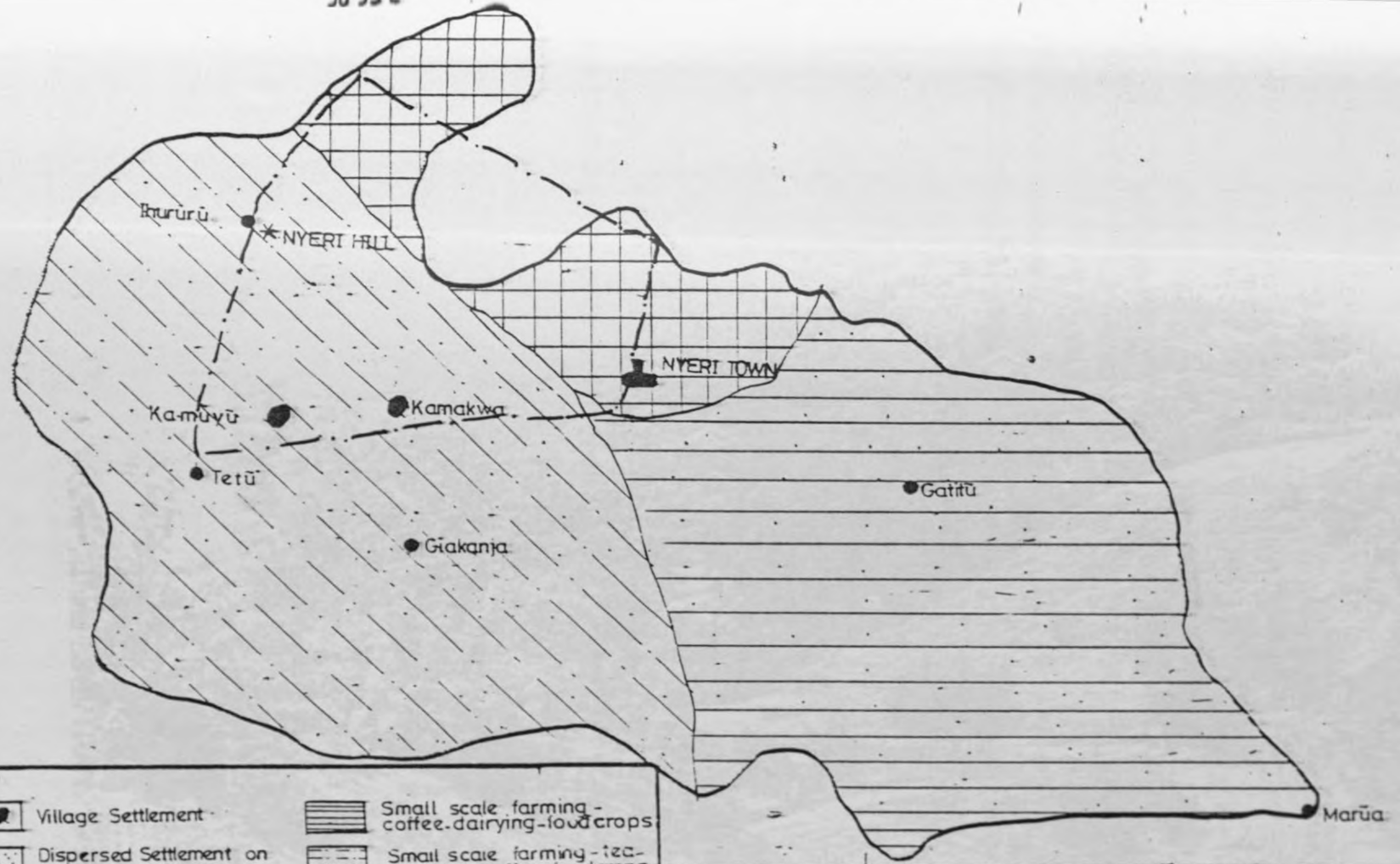
KEY

	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 |

3   0   5
Km
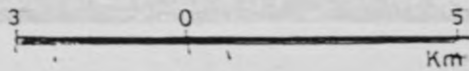
TITLE

LAND USE AND SETTLEMENT TYPES IN TETU DIVISION, NYERI TOWN

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 wood-lots or plantations require sufficient land with suitable terrain and soils and where the peoples legal patterns governing land are considered as agreable 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 9i 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.

EQUATION NUMBER	REGRESSION EQUATION	ESTIMATED PARAMETERS
4.7	$\hat{C}$ = -0.1737 + 2.3056 HS (3.4266)	r = 0.52, S=10.57365511, P< 0.01 s.e. (B$_1$) = 0.6729, F - Ratio = 11.7414 with 1 & 32 d.f.
4.8	$\hat{WP}$ = -2.1247 + 1.8309 HS (2.7334)	r = 0.32, S=9.9779, P<0.01 s.e.(B$_1$) = 0.6698, F - Ratio = 9.0649 with 1 & 32 d.f.
4.9	$\hat{WP}$ = -2.1247 + 4.3040 C (2.2231)	r = 0.47, S= 9.9779, P<0.01 s.e.(B$_1$) = 1,9361, F - Ratio = 9.0649 with 1 & 32 d.f

• The figures in brackets are the 't' statistics values for B$_1$ with 32 degrees of freedom.

TABLE 9ii: 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.

EQUATION NUMBER	REGRESSION EQUATION	TREE TYPE	ESTIMATED PARAMETERS (VARYING SAMPLE SIZE)
4.1	$\hat{V} = -2.6096 + 0.0056$ DBH (4.2288)	CYPRESS	$r = 0.77$ $S=1.658610352$, $P<0.01$ s.e.$(B_1)=0.0132$ F – Ratio = 17.8830 with 1 &12 d.f.
4.2	$\hat{V} = -2.1788 + 0.4853$ HT (3.8943)	CYPRESS	$r =0.75$, $S=1.739591647$, $P<0.01$ s.e.$(B_1) = 0.1246.$ F – Ratio = 15.1655 with 1 & 12 d.f.
4.3	DBH $= -7.2240 + 0.00046$HT	CYPRESS	$r =0.24$, $S=0.6989030691$, $P<0.01$ s.e.$(B_1)= 0.0006,$ F – Ratio = 78.64914 with 1 &12 d.f.
4.4	$\hat{V} =0.7077 - 0.0024$ DBH (4.0458)	PINE	$r =0.61$, $S=0.3290296339$, $P<0.01$ s.e. $(B_1) = 0.0006,$ F – Ratio = 16.3686 with 1 & 28 d.f.

4.5	$\hat{V}$ = 0.3248 + 0.1167 HT (19.7074)	PINE	r = 0.97, S= 0.037345491, P<0.01 S.e. (B_1) = 0.0006, F - Ratio =388.3829 with 1 & 28 d.f
4.6	$\hat{DBH}$ = 46.4004 + -1.05518 HT (0.6572)	PINE	r = 0.58, S=8.300199853, P<0.01 S.e. (B_1) = 1.9000, F - Ratio = 9.2947 with 1 & 28 d.f.

*The figures in brackets are the "t" values for B_1 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.

Variable	Regression Coefficients $(B_i{'}_s)$	$S.e\,(B_i{'}_s)$	$t(B_i)$	Significance
Constant	-7.2240	-	-	-
HT	0.3877	0.0052	7.5221	$p < 0.01$
DBH	0.0046	0.0006	7.9589	$p < 0.01$

$$n = 14 \qquad R = \sqrt{\frac{76.834784}{82.2079174}} \qquad S = \sqrt{0.4884655} \qquad P < 0.01$$

$$= \sqrt{0.9346} \qquad\qquad = 0.6989$$

$$= 0.9667$$

Regression Model: $\hat{V} = B_1\,(HT) + B_2(DBH) - B_0 + E_i$

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.

Variable	Regression Coefficient $(B_{i's})$	$s.e(B_{1's})$	$t(B_i)$	Significance
Constant	44.5782	-	-	-
HT	-0.0072	1.6353	0.0044	$P < 0.01$
V	16.1668	14.8760	1.0878	$P < 0.01$

$n = 30$ $R = \sqrt{\dfrac{1158.8568480}{3140.7999999}}$ $S = \sqrt{73.4053019}$ $P < 0.01$

$= 0.6074$ $= 8.5677$

Regression Model: $\hat{DBH} = B_0 - B_1(HT) + B_2(V) + \varepsilon_i$

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 it's 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 <u>Cypressus lusitania</u>, <u>Grevillea
robusta</u> and the Eucalyptus species (Table   11)

YEAR	EUCALYPTUS SP.	C. LUSITANICA	G. ROBUSTA	L. LEUCOCEPHALA
APRIL 1983	46,939	6559	4150	3976
SEPT. 1983	784	3672	2739	642
1985	971	4680	1945	1282

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

The demand for Eucalyptus species declined in two
years while that of cypress and $\underline{G}$. 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 environment-
ally in terms of maintaining such balance. These
include <u>Cordia abyssinica</u>, <u>Albizia gummifera</u> and
<u>Croton macrostachyus.</u>

The supply side

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

Supply source	Million tonnes
Sustainable supply	0.99
Supply from stocks	1.63
Total Supply	2.62
Total Demand	2.64
Shortfall	0.02

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 upto 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

$$\frac{20000}{2640000} \times 100 = 0.75\%$$

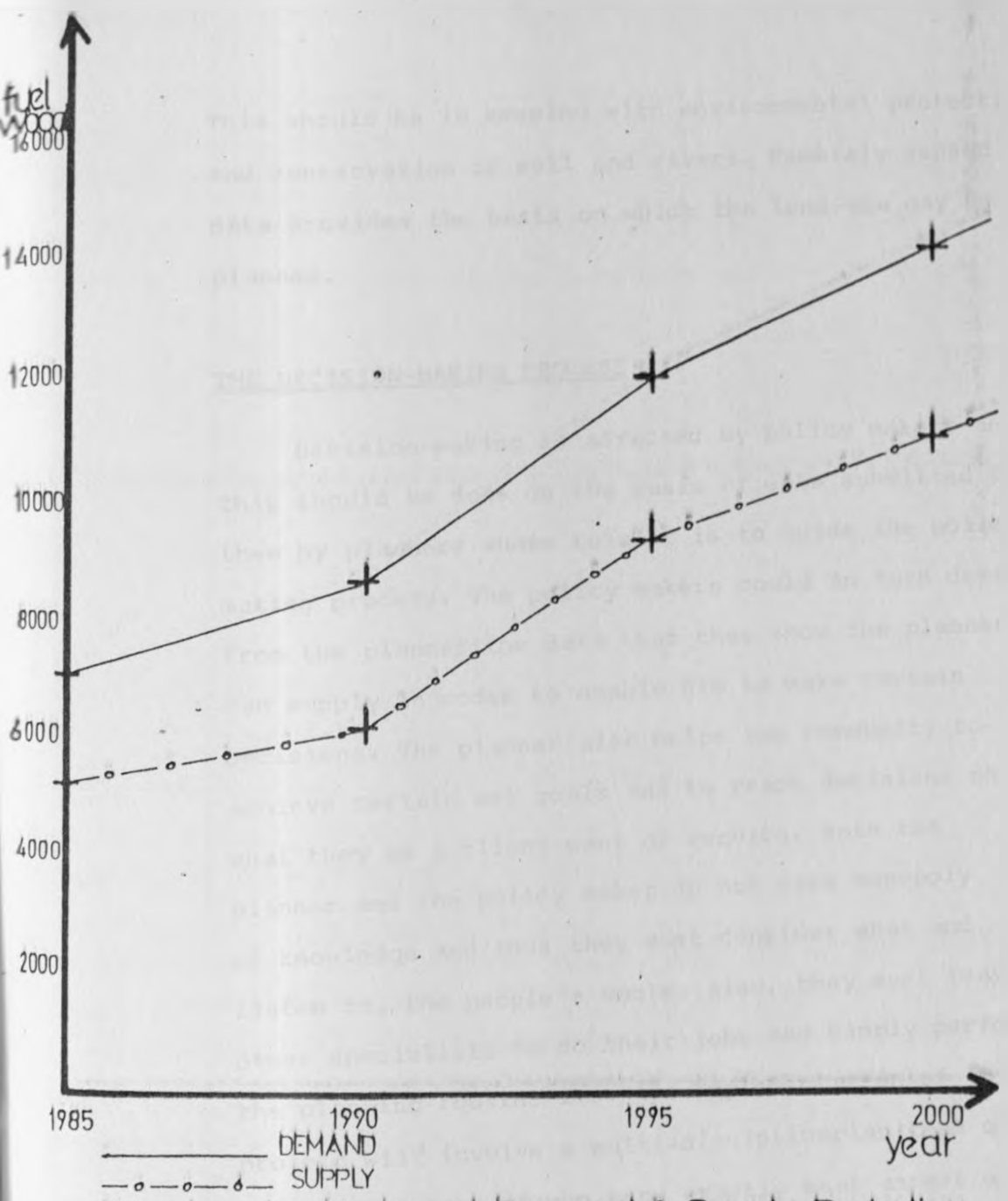If demand is 14684t in AD 2000, then Supply expected will be 0.75 x 14684 = 11013t and shortfall will be 3671t in that year. Consumption will exceed supply by 3671t by year 2000. (Graph b).

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 . ICHANG'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 regard-
ing 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 photo-
graph 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 it's

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 it's nearby tribu-

taries, Muringato River Valley slopes and the valley

of one other river with it's 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)
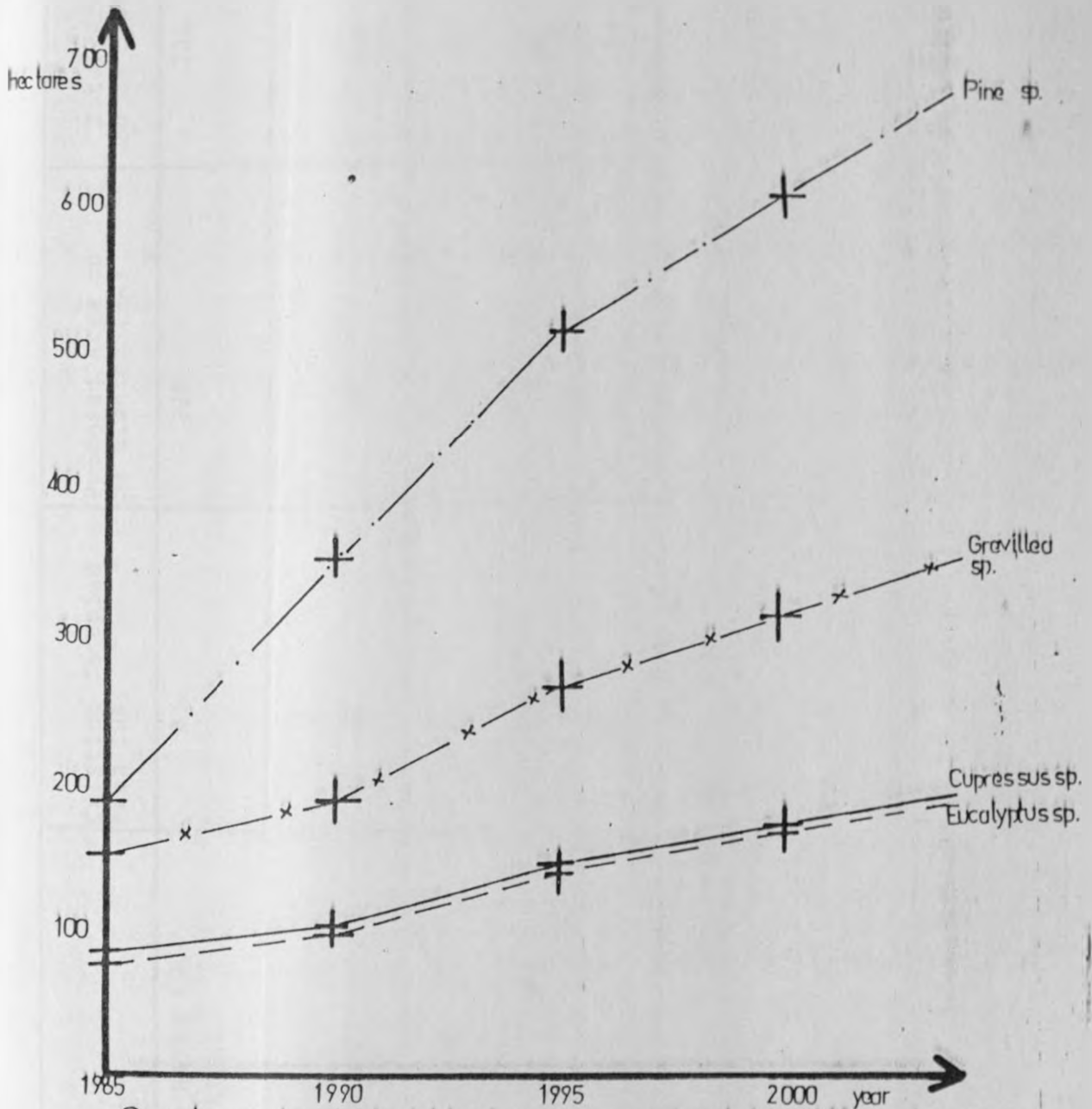
Graph c: Projected Hectarages required for different species in the study area.

source: G.N. ICHANG'I M.A. (PLAN) 1987.

AREA	Existing Canopied Area (HA)	Proposed Area to be planted (HA)	Total Area To be covered(HA)
CHANIA RIVER AND TRIBUTARIES	91	229	320
NYERI HILL FOOT-SLOPES	84	42	126
LOWER RIVER	21	87	108
MURINGATO RIVER	75	58	133
TOTAL AREA	271	416	687

TABLE   13   AREAS PROPOSED FOR PLANTING TREES IN THE STUDY AREA

	1985		1990		1995		2000
Tonnes of Fuelwood	8576.5		10260.2		12274.5		14684.4
Cubic Metres of Fuelwood	16981.5		20315.2		24303.5		29075.1
Cubic metres increased over 5 years	←——3333.7——→		←3988.3——→		←4771.6——→		

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 suppliment. 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 fuel-
wood, 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   ).

PI
(1960)

P

Coffee

Coffee plantation

E

MATHARI OPHANAGE
HOSPITAL

P

NYERI HILL
FOREST

2100
2050
2000
1950
1900

P
MATHARI

E

G

E

RESIDENTIAL
AREA

1900
CHANIA RIVER
1850

P

CHANIA RIVER

G

NYERI
TOWN

E

AF

AF

AF

G

AF

AF

KAMUKUNJI
STADIUM

1700

AF

KIRITI

AF

AF

Coffee

E

TO KIHATHA

AF

AF

KAMUYU

E

1800

AF

AF

AF

AF

G

AF

AF

AF

AF

AF

G

AF

P2
(1950)

SLAUGHTER

AF

AF

AF

AF

AF

AF

AF

TETU

AF

AF

AF

P6
(1820)

KAMAKWA
OLD MKT

AF

KANOGA RIVER

AF

Legend

E - Eucalyptus
G - G. robusta stand.
L - L. leucocephala
P - Pinus sp. stand
→ - Direction of growth
AF - Encourage agroforestry

⊟ Densely populated area
⊞ Extension offices Fuel-wood stores and centre
▨ Proposed wood fuel zones.
▱ Existing tree canopies
≡ Major roads
∿ Rivers

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 constru-
cted 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 availa-
ble 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.

CHAPTER FIVE

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 fuel-
wood 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 desparately 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 vegetaion
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 informa-
tion for making recommendations and guiding the
policy-maker. The nature of built up areas, infra-
structure 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 utiliza-
tion. (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
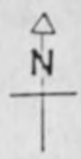variables useful to the planner. (Map 8i-ix).

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 suppliments 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 8i - ix

NYERI FOREST

Muringato
forest station

NYERI
TOWN

KAMAKWA

LEGEND

large scale
coffee estates

vegetation
tree lots/stand

Farm land

rivers

VEGETATION (1960'S)

Map n

8i

107

To Iberara

Labour lines

NYERI
PRIMARY
SCHOOL

W/L POSHO MILL

STAFF
HOUSES
(N P S)

To Kiganjo

MIN. OF WORKS

KINGONGO
PRISON

To Kihatha

KAMUYU

KAMAKWA

LEGEND

villages

GITATHI INI

shopping
centres / markets

roads

To Bariaga

To Mweenga-ini

KAMAKWA
MARKET

SCALE.   1:12,500

Map

ROADS (1960'S)

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

NYERI
HILL

VEGETATION (1970'S)

N

Muringato
forest station

NYERI
TOWN

SCALE 1: 25000

G.N. ICHANG'I
M.A. (PLANNING) 1987.

LEGEND

	large-scale coffee estates
	vegetation tree lots/stand
	farm land
	rivers

Map no.
8iv

ROADS   (1970'S)

TO Nyahururu

N

TO
Kiganjo

LEGEND

villages

shopping
centres/markets

roads

NYERI
TOWN

SCALE . 1: 25000

G.N ICHANG'I
M.A. (PLANNING) 1987

Map no.

LAND USE MAP (1970'S)

To Nyahururu

N

IHURURU
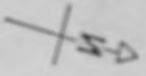
Kamwenja Teachers
Training College

P1

Nyeri Hill

Nyeri High Sch.

Muringato
forest station

Mathari Orphanage
Hospital

Labour
lines

Saw Mill Offices

Aberdare
national park

Mathari

Ministry
of Works

To Kiganjo

Kamuyu

Golf Course

Nyeri
Town

Kamakwa

Gitathi-ini

Tetu
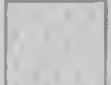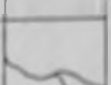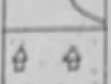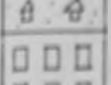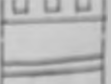
SCALE 1:25000

G. R. ICHANG'I
M.A. (PLANNING) 1987.
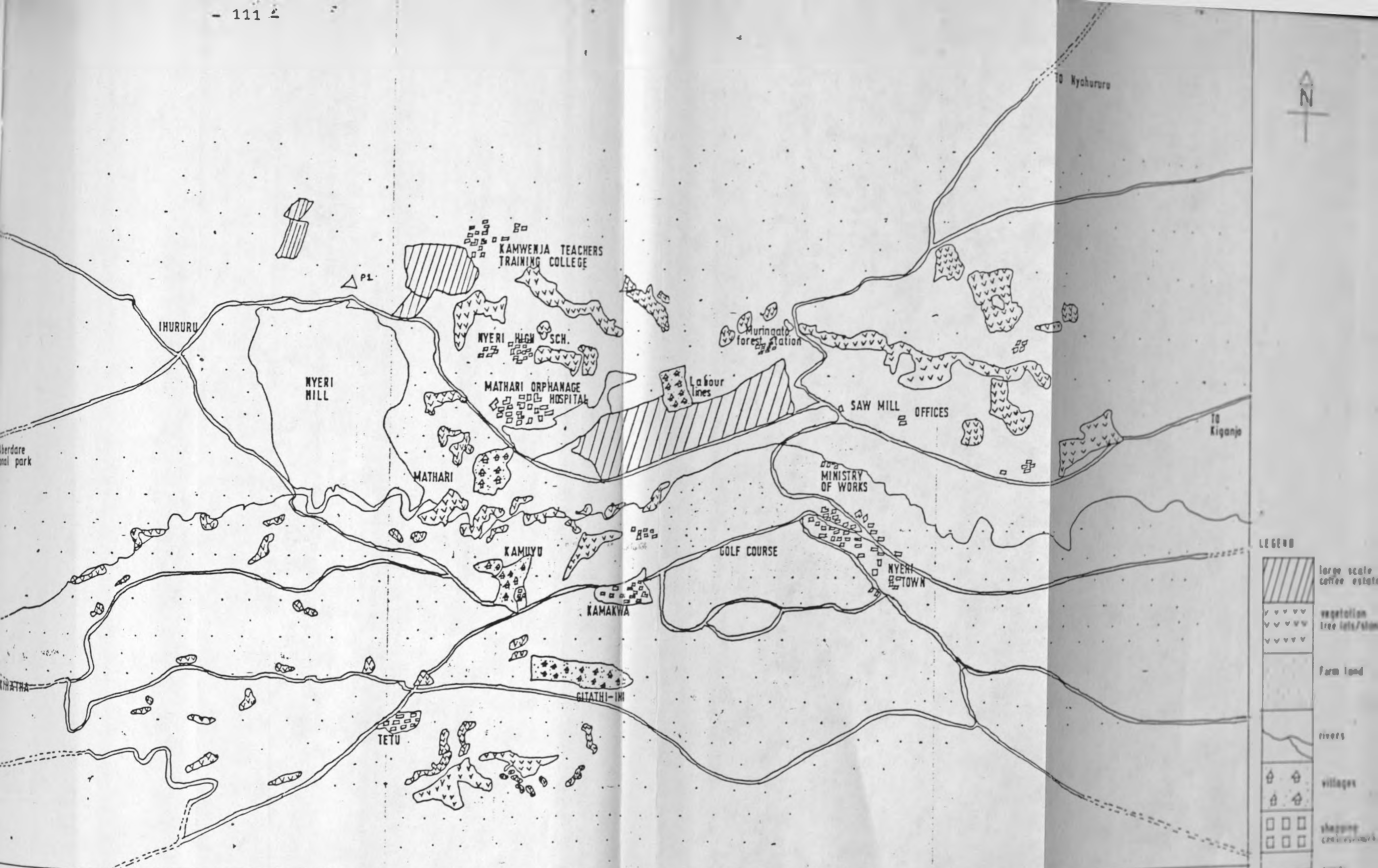
LEGEND

large scale
coffee estate

vegetation
tree lots/shrubs

farm land

rivers

villages

shopping
centres/market

roads

Map no.
8vi

LAND USE TYPE

(1986)

NYERI FOREST

Muringato river

Nyeri hill Forest

Chania river

NYERI TOWN

LEGEND

—•—•— Municipality boundary
— — — Study Area boundary
///// — woodland / forest
ΛΛΛ/ — woodland / Natural
ΛΛΛΛΛ — woodland / Plantation

OOO — Fallow land

0101 — Permanent grass

0202 — Wooded pasture

0303 — Pasture with scattered tree or bush.

04040 — Bushland

xxxx — Tilled. land.

x1x1x — Maize & beans

x2x2 — Coffee & Tea

x3x3 — Bananas fruits & vegetables.

x4x4 — Napier grass

x5x6x — Fuel wood lots

SCALE. 1:50,000

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

map no. 8

NYERI
FOREST

△2△
2△2

△2△   △3△
△3△
△3△3

Nyeri hill   △2△2
forest   △3△
△3   △3△ △
△3   △3△
△2   △3△   NYERI   △3△3
△3△ △3△ △3△   △3△   TOWN
△3△3△   △ △3   △1△1   △4△   △1△ 1
△ △2△2   △△△   4△4
△3△ △2△2 KAMAKWA
*KAMUYU△2△2
△3△   △3△
△3△ △   △3△   2△3
△3△ △   △1△1
△3△ △   △3△
△3△
△3△

△3△   △1△
3 △ △   1△   △3△   △1△1
△   △3△   △1
△ △   △△
△ △
△   △3△   △3△
△1△   △3   △3△
1△△1
△1△   △3 △3△
△ 3 △△
△ 3 △
1 △1△   3 △△
1 △1

SCALE. 1:50,000

(1986)

SETTLEMENTS

N

NYERI
FOREST

⊙76R

⊙76R
a

⊙76R
b

⊙76R
b

⊙76R

⊙76R
b

⊙77R
c

⊙77R
b

⊙76R

⊙76R
b

⊙76R
a

Nyeri hill
forest

⊙77R
c

⊙77R
b

⊙76R
a

⊙76R
a

⊙76R
a

⊙77R
a

⊙77R

⊙77R
a

⊙77R
a

⊙76R
a

⊙76R
a

⊙76R
a

NYERI
TOWN

⊙76R
c

⊙76R

⊙76R
a

⊙76R
l

⊙76R
c

⊙76R
d

⊙76R
a

⊙76R

⊙76R
c

⊙76R
c

⊙76R
a

⊙76R

⊙76R
c

⊙76R
c

⊙76R
c

⊙76R

⊙76R
b

⊙76R
b

⊙76R
b

⊙76R
b

⊙76R
d

LEGEND

⊙ — Drainage good

76R
77R } — soil types

a — level slope 0—3°

b — Rolling slope 3—9°

c — Rough 10—15°

d — steep > 15°

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:-

CHARACTERISTIC	AERIAL PHOTOGRAPHY Technique
1. Traditional Use (Historial use)	Long use in the past
2. Cost	High
3. Resolution	Large
4. Coverage	Small
5. Cycle	Irregular
6. Identity	Ground Surface
7. Differentiation	High
8. Penetration	Nil

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 │───────┴─┘
└─────────────────────────┘
```
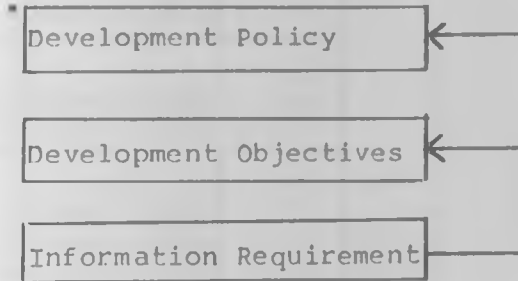
<u>Information requirement in relation to development
policy and objective.</u>

Mwanje <u>et al</u>, (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)

DEVELOPMENT OBJECTIVE	TYPE OF INFORMATION	ENERGY (FUELWOOD)
SELF SUFFICIENCY IN FOOD NUTRITION		+
CONSERVATION OF NATURAL RESOURCES		+
OPTIONAL USE OF NATURAL RESOURCES		+
DEVELOPMENT OF APPROPRIATE TECHNOLOGY		+ +
IMPROVEMENT OF INFRA STRUCTURE		+ +
PROVISION OF BASIC NEEDS-HEALTH, EDUCATION, HOUSING E.T.C.		+ +
PARTICIPATION IN DEVELOPMENT PROCESS		+ +
MINIMIZATION OF UNEMPLOYMENT		+
ENVIRONMENT PROTECTION		+ +
RURAL DEVELOPMENT		+
NATIONAL SECURITY		

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 dynami-
sm 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 managment 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 informa-
tion 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 intesnity 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 it's 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 situa-
tion 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.

BIBLIOGRAPHY

Agatsiva, J.L. Detailed Landuse mapping at district
Level (Scale 1:250,000). of the high potential
agricultural areas of Kenya using Remote
Sensing Techniques KREMU, 1982.

Agatsiva, J.L. & Mwendwa, H., Landuse Mapping in Kenya,
KREMU, 1982.

Beek, K.J. et al (eds), I.T.C. Journal, 1983 - 1.

Blum, W.E.H. et. al. Landsat Imagery for the
assessment of soil erosion in Large
Mountain Water sheds" in Applied Geography
and Development, Vol.26, 1985

Buck, L. (ed), Proceeding of the Kenya National Seminar
on Agro-forestry, ICRAF - University of Nairobi,
1980.

Burke III, R. and Heaney, J.P., Collective Decision
Making in Water Resource Planning, Lexington
Books, 1975.

Burley, T.M., "Landuse or Land Utilization?,"
in Professional Geographer 13, p.18-20, 1961.

Chapman, G.W. and Allan, T.G., Establishment Techniques
for Forest Plantations, FAO, Rome 1978.

Chege, O.J.N., Nyeri Town: Land Constraint to Urban
         Development. M.A. Thesis, University of
         Nairobi, 1977.

Christian, C.S. and Stewart, G.A., Methodology of
         Integrated Surveys in Proc. Conf. Aerial
         Surveys and Integrated Studies, Toulouse,
         UNESCO, P.233 - 80, 1968.

Clawson, M. and Stewart, C.L., Landuse Information.
         A Critical Survey of U.S. statistics
         including possibilities for greater uniformity
                John Hopkins University Press, 1965.

Conitz, M. et. al.; Landsat Data for Development, East
         African Examples, Regional Remote Sensing
         Facility, Nairobi.

Daily Nation, "Wood Crisis Looms", in Daily Nation,
         30th March, 1987.

FAO, "A framework for land evaluation" in Soils Bull.
         No.29, 1976.

Firey, W., Man, Mind and Land, The Free Press, 1960.

Gibbon, H. and Mather, P., "The use of Remote Sensing
         Techniques for Landuse Assessment and
         Planning at District level in Kenya: A Case
         Study of Meru District".
         A paper presented at the Twentieth
         International Symposium on Remote
         Sensing of Environment, Nairobi Kenya, 1986.

I.C.R.A.F., <u>Landuse System Evaluation for Agro-forestry: Guidelines for Using AFRENA Worksheets.</u> ICRAF Nairobi, 1986.

Kenya, Republic of, <u>Forest Resources Inventory Report, Pinus radiata Overbark Volume Tables,</u> Forest Department, Kenya.

Kenya, Republic of, <u>Forest Resources Inventory Report. Cypress Overbark Volume Tables,</u> Forest Department, Kenya.

Kenya, Republic of, <u>National Population Census,</u> Government Printers, 1979.

Kenya, Republic of, <u>Nyeri District Environmental Assessment Report,</u> NES, 1980.

King, R.B., <u>Remote Sensing Manual of Tanzania,</u> University of Dar-es-salaam, 1984.

King'oriah, G.K., <u>Some Methodological Approaches to Planning and Landuse Studies in Kenya,</u> Associazione Italiana Di Ricerea operative Volume Primo, 1984.

Kinyua, P.M. <u>Water Resources Planning in Rural Development: A Case Study of the Water Supply Project in Embu District,</u> M.A. Thesis, University of Nairobi, 1977.

Kishk, M.A., "Evaluation of Desertification in Egypt,"
        Paper presented at the I.T.C. Conference
        on Remote Sensing - Decision making,
        Nairobi, 1982.

KREMU, Landuse in Bungoma and Kericho Districts, 1985.

KREMU, Landuse in Kisii, Technical Report No. 97, 1983.

IPAL, Annotated Check-List of the Plants of Mount Kulal,
        Marsabit Kenya, Technical Report No.D - 3,
        UNEP - MAB, 1981.

IPAL, The Hydrology of South-Western Marsabit District
        Kenya, Technical Report No.B - 2 UNEP - MAB,
        1984.

IPAL, Integrated Resource Assessment and Management
        Plan for Western District, Marsabit, Kenya,
        Technical Report No.A - 6, PI, UNEP - MAB
        1984.

Johannson, J., and Saunders, J.L., (eds), Remote Sensing
        for Resource Management, Soil Conservation
        Society of America, 1982.

Kalyango, S.N. and Ting-Tiang, W., Remote Sensing of
        Natural Resources in Eastern and Southern
        Africa, Soil Survey and Mapping, Regional
        Remote Sensing Facility, Nairobi.

Kanani, S.S., Use of Remote Sensing in Land Degradation
        Mapping in Kenya, unpublished , 1982.

Kanani, S.S. Use of Remote Sensing in Agriculture A
Kiambu District Case Study, MSc. Thesis,
University of Nairobi, 1979.

Kanani, S.S., Land Cover Mapping and Change Detection
in Kitui, Kenya: A remote Sensing Approach,
MSc. Thesis, University of California, 1981.

Kenya, Republic of, Human Settlements in Kenya,
Government Printers, 1978.

KREMU, Forest Cover Mapping in Kenya Using Remote
Sensing Techniques, 1982.

- KREMU, The Use of Resource Survey Data in Decision-
Making with Reference to Kitui District in
Kenya Technical Report No.93, 1982.

Logie, G. Glossary of Land Resources, Elsevier Science
Publishers, 1984.

Lynch, T.D., Policy Analysis in Public Policy Making,
Lexington Books, 1942.

McRae, S.G. and Burnham, C.P., Land Evaluation
Clarendon Press, 1981.

Mitchell, C.W., Terrain Evaluation, Longmans, 1973.

Muret, J.P. (ed), Aerial Photography and City Planning,
International Federation for Housing and
Planning-Centre de Recherche D'urbanisme 1978.

Mwanje, J.I., <u>Feasibility Study of Using Airborne</u>
<u>Digital Radiometers (Biometers) To Inventory</u>
Range Forage, M.Sc. Thesis, University of
British Columbia, 1981.

Mwanje, J.I., and Ottichillo, W.K. (eds),
"Identification of the Range of Information
Requirements for Decision-Making on which
Remote Sensing may have an Impact," in <u>I.T.C.</u>
<u>Special Journal</u> p.119 - 205, 1982.

National Academy of Science, <u>Remote Sensing from Space,</u>
Prospects for Developing Countries, NAS, 1977.

Njuguna, C.N. <u>Planning for Water Supply in Gatundu Division,</u>
M.A. Thesis, University of Nairobi, 1981.

Ochanda, N. <u>A forestry Inventory of Kenya Using Remote</u>
<u>Sensing</u> Techniques, KREMU, 1982.

O'Keefe, P.O. et. al. (eds), <u>Energy and Development in</u>
<u>Kenya: Opportunities and Constraints,</u>
The Beijer Institute, 1980.

Otieno, J.O., "The application of Remote Sensing
Technology to the Process of Natural Resources
Planning in Kenya, Future Needs and Potentials"
in <u>I.T.C. Journal</u> Nov. 1982.

Ottichillo, W.K., <u>A Survey of Natural Wood Supplies</u>
<u>in Kenya Rangelands Using Remote Sensing</u>
Technique, KREMU 1978.

Pauludan, C.T.N., <u>Land Resources Information from</u>
<u>Satellites and the Impact on Rural</u>
Development, University of Tenessee, 1984.

<u>Proceedings of the International Workshop on Energy</u>
<u>Survey Methodologies for Developing</u>
<u>Countries,</u> N.A.S., 1980.

Remote Sensing Centre, Report on <u>Remote Sensing</u>
Applied to Renewable Resources, FAO, 1982.

Rudd, R.D., Remote Sensing, <u>A Better View, Duxbury</u>
Press, 1974.

Short, N.M. et. al., <u>Mission to Earth: Landsat Views</u>
the World, N.A.S., 1976.

Snedecor E. and Cochran, C., <u>Multiple Linear Least</u>
<u>Squares Regression Analysis,</u> Duxbury Press,
1980.

Solomon, M.J., <u>Elements of Project Management,</u> U.S.
Department of Agriculture, 1976.

Steiner, D., "Remote Sensing input to information
Systems," in <u>Geographical Data Handling</u>
p.541 - 631, International Geographical
Union. 1972.

Stuart, D.G., <u>Systematic Urban Planning,</u> Praeger
publishers, 1976.

The Beijer Institute, <u>Stand Volume Tables for Cupressus</u>
<u>Lusitanica, Pinus Patual and Pinus radiata</u>

in Kenya, Forest Department, Kenya.

The Courier, "Woodfuel" in <u>The Courier Journal</u>
<u>No. 95,</u> Africa - Caribbean - Pacific -
European Community, Feb., 1986.

Tivy, J. and O'Hare, G.M. <u>Human Impact on the</u>
<u>Ecosystem,</u> Oliver and Boyd, 1981.

Townshend, J.R.G. (ed), <u>Terrain Analysis and Remote</u>
<u>Sensing,</u> George Allen and Unwin Ltd., 1981.

Van Den Broek J.M.M. and Epp, H. (eds)

"Potential Influences of Remote Sensing
Surveying on decision-making,
Proceedings of The Fourth International
Seminar, remote sensing - decision-making,"
Nairobi, Kenya, in <u>I.T.C. Journal,</u> Nov. 1982.

Vink, A.P.A. <u>Landuse in Advancing Agriculture,</u>
Springer Verlag, 1975.

Wambugu Agroforestry/Energy Centre, <u>Information</u>
<u>Bulletin No.1,</u> Kenya Renewable Energy
Development Project, 1985.

Western, <u>et. al.,</u> <u>A Survey of Natural Wood Supplies in</u>
<u>Kenya and an assessment of the ecological impact</u>
of it's usage, KREMU, 1981.

Whyte, A.V.T., <u>Guidelines for field studies in</u>
    Envrionmental Perception, UNESCO - MAB,
    1977.

Yamane, T., <u>Statistics: an Introductory Analysis,</u>
    Harper and Row, 1973.