Photographie n° 6a et b. Deux thermographies, l'une au début (a), l'autre pendant les travaux de terrassements (b) - c'est-à-dire pendant le maintien de l'enveloppe congelée - de la paroi de béton, zone de contrôle, de la congélation. Les surfaces blanches sont à une température comprise entre 0 et -5 °C (a) et entre 0 et -10 °C (b). Les butons métalliques qui maintiennent la paroi sont fortement émissifs : leur température est de l'ordre de 12 à 15 °C.

WG VII-11

SURVEILLANCE DE LA VEGETATION EN AGRICULTURE ET FORET.

VEGETATION DAMAGE IN AGRICULTURE AND FORESTRY.

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UTILIZATION OF LANDSAT DATA TO MONITOR DEFORESTATION OF KENYA'S MAU FOREST

by

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ABSTRACT

The Mau Forest, the largest forest in Kenya, is under constant pressure for alternative land use. Settlements, due to population pressure, are encroaching and the need for agricultural land is ever increasing. Squatter settlements are leaving an imprint of deforestation which might have devastating results in the area.

Major factors responsible for the depletion of the Mau Forest include: 1) Fire (often attributed to human carelessness), 2) Conversion of bushland to grassland by itinerant charcoal burners, 3) Unplanned harvesting and general exploitation (e.g. pit sawing, cutting of fuel wood), 4) Clearing of trees to create pasture land and the clearing of forest in order to plant food crops, disregarding the terrain, 5) Cutting of trees for building poles, and 6) Multiplication of forest diseases.

The extent of forest change is far-ranging in the Mau Forest. Data obtained through LANDSAT provides a mechanism to monitor the rate and magnitude of the change. Data for January 1973 and December 1978 were analyzed through the aid of digital data processing. The procedure included a traditional and nontraditional cluster algorithm technique to measure the extent of deforestation. The classified data sets were compared with aerial photography and other geo-referenced information. The two data sets were subsequently compared to determine the extent of deforestation during the time interval. Results show that the trends in deforestation for a geographic region can be effectively monitored through digital data processing and analysis of LANDSAT data. The data processing was accomplished through the Earth Resources Data Analysis System (ERDAS) 400, housed at Ohio University's Ohio Center for Remote Sensing. Digital data processing of this type certainly provides an additional tool for forest resources management.

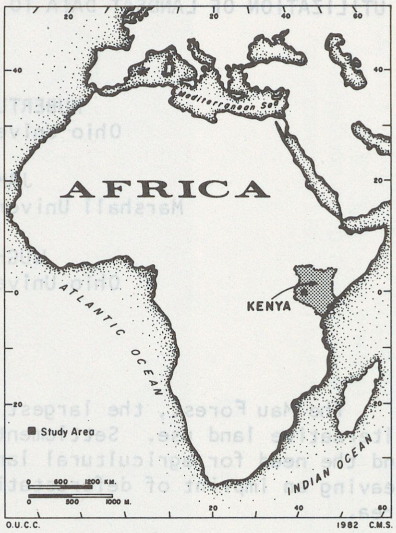
INTRODUCTION

Forests, even though they are considered a renewable resource, are declining at an alarming rate (Cannon et al.,1978; Lachowski et al., 1978; Persson 1977). This is particularly true of the tropical rain forest which includes the Mau Forest in Kenya. (See Figure 1.) Deforestation is not merely a matter of land cover or land use change; rather the environmental ramifications of such occurence can lead to disastrous results if the practice goes unchecked.

Man's impact on the environment has been multifarious and often synergistic throughout the time of habitation of planet earth. It has only been in recent decades, for the most part, that man's relationship with the land or his environment has been looked at with any degree of scrutiny. The major factors responsible for the depletion of the Mau Forest include land clearing for agricultural land use, wood gathering for fuel and lumbering for commercial and industrial

RELATIVE LOCATION
OF STUDY AREA

Figure 1



uses. (FAO, 1980). These causations are further aggravated by increasing populations, increased demand for food and greater energy needs in the face of diminishing supplies. It is, therefore, essential to develop innovative approaches in resources management which can meet the increasing needs while protecting and maintaining the environment of Kenya.

Kenya, with an area of over 500,000 square kilometers, dissected by the Great Rift Valley, provides a wide range of physiographic features as well as climatic regimes. The latter is closely tied to the elevation changes from sea level to 5,200 meters on top of Mount Kenya fueled by two opposing climatic patterns. Kenya's forests are of the upper and lower montane types and constitute only three percent of the total land cover of the country. The former type are conifer and comprise the largest forest area in Kenya. The lower montane are semi-tropical rain forest of broad leaf evergreens. The upper montane forests are the most significant for Kenya in economic terms (Doute, 1980).

Nature's ecological harmony depends on its ecological balance. The disruption of this balance through changes other than slow evolutionary processes results potentially in detrimental alteration of the environment. Unchecked deforestation of the Mau Forest results in soil erosion, reduction of water catchment potential, increased stream siltation, disruption of the aquatic ecosystem, added danger of more severe flooding, destruction of agricultural lands and further reduction of hydro-electric potential for the region (The Weekly Review, 1982). Presently, deforestation has resulted in all of the above in the Mau Forest and the socio-economic implications for this region associated with this practice cannot be readily absorbed by the economy of the country.

To prevent unchecked deforestation in any region, it is necessary to apply monitoring techniques suitable for any specific geographic area. It is not uncommon to find extensive air surveys and field surveys to monitor parts of Europe or the United States of America. However, these time and money consuming techniques are frequently not available in so-called less developed nations such as Kenya (Doute et al., 1980). Furthermore, the whole concept of forest management may be fairly new to the government of such developing nations and coupled with limited financial resources the idea of repetitive air photo coverage, ideally suited for this purpose, may be remote at best. Therefore, alternative options or avenues must be explored to be applied to effective forest management of such areas as Kenya's forests. Since 1972 the LANDSAT system has made data available that have the potential to be used for the purpose of forest management and monitoring of forest cover changes in such regions as the Mau Forest (Miller et al.,1978).

The objectives of this study are to demonstrate that: 1) Excision in forested areas are discernible with LANDSAT data; 2) LANDSAT data can be used to discriminate landcover types generally associated with land use of forest change; 3) forest change, using temporal LANDSAT data, is discernible on a regional basis and 4) the Earth Resources Data Analysis System (ERDAS) 400 is a compact, viable data processing system amenable to limited training and budgets of developing nations for natural resources management in a cost effective and timely fashion.

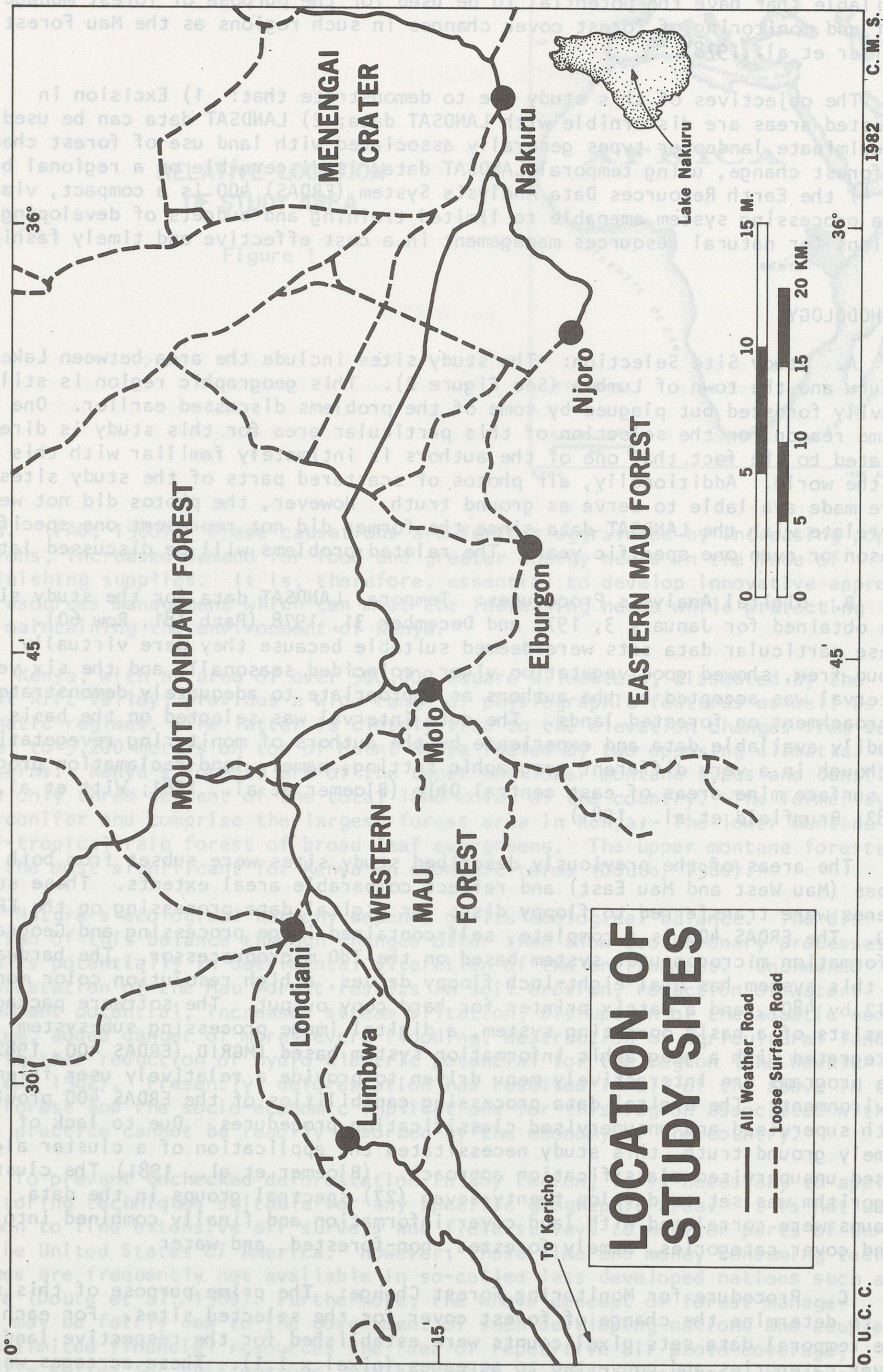
METHODOLOGY

A. Study Site Selection: The study sites include the area between Lake Nakuru and the town of Lumbwa (See Figure 2). This geographic region is still heavily forested but plagued by some of the problems discussed earlier. One prime reason for the selection of this particular area for this study is directly related to the fact that one of the authors is intimately familiar with this part of the world. Additionally, air photos of scattered parts of the study sites were made available to serve as ground truth. However, the photos did not well correlate with the LANDSAT data since the former did not represent one specific season or even one specific year. The related problems will be discussed later.

B. Digital Analysis Procedures: Temporal LANDSAT data for the study site was obtained for January 3, 1973 and December 31, 1978 (Path 181, Row 60). These particular data sets were deemed suitable because they were virtually cloud free, showed good vegetation vigor, coincided seasonally and the six year interval was accepted by the authors as appropriate to adequately demonstrate encroachment on forested lands. The data interval was selected on the basis of readily available data and experience by the authors of monitoring revegetation although in a very different geographic setting, namely land reclamation progress in surface mine areas of east central Ohio (Bloemer et al., 1981; Witt et al., 1982; Brumfield et al., 1981).

The areas of the previously described study sites were subset from both data tapes (Mau West and Mau East) and reflect comparable areal extents. These subscenes were transferred to floppy discs for digital data processing on the ERDAS 400. The ERDAS 400 is a complete, self-contained image processing and Geographic Information microcomputer system based on the Z80 microprocessor. The hardware of this system has dual eight-inch floppy drives, a high resolution color monitor (512 by 480), and a matrix printer for hard copy output. The software package consists of a basic operating system, a digital image processing sub-system integrated with a geographic information system based IMGRID (ERDAS 400, 1982). The programs are interactively menu driven to provide a relatively user friendly environment. The digital data processing capabilities of the ERDAS 400 provide both supervised and unsupervised classification procedures. Due to lack of timely ground truth, this study necessitated the application of a cluster algorithm based unsupervised classification approach. (Bloemer et al., 1981) The cluster algorithm was set to develop twenty-seven (27) spectral groups in the data. These groups were correlated with land cover information and finally combined into three land cover categories, namely forested, non-forested, and water.

C. Procedure for Monitoring Forest Change: The prime purpose of this study is to determine the change of forest cover for the selected sites. For each of the temporal data sets pixel counts were established for the respective land cover categories and converted to acreages (pixel x 1.1). These acreages were then compared for each land cover category for the two dates. The geographic


LOCATION OF STUDY SITES
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Lake Nakuru
Njoro
EASTERN MAU FOREST
Elburgon
Molo
MOUNT LONDIANI FOREST
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Figure 2

position of these changes were determined on a qualitative basis through visual inspection and correlation with the aid of the available limited ground truth. (Short, 1982) The percentages were calculated by dividing acreage per category by acreage for the whole subscene for both data sets.

RESULTS AND CONCLUSION

Changes in the land cover categories between the two dates and particularly forestation, are based on the acreage estimations as developed in the above procedure. The results of the acreages and percentages for each of the categories for the two dates are noted in Tables I and II. As indicated in Table I, for the Mau East site, there is a decrease of over five percent in the forest cover category between the two dates. However, for the Mau West site, there is no significant difference in the overall forested category between 1973 and 1978. Visual inspection of the data and ground truth imply that there is notably more agricultural encroachment in the Mau East study area as compared to the other. The results clearly indicate that there is a considerable change of ground cover for the Mau Forest. LANDSAT data provide a valid basis for monitoring forestation changes and trends in areas where traditional data collection methods are at best infrequently utilized to provide reliable information for the management for such resources. A more detailed analysis of the study sites would require more reliable ground truth. Additional data processing would make data sets such as the Mau West and Mau East reveal more insight, but it would be essential that the information be verified to validate the findings.

This study supports the premise that relatively simple data processing procedures and limited ground truth application can indeed serve as an effective monitoring device of the forest changes in Kenya. More sophisticated techniques or additional data bases would undoubtedly result in more refined findings but not change the basic premise.

TABLE I

Cluster Analysis

MAU EAST 1973

Category	Pixel	Acreage	Percent
Water	4242	4666.2	6.90
Forest	6931	29624.1	43.83
Non-Forest	30269	33295.9	49.26
TOTAL	61442	67586.2	99.9

MAU EAST 1978

Category	Pixel	Acreage	Percent
Water	6151	6766.1	9.40
Forest	25168	27684.8	38.48
Non-Forest	34082	37490.2	52.11
TOTAL	65401	71941.1	99.9

TABLE II

Cluster Analysis

MAU WEST 1973

Category	Pixel	Acreage	Percent
Water	816	897.6	1.7%
Forest	21429	23571.9	44.5%
Non-Forest	25899	28488.9	53.8%
TOTAL	48144	52958.4	100 %

MAU WEST 1978

Category	Pixel	Acreage	Percent
Water	420	462	0.9%
Forest	20573	11630.3	44.7%
Non-Forest	24987	27485.7	54.3%
TOTAL	45980	50578	99.9%

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