DETECTING AND QUANTIFYING LAND COVER AND LAND USE CHANGE IN EASTERN MAU BY REMOTE SENSING

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Abstract

Eastern Mau is an important water catchment area for lake Nakuru drainage basin. It has great potential for agricultural development as manifested by the high yields of wheat, barley and dairy products from the few remaining large scale farms. This area was once covered by rich vegetation of highland evergreen forests which extended from the Mau hills and turned into woodland dominated by acacia trees in the Rongai-Njoro plains. Remote sensing techniques and ground survey methods were used to evaluate the land cover /land use change that occurred in the area over a period of about 40 years since 1964. A significant change of land use from forest to agriculture was evident from the interpreted results of the photos taken in 1964 and 1969, the SPOT image of 1987, the Landsat image of 1989 and the ground survey of 2003. Deforestation, land fragmentation, cultivation of wetlands and rapid increase in human settlements have had negative impacts on water resources resulting in reduced stream flows and ground water. Land use has changed from planted forests and large scale farms of wheat, barley, and dairy to homesteads, kitchen gardens and small farms of maize, beans, potatoes and vegetables with some people keeping one or two dairy animals. Currently, studies show increasing land degradation in the area. Sheet and rill erosion is observed when it rains and gullies are beginning to develop along some of the farm tracks. To contain the situation, satellite remote sensing was used to monitor and provide data that can be used to evaluate and manage land use and land use change for sustainable development in Mau East.

Keywords: Remote Sensing, Air photo-interpretation, Landsat, SPOT, Catchment

Introduction

Eastern Mau is in the Rift Valley Province of Kenya and lies between Rongai-Njoro plains and the upper slopes of the Mau hills. It is mainly covered by the Quaternary and the Tertiary volcanic deposits. The area is drained mainly by rivers Njoro and Lamriak which originate from Eastern Mau escarpment and empty into Lake Nakuru and rivers kaumara, Nessuit and Rongai which drain northwards to lake Baringo and Bogoria.

Remotely sensed data and ground survey methods were used to evaluate the land cover /land use change in the area for a period of about 40 years. A combination of fine, medium and coarse resolution images from different platforms were used to detect changes. The study showed a significant change of land use from forest and woodlands to agriculture, and rural built-up lands. This was evident from the analysed results for the air photos of 1969, the SPOT image of 1987, the Landsat images of 1984 and 1989 and the ground survey of 2003 which gave a chronological landscape record. Deforestation, land fragmentation, cultivation of wetlands and rapid increase in human settlements have had negative impacts on water sources resulting in reduced stream flows. Land use has changed from planted forests, large farms of wheat, barley, and dairy to homesteads, kitchen gardens and small farms of maize, beans, potatoes and vegetables with one or two dairy animals.

Methodology

A systematic sequence of API was done on air photographs of 1969 to ensure that definite, reliable and significant information was extracted. The central photograph was analysed using mirror stereoscopes. A full scene SPOT image (fig.5) covering Lake Nakuru and Lake Naivasha drainage basins was manually interpreted and analysed. The general character as well as details of the geology, drainage, plant cover and land use were drawn from surrogate indicators and interpretation elements in the images. Vegetation cover was determined by the colour tone, the distribution, form and texture of plant-covered areas. Land cover change was determined by comparing multi-temporal images. A subscene Landsat image of 1989 (fig.8) covering the recharge areas and the mature sections of the rivers originating from Mau hills were interpreted. The large area covered in one image was important for various kinds of regional studies with details of size 30-80 m being observed. TM bands 4, 5, 3 were selected as they showed vegetation and land use features more clearly.

Ground survey was carried out in the selected sample sites in 2003. In order to achieve unbiased samples, surveys were based on an unaligned systematic random sample of fixed-size segments of 1 km x 1 km. Individual land parcels and ground cover classes were identified in each sample segment. By the method of direct expansion, the area for each cover class was determined for the entire study area. A high densification of sample sites was preferred in order to validate the consistency of land use cover database.

In order to classify the heterogeneous land use in eastern Mau, a simplified method known as EU-LUCAES based on Anderson 1977 was applied. Field survey provided the locations of known land use cover types such as wheat farms and improved pasture fields. It provided the locations of unknown features such as rural built-up lands, heterogeneous crop and subsistence farms which cannot be identified on the image using visual interpretation techniques. It helped identify the main physical environments of the study area such as hills, valleys and rolling land. Data verification process involved rechecking photographs and images to determine if the interpretation was correct, and where questions existed, the site was field verified. At least a third of the segments were field checked, results tabulated and compared to the original interpretation.

Area by direct expansion

Mean proportion:

$$\bar{y}_c = 1/n \sum_{i=1}^{n} y_i \qquad (1)$$

Where,

$\bar{y}_c =$ Mean proportion of each coverage area

$y_i =$ Coverage proportion for each segment

n = number of segments in the sample

Total area under coverages

$$Z_c = D y_c \qquad (2)$$

Where,

Z_c = Estimate of the coverages area

D = Total study area

Variances of area estimator

$$Var(\bar{y}_c) = (1 - n/N) 1/(n(n-1)) \sum_{i=1}^{n} (y_i - \bar{y}_c)^2 \qquad (3)$$

$$Var(Z_c) = D^2 Var(\bar{y}_c) \qquad (4)$$

Where,

N= Total number of segments in the study area

Results and Discussion

The land cover classes identified in the area were as shown in table 1.

Table 1: Land cover classes

Category	Air Photograph (1969)	Landsat Image (1989)	Ground Survey (2003)
Natural forest	y	y	0
Planted forest	y	y	0
Plantation eucalyptus	x	x	y
Cultivated land	y	y	y
Wooded grassland	y	y	y
Grassland	y	y	y
Built-up land	y	y	y
Riverine vegetation, fence lines/belts,	y	y	y
y = positively identified x= not identified 0 = nil			

Visual Image Interpretation

Air Photograph (1969)

The photograph was enlarged to show the land use cover clearly. The fields on Tatton farm at Egerton college as it was known then can be clearly seen in figure 6. Other large scale farms shown are Finerose (present Ndichu and Kiringu farms) and Growtch (present Ngondu farm). Planted forest of coniferous occupied the western part of the area. Woodland/wooded grassland was found on the southern and eastern parts of the area under study. Arable agriculture and animal keeping was at the middle and northern part. Woodlots and tree fence belts/lines were common on farmland.

Landsat MSS (Jan. 1973)

The locational information provided in figure 4 shows the main land cover types in this part of the Rift valley. The Mau range, the Bahati escarpment and the Aberdare range are covered in bright red which is solar infra-red radiation by healthy chlorophyll-rich vegetation. Although January is a dry period, the richness of the red indicates the vigour of the leafs and their sizes. Dark red represents broad leaved trees or woody shrubs seen on hillsides as seen on Menengai crater and as strings of dark red lining stream channels, fault lines and hillside gully valleys in many parts of the image. The bright yellowish areas have high reflectance in all wave-lengths. These are areas of open pasture and grassland, bare soil, overgrazed, just harvested, roads or built-up areas. Patches of dark red represent trees or scrub vegetation. In agricultural lands, the bright tones are an indication of cleared or fallow fields at this time of the year in January. The greenish tones are ploughed fields. Water bodies like lake Nakuru, Lake Elmentaita, Lake Bogoria and Sasumua dam are indicated in black tones. Lake Baringo appears as bright green because of high sedimentation. At the middle of Lake Nakuru, the bright red indicates aquatic vegetation. Woodlands in the image appear as red mottled tones.

Landsat TM (July 1989)

Land use cover change was detected on the image after analyzing it and comparing the results with the photograph of 1969. The colour key shows a significant change of land use from the dominant forest and large scale farms seen on the photograph. It can be seen from figure 8 that the forest which was at the confluence of the little shuru and enjoro has been cleared. The blue patches within the forest indicate new-clear lands now under subsistence cultivation.

Configuration and Composition of Land cover/Land Use

It was ascertained through remote sensing and time series analysis that there has been a significant land use cover change, particularly the conversion of forest and woodlands to arable land as shown in table 2 and figures 1 and 2. The air photographs of 1969 showed large scale farming, forest conservation and little built-up lands. The pre-change geo-topes of planted forests and farms showed clear corridors, sizes, shapes and connectivity. The dominant land use cover types were forests (75%), woodlands (12%) and farms (13%). By 1989, the landscape had changed tremendously as showed by the landsat sub-scene image which showed 60 % forest and woodland and 40 % agriculture and built-up area. The dominance of mixed agriculture and subsistence farming in much of the former Nessuiet forestlands and Ngondu large scale farm is shown by the different shades of blue and whitish patches. Due to decrease of spatial resolution on the images, the dominant land use cover types of forest and mixed farming exhibit a rapid increase and overestimation at the coarse levels of spatial aggregation at the expense of non-dominant land use cover types like rural built-up lands. The dominant land use cover types are overestimated due to spatial mixing of covers hence the high variances. Settlements like Ngondu and Njokerio now stand on former large scale farms and grasslands. Ngondu formerly known as Wright farm produced wheat and dairy products while Njokerio formarly Sebiens farm for horses and flower production. Forest lands in Beeston area have been converted into arable and built-up lands. Expansion into forest and riverine areas has been taking place for quite a while now. From ground survey of 2003, the dominant land cover types were 5% forest, 7% woodland, 82% agriculture and 6% built-up area. It was evident that loss of forest cover in the reserves was by both clear cut and progressive thinning due to poaching by local residents. There are many small land use patches of maize, beans, potatoes, wheat, pasture and homesteads with spectrally similar land cover which tend to clump to the bigger entities contaminated by mixed pixels in remotely sensed data. The EU-LUCAES method used for this study provided a simple calibration which has been validated to assist with interpreting images to determine land use cover types of heterogeneous type, especially subsistence agriculture and rural built-up land on former forests and large scale farms.

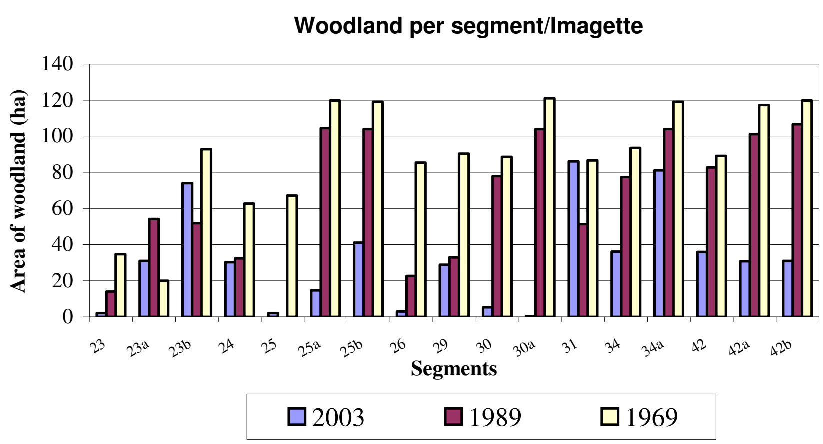

Figure 1: Change in woodland

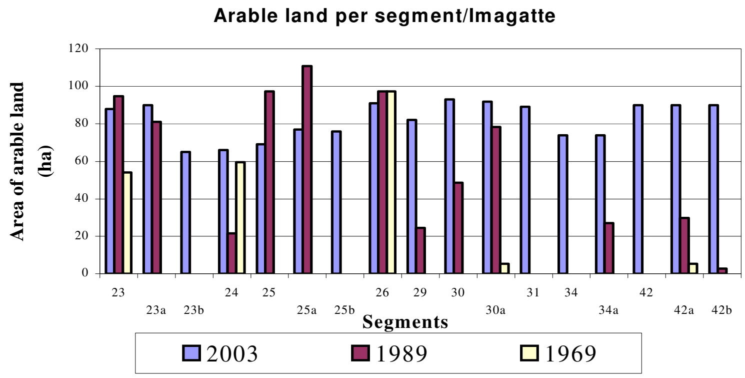

Figure 2: change in arable land

Table 2: Land use cover statistics

Data source	Ground survey	Landsat image	Air photo
Year	2003	1989	1969
Geog. area (ha)	7000	8404	8373
Arable land (ha)	5748	3516	1092
Wood/grassland (ha)	2440	5574	7677
% Arable land	82	42	13
% Wood/grassland	35	66	92

Impacts of Land use cover change

As land use changes from forest to rural built-up lands, urban lands and subsistence agriculture, surface runoff increases while surface and groundwater quantity and quality deteriorates. The effect is manifested in reduced natural recharge, reduced stream flow and elimination of wet lands. Currently, there is a steady recognition that surface and groundwater sources are declining. River Njoro no longer flows throughout the year. Boreholes are drying up, especially at Egerton University where 4 out of 11 have dried up. Reduction in the water quantity in Lake Nakuru has been blamed on deforestation in the Mau range which is the source of rivers Njoro and Lamriak, the main rivers flowing in the lake. Agriculture has moved up the slopes and in the riverine areas as shown in figure 7. There is no forced fallow any longer even as land loses fertility. The practice of continuous cultivation is impoverishing the soils. Sheet and rill erosion is observed when it rains and gullies are beginning to develop along some of the farm tracks. Deforestation and break down of the soil conservation structures which were established by the settler farmers has led to increased soil erosion and sedimentation of lake Nakuru.

Conclusions

The use of remotely sensed data showed that eastern Mau has had a significant change in land use cover over the last 40 years. The temporal images showed the pre-change and post-change cover types. The landsat image of 1973 clearly showed rich vegetation cover. Deforestation, land fragmentation, cultivation of wetlands and rapid increase in human settlements have had negative impacts on water sources resulting in reduced stream flows and water shortages. Groundwater sources continue to dwindle, necessitating the sinking of new and deeper wells and boreholes in places like Egerton University and farms around Njoro. Inadequate or lack of data on hydrology, meteorology, biodiversity and land use in eastern Mau inhibits proper development and management. The study showed that remotely sensed data can provide information for effective routine tasks related to environmental inventorying and monitoring. The results from manual interpretation closely matched those of supervised classification of the landsat image shown in figure 9. Since manual interpretation is cheaper, its use will go a long way in providing data for managing the Mau complex which is an important water tower in Kenya by remotely sensed data and hence enable sustainable development of resources in this part of Kenya.

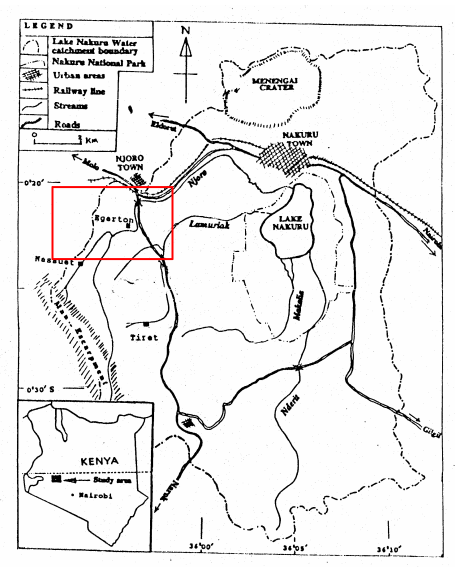

Figure 3: The study area is shown in red line

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