Monitoring Deforestation in Kenya

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Abstract
Multi-temporal data is used to determine the rate of deforestation between the years 1976, 1987 and 2000. Three Landsat TM images, for each period, are pre-processed, mosaicked and normalized difference vegetation index (NDVI) values computed. Based on the values, totally non-forested areas are masked out. The forested areas, both partially and wholly, show a very high degree of correlation between all the bands (reflective), thus necessitating application of principal component analysis. The first two principal components and NDVI values (scaled to 0 – 255) are used in K-means unsupervised classification to distinguish forest from non-forest areas (that appeared as forest at first).
Comparison of the resulting thematic maps gives an annual deforestation rate of roughly 15 0000ha. or 2% between any two epochs.

1 Motivation

Only 2% of Kenya is forested (against 9% and 21% for Africa and the world, respectively). The figure is far way below the United Nations Environmental Programme (UNEP)-recommended per-country one of at least 10%. The socio-enviro-economic role the forests have and continue to play in the daily life of the citizens cannot be overemphasized. However, encroachment has been an ongoing process regardless of the impact and ramifications. Comprehensive studies have not been carried out to determine the rate of deforestation.

2 Objective

The study focuses on determination of the rate of deforestation in Kenya between the years 1976, 1987 and 2000.

3 Study area

The study area is located in the third quadrant of the country (figure 1) where many of the remaining forests are found. Most of them are water catchment areas and have rich biodiversity including unique and rare fauna and flora.

4 Deforestation studies

Nowadays deforestation is a buzzword in environmental problems – a tree cut down is at the very least a double tragedy; a tree less in carbon sinks and a tree-worth of more pollution. Almost all researches paint a grim picture of the trend world forests are taking. Though domestic factors are mainly to blame, demand for wood products in the developed world is fuelling deforestation in the other countries. Around 80% of all tropical timber consumed in the US originates from Indonesia and Malaysia. In Japan, 54% is from Malaysia.

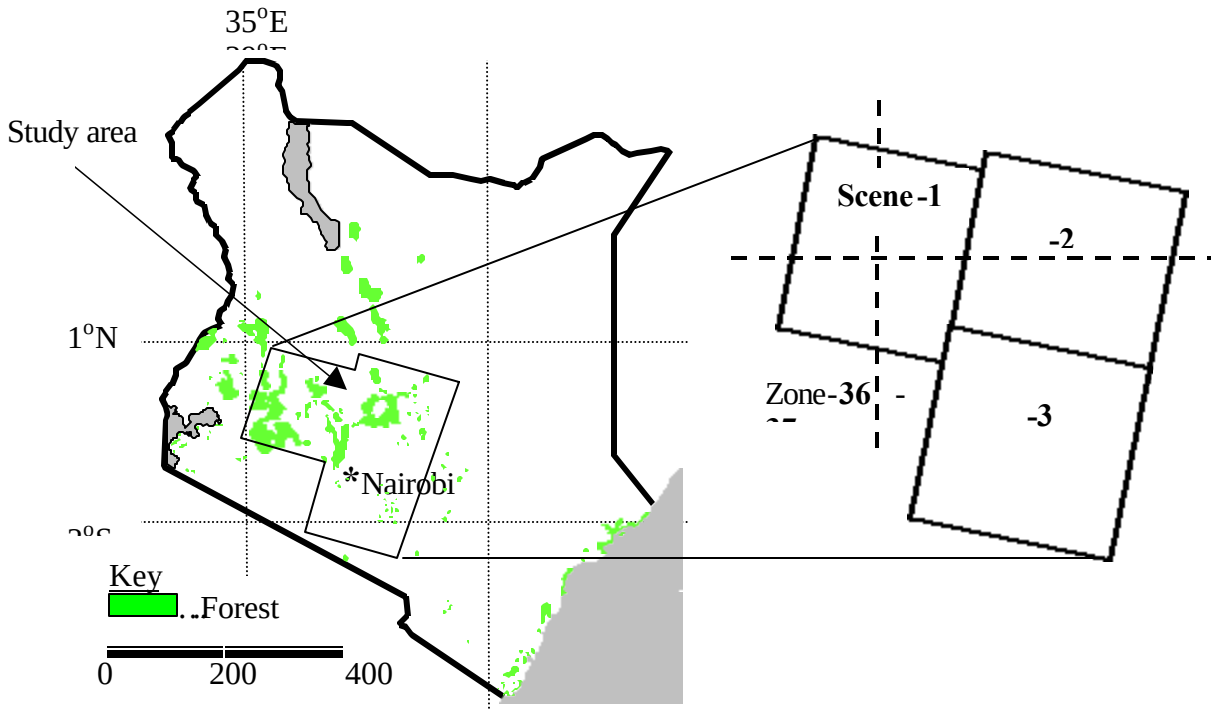

Figure 1: Location of the study area

5 Data

Three Landsat images for each of the three scenes (figure 1) are utilized (table 1).

Table 1: Landsat data used
(ETM+ = enhanced thematic mapper plus, TM = thematic mapper, MSS = multi-spectral scanner)

S. No.	Sensor	Path / row	Date of acquisition	Code	Scene
1	Landsat 7 ETM+	169 / 60	03 / 04 / 2001	ETM1	1
2	”	168 / 60	21 / 02 / 2000	ETM2	2
3	”	169 / 61	”	ETM3	3
4	Landsat 5 TM	169 / 60	28 / 01 / 1986	TM1	1
5	”	168 / 60	25 / 02 / 1987	TM2	2
6	Landsat 4 TM	169 / 61	17 / 10 / 1988	TM3	3
7	Landsat 2 MSS	169 / 60	25 / 01 / 1976	MSS1	1
8	”	168 / 60	24 / 01 / 1976	MSS2	2
9	”	169 / 61	11 / 02 / 1976	MSS3	3

6 Image (pre) processing

6.1 Image geo-coding/registration and validation

The ETM images are geo-coded to topographical maps of scale 1:50 000. A map interpolation accuracy of 20m is deemed okay for the image resolution of 30m. One image straddles zones 36/37 border and another one the equator (figure 1).The processing software used (ENVI 3.4) doesn’t handle two zones’ or both hemispheres coordinates

simultaneously. The problem is circumvented by reducing zone-36 coordinates to zone 37 and southern hemisphere coordinates to northern hemisphere.
The geo-coded images are then validated against the maps using non-GCPs (ground control points). TM and MSS images are registered to the rectified ETM images and validated against the maps. Table 2 shows the average RMS errors of GCPs and validation points (VPs) of the images. The errors are less than one pixel size of respective images.

Table 2: RMS errors of GCPs and VPs

Image	ETM1	ETM2	ETM3	TM1	TM2	TM3	MSS1	MSS2	MSS3
GCP	26m	24m	24m	0.4pxl.	0.3pxl.	0.4pxl.	0.4pxl.	0.5pxl.	0.7pxl.
VP	18m	21m	21m	21m	20m	19m	42m	58m	52m

6.2 Normalization

For each period, scene-2 image is the basis. Overlapping forested areas' DNs are compared and the average difference in each band applied to the entire band.

6.3 Mosaicking and trimming

The now spatially referenced (and normalized) images are mosaicked (period by period) and the mosaics trimmed down to common geographical coverage.

6.4 Normalized Digital Vegetation Index (NDVI)

Each mosaic is NDVI'd. NDVI values representing wholly- and partially-forested areas are used in formation of a mask to block out the other areas.

6.5 Principal Component Analysis (PCA)

The 'forested' areas exhibit a very high degree of correlation between all the bands (reflective), thus necessitating application of PCA.

6.6 Classification and identification of forest clusters

K-means unsupervised classification is ran on PCs 1 & 2 and NDVI (scaled roughly to 0 – 255) combination for each of the mosaics. On the basis of topographical maps, aerial photographs and experience, resulting clusters (50) are grouped into forested and non-forested areas that appeared as forest initially. Figure 4.

6.7 Accuracy assessment

Ground truth sites are randomly selected by people with no knowledge of the research area. From the sites, pure forest and non-forest pixels are used in computation of accuracies. Table 3.

Table 3: Accuracies of classification images

Accuracy	Producer's	User's	Overall	Kappa	Overall forest accuracy
ETM	99.77%	98.99%	99.46%	98.90%	98.76%
TM	99.11%	99.81%	99.29%	98.45%	98.92%
MSS	99.24%	97.26%	97.96%	95.82%	96.52%

7 Results

From thematic maps, forest acreages for the three epochs and deforestation acreages and rates between them are as shown in table 4.

Table 4: Forest acreages and deforestation acreages and rates

Year	Acreage		Period	Deforestation acreage		Period	Deforestation rate
1976	1,088,611±37,884		1976-1987	169,573±39,163		1976-1987	15,416±11,808
1987	919,038±9,926		1987-2000	182,604±13,448		1987-2000	14,406±3,740
2000	736,434±9,132		1976-2000	352,177±38,969		1976-2000	14,674±7,955

8 Observations

Although not part of the study, it is worth mentioning that;

- Generally, the new landcovers are crops and human settlements inside and at the fringes of forests, respectively
- Ironically, UNEP headquarters is located in previously forest land
- The research introduces a new accuracy: **per-class overall accuracy**

9 Conclusions

- At the current rate of deforestation, ≅15 000ha./yr., all remaining forests are bound to disappear in 50 years
- Generally, deforestation rate' s consistent for the 24 years.

10 Recommendations

- Deforestation stoppage, reforestation and afforestation should be deemed as long-term means of solving the problem (deforestation). However, regeneration should be given a chance before reforestation
- There is an urgent need to comprehensively determine not only the causes of deforestation but as well as the underlying factors
- Alternative sources of resources from forests need to be harnessed/formulated
- Measures ought to be put in place for sustainable exploitation of forests.

References

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