Application of Remote Sensing in Deforestation Monitoring: A Case Study of the Aberdares (Kenya)

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Key words: Remote Sensing, Deforestation, Unsupervised Classification, Normalized Difference Vegetation Index (NDVI) and Change Detection.

SUMMARY

Reported cases of deforestation in the Aberdares have drawn substantial concern due to the value of this forest resource. The Aberdares is a water catchment for many rivers and streams, which traverse a large section of Kenya, providing fresh water to millions of Kenyans including more than 3 million Nairobi residents. It is in this view that a project was carried out to analyse the extent of deforestation in the area within a period of 13 years between 1987 and 2000. Landsat TM images were used as a source of data. The images were processed and analysed using IDRISI software. The analysis involved carrying out post classification change detection. Unsupervised classification of images of different epochs was carried out and then areas of the resultant classes compared for change detection. This analysis reflected a significant decline in forest cover within the period of study. Normalized Difference Vegetation Index (NDVI) differencing was also employed as a support technique to determine change in biomass. This paper presents the results of the study and advances suggestions on policies that can be employed to mitigate the depletion of this forest and other vulnerable forest resources in the country and the world at large.

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1. INTRODUCTION

Forest resources contribute significantly to Kenya's economy. The Agricultural sector, manufacturing and processing industry and the tourism sector which are the backbone of the country's economy directly or indirectly rely on our dwindling forest resources. Kenya's major river systems (Tana, Athi, and Ewaso Nyiro) source their water from mountain forest catchments. These rivers traverse the country, providing fresh water for domestic use, industrial processing, irrigation and hydro-electricity generation. River Tana alone supplies water for the seven folk hydro-electric power stations, providing more that half of the country's electricity. In addition, forests provide building and weaving materials, pulp for the paper industry, herbal medicine, wild fruits and honey, regulate rainfall patterns, reduce sedimentation load in our rivers and provide environmental stability.

Once thriving on 56.9 million hectares (15% of Kenya's land area), now closed canopy forests cover only 1.4 million hectares which is less than 2% of the county's land area (Kenya Forest Working Group). Kenya is thus environmentally unstable. According to the *United Nations FAO*, "Any country with less than 10% of its land covered by forests is environmentally unstable." *(United Nations FAO)*. There is eminent danger of depletion of our forest resources beyond these worrying levels. Increased logging of indigenous trees, illegal charcoal burning, illegal cultivation, grazing and settlement on our remaining forests poses a great danger to the lives of Kenya's present and future generations together with her ailing economy. Notable among deforestation effects is falling of our river flows and water levels at the hydro-electric power stations. Power rationing in 2000 that adversely hit the economy was as a result of the low water levels. There was also reduced water supply to town municipalities which touched lives of many. With the shrinking water levels, irrigation has been affected leading to reduced crop yields.

Although the effects of deforestation are clear and biting hard, the former Kenyan government did not adequately commit itself to addressing the problem. The gazetting of a notice to excise 167,000 hectares of forest land in February 2002 confirms this, especially considering that the gazette notice came just after it had signed the Environmental Bill meant to help curb environmental degradation. The future of our forests is however, not yet bleak with the wake of new governance with numerous promises to address the issue. The suspension of a record 823 forest officers on 24th October 2003, including the Chief Conservator of Forests for abating deforestation *(Daily Nation, Nairobi. 25th October 2003)* adds to the optimism.

Combating deforestation requires factual information on what is going on in our forests. This is however, not readily available. Remote sensing is a very powerful tool in the provision of such information. It involves the acquisition of information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, phenomenon or area under investigation *(Lilesand and Kiefer, 19871987)*. It has come to be associated more specifically with the gauging of interactions between earth surface materials and electromagnetic energy. Sensors aboard satellites in space record the amount of electromagnetic energy reflected from various objects on the earth's surface at various wavelengths. From the spectral response patterns, information about the objects is derived.

Through the analysis of remotely sensed data for different epochs, change detection is possible. With time changes analysis, monitoring of forest destruction can be done. The knowledge acquired from this information forms a basis for decision making in efforts to address the deforestation menace. It is with this in mind that this project was carried out to establish factual information on the state of the Aberdare forest whose reported danger of extinction has attracted attention from the public and many environmental organizations considering the value of this forest resource.

2. DESCRIPTION OF THE STUDY

2.1 The Study Area

The Aberdare forest is located on the Aberdare Range in the central province of Kenya. It lies on the equator at a longitude of 36^0 45'. It stretches 130km North-South from Nyahururu to Limuru. Its highest peak has an altitude of 4000m above sea level. The range has a rugged topography that slopes gradually to the East.

The area experiences rainfall in two seasons. One season is between April and May and the other comes later in the year between October and November. The Eastern slopes which fall on the windward side receives the highest rainfall (up to 2600mmper year) while the leeward western and Northern slopes receive the lowest (less than 1000mm per year).

The Aberdare forest is one of the five main water catchments in Kenya. Others are Mt Kenya, Mt. Elgon, Mau and Cherengani Hills. The Eastern slopes of the Aberdares together with Taita hills are the source of the Athi Drainage System which covers an area of 67,070 km^2This is the source of Sasuma and Ndakaini dams serving the city of Nairobi and surrounding municipalities with clean water. The Tana River System (The biggest river in Kenya) sources its water from the Eastern slopes of the Aderdares and the Southern slopes of Mt. Kenya and Nyambene Hills. This river supply water to the 7 folk hydro-electric power stations and feed s Mwea, Bura and Tana Delta irrigation schemes. The Northern slopes are a catchment for Ewaso Nyiro River. River Malewa which is the major surface source of Lake Naivasha originate from the North Eastern slopes.

The Aberdares National Park located north of the forest receives more than 50,000 tourists every year. The forest has a rich diversity of fauna and flora which make it of interest to tourists. It is a host to numerous endangered species of international conservation interests.

2.2 Objectives of the Study

The project was carried out to:

- Demonstrate how remotely sensed data can be used to perform spatial change detection and analysis.
- Quantify (in acres of area) the shrinkage of the Abedares forest between 1987 and 2000.
- Propose policies that can help curb the depletion of the Aberdares forest and other forest resources at the danger of extinction.

2.3 Study Material and Data

The satellite data used was Landsat TM images for two epochs (1987 and 2000).The images were obtained from Regional Centre for Mapping of Resources for Development (RCMRD). Topographic maps covering the study area were also obtained from RCMRD.
A personal computer with IDRISI 32 image processing software was used.

2.4 Methodology

2.4.1 Post classification change detection

False colour composites were created using bands 2, 3, and 4 for each of the two epochs.

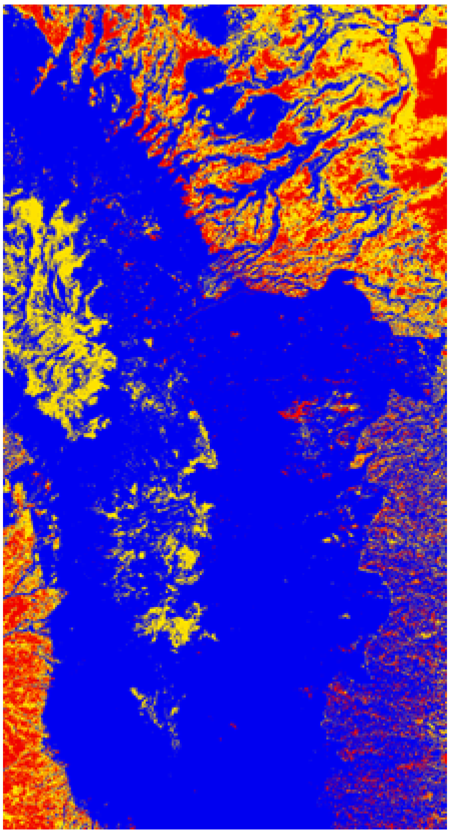
Using the 2000 image (geo-referenced in UTM projection, WGS84 ref. ellipsoid) as a base, the other image was registered to the base image. This was performed using the RESAMPLE module of the software. Linear resampling was performed using four well defined and distributed control points. The result was refined by continued recomputing of the Root Mean Squares (RMS) with improved correspondence file coordinates until an acceptable RMS of below 0.5 was obtained for all control points.

After successful registration, extraction of sub- images of the study area from the whole scene images of the two years was carried out using the WINDOW module. The scene images available did not fully cover the Aberdares forest, but contained more than three quarters of the area. All the contained area was included in the extracted sub-images.

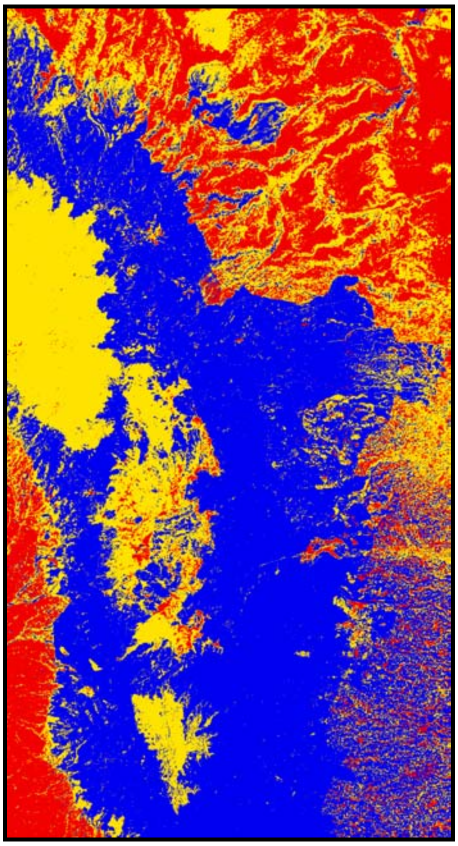
Unsupervised classification was then carried out on each of the images. This was performed using the CLUSTER module. Broad generalization level was adopted. In performing unsupervised classification using the cluster analysis algorithm is used. Pixels with similar reflectance are grouped together into spectral classes out of which information classes are established by the analyst.

Results:

Below are the results of the classification:



a) 1987 classified image



c) 2000 classified image

In the classified images above forest cover is represented by blue colour.

After classification, the AREA module was used to compute areas of the classed that resulted from the classification. Below is a summary of the forested area results:

Forest area 1987 (hectares)	*Forest area 2000 (hectares)*
149267.19	104047.66

2.4.2 NDVI differencing Change Detection

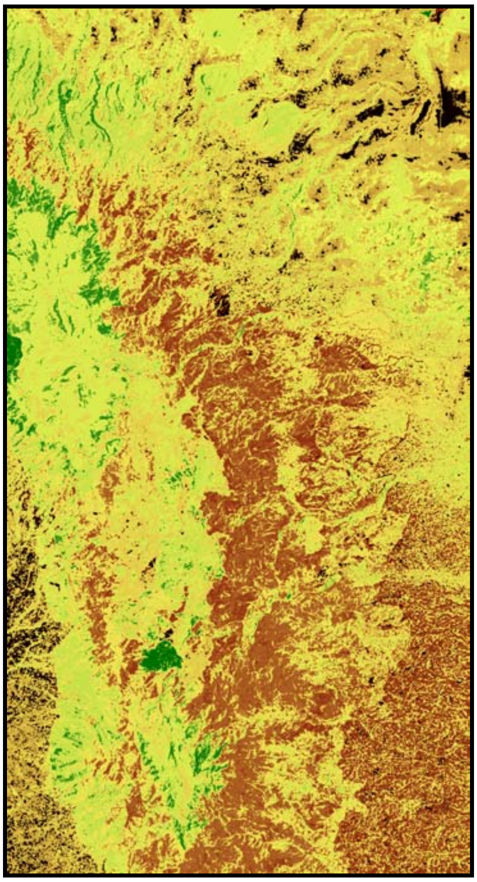
Normalized Difference Vegetation Index is a non-linear transformation of the red and near infra-red bands of remotely sensed data. The index contrasts the absorption features of chlorophyll in the red region of the electromagnetic spectrum and the strong reflectance of the near infra-red region. The index is represented by the equation:

NDVI = (near I.R - Red)/ (near I.R + Red)

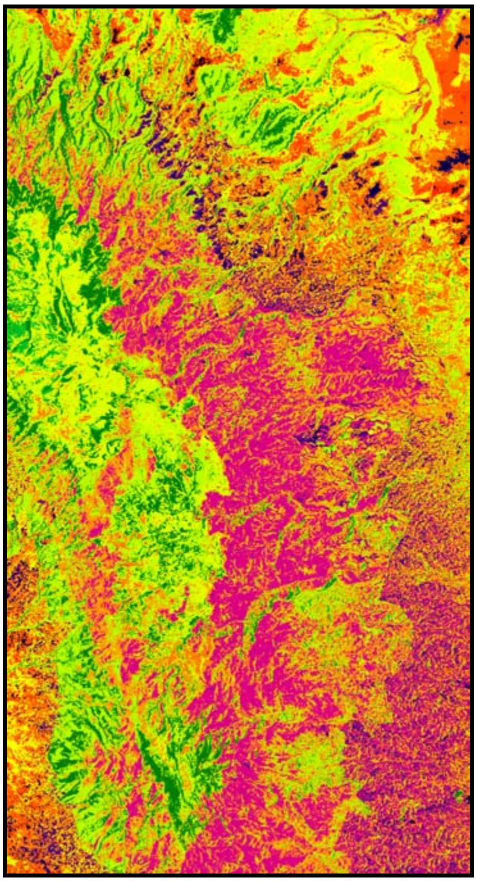
This index is useful as a relative measure for monitoring biomass.

The sub-scene bands 2 and 3 for each were used to create an NDVI image for each year and then differencing of the images was carried out to detect change. Differencing involved the subtraction of the 2000 ndvi image from the 1987 NDVI image using an image calculator in the software.

Below are the results:



a) 2000 NDVI image



b) 1987 NDVI image

Histogram data for NDVI difference (NDVI1987-NDVI2000)

Class	Lower Limit	Upper Limit	Frequency	Cum. Freq.
1	-214.0000	-204.0001	19	19
2	-204.0000	-194.0001	47	66
3	-194.0000	-184.0001	26	92
4	-184.0000	-174.0001	452	544
5	-174.0000	-164.0001	129	673
6	-164.0000	-154.0001	133	807
7	-154.0000	-144.0001	1936	2743
8	-144.0000	-134.0001	666	3409

Class	Lower Limit	Upper Limit	Frequency	Cum. Freq.
9	-134.0000	-124.0001	1303	4712
10	-124.0000	-114.0001	3527	8239
11	-114.0000	-104.0001	2553	10792
12	-104.0000	-94.0001	23220	34012
13	-94.0000	-84.0001	10320	44332
14	-84.0000	-74.0001	4544	48876
15	-74.0000	-64.0001	19860	68736
16	-64.0000	54.0001	39453	108189
17	-54.0000	-44.0001	128760	236849
18	-44.0000	-34.0001	105448	342397
19	-34.0000	-24.0001	81489	423886
20	-24.0000	-14.0001	2366	426252
21	-14.0000	-4.0001	1584	427836
22	-4.0000	4.9999	20507	448343
23	5.0000	14.9999	780301	1228614
24	15.0000	24.9999	340914	1569528
25	25.0000	34.9999	177096	1746624
26	35.0000	44.9999	223959	1770713
27	45.0000	54.9999	217929	1988642
28	55.0000	64.9999	147493	2136135
29	65.0000	74.9999	125078	2261213
30	75.0000	84.9999	17077	2278290
31	85.0000	94.9999	72596	2350866
32	95.0000	104.9999	99799	2450685
33	105.0000	114.9999	91621	2542306
34	115.0000	124.9999	5181	2547487
35	125.0000	134.9999	10585	2558072
36	135.0000	144.9999	36758	2594830
37	145.0000	154.9999	20099	2614929
38	155.0000	164.9999	4967	2619896
39	165.0000	174.9999	24	2619920
40	175.0000	184.9999	28	2619948
41	185.0000	194.9999	48	2619996
42	195.0000	204.9999	387	2620383
43	205.0000	214.9999	4018	2624041
44	215.0000	224.9999	0	2624041
45	225.0000	234.9999	1414	2625455
46	235.0000	244.9999	0	2625455
47	245.0000	254.9999	349	2625804

Actual maximum = 255.0000
Mean = 25.4097
Stand. Deviation = 49.7499

2.5 Analysis of Results

From the post classification results there was a reduction in forest cover area by 45,219 hectares within a period of 13 years between 1987 and 2000. This figure is equivalent to 30% decrease in forest area.

A positive mean of 1987-2000 NDVI differencing is an indication of reduction in biomass within this period of study. This implies a decline in vegetation. It thus confirms the change detected through post classification analysis.

3. RECOMMENDATIONS

Losing 30 percent of a valuable forest resource within such duration leaves a lot to be desired. Both the present and the future generations stand to suffer bitter consequences if this trend goes on. At this rate, if necessary steps are not taken to save the forest this valuable resource will definitely get depleted. Below are policies that can possibly help in curbing deforestation at the Aberdare forest and other threatened forests.

- Exploitation of alternative sources of energy. One of the causes of deforestation is charcoal burning in our forests for wood fuel provision. To ease pressure on the forests resources as a result of this call for alternatives in energy needs fulfillment. Cheap alternatives include biogas, solar energy and wing power. Significant efforts are underway in the exploration of wind power resources in Kenya.
- Re-afforestation. This involves the planting of trees where forests have been destroyed. The government of Kenya ought to take an initiative of supporting re-afforestation programmes through the provision of resources to support the same. Environmental conservation groups need to work hand in hand with the government in conducting tree planting where forests have been destroyed.
- Revoking of illegal forest allocation. In the past, there has been widespread grabbing of forest land by politically well individuals. The government in showing its commitment to addressing environmental issues should come out and not only revoke the allocations, but also take legal action against the culprits. The laying off of 823 forest officers for failing to prevent deforestation by allowing illegal activities in our forests is a big step towards realizing this.
- By passing the Forest Bill. The bill currently on debate in parliament spells out policies meant to support forest conservation. The bill also recognizes the role of the Environmental organizations and community groups. The bill thus ought to be passed to give a leeway to the curbing of forest destruction.
- Through guidance and training. As much as most of the people knowingly deplete our forest resource, there are those who unknowingly do so, for they lack knowledge on the importance of the resource. Educating people (especially in rural areas) on environmental issues will thus go a long way in creating awareness and boosting responsibility in environmental care. The Environmental working groups and Non-governmental organizations have great potential in performing this task.
- By constructing of a perimeter fence around the forest. The process of constructing a 320 km electric fence around the Aberdare forest is on (Bongo W., Colin C., Christian L. and

Gachanja M, 2003). Already 160 km have been fenced and there is a countrywide campaign to raise money to complete the remaining portion. The fence will protect the forest from illegal settlements, cultivation and grazing, logging and charcoal burning.

4. CONCLUSION

The study confirms reports of destruction of the Aderdare forest. The results of the study calls for the government, governmental organizations and the general public to respond fast and address the problem. The problem here is not only to do with the Aberdare forest alone, but also all other forests in the country. Otherwise, the lives of present and future generations are at stake. By adopting the recommended measures, and others which may be appropriate the current situation on our forests is likely to improve**.**

In general, the project was successful since it achieved its objectives. The change in forest cover was successfully quantified using remote sensing data. However, with two epochs, monitoring of change was could not be effected. Efforts are still being made to acquire images for more epochs and keep refining the monitoring process. The study is thus still on and there is an intention to expand the scope to other threatened forests in the country.

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BIOGRAPHICAL NOTES

Hesbon M. Ochego (born 1980), Kenyan

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Professional Organizations:

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Achievements:

- Chairman Surveying Students Association, University of Nairobi –20002/2003
- Vice Chairman Surveying Students Association, University of Nairobi – 2001/2002
- Deputy Secretary General Surveying Students Association, University of Nairobi – 2000/2001

Interests and hobbies:

Research, music, swimming and fitness.

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