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ASSESSMENT OF ANTHROPOGENIC ACTIVITIES AND THEIR IMPACT ON NGONG HILLS FOREST IN KAJIADO COUNTY, KENYA: A REMOTE SENSING APPROACH

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ABSTRACT: *Human beings are dependent on forests for various livelihood needs. Forests offer a variety of benefits, including ecological, social as well as economic benefits. As such, the development and conservation of forests around the world is vital. Monitoring of the forest ecosystem is mandatory in order to detect any changes in the ecosystem. Forest cover change detection gives an opportunity to track the productivity, health and the forest cover as well over the years so as to enable proper management, promote conservation and enhance functionality. Optical and radar remote sensors make it possible to monitor changes by use of various analytical techniques that include visual interpretations. The study investigated how remote sensing can be applied to detect change in forest ecosystem and to assess the rate of change of Ngong Hills Forest in Kenya. The project sought to determine whether anthropogenic activities are the major cause of the change in Ngong Hills Forest. Data from satellite images was analysed from 1984 to 2019 to identify the changes that have occurred on the ecosystem. Landsat and Rapid-Eye images were used to inform on change detection. In this case, rapid eye data was found to be better than Landsat data in informing on change detection because of its high resolution thus high precision and better results. The changes depicted by the remotely sensed data were mapped for ease of analysis and visualization. The research depicted a massive decrease in the forest cover despite the afforestation efforts by the Kenya Forest Service (KFS) in the 1990s. The forest has been depreciating massively from 1995 depicting greater deforestation rates between the years 2010 and 2019. This depreciation has been acknowledged by the KFS as it is said to be occurring due to the anthropogenic activities mainly settlement and logging. The means of detecting change by use of remote sensing is thus able to identify the exact areas that change has occurred and thus provide insight for the Kenya Forest Service and other ecosystem protection bodies on the most affected areas and the extent of change. Once the study area is mapped, it is possible to calculate the areas that have decreased in vegetation quantity, areas where increase has occurred as well as the areas that have remained unchanged. The findings of the study make it possible for management agencies to enforce conservation because of the presence of reliable data.*

KEYWORDS: assessment, anthropogenic activities, impact, Ngong Hills Forest, Kajiado Kenya, remote sensing

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INTRODUCTION

Ngong Forest is located 6 kilometres from Nairobi city. It was first gazetted in 1932 with coverage of over 2,900 hectares. Railway was a key means of transport back then and this forest supplied all timber and its products including fuel. Following a series of legal excisions, this parcel of land was reduced drastically. Some of these illegal practices included land grabbing by private developers. Intense lobbying in the 1990s led by Trustees of Ngong Forest Road Sanctuary secured the forest with acreage of 1,224 hectares. In 2005, the Forest Act 2005 was assented into law. It is at this point that the Kenya Forest Service (KFS) was given the mandate to protect the forest (Republic of Kenya, 2005). This Act has since been repealed by the Forest Conservation and Management Act 2016, to comply with the Constitution of Kenya 2010.

The forest is under the management of the Ngong Road Forest Sanctuary Trust. The Sanctuary protects, conserves and manages the forest of over 80 percent indigenous trees and the rest exotic eucalyptus plantations within the Ngong Road Forest Reserve. The forest is rich in biodiversity and is home to more than 35 mammals and numerous insects, 120 bird species, amphibians, and fish. The goal of the Trust is to secure the natural environment and create a multifunctional and self-sustaining reserve which is meant to serve educational, social as well as the economic needs of the dependent communities.

The use of remote sensing data for change detection means the changes in the land cover will definitely lead to the changes in the radiance values as well as changes in the radiance. According to Ingram *et al.* (1981), the changes in radiance caused by changes in land cover have to be large with respect to the changes in radiance that are caused by other factors such as the differences in the sun angel, changes in the atmospheric conditions and soil moisture differences. The effect caused by these factors can however be reduced by selection of the appropriate data. For instance, Landsat data belonging to the same time of the year, for instance February 1995 and February 1996, lead to reduction of the problems from vegetation phenology changes and sun angle differences.

Anthropogenic Activities

The drivers of forest biodiversity loss can be categorized as either primary or secondary. The primary drivers include human activities, such as fragmentation and destruction or change of land use, over-exploitation, invasive species and the indirect human activities as well, which in the long-run lead to climate change (Millennium Ecosystem Assessment, 2005). According to Barlow and Peres (2004), the primary drivers can induce the secondary effects such as altered disturbance dynamics. Of relevance to this paper are the four major anthropogenic activities that cause biodiversity loss.

Fragmentation and Deforestation

Change in land-use greatly affects forest biodiversity (Sala *et al.*, 2000). The clearance of forests destroys the ecosystem and leads to a decline in forest diversity and species. Due to deforestation, the new plants and animals will be the determinant of the biodiversity. For instance, after the primary forest has been cleared and there is a regeneration of the secondary forests, they might never get to the same composition and species richness as with the primary forest (Chazdon, 2008). Apart from destruction of the habitat, the clearance of forests might lead to the fragmentation of the remaining part of the forest thus leaving the parts that are excessively small for species to live comfortably or survive (Fahrig, 2003).

Over-exploitation

The over-exploitation of species can result in their extinction in the long-run. Milner-Gulland, Bennett and the SCB (2003) hold that the most common form of exploitation of species is where the large mammals are exploited for bush-meat and the harvesting of hardwood for timber. Risk exists when over-reliance on these species is inevitable; as such, strategies have been adopted to ensure conservation and management of forests is a collective communal responsibility. However, observations indicate that these factors are largely driven by economic demands over social behaviours.

Kenya Legal Frameworks on Forest Conservation

The Kenya Forest Conservation and Management Act, 2016 (Republic of Kenya, 2016) provides for, "the protection, rehabilitation and maintenance of forest ecosystem." This is meant to benefit each and every citizen by making sure there are sustainable utilization, exploitation, management and conservation of the natural resources while making sure the 10% forest cover is maintained. Every individual thus has a duty to conserve and protect forests. The Constitution of Kenya, 2010 in article 69, "provides for the development and sustainable management, including conservation and rational utilization of all forest resources for the socio-economic development of the country and other connected purposes" (Republic of Kenya, 2010). This Act has established a number of monitoring units in charge of forest covers; this includes the KFSB, whose role is to develop the annual forest resource assessment report and a forest status report every two years. The Act also provides that County governments shall adopt the Act and protect the forest covers within their jurisdiction; to ensure participatory development of regulations and policies.

Invasive Species

Invasive species are those that are established away from their natural range. Introduced species, on the other hand, are ones that have been established away from their natural range mainly by natural actions. According to Bradshaw, Sodhi and Brook (2009), both the introduced and invasive species can alter the Abiotic environments, cause extinction, introduce diseases or become pests. These species in most cases target species possessing lower reproductive potential. For instance, in the island of Guam, the introduction of the brown snake has led to the extinction of 12 native birds (Wiles, Bart, Beck & Aguon, 2003). Therefore, invasive species might be the lead cause of native species loss or might be enjoying the benefits of habitat modifications. According to Denslow and Walt (2008), intact forests are resistant to invasion majorly because of the high number of species, exclusion rates that are highly competitive and functional group richness. Invasive species, however, can take advantage of the disturbed forests and cause a great impact to their recovery.

Climate Change

Climate change rivals land-use change as it affects forest biodiversity greatly. Many studies have revealed that climate change causes the plant and animal species to shift to higher elevations and latitudes as these species expands to the areas that fit them climatically and contracts in the areas that pose to be warm (Wilson, Davies & Thomas, 2007). Climate change also leads to mismatches between the species that interact for instance mismatch between the pollinators and the plants (Stenseth & Mysterud, 2002). The change affects species indirectly by causing a reduction in the availability and the amount of habitation environment. However, it is quite hard to delineate the link between changes in species richness and climate change because of several other variables that are involved.

Forest Ecosystem Changes Monitoring System

Over 40 countries are under the support of the Food and Agricultural Organization (FAO), which assists them in developing their NFMS as well as carrying out assessments (FAO, 2014). It aims at developing efficient forest resource information that can be beneficial in the creation of reliable national forest policies and achieve sustainable development. Forest monitoring systems comprises of measuring, reporting and verification also known as (MRV) functions and it is aimed at the production of high quality data on forests. The components of NFMS include SLMS and NFI.

Satellite Land Monitoring Systems

FAO is at the forefront in helping countries in the identification and collection of activity data for each country's REDD+ activities. For instance, data on afforestation and deforestation is collected from satellite data. SLMS can be used to monitor changes. FAO facilitates and supports the country's processes to put in place the capacities to design, conceptualize as well as implement a functional SLMS as well as monitor forest changes.

National Forest Inventory

The NFI is designed to monitor the macro-changes of forest resources at every 5 years on a continuing basis in terms of forest, quality, quantity and functions. NFI is aimed at is to identifying forest volume, extent, consumption, growth, function as well as their dynamics during the interval of NFIs (FAO, 2014). In addition, the brief on national inventory in India states that NFIs provide basic statistics to help in providing guidance for forest management, making forest policy, and development of plans for forestry development and ecological conservation (FAO, 2014).

Techniques for Change Detection

Remote sensing is the acquisition of information about an object or phenomenon without physical contact with the object. It is useful in monitoring forest activities including deforestation processes using visual and digital analysis. Satellite images are valuable tools for easy and fast access to areas that face some ecological disasters or protected areas. They have an advantage of covering a wide area, the ability to view quickly an area and evaluate their situation, where the consequences of the calamity hinder the other types of approach, are key factors in management of the recovery actions after the event.

Univariate Image Differencing

This technique subtracts spatially registered images of different time periods for instance T1 an T2, pixel by pixel in order to come up with a new image which is a representation of the change between the two time periods. A difference distribution is yielded for each band in this procedure. Stauffer and McKinney (1978) aver that pixels showing radiance change in this distribution are located in the tails of the said distribution while the pixels, which show no change in the radiance, are grouped at the mean.

Image Regression

In this method, assumption is made that T1 pixels are a linear function of the pixels at T2. The regression techniques makes accounts for the differences that occur in the mean as well as the variance between the pixel values for the different dates so as to reduce the adverse effects from differences in sun angles and atmospheric conditions.

Image Rationing

Image rationing is considered as one of the fastest means of depicting change (Howarth & Wickware, 1981). Two registered images having different dates and either one or more bands in one image are rationed band by band. The data are then compared on a pixel basis. In areas where change has occurred, the ratio value should be greater or less than one (1) this is depending on the nature of the changes that have occurred between the two dates.

Vegetation Index Differencing

Spectral radiance values as per what is recorded on a Landsat computer compatible tapes (CCTs) can be independently analysed on a band to band basis or two or more bands can be combined. Curran (1981) and Tucker (1979) argue that band rationing is the most commonly used band combination technique, which is used in vegetation studies. Rationing two spectral bands normally negates the effect extraneous multiplicative factors might have on sensor data which act equally in all the wave bands used for analysis (Lillesand & Kieffer, 1979). The difference in vegetation indices should be able give an avenue for checking whether the vegetation cover has been altered (Nelson, 1982).

Post-classification Comparison

This is the most commonly used method of detecting change. It involves comparing independently produces classified images. By cording appropriately classification results for images of different times, the analyst is able to produce several change maps, which shows the changes that have occurred. In addition, grouping of classes selectively into different classes allows the analyst to have a closer look to the changes that may be of interest. In post-classification comparison data from two dates are classified separately thus reducing the problem of normalization of sensor and atmospheric differences between the two selected dates. If one however considers the land cover classification that is generated from a single date of Landsat data, it is quite easy to see that the change map product of multiplying the accuracies of each classification (Stow, Tinney & Estes, 1980).

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Satellite imagery supports: Landsat 4 and 5 Thematic Mapper ™, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Satellite pour l'Observation de la Terre 4 and 5 (SPOT), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Earth Observing-1 Advanced Land Imager (ALI), and the Moderate Resolution Imaging Spectrometer (MODIS) (Matthew, David, Erik, Bernard, Christopher & Alice, 2008). According to the United States Geological Survey (USGS) (2017), satellite imagery especially the Landsat images have been used in various countries such as Canada to monitor forest cover changes. The Landsat data has been put in use for detection of these changes, identification of the year the changes occurred as well as the estimation of the change type such as wildfire or forest harvest. There was application of change detection approaches to the annual tine series data, which has enabled the detection of abrupt changes such as fires as well as the gradual changes such as drought. These time series data can be used to detect the recovery of forests after a disturbance has occurred. By monitoring these changes, scientists are able to prepare for any future changes by use of trend model developments.

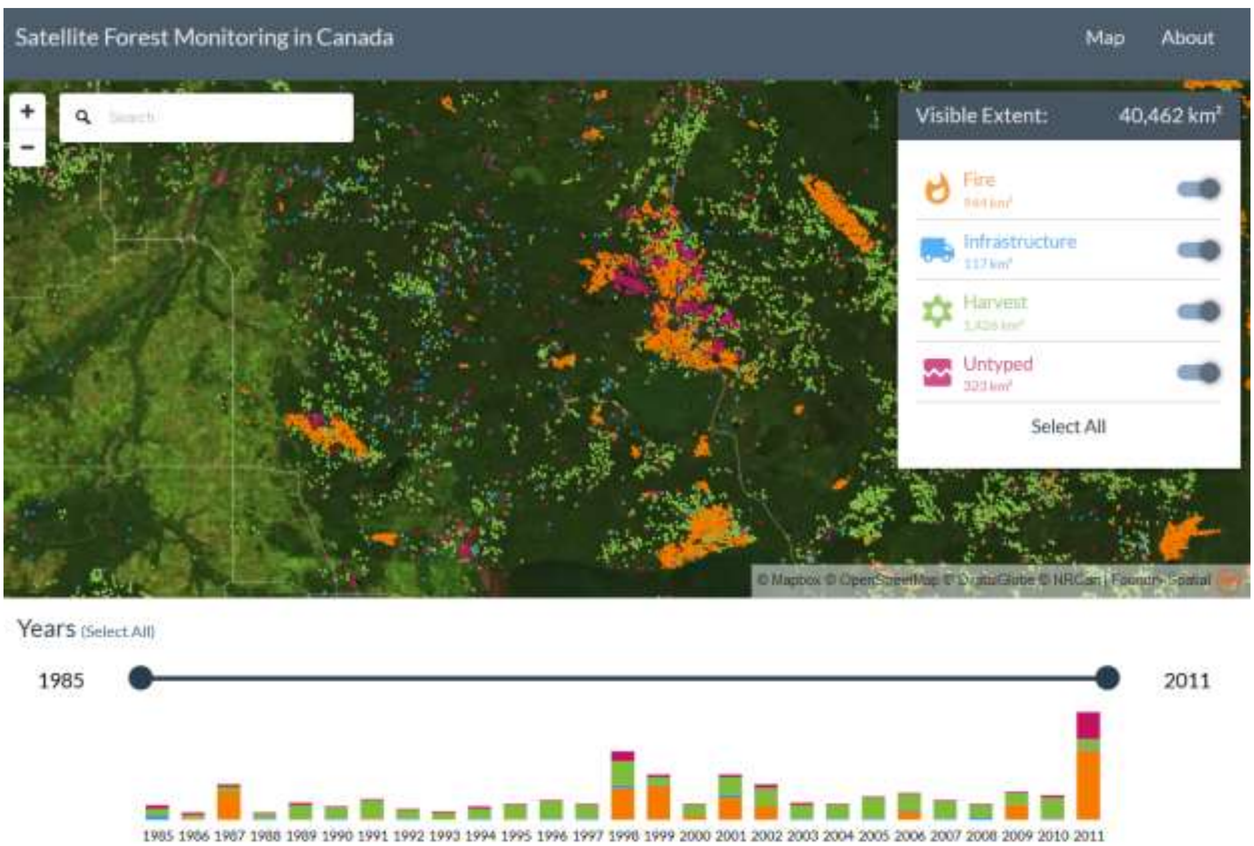

Figure 1: Satellite Image showing forest change detection in Canada

The above is a screenshot of an image acquired from the USGS website showing how Canada has incorporated forest monitoring in acquisition of data for change detection this is a section of central Alberta and it depicts changes on the land surface by use of coloured points. The scale shows the changes that have occurred over the years from 1985 to 2011 (USGS, 2017). The study used the

Landsat images to analyse changes that have taken place since 2010-2018 this will give us a basis, as the Kenya Forest service reports give us the evaluative factors observed in the images.

Statement of the Problem

Forest ecosystems especially in Kenya face a lot of disturbance and fragmentation. This is majorly because of the increasing population, development and overdependence on forest products such as timber, and a variety of foodstuffs. The main cause of disturbance has been natural causes including fire and topography. This has contributed to diminishing forests over the years. Kenya being a developing country is majorly dependant on the natural ecosystem as a source of livelihood for both subsistence and export use.

The forest management agency such as the Kenya Forest Service has to ensure continuous monitoring of this ecosystem for them to effectively carry out their mandate. Inventories have been used for quite a long time to build national databases necessary for integrated monitoring of forests and are central to conservation. They give direction on the best management and conservation practices and have a great potential for the improvement of forest management strategies. As much as one appreciates the use of inventories in management of this ecosystem, the information it provides is hardly sufficient.

Management of forests is increasingly an urgent challenge worldwide. Forests are degrading at a very fast rate and thus posing socio-economic implications creating global concerns. This is due to an impact on the environment due to loss of biodiversity as well as climate change. There is a rising need for effective forest monitoring interventions due to the diversity of these ecosystems worldwide. Technological systems have been established to aid in effective and real time mapping and monitoring of ecosystem changes. For instance, the use of remote sensing to monitor forest ecosystem has been widely adopted in countries like Canada, Brazil and India.

The Department of Resource Surveys and Remote Sensing which is mandated to conduct forest monitoring to reduce conflict of interest where KFS was the monitoring unit and the overall lead in protection of forests. Therefore, the study reviewed previous reports and data since 2010 to 2018 to understand the ecosystem changes in Ngong Forest. These changes will be focused on land cover and biodiversity. The use of remote sensing technique in particular the Landsat will be used as it is cost effective, less time consuming and requires less manual labour. Landsat data is updated on a yearly basis and thus help speed up forest change detection.

MATERIALS AND METHODS

The study adopted a time series study design. This involved the collecting data for four epoch then analysing this data to assess whether there has been an increase or decrease in the vegetation cover. The study majorly involved three phases. These are: the preparatory phase, data collection phase and data analysis. For materials, satellite images for the year 1984 and 1995 were downloaded from the USGS website. High-resolution images from Rapid eye were downloaded from planet labs. The software used for analysis of these data was ERDAS Imagine and ARC GIS was used in map creation. GPS points were collected from KFS. These points were for the years 1984, 1995, 2010 and 2019.

Primary data was collected through unstructured interviews that were carried out to the KFS personnel so as to determine the cause of the degradation of the forest and also to gain insight on the measures that have been put in place to ensure restoration of the forest. Secondary information was collected from the free published and unpublished journals, articles, reports and satellite images. Satellite images downloaded were then fed into remote sensing software (ERDAS). The images for 1984 and 1995 were layer stacked in order to combine the different bands. The 2010 and 2019 images acquired from rapid eye were already layer stacked upon downloading and thus required mosaicking since there were two scenes. Mosaicking was done in order to combine two scenes to cover the study area fully. The four images were then clipped to cover the study area. Training sets were created and supervised classification was done on the four images. Change detection was done as the final step so as to identify the change that has occurred over the years.

The images for 1995 and 1984 acquired from Landsat 5 were layer stacked to combine the 7 bands. The 2010 and 2019 images acquired from rapid eye required mosaicking since it provided two scenes for the study area. Clipping was done by use of the shapefile provided by KFS. This was done purposely to remain with the study area (Ngong Hills Forest). The clipped images for each year are as shown in the Figures 2, 3, 4 and 5.

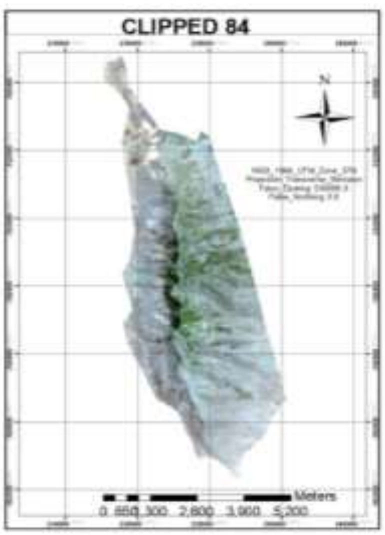

Figure 2: 1984 Clipped Image

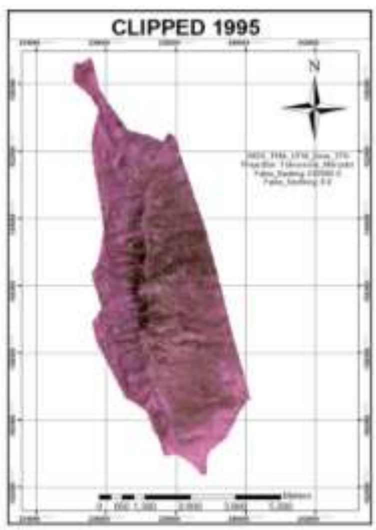

Figure 3: 1995 Clipped Image

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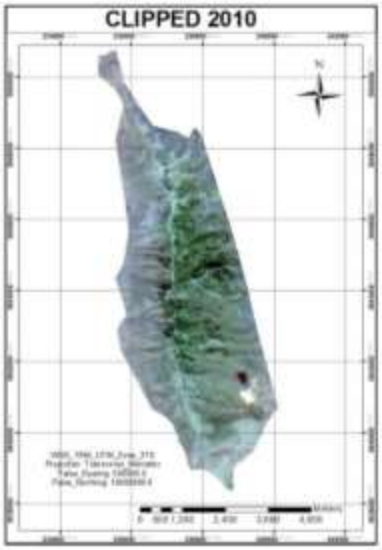

Figure 4: 2010 Clipped Image

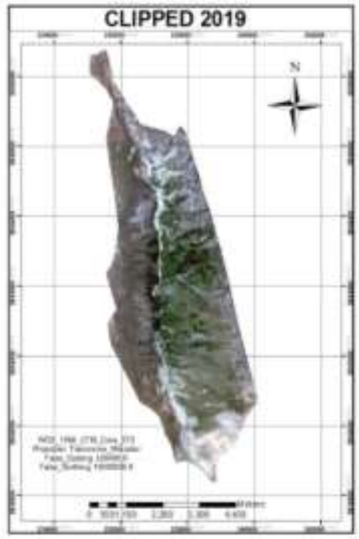

Figure 5: 2019 Clipped Image

RESULTS

Supervised Classification

Supervised classification was carried out on all the four images through the creation of training sets. The following three classes were extracted: Dense, sparse and bare land and settlement. The area classified as sparse is composed of grassland, shrubs, bushes and trees that are scanty. Bare land was merged with settlement because most of the bare areas are populated and include roads to the populated areas as well. The maps below depict the supervised classification of the various years.

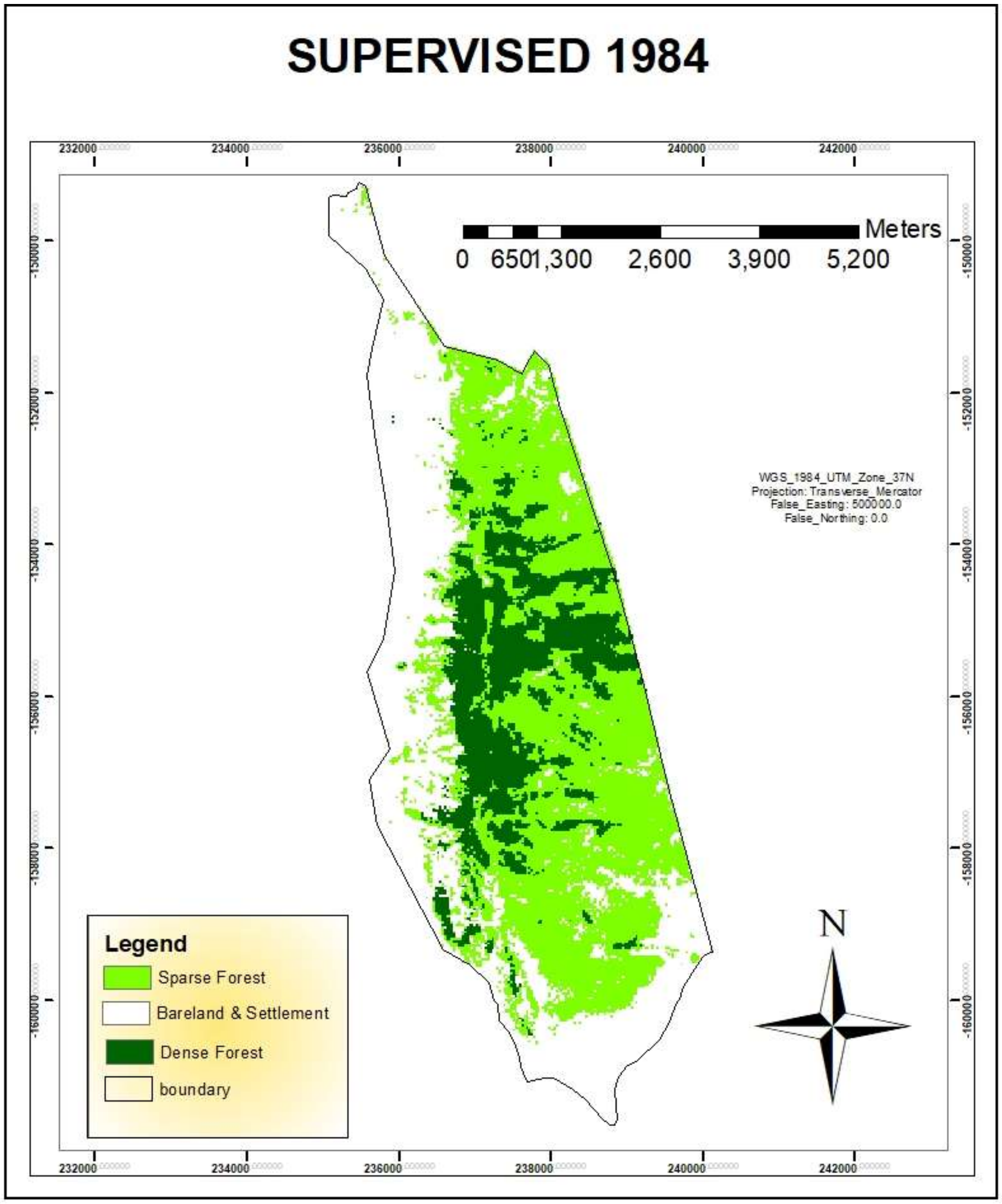

Figure 6: Supervised classification 1984

Figure 6 depicts supervised classification for the year 1984 having the sparse at 21.70%, dense vegetation at 8.67% and bare land and settlement at 18.79%.

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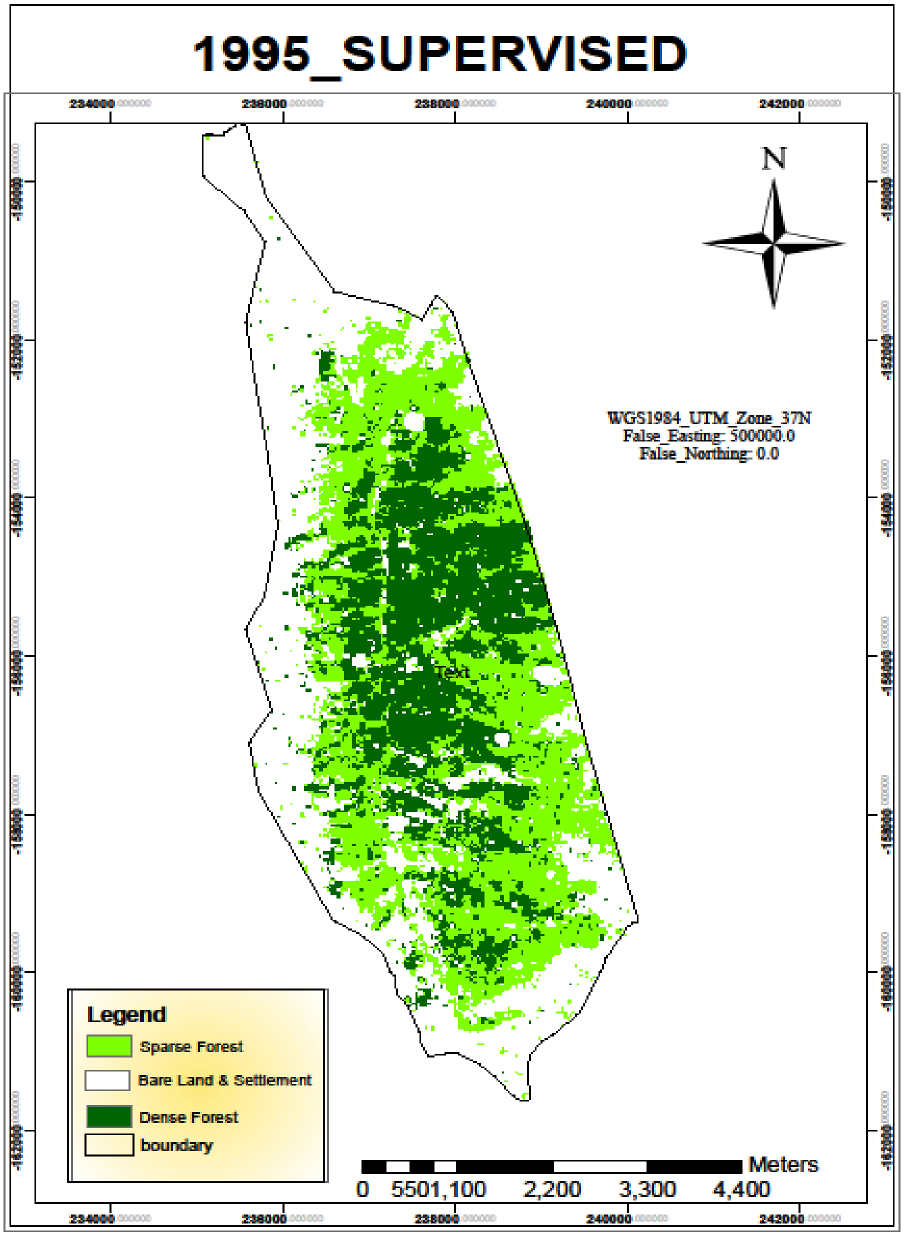

Figure 7: Supervised Classification 1995

Figure 7 shows the 1995 supervised classification map with bare land and settlement at 19.10%, Sparse 16.98% and Dense at 13.08%. This increase in the dense vegetation has been attributed to afforestation. The forested area increased by 4.41% due to afforestation efforts by KFS coupled with better rainfall experienced in the same year.

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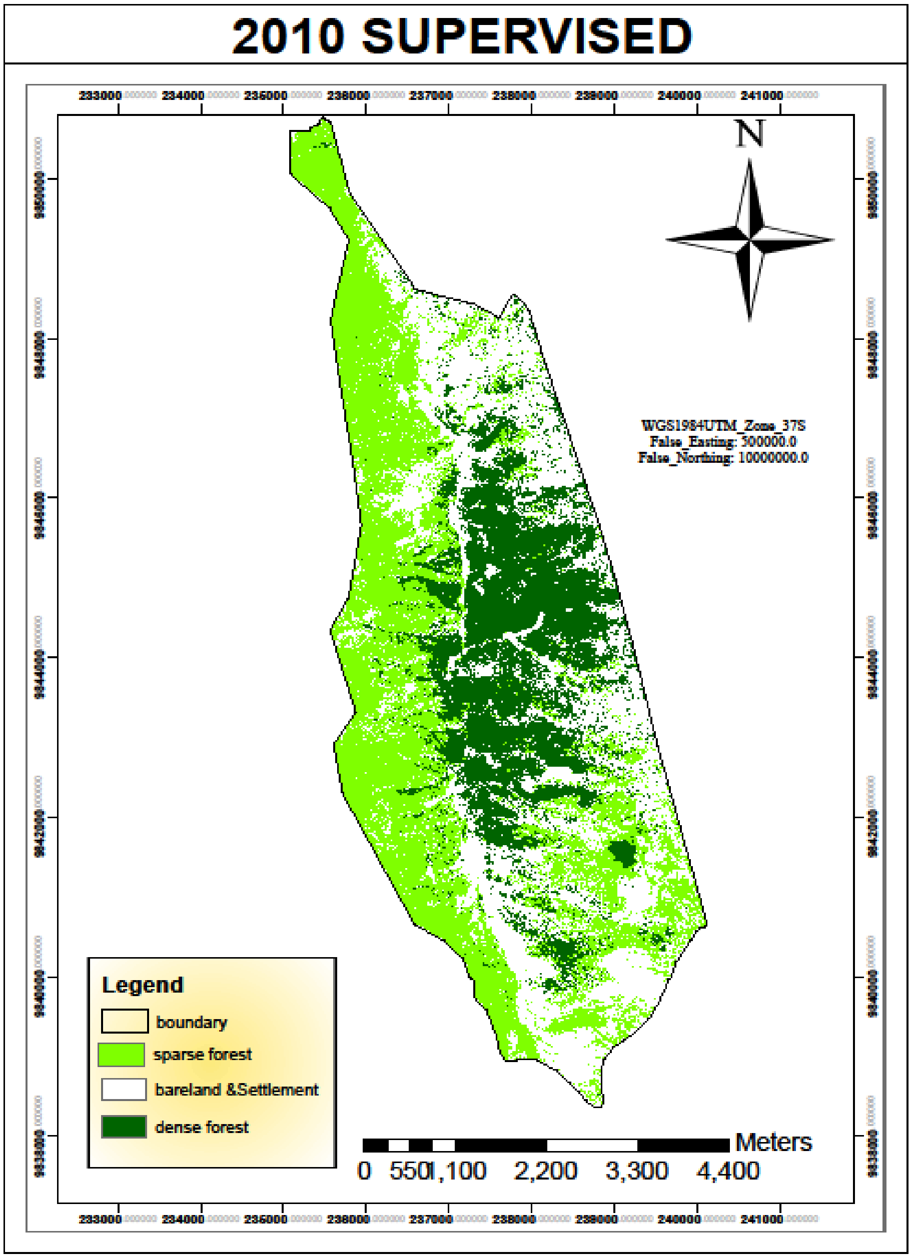

Figure 8: Supervised classification 2010

Figure 8 depicts supervised classification for 2010 with sparse vegetation at 19.11%, dense vegetation at 12.34% and finally bare land at 17.39%. The densely forested area is seen to have decreased by 0.74% as compared to the year 1995. This is attributed to logging.

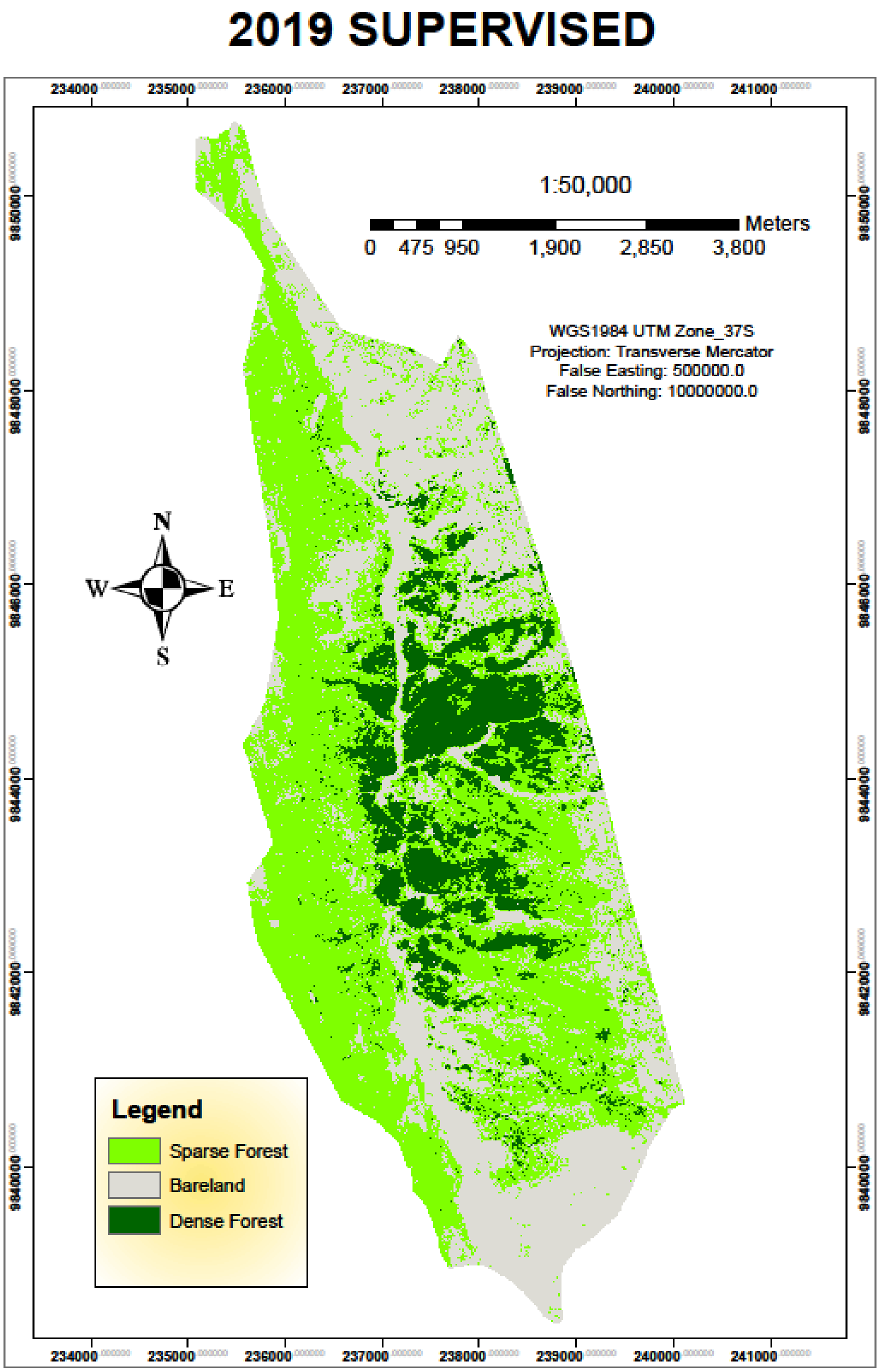

Figure 9: Supervised Classification 2019

Figure 9 shows supervised classification for the year 2019 showing sparse vegetation as 24.60%, Dense 7.25% bare land and settlement at 16.99%. There is 5.09% decrease in densely forested areas related to massive logging in the forest to pave the way for settlement.

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After carrying out supervised classification, it was possible to compute the areas occupied by the three classes (dense, sparse, bare land & settlement). Percentages of these were thus calculated by getting the total of the areas occupied by sparse, dense, bare land and settlement, and the unclassified the dividing the specific areas with the total and multiplying by 100. These percentages were computed by using the formula below.

$$\frac{Area}{Total\ Area} * 100\%$$

For instance, calculating the percentages for the year 2010 as in table 4.3 was done as shown below.

Total area = 6270.73 hectares
Sparse = 1198.07 hectares

$$\frac{Area}{Total\ Area} * 100\%$$

=1198.07/6270.73 *100= 19.1058
=19.11%
Dense = 773.678 hectares
=773.678/6270.73 *100 = 12.338
=12.34%
Bare land and settlement= 1090.74 hectares
=1090.74/6270.73 *100 =17.394
=17.39%

The same formula shown above was used for all the other years to come up with the percentages. The total areas for 2010 and 2019 were similar standing at 6270.73 hectares while for 1984 and 1995 were different from the latter ones both having an area of 6296.94 hectares. These are the areas the researchers worked with as the totals. The results for all the epochs were as shown in the table below which were computed by use of the formula and example shown above.

Vegetation Density

Table 1: Supervised Classification for Dense 1984-2019

	Area	**Percentage**
Supervised classification for dense 1984		
Dense Forest	545.94	8.67%
Sparse Forest	1366.74	21.70%
Bare land	1183.05	18.79%
Unclassified	3201.21	50.84%
Supervised classification for dense 1995		
Dense Forest	823.86	13.08%
Sparse Forest	1069.02	16.98%
Bare Land	1202.85	19.10%
Unclassified	3201.21	50.84%
Supervised classification for dense 2010		

Dense forest	773.678	12.34%
Sparse forest	1198.07	19.11%
Bare land	1090.74	17.39%
Unclassified	3208.24	51.16%
Supervised classification for dense 2019		
Dense Forest	454.808	7.25%
Sparse Forest	1542.47	24.60%
Bare land	1065.21	16.99%
Unclassified	3208.24	51.16%

Ground Truthing and Accuracy Assessment

After the percentages were computed, ground truthing was carried out on the 2019 image by collecting the GPS points in Ngong Hills Forest and inputting these points in ERDAS Imagine to do accuracy assessment. Accuracy assessment was also done for the other years by using GPS points provided by the Kenya forest service in form of shape files. The accuracy report provided for the various years were as shown in the table below.

Table 2: Accuracy Report for the Years 1984 to 2019

Year	Overall Classification Accuracy
2019	92.00%
2010	92.31%
1995	85.71%
1984	84.62%

Change Detection

After classification of the images and computation of accuracies, change detection was as well carried out by use of ERDAS Imagine to come up with the four images depicting the percentages of the decreased and increased areas. This process involves selection of two images from different years, selecting the output image and selecting the colours that will show either a decrease of increase in the phenomenon intended and in this case increase and decrease in forest cover. In this case, decrease in forest cover is depicted by red while increase is depicted by green as shown in maps below.

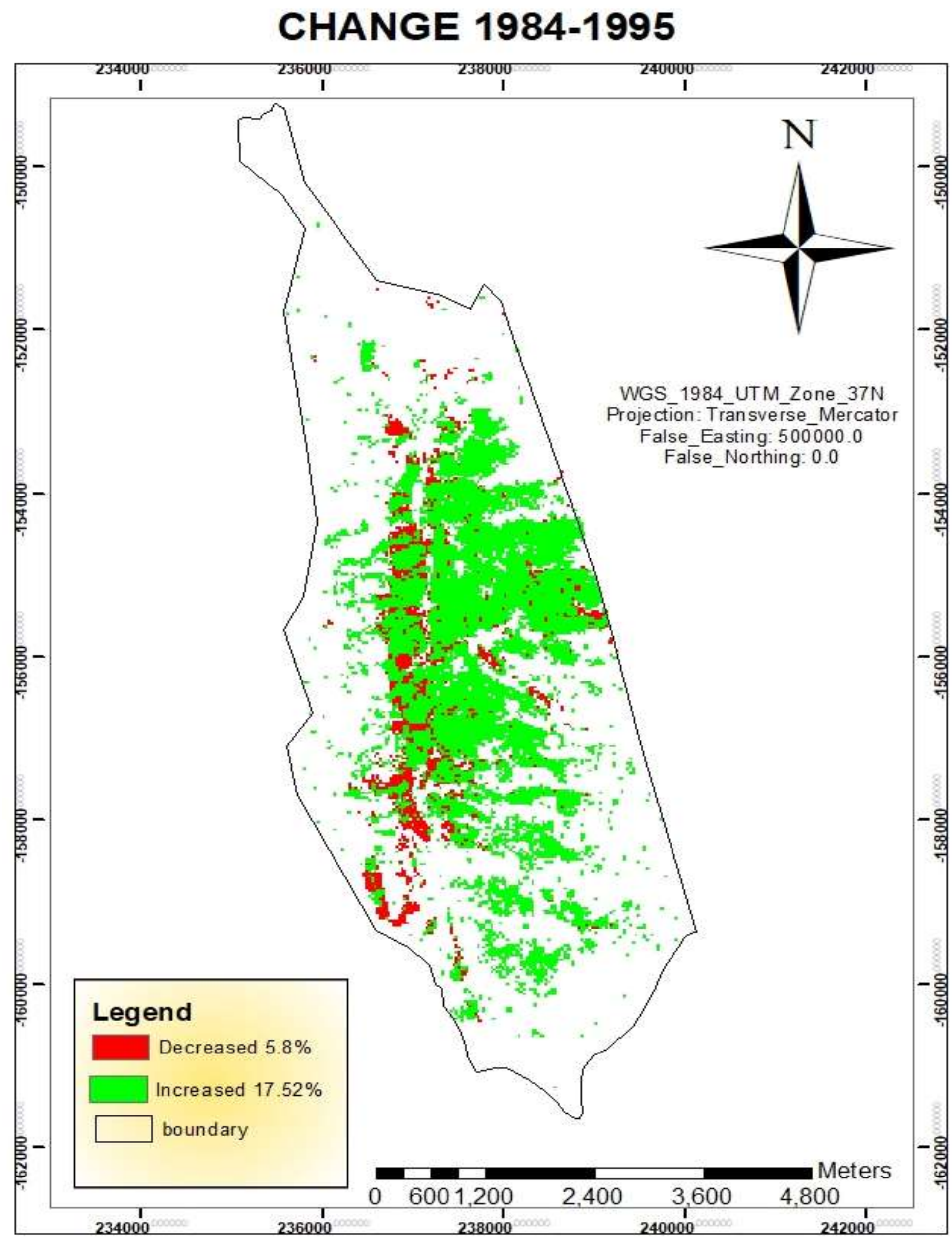

Figure 10: Change detection 1984-1995

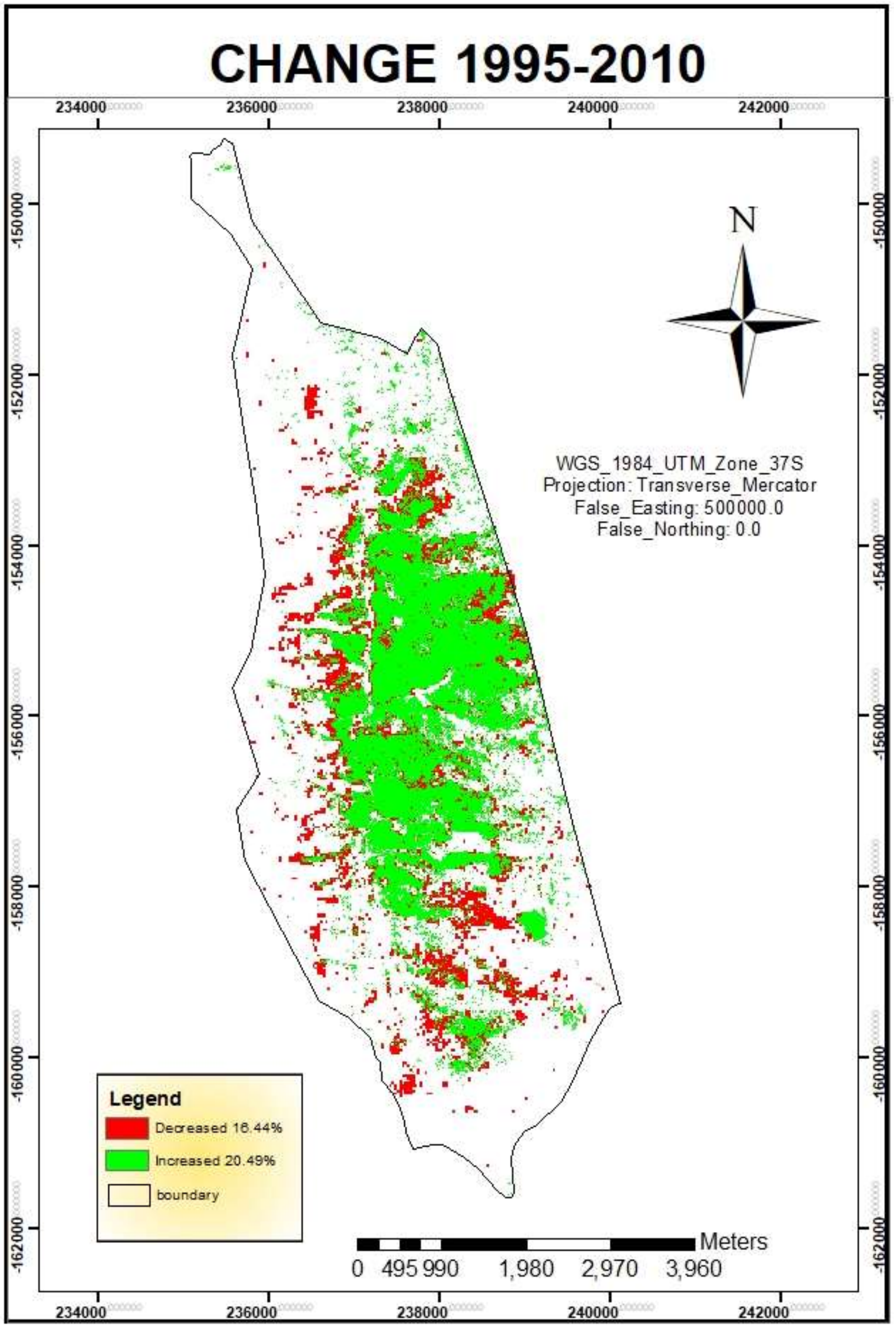

Figure 11: Change detection 1995-2010

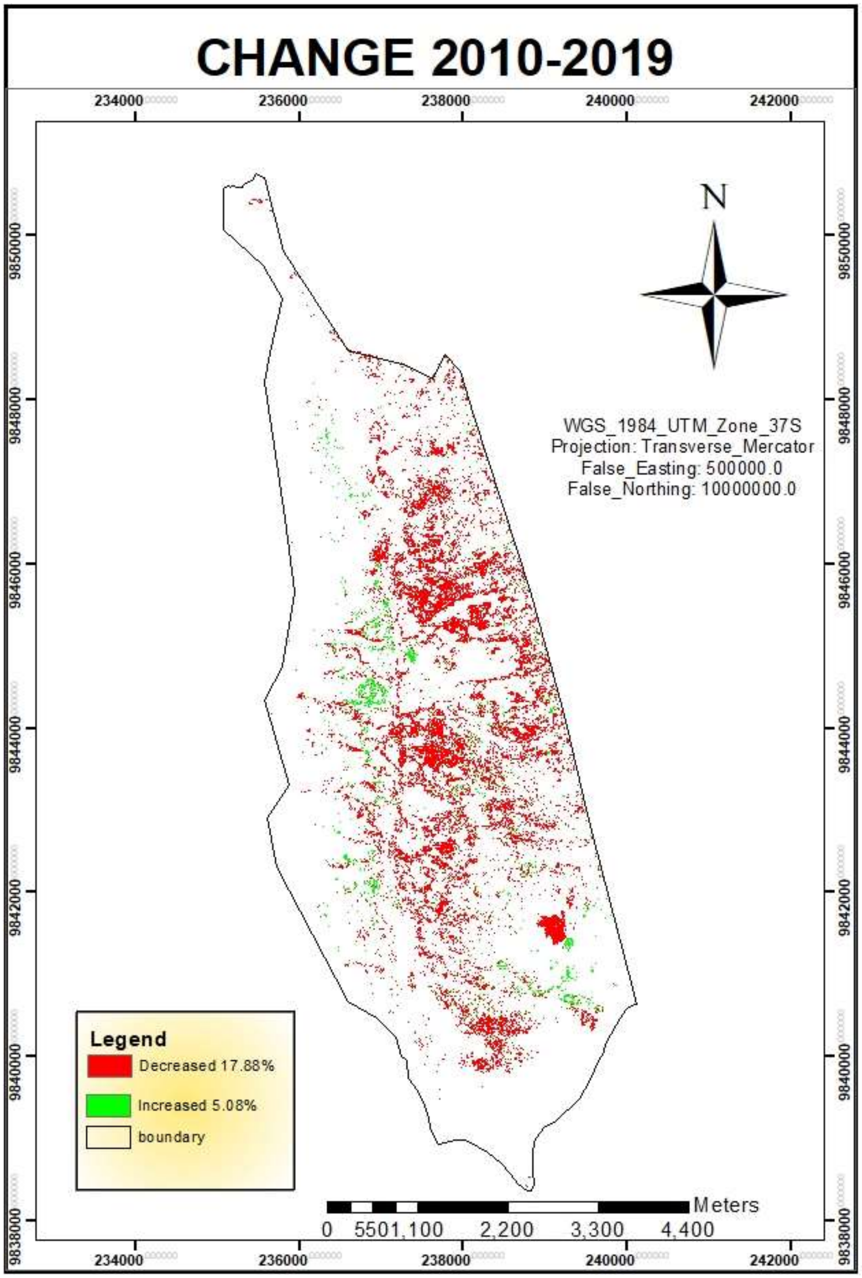

Figure 12: Change detection 2010-2019

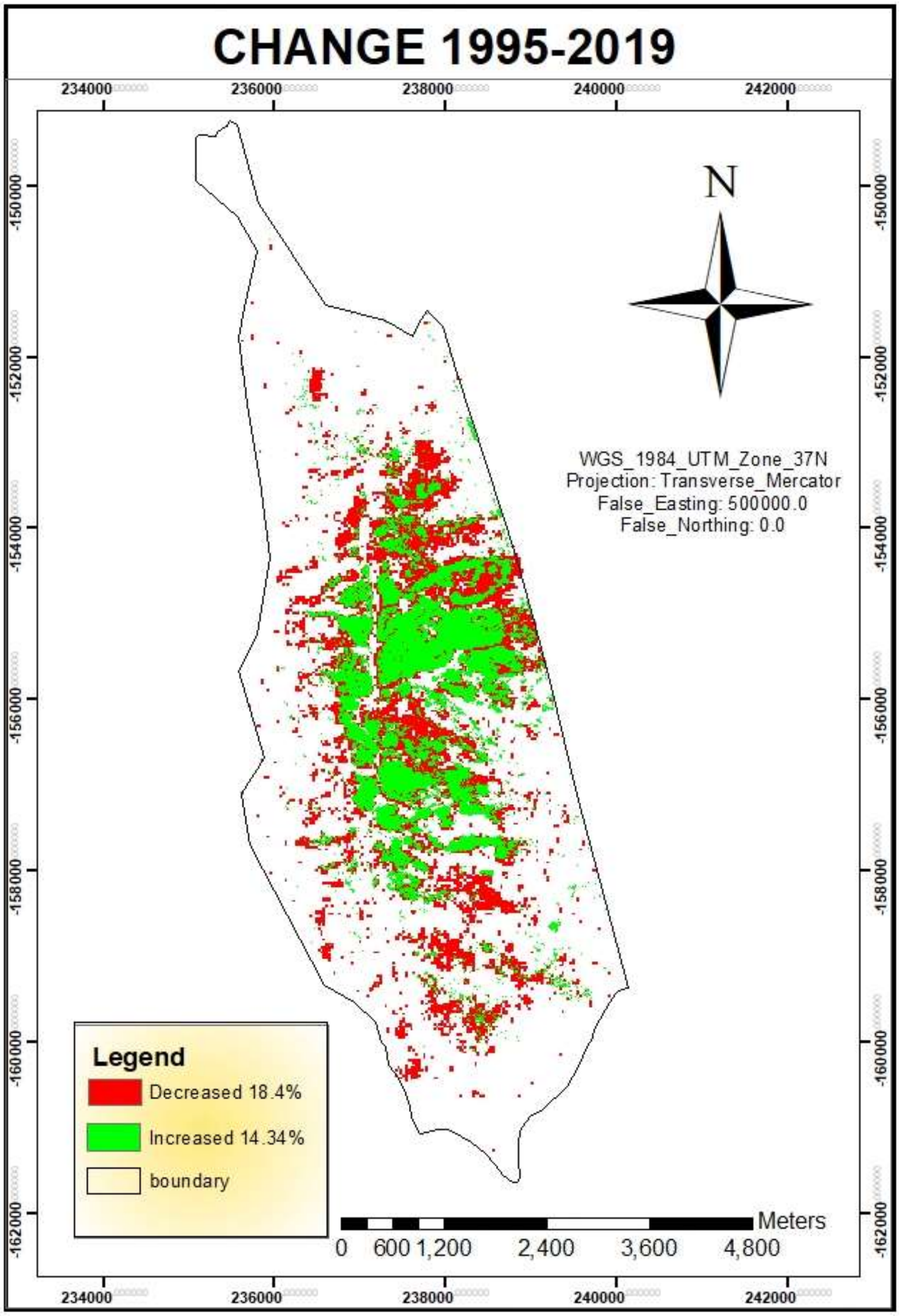

Figure 13: Change detection 1995-2019

The table below shows the increase decrease together with the unchanged ecosystem in Ngong hills forest. The percentages were computed using the formula

$$\frac{Area}{Total\ Area} * 100\%$$

2010-2019 example
Total area= **6270.73 hectares**
Decreased= 1121.248 hectares
=1121.248/6270.73*100
=17.881
=17.88%
Unchanged= 4830.9 hectares
=4830.9/6270.73*100
=77.038
=77.04%
Increased= 318.5745
=318.5745/6270.73*100
=5.08%

Change Detection Area and Percentages

Table 3: Change Detection Area 1984-1995

1984-1995	**Area**	**Percentage**
Decreased	365.31	5.8%
Unchanged	4827.96	76.67%
Increased	1103.67	17.52%
1995-2010		
Decreased	1026.678	16.44%
Unchanged	3938.46	63.07%
Increased	1279.42	20.49%
2010-2019		
Decreased	1121.248	17.88%
Unchanged	4830.9	77.04%
Increased	318.5745	5.08%
1995-2019		
Decreased	1149.32	18.4%
Unchanged	4200.13	67.26%
Increased	895.112	14.34%

The histogram and the flow chart below show the percentage change of the increased, decreased and the unchanged.

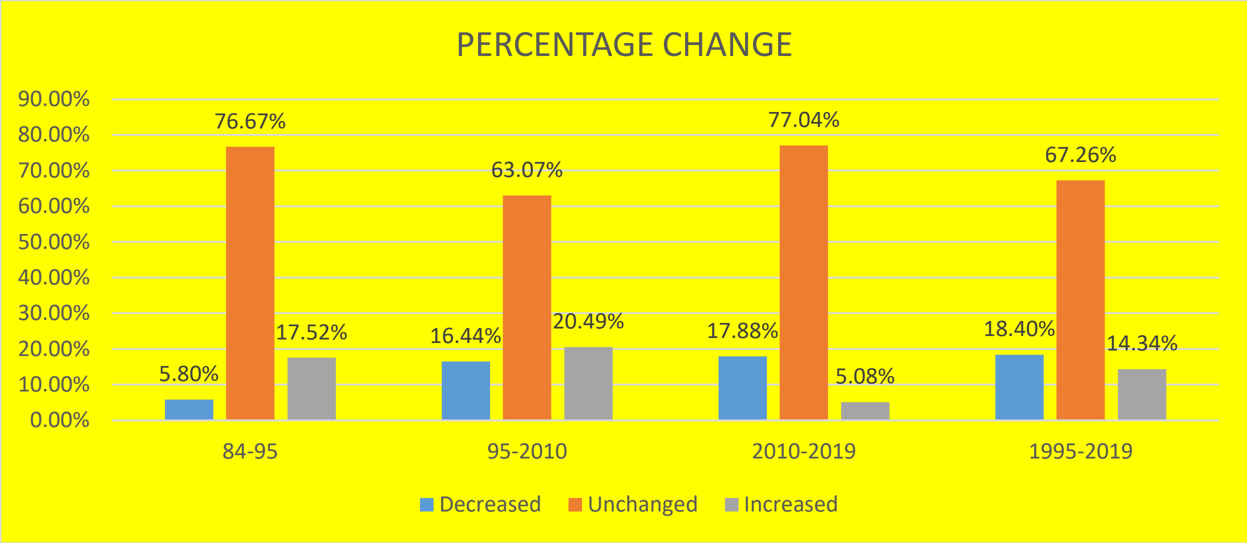

Figure 14: Percentage change in detected areas

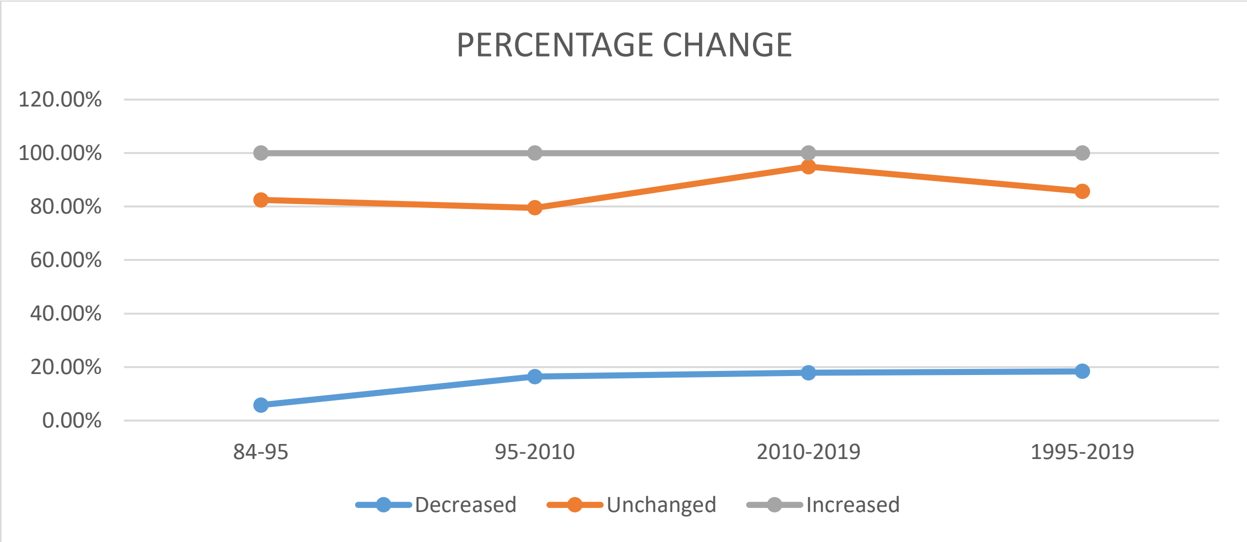

Figure 15: Percentage change

Indicated below is a zoomed in Rapid eye images for years 2010 and 2019. They are meant to further help in getting insight on the changes that have occurred in the forest. The 2010 image shows less settlement and bare land as compared to the 2019 image. Some vegetation has also reduced in 2019 as compared to 2010. This can be seen in Figure 18, which shows the areas that have changed with either increase or decrease between the two years. The areas shown in red is where reduction has occurred and the areas in green are areas where an increase has occurred.

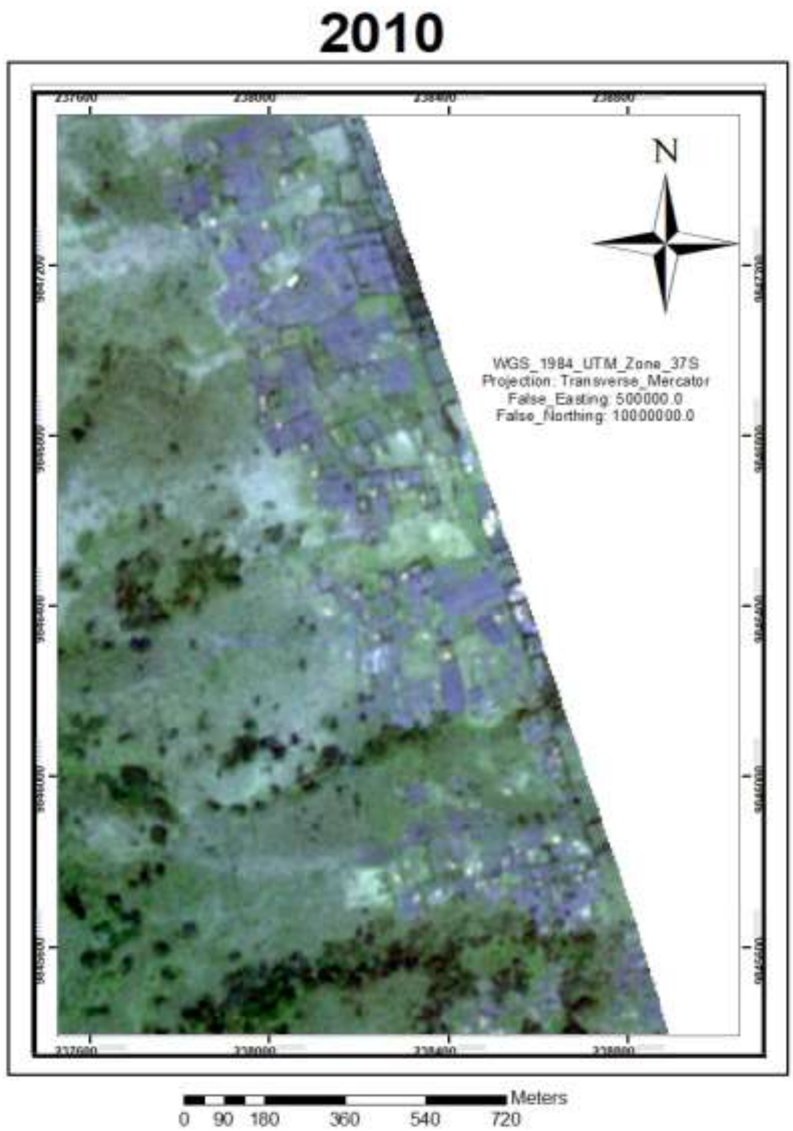

Figure 16: Zoomed in rapid eye 2010

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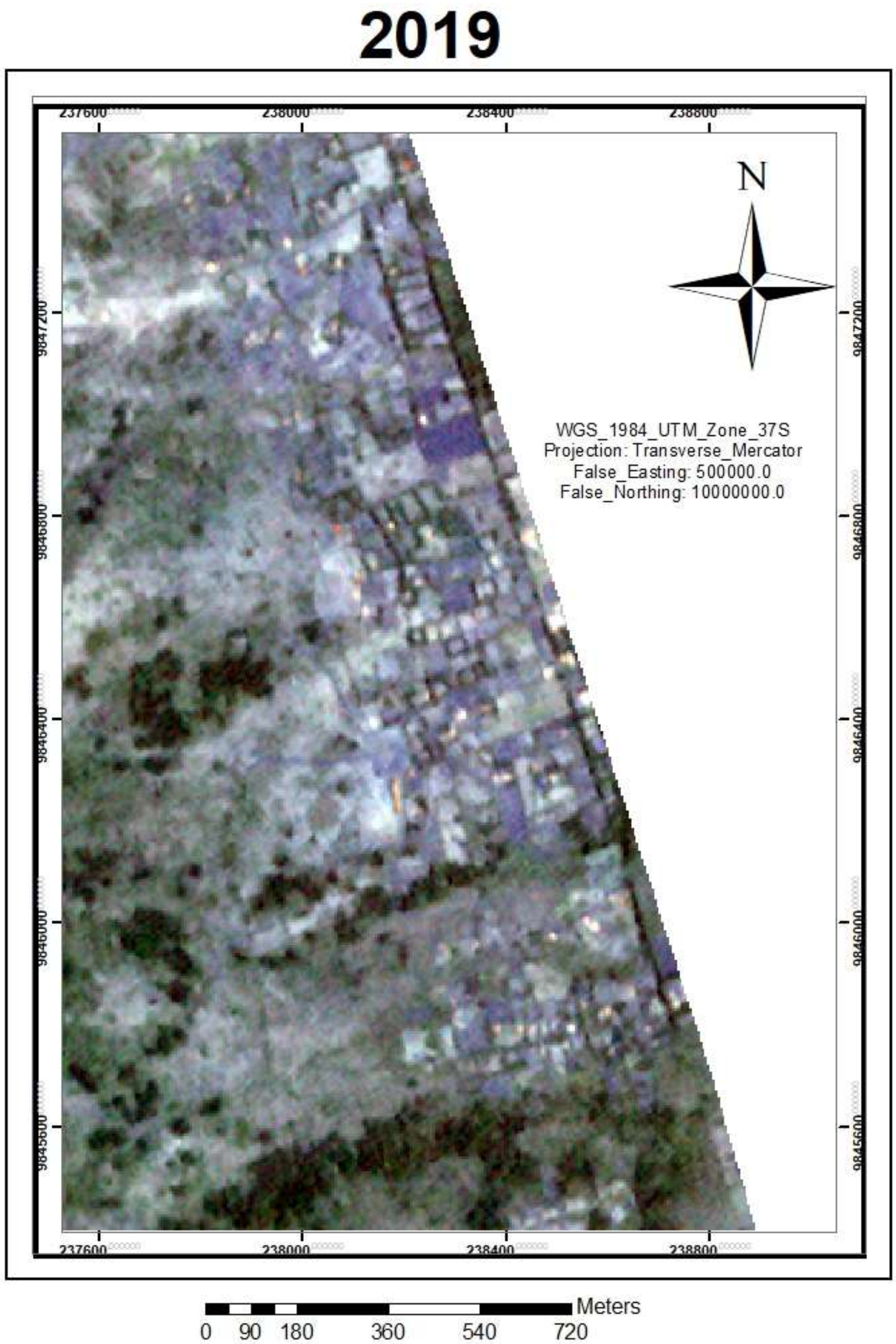

Figure 17: Zoomed in rapid eye 2019

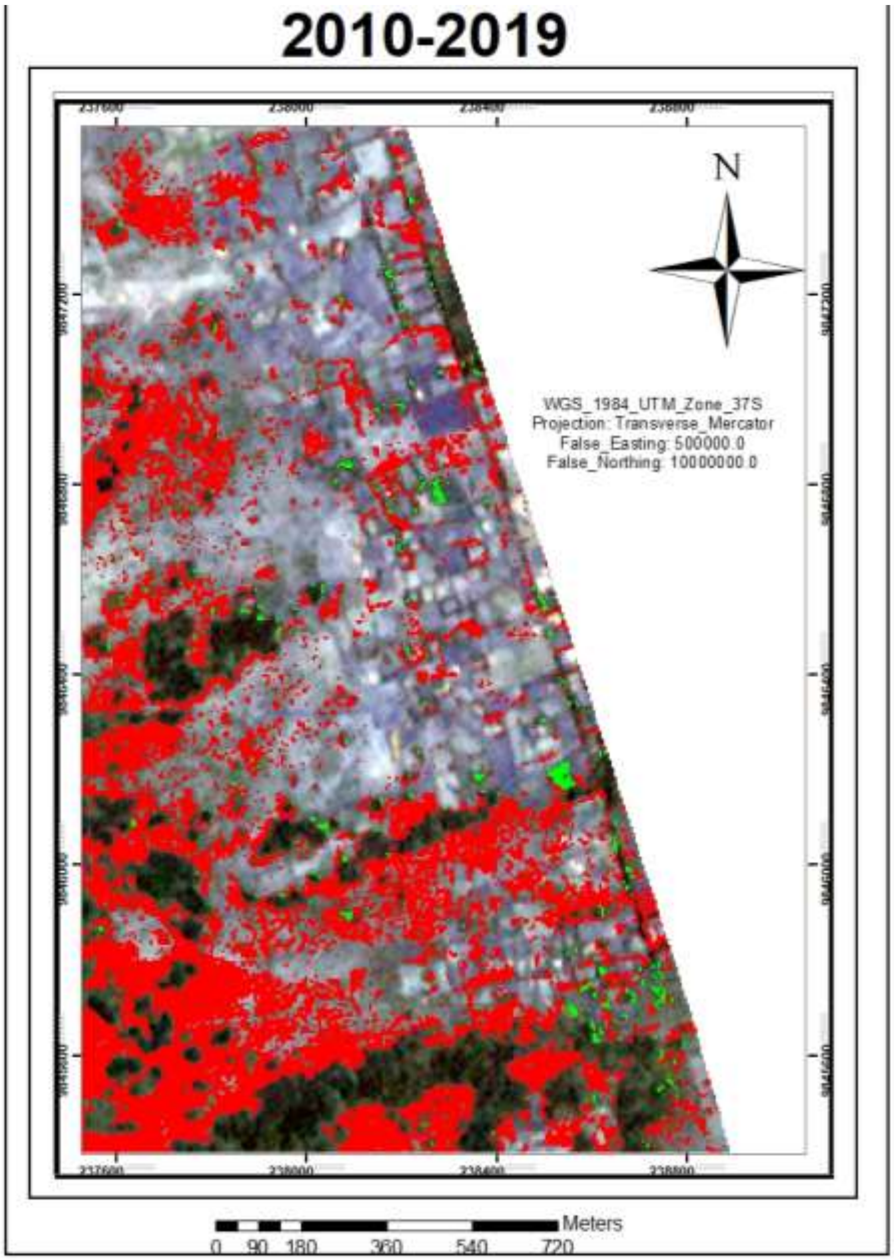

Figure 18: Zoomed in rapid eye 2010-2019

DISCUSSION

The main objective of this research was to review on the ways in which satellite images are used to inform on change of forest cover over a period of time. In this case, the change is assessed for 35 years. This is from 1984, 1995, 2010 and 2019. Satellite images for these years were acquired and assessed by use of a remote sensing software, ERDAS.

As shown from the results, the forest cover in 1984 was at 8.67% for dense and the dense area increased to 13.08% in 1995 due to afforestation efforts from KWS. Since 1995, the forest cover has however been decreasing from the 13.08% to 12.34% in 2010 and lastly to 7.25% in 2019. As per the KFS, the decrease in Forest cover is as a result of logging and massive settlement in the forest. This is further proved when change detection was done as the percentage decrease and increase were provided as seen in the tables depicting the percentage change. As from 1995, the change has been increasing constantly with a sharp increase between 2010 and 2019. The increase rate stands at 17.52% from 1984 to 1995 with an increase in the percentage from 1995 to 2010 with 20.49%. The increase however declined in 2010 to 2019 standing at 5.08%.

The main means of keeping track by the forest service in Kenya is mainly inventories and scanty use of remote sensing. As per the objectives that were stated earlier, it is very clear that remote sensing can be used to better inform on forest change. This has proven to be less costly and less time consuming. Remote sensing thus provides the best source of data to inform on change detection and is much better than inventories.

The specific objectives of this research were achieved and the findings are as well at per with what was done in previous studies. The change in Ngong Hills Forest was found to be caused majorly by human activities. This is majorly settlement and logging. As depicted by the 2019 high-resolution image, it can be seen clearly that there is massive encroachment in the forest as people have settled deep inside the forest past the boundary.

CONCLUSION

The loss of trees and other vegetation can lead to desertification, climate change, fewer crops, soil erosion, increased greenhouse gasses, flooding and many more problems to the environment. Deforestation of the Ngong Hills Forest has occurred for a number of reasons. Logging is on the rise for material needs the most important one being timber for construction and for industrial purposes such as making of paper. Destruction of the forest for settlement is also another factor. Trees are perennial resources and although this is true, many people do not understand that excessive exploitation of these resources makes its revival difficult.

With the use of remote sensing, it is thus very clear that the Kenya Forest Service along with other forest protection agencies need to implement this technology fully to help in monitoring the forest ecosystem as it provides timely information, up to date and cheap way to monitor the forest ecosystem. Remote sensing has been used in different parts of the world mostly in developed countries like Canada to monitor forest change. Most of the forest ecosystems occupy a very large area so keeping inventories may be tiresome, costly and might take a longer period of time to analyse these data so as to inform on change of the forest cover. As depicted, remote sensing can date to many years back and inform on the changes that have occurred as well as the areas that have been affected greatly.

Landsat data is what is used largely to inform on change detection. Some of the Landsat images used were for the years 1984 and 1995 since there was not any high-resolution images back then. However, for recent years, 2010 and 2019, high-resolution images from Rapid eye were used and have been able to give more accurate results as compared to Landsat data. Ngong Hills Forest has evolved gradually for the past years attributed to mainly logging. Massive loss of the forest is mainly by anthropogenic activities as natural causes of forest loss in the forest is minimal. These changes can be clearly seen and analysed as per the maps that were generated.

RECOMMENDATIONS

As per the results obtained after the research was carried out, it is evident that Ngong Forest is at the verge of depletion. The following recommendations are thus made:

i. Remote sensing works perfectly in depicting change as it can date back to many years and thus making it the most suitable data for informing on change detection.
ii. Remote sensing data, mainly from Rapid-eye, is recommended for use to inform on change detection mainly for its ability to produce high resolution images hence aid in better analysis.
iii. The changes in Ngong Hills Forest were mapped and thus making it easier to monitor change in pictorial form. It is thus advisable for the Kenya Forest Service to map the changes that occur constantly on this forest as it also aids to know the areas that are greatly affected.
iv. Anthropogenic activities have led a major change in the forest ecosystem. Settlements have encroached a big part of the forest as depicted. It is thus recommended that the Kenya forest service use remote sensing to find out the areas that have been largely affected by these activities and provide strict rules that will help in saving the forest from further destruction.

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