Spatial-Temporal Assessment of Forest Rehabilitation along Mt. Kenya East Forest Buffer Zone Using Remote Sensing and GIS

International Journal of
Environmental Planning and Development

Vol. 5: Issue 1
www.journalspub.com

Spatial-Temporal Assessment of Forest Rehabilitation along Mt. Kenya East Forest Buffer Zone Using Remote Sensing and GIS

***Kibetu Dickson Kinoti*[1,*], *Kiambi Milliam Mwende*[2]**

[1] Research Fellow, Department of Social Sciences, Chuka University, Kenya

[2] HoD, Geography Section- Department of Humanities, Maraa Secondary School, Kenya

ABSTRACT

Nationwide ban on harvesting of forest products in 1999 was meant to enhance regeneration of forest resources in the country. Restocking was then started to aid in rehabilitating degraded forests through tree planting initiatives coordinated by the Kenya Forest Services. One of the most affected forests then was Mt. Kenya Forest, an important montane forest and one of the country's water towers due to its endemic tree species (Ocotea Usambarensis) as well as biodiversity habitation. Dense population settlements along the forest borderline especially on the eastern slopes of this mountain (Nyanyo Tea Zones) exacerbate the very challenges of illegal and selective logging. Despite concerted management and planning efforts to salvage this important forest cover, comprehensive mapping to evaluate effects of restocking after the logging ban and series of extensive rehabilitation programs along the Nyanyo Tea Zones buffer strip has not been carried out. To address these gaps, this study sought to remote sensely monitor progress of rehabilitation efforts undertaken by the state between 2011 and 2018, duration coinciding with implementation period for the ten year Mt. Kenya strategic management plan of 2010-2020. Integrating geospatial knowledge and methods in mapping forest rehabilitation progress has revealed mixed stories of success and failed restocking along the extensive 187km border stretch covered by in this study. This study proposes adoption of Conservation Action Planning (CAP) approach in developing future ecological management programs and strategic plans for forest ecosystems in the country.

Keywords: *Remote sensing, Mt. Kenya, Ban, Restocking, CAP*

****Corresponding Author***
E-mail: kinotikibetu@yahoo.com

INTRODUCTION

Globally, forests are an important natural resource providing habitats for biodiversity, food for humanity as well as livelihood to many people. For these reasons, protection and restoration of forests is crucial for continuation of social, ecological and economic benefits [1, 2]. Internationally, uncontrolled exploitation of forest resources has resulted to loss of global forest cover with an estimated 129 million hectares alone cleared between 1990 and 2015 [3]. Although there exists international treaties and national directives on forest resources management, forests continue to face threats from population pressure related outcome and climate change risks. Locally the unabated encroachment and destruction of forests attests to this fact. This calls for reevaluation of forests conservation and related land use management practices at local levels in order to understand the multifaceted spatio-temporal dynamics of forest management approaches embraced within different ecosystems in the country.

Kenya has diverse forest typos' ranging from low land tropical rainforest, montane complexes to coastal mangrove forests existing at varying altitudinal range. Assessment of diverse conservation approaches practiced across the country can inform good management practices for sustainable development of national forest resource base. Given the then high rates of deforestation in the country during 1990s, a nationwide ban on harvesting of forest resources was issued in 1999 and came into effect in 2000. The decree aimed at promoting regeneration of forest vegetation in the country after years of destructive logging. This was to be achieved through tree restocking and afforestation campaigns. Rehabilitation of degraded areas through annual tree planting exercises coordinated by Kenya Forest Services gave out millions of tree seedlings for restocking and regeneration of affected forest blocks. For effective management of forests, integrated information on forest spatial extents, elevation location and areas degraded is essential. National aerial survey to assess state of national forests stocks in 2017 revealed extensive destruction of forests cover through illegal logging and uncontrolled allotment of forests excision rights. The report findings of this survey seem to agree with many other related studies done on the state of the country's forest cover [4, 5].

Locally, most studies on forest change analysis have focused majorly on monitoring of forest cover changes caused by deforestation and using optical remote sensing data [6,7]. Satellite remote sensing technologies have gained popularity in the field of forest studies due to its synoptic view of the earth surface and continuous observation capabilities. These characteristics make remote sensing less costly and effective in monitoring and assessment of dynamics introduced from human-environment interactions on any part of the earth's surface. For instance, remote sensing has been used widely in the domains of forest resources mapping [8, 9] and forest cover change detection analysis [10, 11]. Understanding changes in forest cover is important from an operational forest management perspective more so those geared towards assessing effectiveness of large scale rehabilitation and restocking programs [12,13]. Globally, forest cover changes arise from fires, diseases and illegal logging. These factors undoubtedly interplay to influence the rate of deforestation and regrowth of rehabilitated forests. Most activities of illegal logging are reportedly common along forest borderline areas in most Kenyan forest complexes. Mt.Kenya forest reserve was gazetted in 1932 as national reserve conjointly managed by Kenya Wildlife Service (KWS) and Kenya Forest Service (KFS). KFS is mandated to ensure establishment of plantations in areas where harvesting of indigenous stands has occurred in the forest complex. Despite development of a ten year Mt.Kenya ecosystem management plan (2010-2020) in order to address threats facing bio resources in this vast montane forest, comprehensive aerial mapping of degraded areas to inform suitable rehabilitation has not been carried out effectively along the Nyayo Tea buffer zones. One of the key action areas envisaged in the ten year management plan is to carry out assessment of forest degraded areas to inform the type of enrichment plantation to restock. In any restocking program, effective reforestation requires assessment of target enrichment areas to identify tree cover density among other factors.

Hitherto now there has not been any aerial based survey of Mt.Kenya forest complex to assess vegetation cover dynamics after the 1999 ban especially along the degraded eastern and south eastern forest borderline zones. This in the long run impedes effective monitoring of tree establishments after seasons of annual tree planting activities which have been in place since 2000. Every year, national as well as local tree planting activities are organized and carried out by institutions, corporates and individuals within Mt.Kenya Forest Reserve. Although some success has been achieved this far, what is not known precisely are which spot areas of the degraded forest have regenerated and the effectiveness of restocking strategies on the overall forest regeneration of mount. Kenya forest. Sustainable management of Mt. Kenya forest is faced with threats of illegal logging and forest resources depletion especially along the densely populated low lying areas of the forest borderline zones.

Previous studies done on Mt. Kenya forest using Landsat imageries have showed consistent patterns of increased forest cover loss over time. According to Yi-Hua, 2011 [14], between 1980 and 2000 alone, Mt. Kenya forest cover decreased to about 12.7 %, while Ngigi & Tateishi in 2004 observed a 2% drop in forest cover between 1987 and 2000. Another study by Ndegwa in 2005 showed about 17.5 % of this Montane forest was destroyed between 1978 and 2002 [15,16]. All these findings confirm the fact that Mt. Kenya forest is under immense threats from both urbanization and agricultural land use practices. A major challenge towards effective monitoring of forest cover dynamics in the country is the over reliance on ground based field collection data and methods. Similarly, main focus of these methods is mostly on forest degradation along access trails as if these were the only degraded regions of local forest stands. This clearly shows a need to re-shift paradigms and focus from forest degradation and it drivers to matters of restocking, rehabilitation and regeneration of forests. To achieve this, integration of remote sensing data with field surveys will offer a multifaceted approach for quantifying areas of forest plantations requiring regeneration, restocking and rehabilitation.

This study seeks to assess effectiveness of plantation establishment activities within the forest resource management program component of the Mt. Kenya ecosystem management plan. Most studies carried out in Mt. Kenya montane ecosystem have largely applied optical remote sensing to map the extent of forest cover loss between 1978 and 2002. The use of optical sensors in the acquisition of high quality cloud-free imageries is hampered by the presence of frequent cloudy conditions in the area. This limitation leads to misclassification of land cover and land use features (Asner, 2001; Yi-Hua, 2011) [14, 17]. Due to these challenges, this study will still apply Landsat 8 OLI imageries but selectively use those imageries which have less than 8% cloud cover and those captured in low humidity months of January. Recent developments have shown potential application of Synthetic Aperture Radar data in forest cover mapping and discriminating forests (Hamdan et al, 2017) [18], derivation of forested areas (Dostálová et al, 2016) [19] and forest change detection analysis (Olesk et al., 2015)[20]. This shows novel developments in the area of remote sensing meant to address challenges paused by cloudy conditions in most forested areas in the tropics.

Study Area

Mount. Kenya Forest reserve was also gazetted in 2000 as a national reserve to be co-managed by Kenya wildlife service and Kenya Forest service respectively. It is a protected area of national importance due to its biodiversity and water catchment values. This study was done along the Eastern and South Eastern forest border zones (Figure 1). The stretch has minimal potential for tourism development and comprises of community lands as well as forest resources dependent population. As such this zone is usually threatened by illegal logging and charcoal burning owing to its proximity to settlement areas. It contains Nyayo Tea plantation Zones and farming activities (MKE Management Action Plan, 2010-2020).

Data, Materials and Methods

Data and Materials

Multispectral Landsat 5 TM and Landsat 8 OLI/TIRS Path 168 and Row 60 for the study area were downloaded from US geologicalSurvey official website (http://www.earthexplorer.usgs.gov). Images for 2011, 2015 and 2018 with minimum cloud cover were used. All images were acquired during the dry month of january inorder to reduce reflectance attenuation associated with seasonal variation. Visible and Near-infrared wavelength bands were used to map the greennes of forest (Table.1). A 30m ASTER digital elevation model of the area was used to extract slope and elevation. Roads and towns data used was obtained from Kenya Open data portal as shapefiles. Population data was downloaded from WorldPop portal. Land use/land cover validation data was collected from both field visits and google earth virtual globe (Figure 2).

Method

Extraction of Study's Area of Interest

Forest buffer zones of interest comprised of the Eastern and South eastern borderlines of mt.Kenya forest. These regions occupy the expansive nyayo tea zones belt cutting across Kirinyaga,Meru,Tharaka Nithi and Embu counties. The border zones were clipped from the imagery sets of years 2011, 2015 and 2018 through raster extract module. Shuttle radar terrain model DEM image was acquired from Glovis portal and similarly raster clipped to the area of interest geometry.

Image Processing and NDVI calculation

Subset Landsat images were pre-processed to correct for atmosphere errors using cost(t) atmopsheric correction model. This was considered important to help reduce effects of scene illumination variations which may result to false quantification of vegetation greenness. The resulting images comprised of top of atmosphere reflectances. Red band and NIR band were used to discriminate the various vegetation classes and related land cover. Specifically Normalised Difference Vegetation Index(NDVI) was used to quantify forest vegetation abudance by measuring greeness. Although there exists sevral vegetation indices, NDVI has been applied widely in discriminating vegetation from other landuses/cover because it is simple and thus it is a useful vegetation index (Pettorelli et al., 2005; Mancino et al, 2014; Slimani et al., 2017) [21,22,23].

Vegetation Cover Density Classification

NDVI values for the images of 2011, 2015 and 2018 ranged from 0.18 to 0.75. An appropriate NDVI threshold value to classify forest vegetation cover density was selected based on published NDVI literature and visual interpretation of Google earth images of the same area.

Interpretation of resulting NDVI Values

Effective interpretation of the resultant greenness maps was based on integrated field data, google earth images and socio-demographic data of the regions. With these it was possible to understand and attribute causes of the observed forest vegetation changes along the high contact zones of the human-forest borderline.

Results and Discussion

Dynamics of Forest Vegetation Greenness

Forest vegetation greenness intensity for 2011, 2015 and 2018 was classified as grassandgroundfoliage(0.18<NDVI<0.42), shrubs and small trees (0.42<NDVI< 0.60) and dense forest cover (0.36<NDVI<0.69) based on the calculated NDVI values. Analysis of the spatial distribution for vegetation cover along the forest border showed areas of high density are concentrated about 1000m from the borderline.The quantity of vegetation cover was not symmetrical across the three years. In 2011, 10250.73 ha of assorted shrubs were mapped compared to 8947.17 ha of the same in 2015. This represents 12.72 % decrease in low and medium dense vegetation. Similarly proportion of high dense vegetation showed a decline from 56639.25 ha (2011) to 50841.90ha (2015) and a total of 48796.74 ha in 2018 (Table.2). This shows a decline of about 13.85% for the 7 year period (2011-2018). A look at the resultant NDVI maps of 2011, 2015 and 2018 shows a consistent loss of high valued forest woody species within at least 2500 meters from the permittable forest borderline (Figure 3). This means illegal and selective harvesting of trees is still happening deep into the forest away from the forester watch stations especially along the south eastern and eastern mt. Kenyaforestblocks.

Cause factors

Observed variations in forest cover show interesting patterns with scanty vegetation decreasing between 2011 and 2015 and later increasing. Dense forest vegetation cover showed a decrease across the seven year period (2018-2011). This can be attributed to encroaching population and related human activities along these forest border zones. As can be seen there has been increase in population around the forest border areas between 2010 and 2015 (figure.4).

Low elevation,upgraded roads and close proximity of the forest blocks to towns and roadnetworks has contributed substantially contributed to the observed vegetation cover variations along Embu, Chuka, Chogoria and Imenti forest blocks of Mt. Kenya ecosytstem(Figure.5). Woody trees which form the dense vegetation are found on moderate elevation(1850m–2200m a.sl). It is thence important to note that altitude and slope have contributed to the spatial distribution of the forest cover density variations noted in this study [24]. This explains why restocking has persistently been carried out along the forest edge and at low elevation which also are encroached areas by the communities bordering forests.

Table1: *Landsat images and their bands used in calculating Normalised Digital Vegetation Index*

Image	Acquisition date	Resolution	Spectral Bands
Landsat 8 OLI	21st January 2018	30m	Band4:Red Band5:NIR
Landsat 8 OLI	29thJanuary 2015	30m	Band 4:Red Band5: NIR
Landsat5 TM	12th January 2011	30m	Band 3:Red Band 4:NIR

Table 2: *Temporal variation in Forest density areal cover in hectares for 2011, 2015 and 2018*

Forest Cover	2011(Ha)	2015 (Ha)	2018(Ha)
Non Vegetation	4862538.81	4949868.42	4968897.93
Scanty Vegetation	10250.73	8947.17	10676.43
Dense Vegetation	56639.25	50841.90	48796.74

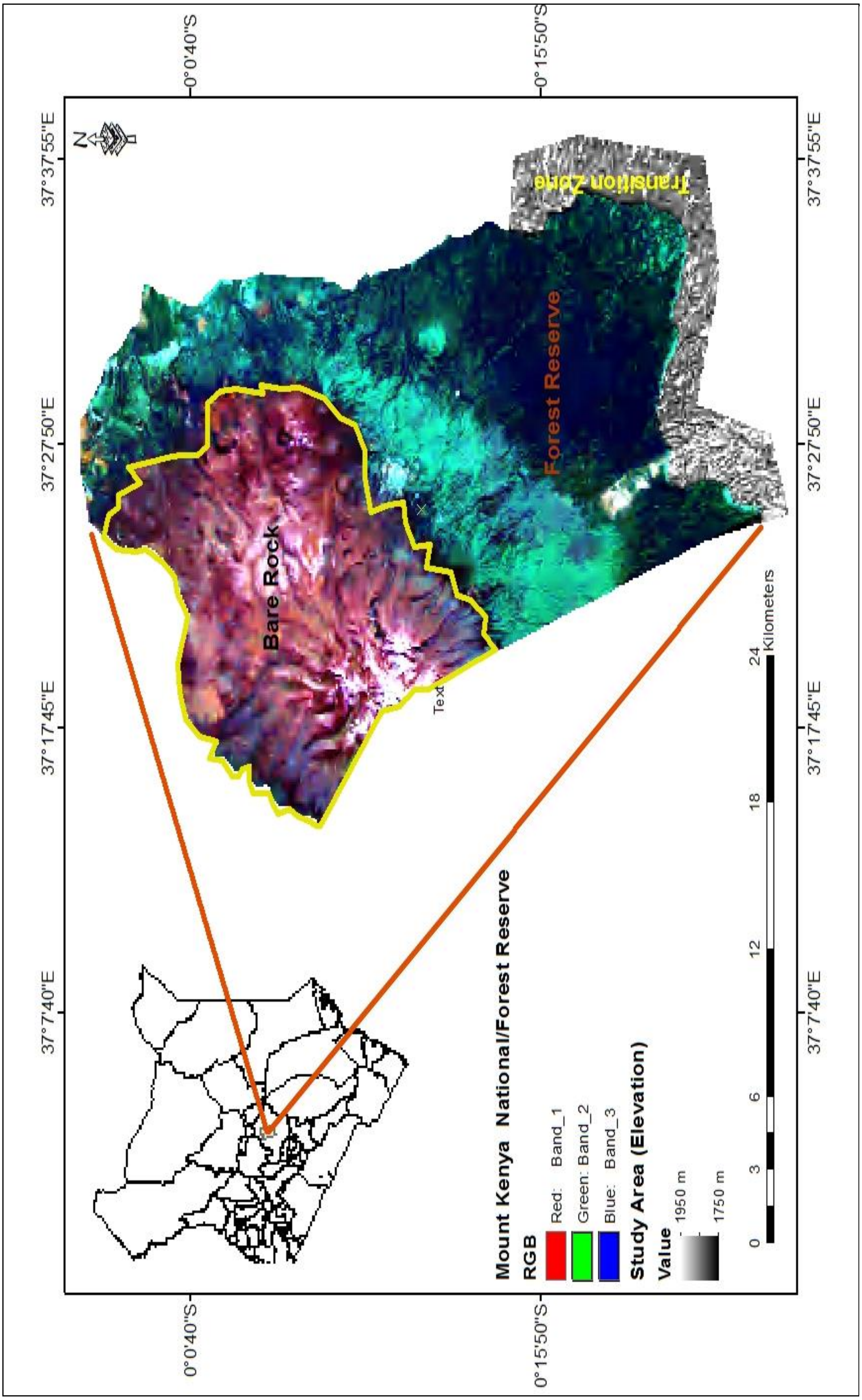

Fig. 1: *Location of the study.*

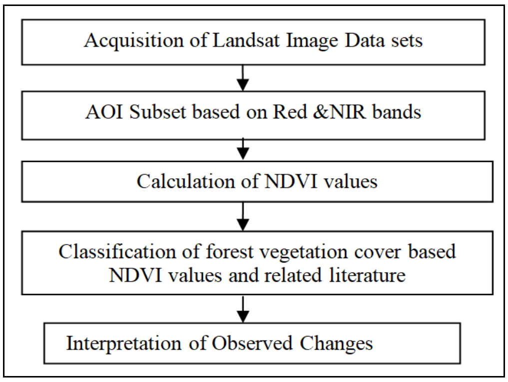

Fig.2. *A schema of the Image Processing and spatial Data analysis.*

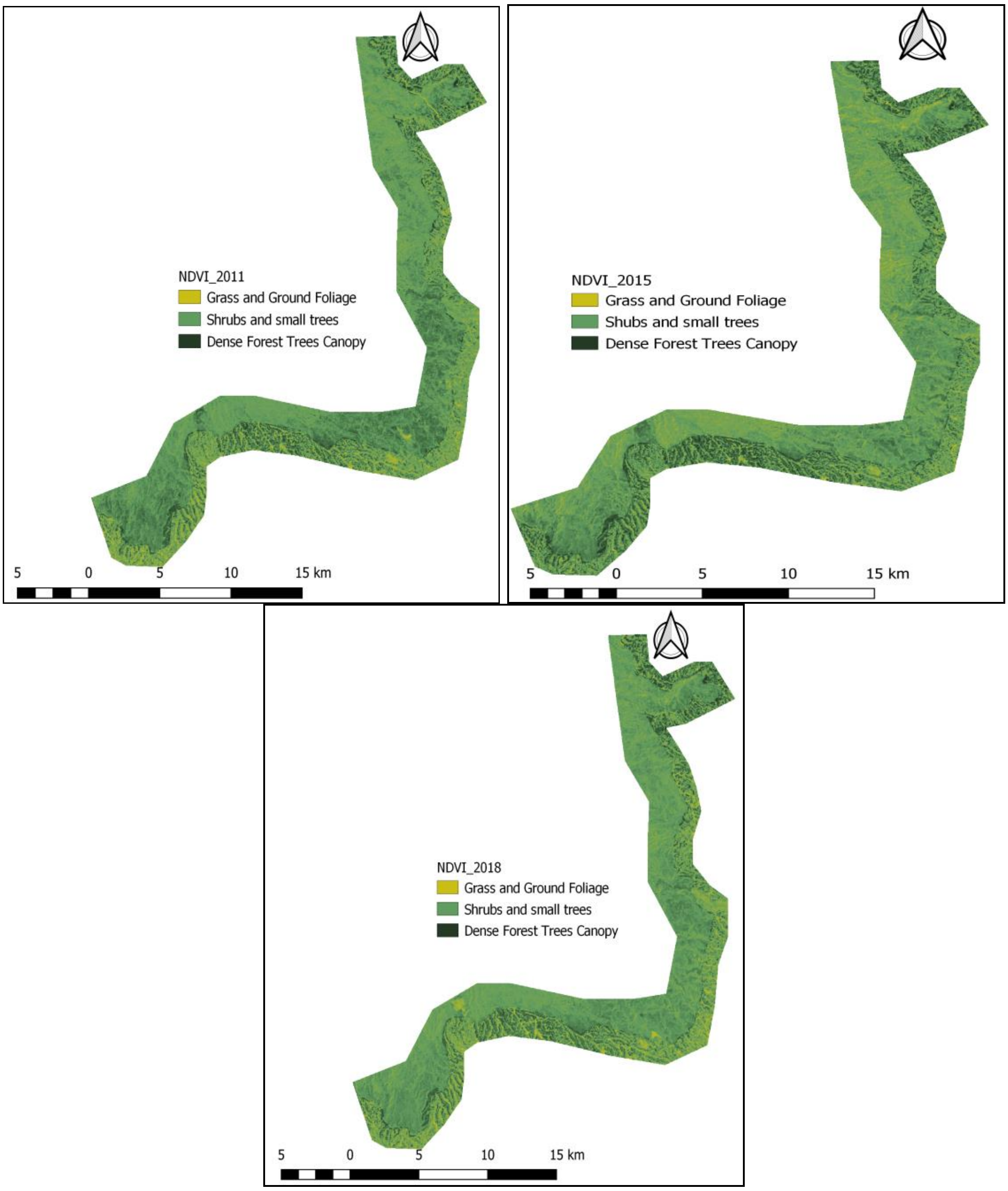

Fig. 3. *Maps of the Resultant NDVI values for 2011, 2015 and 2018.*

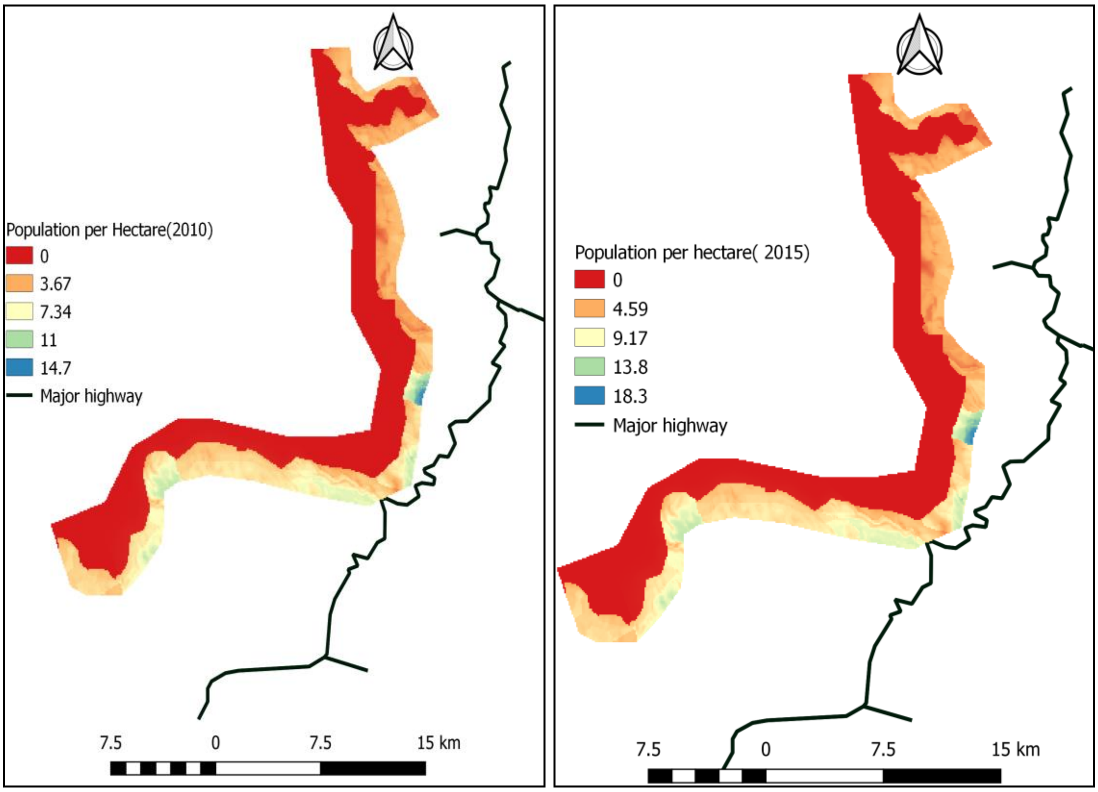

Fig. 4. *Increased population across the forest border zones between 2010 and 2015.*

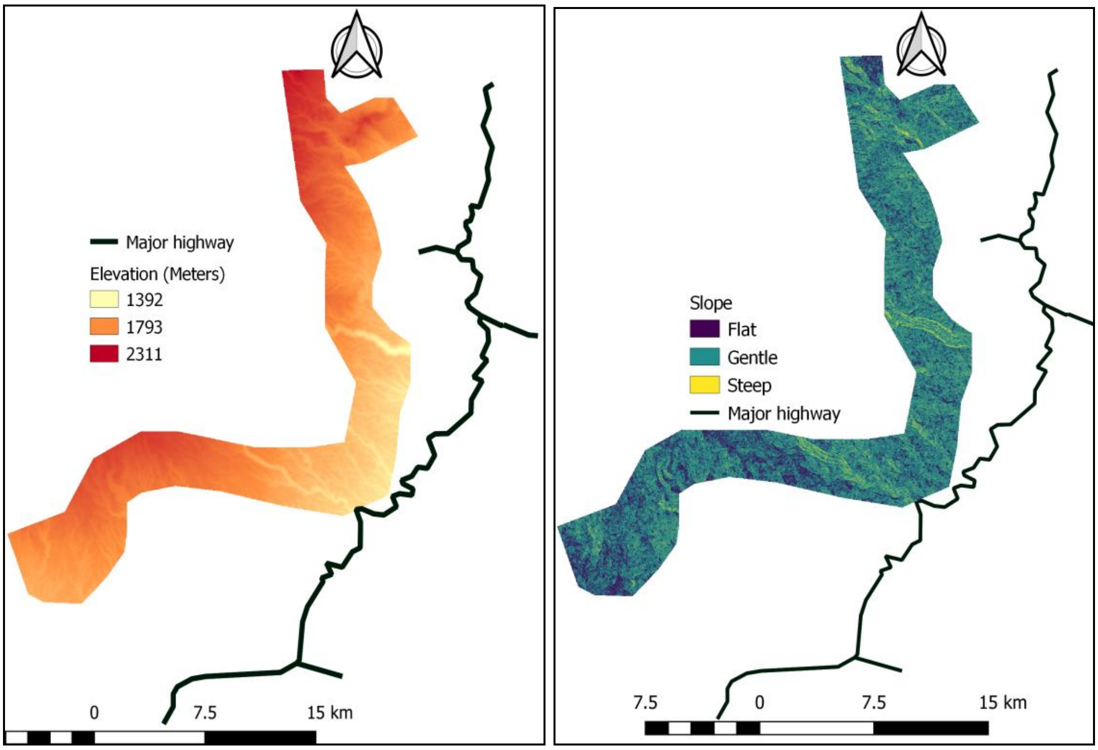

Fig. 5. *Map showing the elevation of the AOI, slope and proximity to Major highway.*

CONCLUSION

Findings from this study show an increase in shrubs and other low to medium density forest vegetation s between 2011 and 2018. The increase realised was about 4.15% for the seven year period comprising of exotic trees planted in the patches within degraded forest stands. The fact that dense forest tree cover has been reducing as shown by this study especially deep into the forest highlights limitaions of the current ground based forest beats and surveys. These approaches restricts forest managers to same areas and only those served by access routes/trails. Generaly the results of this study have shown the significance of integrating remote sensing data, methods and Geospatial science applications in the assessment and monitoring of the Mt. Kenya montaine forest cover changes.

Given the frequent forest fires in Mt.Kenya forest, understanding the changes in forest vegetation cover is important in modeling forest fire outbreak risk. The study has shown a mixed story of success and failure in massive restocking as shown by the proccessed, classified and analysed Landsat imageries generated NDVI maps. Some of the limitations with findings of this study may be attributed to the seasons these images were captured, low spatial resolution of images used and lack of adequate current ground truth information due to the vastness of the forest borderline.

This study proposes a longitudinal research study to analyse the forest's biomass dynamics during wet and dry seasons to measure and account for greenness index variations across the two seasons. Additionally, there is need to explore potential of Synthetic Aperture Radar (SAR) data in mapping complex forest ecosytems since radar imageries have been known to address challenges common in optical remote sensing data especially high cloud cover obstructions. Given the risks paused by climate change and growinng important of developing resilient protected areas ecosytems in Kenya, adoption as well as use of Conservation Action Planning processes in designing ecological management programs and strategic plans is paramount.

REFERENCES

[1] FAO. (2015). Global Forest Resources Assessment 2015-How are the world's forests changing? (Food and Agriculture Organization of the United Nations). Retrieved from http://www.fao.org/resources/infographics/infographicsdetails/en/c/32583 on 23rd January 2018

[2] Gamfeldt, L., Snäll, T., Bagchi, R., Jonsson, M., Gustafsson, L., & Kjellander, P. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature Communications, 4*:13- 40

[3] FAO. (2016). *State of the World's Forests and agriculture: Land-use challenges and opportunities.* Rome, Italy: Food Agriculture Organisation.

[4] Soini, E. (2002).Changing landscapes on the southern slopes of Mt. Kilimanjaro, Tanzania: An aerial photo interpretation between 1961 and 2000. *Working Paper* World Agro forestry Centre (ICRAF)

[5] Nkako. M., Lambrechts, C., Gachanja, M. & Woodley, B. (2005). Maasai Mau Forest Status Report 2005. Ewaso Ngiro South Development Authority, Narok, Kenya.

[6] Baldyga, T. J., Miller, S. N., Driese, K. L. & Gichaba, C. M. (2007). Assessing land cover change in Kenya's Mau Forest region using remotely sensed data. *African Journal of Ecology,* 46**:** 46-54.

[7] Ochego, H. (2003). Application of Remote Sensing in Deforestation Monitoring: A Case Study of the Aberdares (Kenya**).** *2nd FIG Regional Conference.* Marrakech, Morocco.

[8] Wagner, W., Luckman, A., Vietmeier, J., Tansey, K., Balzter, H., Schmullius, C., Davidson, M., Gaveau, D., Gluck, M., Toan, T.L., Quegan, S., Shvidenko, A., Wiesmann, A. & Yu, J.(2003). Large-scale mapping of boreal forest in SIBERIA using ERS

tandem coherence and JERS backscatter data. *Remote Sensing of Environment*, 85:125-144.

[9] Dwyer, E., Monaco, S. & Pasquali, P. (2000). An operational Forest Mapping Tool using space borne SAR Data. In: *ERS-ENVISAT Symposium*, Göteborg, Sweden

[10] Ahmed, B., Rida, K., Aafaf, J., Fatima, T & Samir, N (2018) Monitoring of forest cover dynamics in eastern area of Béni-Mellal Province using ASTER and Sentinel-2A multispectral data, *Geology, Ecology, and Landscapes*, 2(3), 203-215

[11] Gimeno, M., San-Miguel, J., Barbosa, P. & Schmuck, G. (2002). Using ERS-SAR images for burnt area mapping in Mediterranean landscapes. *Forest Fire Research & Wildland Fire Safety*, 14.

[12] Dostálová, A., Hollaus, M., Milenković, M. & Wagner, W. (2016). ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume III-7, 2016 XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic

[13] Johannes, S., Fabian, E., Michael, F & Sebastian, S.(2017). Synergetic use of Sentinel-1 and Sentinel-2 for assessments of heath land conservation status. *Remote Sensing in Ecology and Conservation*, pp 1-15

[14] Yi-Hua, W.(2011).*Investigation of deforestation in East Africa on regional scales*. Unpublished Master's Thesis, University of Stockholm, Sweden.

[15] Ngigi, T. G. & Tateishi, R. (2004). Monitoring deforestation in Kenya. *International Journal of Environmental Studies* 61: 281 – 291

[16] Ndegwa, L. W. (2005) Monitoring the Status of Mt. Kenya Forest Using Multi-Temporal Landsat Data. Department of Geography. Miami University Oxford, Ohio, USA

[17] Asner, G.P. (2001). Cloud cover in Landsat observations of the Brazilian Amazon. *International Journal of Remote Sensing*, 22:3855–3862.

[18] Hamdan, O., Muhammad. M. & Abd, R. K.(2017).Synergetic of PALSAR-2 and Sentinel-1A SAR Polarimetry for Retrieving Aboveground Biomass in Dipterocarp Forest of Malaysia. *Applied Sciences*, PP 1-20

[19] Dostálová, A., Hollaus, M., Milenković, M. & Wagner,W.(2016). Forest area derivation from sentinel-1 data. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume III-7: 227-233

[20] Olesk, A.,Voormansik,K., Pohjala, M. &Noorma, M. (2015). Forest change detection from Sentinel-1 and ALOS-2 satellite images, Synthetic Aperture Radar (APSAR), IEEE 5th AsiaPacific Conference, 1-4 Sept. 2015, pp. 522-527.

[21] Pettorelli, N., Vik, J.O., Mysterud, A., Gaillard, J.M., Tucker, C.J., & Stenseth, N.C. (2005). Using the satellite-derived Normalized Difference Vegetation Index (NDVI) to assess ecological effects of environmental change. *Trends in Ecology & Evolution, 20*, 503–510.

[22] Mancino, G., Nolè, A., Ripullone, F., & Ferrara, A. (2014). Landsat TM imagery and NDVI differencing to detect vegetation change: Assessing natural forest expansion in Basilicata, southern Italy.*Forest -Biogeosciences and Forestry, 7*, 75.

[23] Slimani, M.A., El Aboudi, A., Rahimi, A., & Khalil, Z. (2017). Use of GIS and Satellite Imagery in the Study of the Spatial Distribution of Vegetation in the Entifa Forest (High Atlas Central, Morocco). *Euro-Mediterranean Conference for Environmental Integration*

[24] US Geological Survey Web site from http:// www.earthexplorer.gov. accessed on 16th June 2018 at 11:00am

Cite this Article: Kibetu Dickson Kinoti, Kiambi Milliam Mwende. Spatial-Temporal Assessment of Forest Rehabilitation along Mt. Kenya East Forest Buffer Zone Using Remote Sensing and GIS. *International Journal of Environmental Planning and Development*. 2019; 5(1): 6–16p.