Assessment of Land Cover Change Due to Stone Quarrying in Narok Town Ward

Festus Kiprop Barchok, Samson Okongo Mabwoga & Stella Kirui

[1]*Maasai Mara University, Kenya (barchokfestus@gmail.com)*

[2]*Maasai Mara University, Kenya (smabwoga@mmarau.ac.ke)*

[3]*Maasai Mara University, Kenya (kiruistella@gmail.com)*

https://doi.org/10.62049/jkncu.v4i2.109

Abstract

Land cover change is described as the dynamic change in the terrestrial surface of the earth induced by human activities. Changes in land cover include urbanization, agricultural activities, and increased mining activities/quarrying activities which result in alteration of initial land surface status. Quarrying operations have been reported to cause alteration in vegetation cover and landscape, open cast methods used in stone mining lead to the destruction of land resources including denudation of vegetation cover, loss of soil fertility and soil erosion. Remote sensing and Geographical Information System (GIS) techniques were used to assess land cover changes due to stone mining in the study area. Satellite images covering the study area were downloaded from United States Geographical (USGS) Earth Explorer for the four epochs 1985, 1995, 2010 and 2022 for analysis. Spatial analysis of land cover changes was conducted by processing and analysis of remotely sensed images from Landsat and Sentinel 2 satellite data. Supervised classification was performed on the images into vegetation and non-vegetation cover classes using environmental visualization software, version 5.3. Findings were presented descriptively in tables, charts, graphs and textual forms. The study found that the non-vegetation cover class had increased by 18.70% between the years 1985 and 1995. There was an increase in vegetation cover class between the years 1995 and 2010 by 37.81 %. Between the year 2010 and 2022, vegetation cover was reduced by 18.24 %. The study concluded that quarrying activities have led to reduced land cover over time resulting in negative environmental outcomes such as land degradation and reduced aesthetic value in the study area.

Keywords: Quarrying Activities, Remote Sensing, GIS, Land Cover Classes, Satellite Images

Introduction

Land cover change is described as dynamic change in terrestrial surface of the earth induced by human activities (Brown et al., 2017; Nairuku et al., 2020; Alverez Martinez et al., 2011). Changes in land cover include urbanization, agricultural activities, increased mining activities/quarrying activities which result in alteration of initial land surface status. Quarrying operations have been reported to cause alteration in vegetation cover and landscape, open cast methods used in stone mining leads to destruction of land resources including denudation of vegetation cover, loss of soil fertility and soil erosion (Musah, 2009).

Materials and Methods

Study Area

The study was conducted in Narok town ward which is one of the wards in Narok North Sub-County that covers the Narok Town Municipality. The ward lies between latitudes 0° 50´ and 1° 50´ South and longitude 35º 28´ and 36º 25´ East in Narok County. The Ward hosts County's headquarters. It is divided into two locations namely Oleleshwa location and Narok township location. The ward also has the highest urban population among other wards in the county of about 68000 (KPHC 2019). The study area was purposely selected due intensive quarrying activities in the area. The area is rich in phonolite, a soft volcanic rock – shaped easily. Some the areas are also rich in granitic rocks which are suitable for ballast production

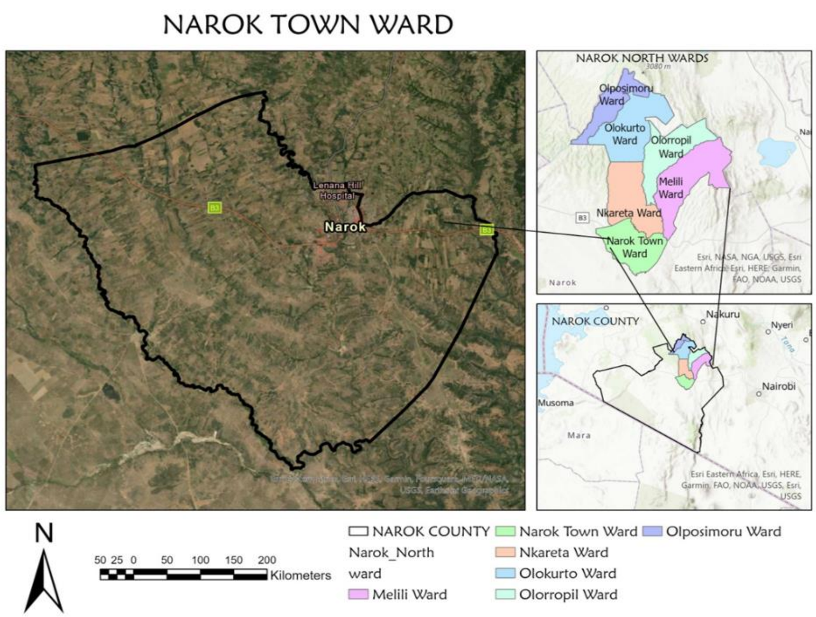

Figure 1: Map of Narok Town Ward

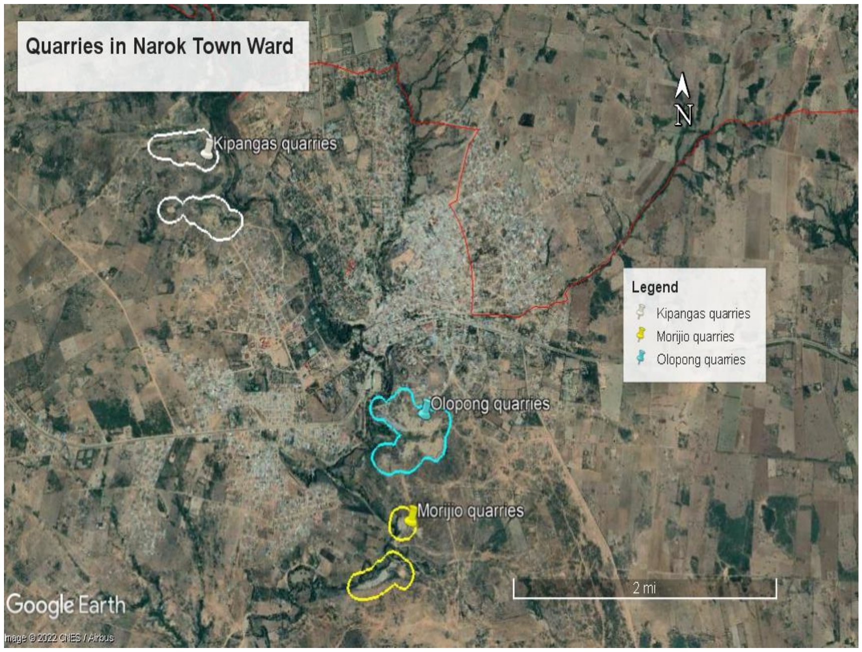

Figure 2: Distribution of quarries in the study area; source Google Earth

Spatial Data Acquisition

Remote sensing and Geographical Information System (GIS) techniques were used to assess land cover changes due to stone mining in the study area. Satellite images covering study area were downloaded from United States Geographical (USGS) earth explorer (https://earthexplorer.usgs.gov) for four epochs1985, 1995, 2010 and 2022 for analysis. Average interval of between ten to twelve years in which the images were acquired was used to facilitate change detection analysis of landcover. The year 1985 was the base year in which the preceding years were compared. The USGS provides users with remotely sensed data which have been collected for over forty years using Landsat satellite with different sensors on board thus providing a wide range of remotely sensed data for different purposes (Hassan, 2009). The satellite images were acquired from Landsat 4 and 5 satellites which carry the thematic mapper sensors for the years 1985, 1995 and 2010 epochs. For the current year 2022, an image was acquired from Sentinel 2 satellite which carries a multispectral instrument. Landsat 5 has 7 bands, comprising of optical bands 1-5 and 7 with a spatial resolution of 30m, and a panchromatic band (band 8) with a spatial resolution of 15m. On the other hand, Sentinel 2B has 13 bands with a spatial resolution of 10m, except for band 8 which has a higher spatial resolution of 5m that enhances the image quality. The satellite images were initially in the WGS 84 coordinate system and later transformed to the UTM coordinate system zone 36 S, WGS 1984 datum. The utilized bands had a spatial resolution of 30m pixels, while for Landsat 5 (TM), band 6 was obtained at a 60m resolution, which was later resampled to 30m pixels. For consistency in the imagery resolution, the Sentinel 2B MSI bands were also resampled to 30m, despite being acquired at 10m resolution.

Image Processing and Analysis

Resampling

Resampling is the method of pre-processing digital image and transforming it into a different resolution for the purpose of changing orientation and required resolution (Lillesand,2015). This is because the images captured have limitations as a result of imaging geometry or sensor orientation difference (Lu & Weng, 2007).

According to Onačillová et al. (2022) Landsat 4-5 images are readily resampled and accessed at a resolution of 30M while Sentinel Images are acquired at 10m resolution a higher resolution than Landsat Images. For this analysis, all the images were required to be in the same standard resolution, therefore, Sentinel images with a resolution of 10m were resampled to 30m. This was done in ENVI software using layer staking tools by adjusting the X-pixel size and the Y-pixel size and used the bilinear resampling algorithm to resample the Sentinel Image from 10m resolution to 30m resolution.

Image Sub-Setting Using Narok Ward Shape Files

The coverage provided by both Sentinel and Landsat images is wider than is needed. The Landsat satellite has a swath width of 185km, while the Sentinel covers an even larger area of 290km, which exceeds the required extent of the region of interest (Roy et al., 2019). Sub-setting involves extraction of the area of interest in the image. Narok Town Ward Quarry Boundaries and its environs shape file drawn from Google Earth pro were used for the purpose of clipping. The Narok Town Ward Quarry Boundaries and its environs were clipped from the full mosaic images of both the Landsat images and the 2022 Sentinel mosaic image.

Image classification

Image classification involves automatically categorizing all pixels in an image into a divined number of individual classes. During the study, a supervised classification approach was employed, utilizing 50 training data sets for each of the two cover classes that were established: Vegetation and Non-Vegetation. The Vegetation class was defined as regions that contain vegetation, using Google Earth Pro's ground-truthing vectors. This class primarily consisted of areas with trees, cultivated crops, and shrub lands, with a minor contribution from the spectral signature of chlorophyll to determine the class values. Training data for the non-Vegetation class were generated from areas devoid of vegetation such as cleared farmlands, human settlements, and bare-lands, with quarry boundaries developed non vegetation class consisted only quarried areas and hundred-meter buffer zone from the quarry boundary. The classification process utilized the Maximum Likelihood algorithm. The known land cover regions were digitized, and spectral reflectance of the land cover types was computed using ENVI 5.3 software during image processing. The study area was examined using Google Earth, and personal knowledge was used to develop training sites for the two land-use/land-cover classes. To generate normalized vegetation index (NDVI) values, the NDVI generation functionality in the ENVI toolbox was utilized. The software automatically selected the near infra-red band and the red band as input variables to calculate NDVI and generated values ranging from -1 to 1. In Landsat 4-5 TM, band 4 was used as the near infra-red band, while for the Sentinel 2B image package, band 8 was used. The red band was band 3 for Landsat 5 and 7, and band 4 for the Sentinel image package. The NDVI was computed for each year, and the resulting grayscale representation displayed values ranging from +1 to -1.

The density slices were generated from the already generated NDVI of the Narok Town Ward Quarry Boundaries and its environs of each epoch. In ENVI software, this was done using the raster colour slices tool in the classification toolbox. In this case colour slices of the NDVI based on the spectral wavelength emission class range of the Near Infra-red of 0.25 to 0.50, 0.50 to 0.75 and 0.75-1.00. The analysis relied on fluctuations in plant health determined by the level of chlorophyll present in the plants. Greater concentrations of chlorophyll correspond to increased green vegetation in the pixel. A standard algorithm was employed for calculations, generating reliable outcomes ranging between -1 and +1, which were subsequently utilized to create density slices from raster colour slices of the NDVI. For this particular study, values ranging from 0.25 to 1.00 density slices were chosen as this corresponds to the range where vegetation exists.

Result and Discussion

Post-Classification Analysis and Discussions

Spatial data were utilized in the analysis of Land Cover Changes in Narok Town Ward Quarries and its environs. These remote-sensed images were obtained from the United States Geographical Survey database. Landsat and Sentinel imageries. Landsat 4-5 Multi-Spectral Scanner/ Thematic Mapper images for years 1985, 1995 and 2010 Sentinel 2B images for the year 2022.

The results are discussed under the post-classification which includes the area comparison, spatial patterns identified in the changes and the rates of change from one epoch to another and the normalized difference vegetation index NDVI results.

Land cover analysis for the base year 1985

This was the initial image used as a starting point for the change detection analysis in Narok Town Ward Quarries and its environs. This particular year formed the basis for comparison since only a few quarries were at the initial stages. The vegetation cover class occupied area percentage of 61.00% which was a huge portion of the classified 1985 imagery this is indicated by vegetation density index above 0.5 .The vegetation cover class was almost fully intact with a high percentage of the area coverage being vegetated while the non-vegetation cover class covers only a small portion of 39.00 % Representing vegetation index of below 0.4 as shown in *Figure 4* The non-vegetated area contains mainly bare land and exposed rocks, an indication that either the Stone Quarrying activity could have started this early or the area had exposed rocks on the surface. Vegetation indices between -0.01 to below 0.1 indicate quarried lands while those above 0.4 indicate dense vegetation cover

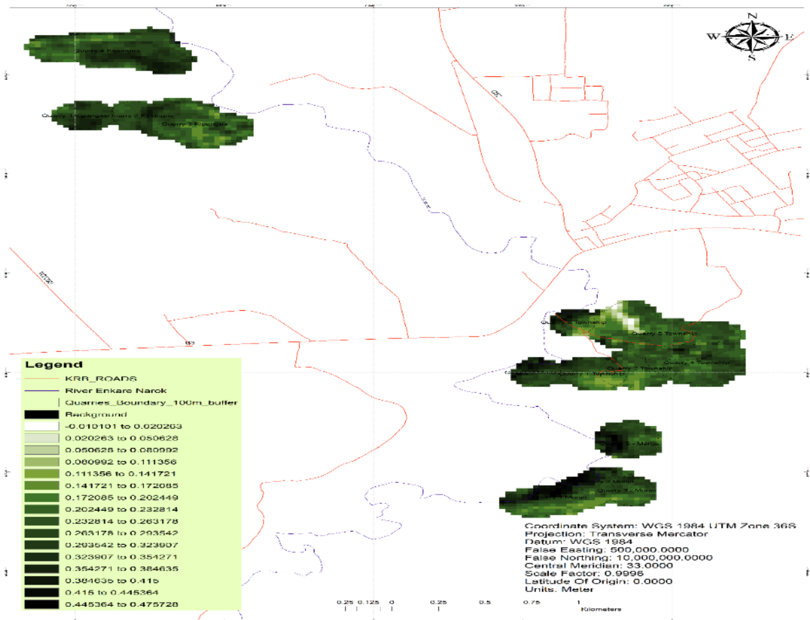

Figure 3: Vegetation density map for the year 1985

Land Cover Analysis for the Year 1995

The vegetation density classification showed a decrease in coverage of the areas under the vegetation cover class while area under the non-vegetation cover class increased in this span of ten years. The areas under the non-vegetation cover (vegetation indices between -0.01 to 0.01) class increased from 39.00% in 1985 to 57.70% in 1995 indicated by increased light tones in the vegetation density map as shown in *figure 4* and a reduction in vegetation cover class. This showed increased quarrying activities from 1985 to 1995 indicated by the reduction of vegetation from 61% to 52.3%. The findings showed an inverse relationship between the expansion of quarry sites and a decrease in vegetation cover class. The high demand for construction stones in the region led to increased quarrying activities in the study area to balance the demand in this period.

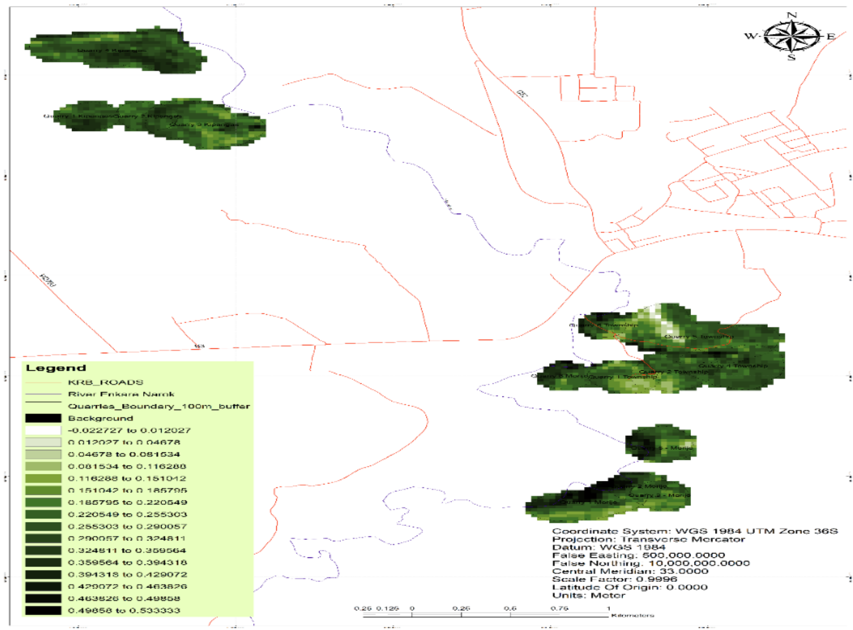

Figure 4: Vegetation density map for the year 1995

Land cover analysis for the year 2010

The classification analysis in this year showed increase in both vegetation cover class (NDVI 03 to 0.7) and expansion of quarries as indicated by increase light tones (NDVI 0.001to 0.1), *figure 5.* The increased vegetation cover outside quarry boundaries to 80% is attributed to increased rainfall between 2006 and 2010 since the country at large experienced elnino rains toward the end of the year 2006 which proceeded early 2007

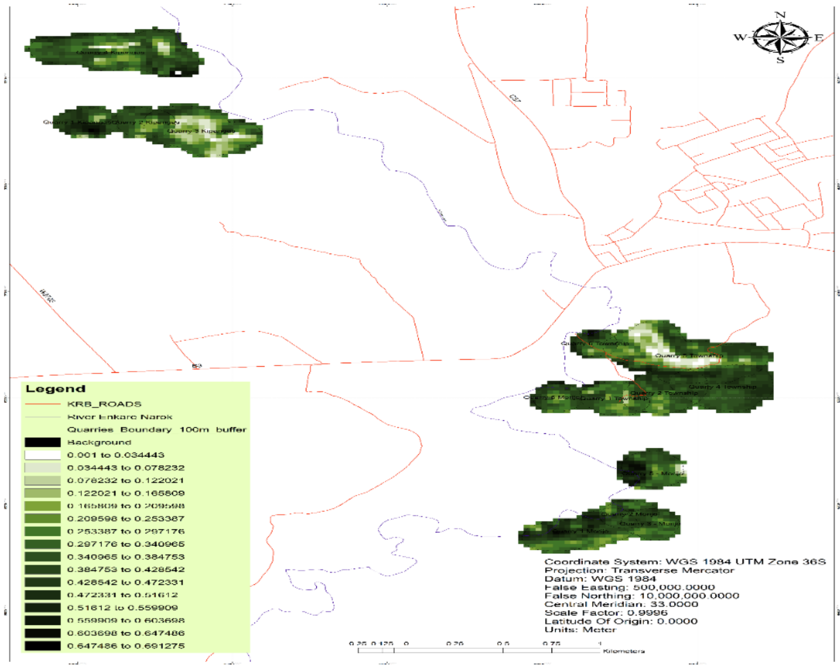

Figure 5: Vegatation density map for year 2010

Land cover change analysis for the year 2022

This final year showed massive increase in quarrying activities indicated by decrease vegetation cover in the area from 80.10% to 61.87%.The image analysis showed increased light tone (NDVI 0.001 to 0.1) marking the increased number of quarries and enlarged quarry boundaries which led increased vegetation degradation in the study area, *Figure 6*. The vegetation cover class area decreased by 18.23% compared to the previously classified 2010 imagery which is an indication of increased stone mining activities during the period of 2010 and 2022. Similarly, this suggest that there was increased demand for quarry stones due increased urban development in the region and the neighboring counties.

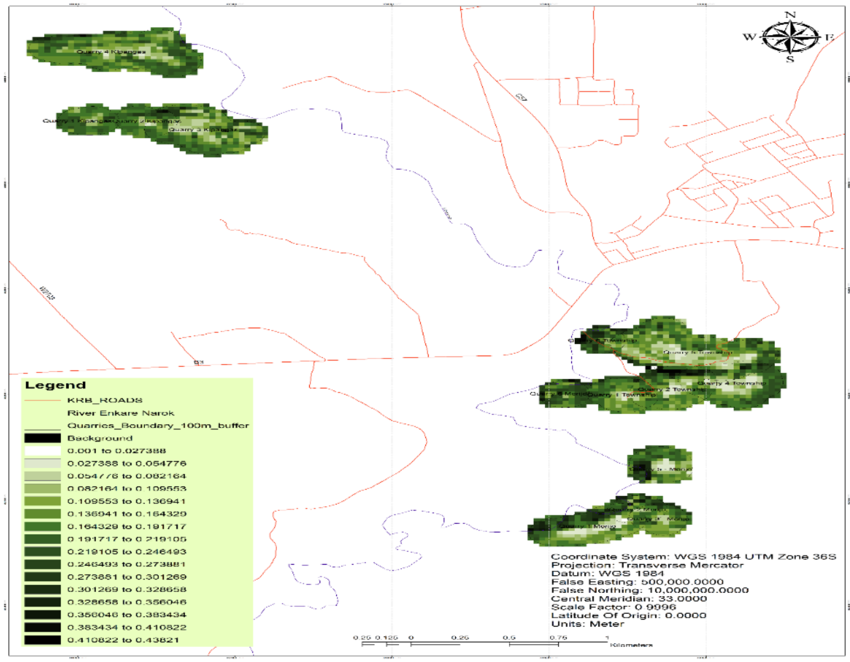

Figure 6: Vegetation density map for year 2022

Area Comparison, Spatial Patterns and the Rates of Land Cover Change

Between 1985 and 1995, vegetated land cover class had reduced by 296,100 m^2 (-18.70%) while non-vegetated cover class representing quarried areas increased by 296,100m^2 (18.70%). The non-vegetated land cover class was reduced by 598.500 m^2 (-38.15%) between the year 1995 and 2010, while an increase of vegetation cover class was experienced by 38.81% in 2010. Between 2010 and 2022, the vegetation cover class decreased by 288,000 m^2 (-18.24%), while area under non-vegetated cover class increased by 288,000 m^2 (18.24%).

The 1985 to 1995, the vegetation cover class had an annual rate of change of -29610 m2, while the area under other non-vegetation cover class had an annual rate of change of 0.0187%. Between 1995 and 2010, there was a positive annual rate of change in the area under vegetation cover class of 39900 m2, while the area under non-vegetation cover class increased by 0.025207% annually. From 2010 to 2022, the area under vegetation cover class experienced an annual rate of change of 24,150 m2, while the non-vegetation cover class had a rate of change of 24,000 per annum (0.0152%).

Table 1: Land cover class changes magnitudes and trend

Class Category	**Change of Area in M2 & Changes in Percentage**					
Cover Type (Class)	1985 -1995		1995 – 2010		2010 – 2022	
	Area (M2)	Percentage	Area(M2)	Percentage	Area (M2)	Percentage
Non-Vegetation	296100	18.70%	-598500	-37.81%	288000	18.24%
Vegetation Cover Class	-296100	-18.70%	598500	37.81%	-289800	-18.24%

Quarrying general has led land degradation contributing to alteration and modification of ecosystem which eventually affects the ecosystem services (ESS) such as nutrient recycling, sediment retention, and carbon sequestration. Similar findings were also noted by Nzunda (2013) in Tanzania who found that mining activities were the main drivers contributing to 50% change in land cover change in the study area. Additionally, Bizimana et al., (2021) who also utilize multi-spectral imagery to assess drivers of land cover changes overtime in Gutumba region in Rwanda noted gradual increase in quarried lands leading to reduction of vegetation cover.

Conclusion

Land cover changes caused by quarrying activities in Narok town ward have not only led to land degradation but also contributed to the decline of the aesthetic value of the area. Clearing of vegetation to pave the way for the extraction of rocks has continually led to the reduction of vegetation cover in the study area. Additionally, quarry waste roads and uncovered pits hinder vegetation regeneration which further reduces the vegetation cover in the area. The study recommends a multifaceted approach which involves all the stakeholders including the county government taking critical actions first to regulate quarrying activities and to put measures to rehabilitate and restore the exhausted quarry pits and convert them into green spaces which will lead to improved urban environment and improvement of land cover.

References

Alvarez Martinez, J. M., Suarez-Seoane, S., & De Luis Calabuig, E. (2011). Modelling the risk of land cover change from environmental and socio-economic drivers in heterogeneous and changing landscapes: The role of uncertainty. *Landscape and Urban Planning*, *101*(2), 108–119

Brown, D. G., Walker, R., Manson, S., & Seto, K. (2004). Modeling land use and land cover change. *Land change science: observing, monitoring and understanding trajectories of change on the earth's surface*, 395-409.

Hassan, S. (2009). Assessment of land use and land Degradation in the North-Western Part of Bangladesh using Landsat Imagery (master's Thesis) Division of Geoinformatics, Royal Institute of Technology (KTH)

KNBS (2019) Population and housing census Narok County.

Musah J.A. (2009) Assessment of sociological and ecological impacts of sand and Gravel mining. A case study of East Gonja District (Ghana) and Gunnarsholt (Iceland). Final Report, Land Restoration Training Program. Keldnaholt, Iceland.

Nairuko, A., Simon O., Mabwoga S.O., (2020). Impacts of Socio-Economic Activities on Land Use and Land Cover Changes in Narok North Sub-County*, Kenya. Maasai Mara university repository 14*(10), 1–16. https://doi.org/10.9790/2402-1410020116

Nzunda, H. P. (2013). *Impacts of mining activities on land cover and forest stock in Mbozi district, Mbeya region, Tanzania* (Doctoral dissertation, Sokoine University of Agriculture).

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). *Remote sensing and image interpretation*. John Wiley & Sons.

Lu, D., & Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing, 28*(5), 823-870.

Onačillová, K., Gallay, M., Paluba, D., Péliová, A., Tokarčík, O., & Laubertová, D. (2022). Combining Landsat 8 and Sentinel-2 Data in Google Earth Engine to Derive Higher Resolution Land Surface Temperature Maps in Urban Environment. *Remote Sensing*, *14*(16), 4076