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Original Article

Spatio-temporal Analysis of Changes in Land Use-Land Cover for Conservation Efficacy of Urban Forest Reserve: The Case of Rau Forest Reserve, Tanzania

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ABSTRACT

Changes in land use and land cover in different places around the globe have a significant impact on ecological structure and functions. Analysis of land use and land cover is useful in management activities, especially forest reserves as it reflects the interaction between adjacent communities and natural resources. We conducted a study to explore the changes in land use and land cover in the Rau Forest reserve to show the management status of this ecosystem which is also located in a nearby urban locality where management activities have been a challenge. The land use and cover (LULC) Spatio-temporal changes in the Rau Forest were classified as Densely Vegetation, Slightly Vegetation, Grassland, Bare land, Built-up, and Waterbodies to evaluate qualitative and quantitative changes in this reserve through the use of GIS techniques and tools over time (1990, 2000 and 2019). Landsat imageries for the year were used to identify the Spatio-temporal changes in vegetation in the area. We found that forest encroachment has driven changes in land use and land cover and transformed parts of the Rau Forest reserve into agricultural area settlements, and grazing lands which has ultimately led to gradual forest degradation. The results demonstrate the urgent need for strong and more severe regulations concerning the protecting the forest and involving local adjacent communities as they provide an extra layer of forest protection for the benefit of present and future generations.

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INTRODUCTION

Ecological areas such as forest reserves, national parks, game reserves, and wildlife management areas, provide many ecosystem services for the population residing in a given locality (Kideghesho *et al.*, 2013; Xu *et al*., 2022). These areas have been set aside for conservation purposes in order to protect the remaining scarce resources of both flora and fauna (Brancalion *et al.*, 2016; Martin *et al.*, 2016). Despite their importance, the aforementioned ecological areas are threatened by the continuing increase in human population (Anderson, 1982, Chapuis *et al.*, 2001; Guneralp *et al.*, 2017; Massawe *et al.*, 2019).

Population growth has been noted to be one of the major causes of the degradation of natural resources (Guneralp *et al.*, 2017, Sembosi, 2019). Indeed, population growth is a major cause of the increasing demand for natural resources to meet developmental needs which has resulted in the unprecedented destruction of forest vegetation and global ecosystems in general (Kironde & Ngware, 2000). The impacts of urbanization on biodiversity conservation include fragmentation of habitats, loss of rare species, edge effects, the introduction of alien species, degradation of the environment, reduced tourism potential, and the loss of ecosystem services vital for the well-being and health of urban residents (Mwasaga, 1991; Child, 1965; Oyan, 2000; Southgate & Hulme, 1996).

Due to human demand, land use and land cover changes have resulted in forest degradation and loss of natural vegetation. This has been driven by the interaction between biophysical and anthropogenic factors. It has been documented no single factor can cause changes in land use and land cover and therefore, it is the interaction of many factors given the expansion of urban centres (Kilcullen *et al.*, 2015; Addae *et al.*, 2019).

As urban areas expand, they take up more land and extend further into ecological areas (Mutaga, 2009: Andrew *et al.* 2004) in their study found that Land use and land cover changes observed across the globe are caused by uncontrolled harvesting of forest products and utilization of services as well as agricultural expansion. This has caused ecological areas to turn out to be the most transformative events across the globe (Hansen *et al.*, 2001; Foley *et al.*, 2005; Pielke *et al.*, 2011). Awareness of this interaction between land use and land cover permits critical measures in managing forest reserves. Various research studies documented population growth to be the main driver of land-use change, especially in developing countries (Hedblom *et al.*, 2017; Guneralp *et al.*, 2017; Sembosi, 2019). Moreover, it is well established in the literature that political, social, and economic drivers, including

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technological advancements, are the most significant drivers of land-use change (Götmark et al., 2000; Hersperger et al., 2018; Shi et al., 2018).

Currently, more attention is located on quantifying the effect of land use/ land cover in relation to biodiversity conservation. Comparatively, Tanzania is a host to twelve nature reserves covering a land of about 311,471 ha (Tanzania Forest Conservation Group, 2017). Nature reserves are protected under the Forest Act Cap 323. There is no utilization of resources allowed inside the forest and activities except research, education, and nature-based tourism (Olson *et al.,* 2003). Nevertheless, over the past three decades, advancements in remote sensing technologies demonstrated to be useful tools for monitoring land use and land cover changes (LULC) and development planning of protected areas (Cohen *et al.,* 2004). These techniques have become important tools for conducting change analysis in different parts of the world (Yuan *et al.,* 2015). For developing countries, where geospatial technologies are not well developed, remote sensing data, especially Landsat images, provide a suitable option for monitoring urban change and expansion (Howard *et al.,* 1998). Several researchers have applied remote sensing data to successfully quantify urban change, as well as its rate of change (Kolehmainen & Ban, 2008; Yuan *et al.,* 2015).

Quantifying this complexity of land cover and land use changes facilitates understanding of the relationship between human activities and the environment (Ramankutty *et al.,* 1999; Taylor *et al.,* 2002). There are several threats facing forest reserves that could seriously lead to forest fragmentation, land degradation, and biodiversity loss at spatial and temporal scales (Rockström *et al.,* 2009). It also helps to develop the capacity of stakeholders to manage land resources sustainably and facilitate improved biodiversity conservation in protected areas (Kaihuwa and Stoking 2003).

Rau Forest Reserve, situated in Moshi Municipality, is one of the forests which currently need special attention since is vulnerable impacts of urbanization. The reserve is an important resource for over 400,000 people who live in Moshi Municipality (Esbah *et al.,* 2007). It is a source of water for domestic purposes and irrigation schemes in lower Moshi. It is home to important plant species, including indigenous species such as *Oxystigma msoo*.

The reserve is also hosting the biggest tree in East Africa which is *Milicia excelsa* with a diameter of about 3 meters (TFCG, 2017). However, over the last few years, the forest has been facing threats that include illegal logging, fuelwood collection, encroachment for agriculture, invasive species, and considered to be major threats (Mhache., 2019).

Therefore, this study attempts to contribute to the limited literature on the changes of LULC around Rau Forest Reserve in Kilimanjaro, Tanzania with the aim investigating the space and time-based changes in land use and land cover that have occurred as a result of human development activities around (RFR) for the period 1990, 2000 and 2019.

MATERIALS AND METHODS

Study Area

Rau Forest Reserve is a lung of Moshi municipal for the supply of fresh air and serves as a catchment forest among the important watershed areas in Tanzania. It is surrounded by six villages which are Msaranga, Mabogini, MandakaMnono, Njoro, Mjimpya, and Kaloleni (Ministry of Natural Resources and Tourism, 2010). It lies between (3^0 23’ S and 37^0 22’ E), and it is 3 km South East of Moshi in the Kilimanjaro region of Tanzania. It covers an area of 25 km^2 from 730 m to 765 m above sea level. Annual rainfall is approximately 870 mm with temperatures of 26^0C in February and 21^0C in July. Rau Forest Reserve is mainly a groundwater forest. Rodgers (1993) observed the reserve vegetation is classified into natural ground forest, swamp forest, and woodland forest. In addition, the forest reserve is famous for two tree species,

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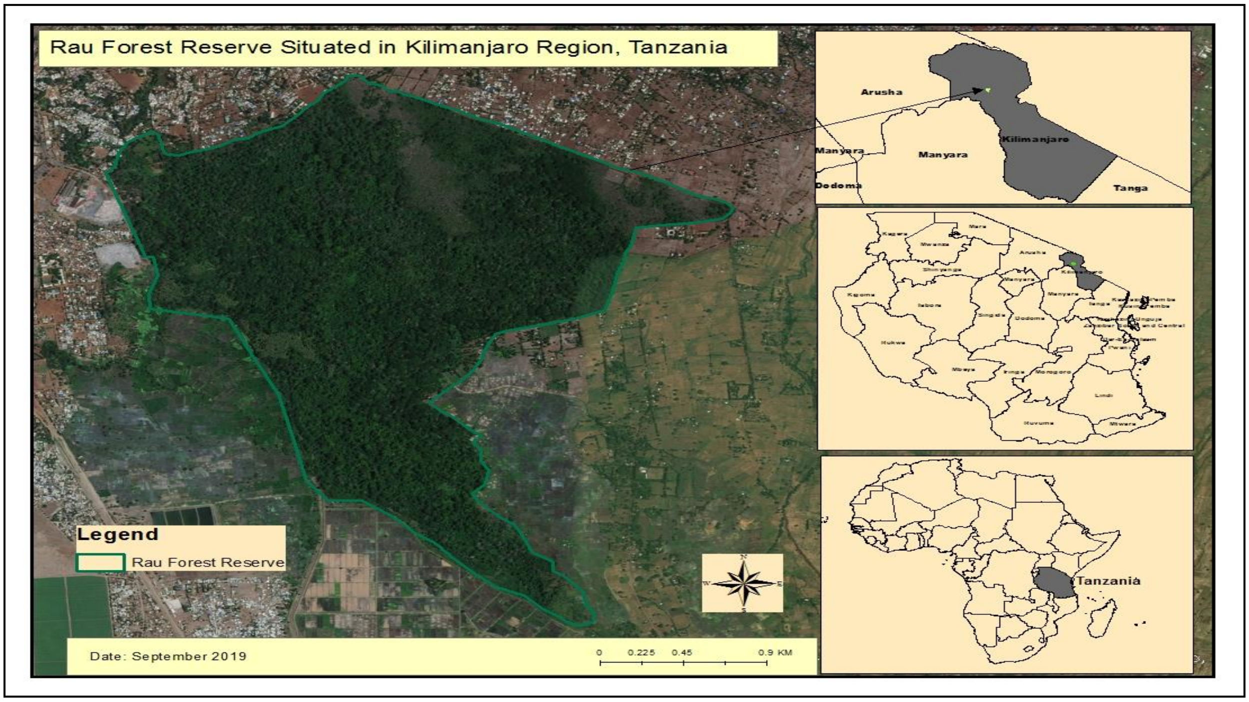
Oxystigma msoo and *Lovoa swynnertonii*, which are rare elsewhere. Both are very tall evergreen trees with valuable timber.

Together with tall Mvule trees (*Milicia excelsa*), they represent an important seed source. The reserve has diverse birdlife and several large mammal species including the black-and-white colobus monkey, blue monkey, and Kirk's dik-dik (Eustace *et al.*, 2015). All the mentioned villages depend on the agricultural activities around the Rau Forest Reserve since it is the source of water catchment that is used to irrigate rice farms and rural water supply around the adjacent community

Figure 1: Study area



Source: Adapted from Google/Administrative Map, 2019

Data Collection and Preparation

For the evaluation and monitoring of land use and land cover, remotely sensed data have been used widely as it is among the cost-effective means of getting data and maps which are georeferenced, as a method adopted from (Sembosi, 2019)

Apart from that, land-use change models have been effective in the analysis of land use and land cover changes over time to produce information that is significant in planning, supporting sustainable developments and decision-making processes (Koomen & Borsboom-van Beurden, 2011). A considerable distance of Moshi Municipality from the Rau Forest is used to delineate the Area of Interest (AOI) in the study. Landsat satellite imageries of the area for the years 1990, 2000 and 2019 were used to determine changes in land use and land cover, while data were selected based on data quality, data availability, and the dry season (*Table 1*). Imageries for the study period were acquired from the Global Landcover Facility (GLCF) website. The software packages ERDAS Imagine 2011, Arc GIS 10.3, and QGIS 3.10 were employed at various stages of data preparation.

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Table 1: Detailed data on Landsat images used in the study

Year	Satellite	Sensor	Path/Row	Resolution (m)	Acquisition Date	Source
1990	Landsat	TM	188/52	30	16, October 1989	Global land cover facility
2000	Landsat	ETM	188/52	30	20, October 2000	Global land cover facility
2019	Landsat	8	1882/52	30	10, October 2019	Global land cover facility

Classification and Change Detection

Using ERDAS Imagine software supervised classification system was adopted to digitally categorize each Landsat image since this technique has been shown to perform better in the case of spectral variability of land cover types (Pradhan & Suleiman, 2009; Verhulp & Van Niekerk, 2016; Phiri & Morgenroth, 2017).

Six spectral classes were identified in the imageries acquired and this includes densely vegetal cover, slightly vegetated, waterbody, bare ground, and built-up land based on ground truth sample points and pre-established spatial patterns. On the other hand, Ground surveys were carried out as means of verification and updating activities, while Global Positioning System (GPS) was used to obtain Ground Control Points at strategic locations. Within the ERDAS environment, the algorithm generated statistics used to quantify the changes in and around Rau Forest Reserve at a Spatio-temporal scale. To test for reliability, classification was also carried out within the “IdrisiSelva” software interface and an accuracy assessment was done thereafter. The classified imageries were then imported into ArcMap 10.3 (an extension of ArcGIS) interface for overlay operation and more exquisite visualization.

Table 2: The classification system of land use types in and around Rau Forest

Code	Name	Explanation
1	Densely Vegetation	This consists of tall trees and shrubs, and the trees are evergreens. Characterised by a unique vegetative structure consisting of several vertical layers including the overstory, canopy, understory, shrub layer, and ground level.
2	Slightly Vegetation	These consist of the next layer of vegetation after densely vegetation parts of Rau Forest. Here the vegetation is sparse and mainly composed of shrubs and scattered trees
3	Grassland	This means a part of the land that grows sedge, grasses, and shrubs which covers not less than 5% of the total area
4	Bare-land	It implies all the areas with no buildings or vegetation and thus bare soil.
5	Built-up	Includes residential areas, public buildings, industrial areas, commercial areas, transportation areas and other man-made features.
6	Waterbodies	Comprise of all-natural areas covered by water or different places with a water conservancy facility

Source: Teckle, K and Hedlund**,** L

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RESULTS AND DISCUSSION

Land Use Category Identification and Change Assessment Using Landsat Images From 1990–2019

This study anticipated providing the results of the land use mapping of Rau Forest and providing information on the aerial distribution of land use classes as well as documentation and valuation of land use variations over the past 29 years. The land use maps resulted from diverse Landsat images are shown in *Figures 3a–3c*. The aerial distribution of various land use classes for the years 1990, 2000, and 2019 and their change states in between different time edges are shown in *Table 3* and *Figure 2*, correspondingly.

Land Use Status of the Study Area from 1990 – 2019

Throughout the ground survey, the study area land uses were characterized into the following 6 sets including (1) Densely vegetation, (2) Slightly Vegetation, (3) Grassland, (4) Bare Land, and (5) Waterbodies correspondingly. After image classification on the basis of the aforementioned land use classes, appropriate map outlines were prepared (*Figures 3a–3c*).

Land Use Pattern of Rau Forest from 1990 – 2019

In order to recognize the past land use pattern of the study area, we concentrated on Landsat ETM imagery for the year 2000. Diverse land use classes had been identified and used as past references for the image of 2000. The identified land use outline was confirmed in cross- an examination way in the current setting, whether or not the category exists or transformed into another class.

Before ground confirmation familiarity is vital to recognize the classes of land use categories during the classification process. Through integrating ground truth information, We recognized the precise pixel along with their colour tone to confirm each land use type during the image classification phase. The 6 land uses classes that were recognized for the year 1990 to 2019 are itemized in *Table 3* and shown in *Figures 3a–3c*.

A total of 3961.7747 ha of the land area was estimated for the whole study area after supervised image classification. Results from this study (*Table 3* & *Figure 2*) revealed that built-up land has increased by 4.72% between 1990 to 2019 in the expense of vegetation and bare land.

From the recognised land use classes, the highest category was bare land (1941.614ha 49.01% of total land area) followed by slightly vegetation areas and densely vegetations (600.95ha 15.17% and 595.32ha 15.03%), Built-up areas by 399.91ha (10.09%), Grassland 360.416ha (9.10%) and 63.56ha (1.60%) of water bodies for the study period of 1990 (*Table 3*).

In contrast during 2000 study period bare land (1757.05ha 44.35% of total land area), slightly vegetation areas and densely vegetations (582.89ha 14.71% and 381.82ha 9.64%), Built-up areas by 577.56ha (14.58%), Grassland 599.97ha (15.14%) and 62.48ha (1.58%) of water bodies (*Table 3* & *Figure 2*).

On the other side as indicated in *Table 3* & *Figure 2* bare land covered 477.63ha (12.06%) of entire area, while slightly vegetation areas and densely vegetations (448.95ha 11.33% and 477.63ha 12.06%), Built-up areas by 586.59ha (14.81%), Grassland 736.93ha (18.60%) and 62.22ha (1.57%) of water bodies for the 2019 study period.

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Table 3: Land use and land cover Classification

Year	1990		2000		2019	
LULC Classification	**Area (Ha)**	**%**	**Area (Ha)**	**%**	**Area (Ha)**	**%**
Densely Vegetation	595.32	15.03	582.89	14.71	477.63	12.06
Slightly Vegetation	600.95	15.17	381.82	9.64	448.95	11.33
Grassland	360.416	9.10	599.97	15.14	736.93	18.60
Bareland	1941.614	49.01	1757.05	44.35	1649.45	41.63
Built-up	399.9147	10.09	577.56	14.58	586.59	14.81
Waterbodies	63.56	1.60	62.48	1.58	62.22	1.57

Source: Authors' GIS Analysis, 2019

Anthropogenic activities have tremendously modified the environment over time and space (Turner *et al.*, 1990). The rapid impacts of humans on the environment have overruled the natural cause of environmental change decades ago. Similar research from (Cochrane et al., 1999) support that human activities range from over-grazing, urban sprawl, deforestation, construction, and agricultural.

Figure 2: LULC Pattern of Rau Forest Area, Tanzania (1990-2019)

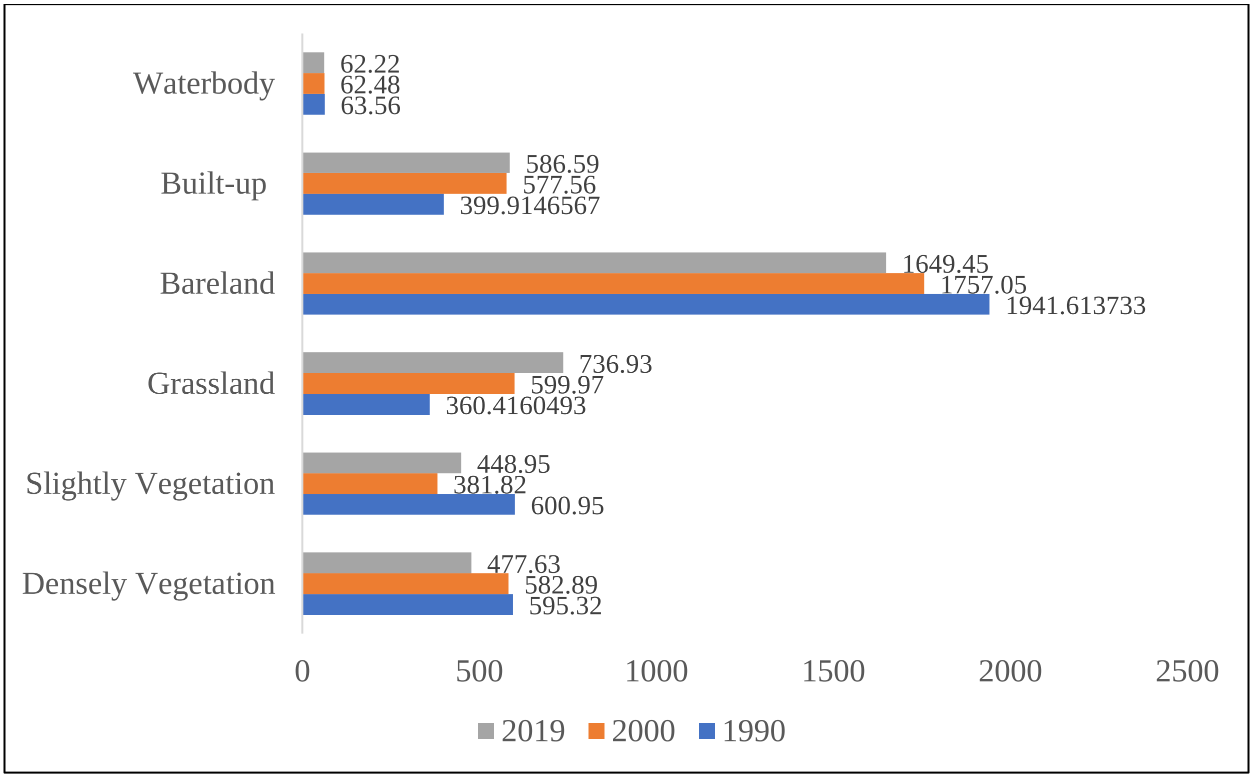

Figure 3a, *3b* and *3c* shows the land use pattern of the study area in 1990, 2000 and 2019 study periods. In this figures, green patches indicate densely and slightly vegetations which was not prominent in the study area as expected for mostly of the forest areas and this is because of increase in bare land driven by human activities, red colour indicates Built up areas which was mostly observed in the western side of the forest. Beside these, bare land was also observed mostly around the study area followed by grass land in south west and waterbodies which were very low compared to all the land cover classes.

Figure 3a: Classified Landsat ETM+ of 1990 Showing Vegetation Cover of the Study Area

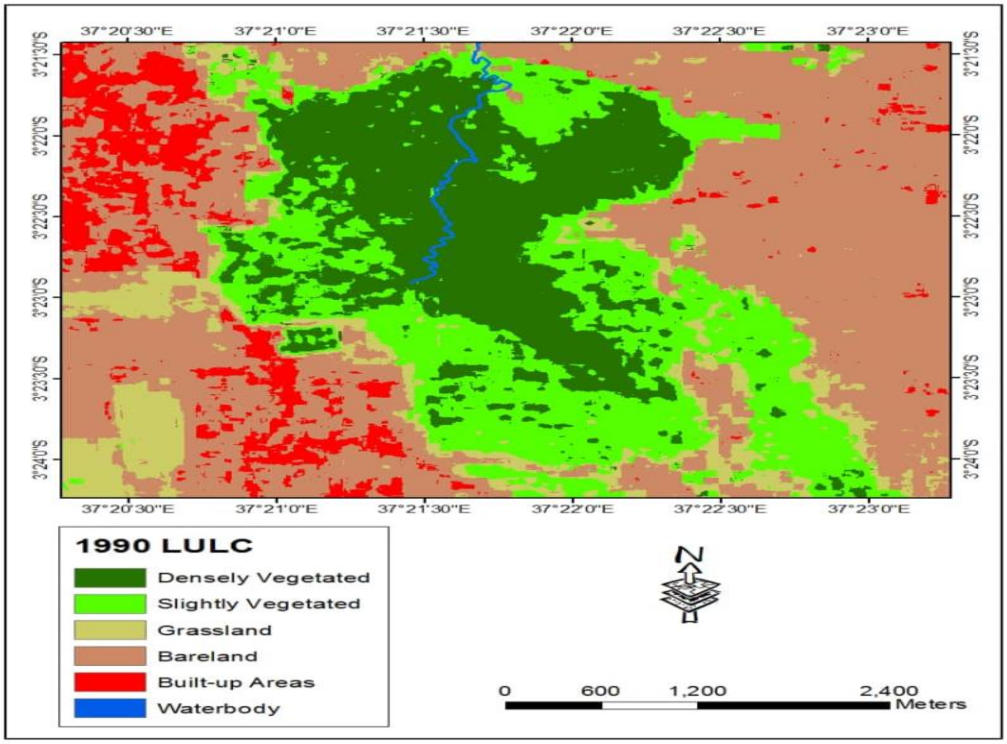

Figure 3b: Classified Landsat ETM+ of 2000 Showing Vegetation Cover of the Study Area

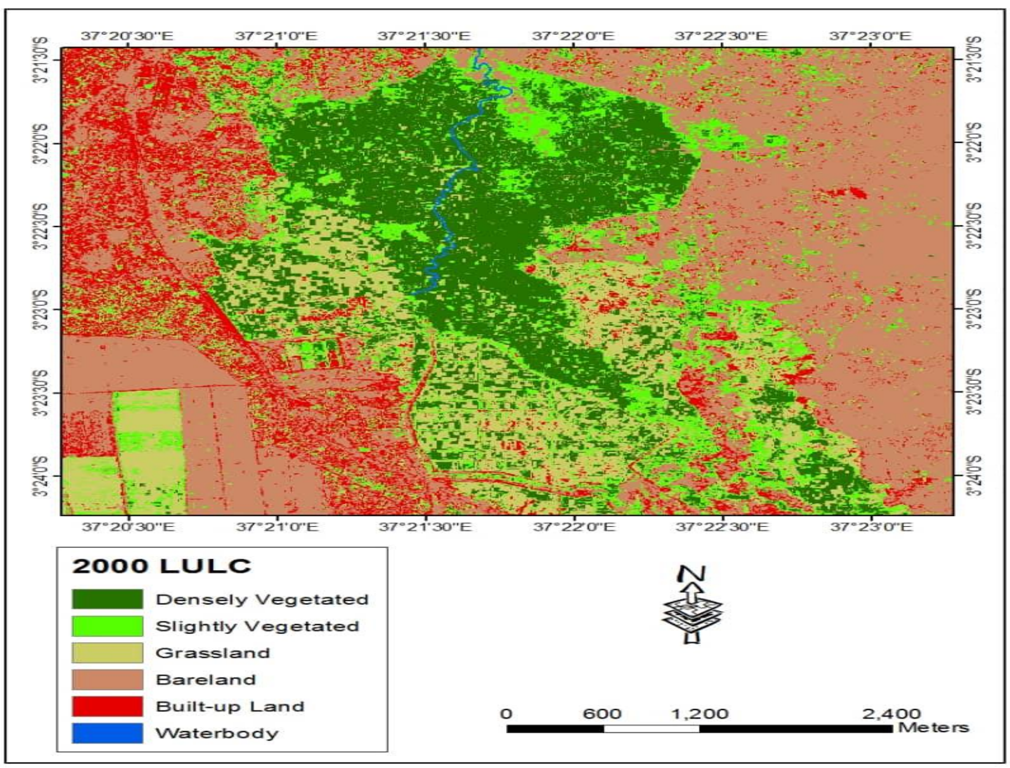

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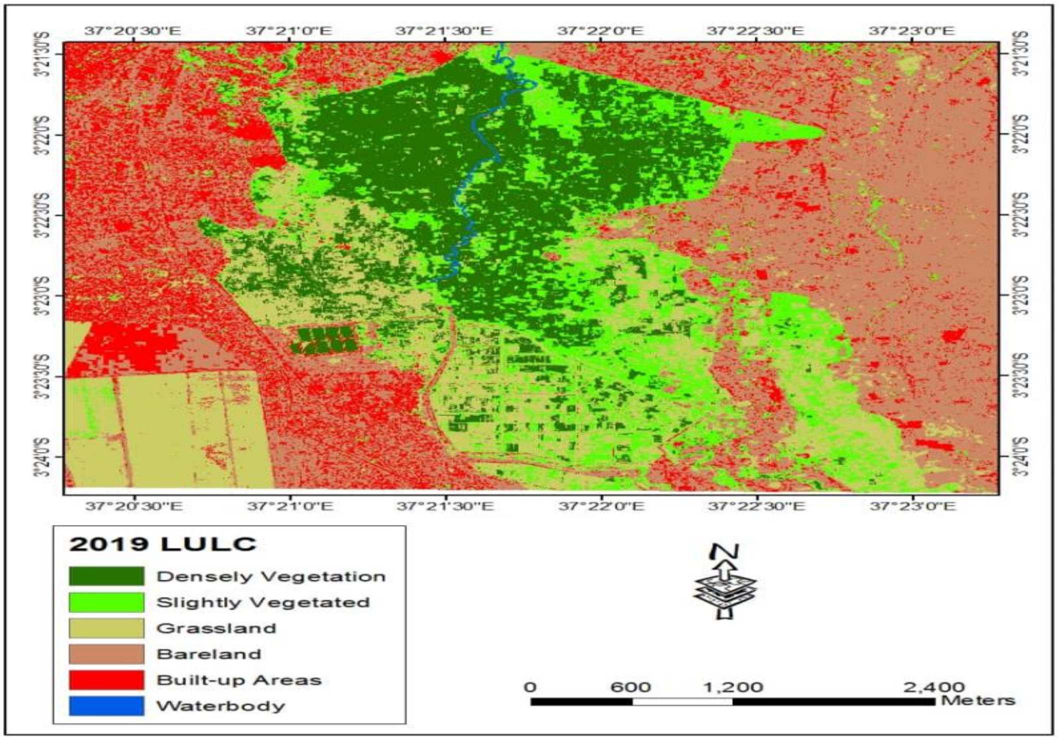
Figure 3c: Classified Landsat ETM+ of 2019 Showing Vegetation Cover of the Study Area



Rau Forest plays critical role in the survival of human beings, as forests sustain different peoples 'cultural spiritual and religious values (Lawman & Sinu 2017), However human activities are major influence causing slightly changing of the forest in terms of composition, diversity, and species richness of Rau forest Reserve.

In 1990, Rau Forest had an area that was densely vegetated of about 595.32 hectares, while in the year 2000, the coverage decreased to 582.89 hectares of land. Furthermore, in almost two decades, in 2019, the densely vegetated part of Rau Forest covered about 477.63 hectares of land. There is a slight or minute change in the densely vegetated parts of Rau Forest between 1990- 2019.

The vegetation is of the lowland, groundwater forest type and includes many rare tree species, for example, *Oxystigma msoo* (known only from Rau and occurs there only in a 5-ha area) and *Tapura fischere* (rare in East Africa). Other important species are *Chlorophora excelsa* (which is one of Tanzania's largest trees, 49.5 m tall and 140 m^3 volume), *Khaya nyasica*, *Cordia abyssinica* (planted), *Croton spp*., *Ficus spp*., *Newtonia buchanani*, *Macaranga spp.*, and *Oiospyros spp*.

However, owing to its (Rau Forest) geographical location, the Rau Forest has the ability of natural regeneration due to the favourable climatic condition and water body that passes through the forest. The part of the forest that is slightly vegetated covering an area of 600.95 hectares of land in the year 1990, which reduced drastically to 381.82 hectares in the year 2000 and it goes up to 448.95 hectares in the year 2019, due to its ability to regenerate.

Grassland also forms parts of the composition of Rau Forest, where grazing of animals takes place, due to the nature, composition, and diversity of different grass species in the area. Therefore, these parts of the forest cover about 360.416 hectares in the year 1990, 399.97 hectares in the year 2000 and 736.93 hectares in the year 2019. This indicates that the area covered by grassland is tremendously increasing due to forest encroachment by

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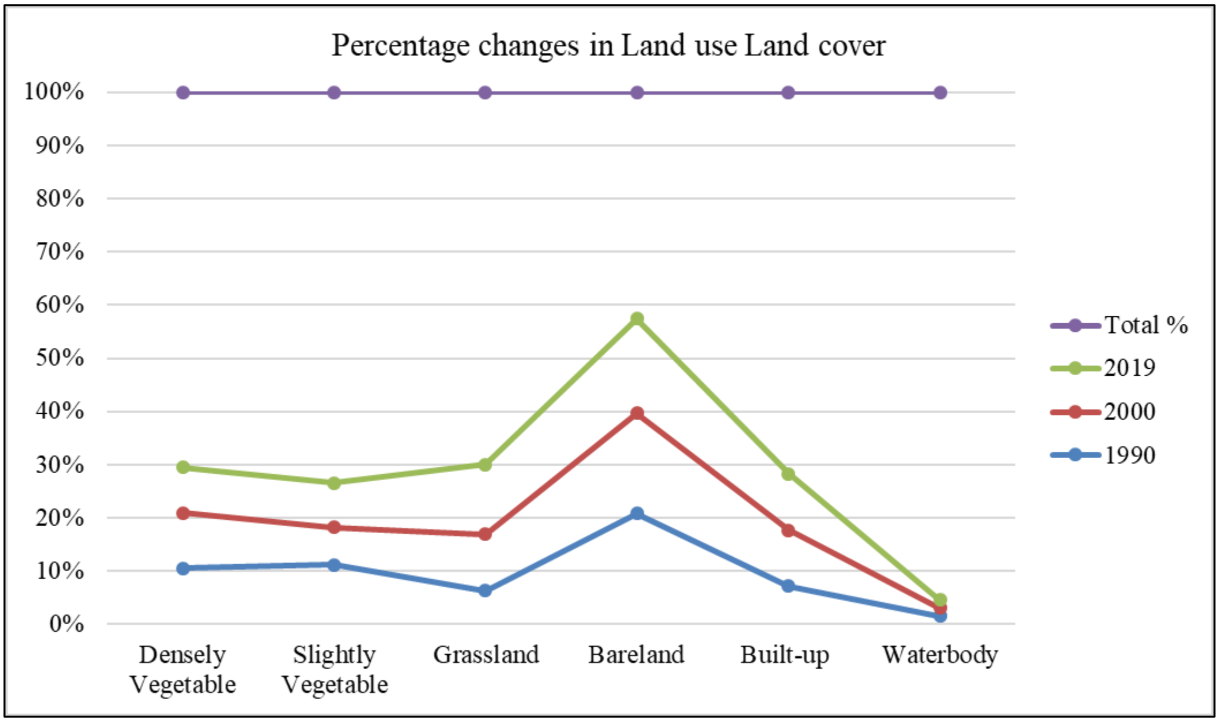
urbanization, over-grazing, and agricultural expansion.

Figure 4: Percentage Change in Land use and land cover



In the year 1990, the total bare land was about 1941.64 hectares; by the year 2000, the bare land had reduced to about 1757.05 hectares and 1649.45 hectares by 2019. This indicates that the bare land is now decreasing dramatically and is directly related to encroachment around Rau Forest. However, the built-up area witnessed a substantial increase from 399.9147 hectares in the year 1990 to 577.56 hectares in the year 2000 and 586.59 hectares in the year 2019.

As encroachment takes place on west side, where the forest has been cleared for cultivation (shambas) as many families in Moshi collect fuelwood illegally in the forest as noted (Mhache 2019).

Waterbody shows little or no changes in the study area from 1990-to 2019. Despite forest degradation that occurred in Rau Forest, there is no change in the water body, due to high water table of springs originates from slopes of Mt. Kilimanjaro. According to (Mhache 2019) forest has six large freshwater springs which are Mtomamba, Chem-chem ya Njoro,Chem-chem ya Bustani, Chem-chem ya Mamioni and Mwananguruwe used to irrigate about 250,000 ha of dry lowland area south of Rau Forest Reserve.

CONCLUSION

This study analysed the changes in land use and land cover patterns over a period of 29 years consecutively which has been considered a period of rapid development in areas around d Rau Forest reserve. We analysed the land-use dynamics, land-use distribution, and possible developmental causes of the decrease of vegetation in and around the reserve.

From the analysis, the transition of the densely vegetated area to grassland, built-up, and slightly vegetated areas have been described well, and thus the degree of land use and land cover changes are high. The dramatic changes in natural vegetation in and around Rau Forest have a significant in the

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regional weather condition of an area as well as the whole ecosystem where endemic species of flora and fauna exist as well.

Therefore, this study found the extent and composition of Rau Forest have changed over the study period as well as most of the endemic species of plants and animals which should be protected from encroachment.

We recommend that enhancing more protection of the forest reserve and seek a win-win way in the world of economic development and natural vegetation protection to boost the sustainable use of limited resources in developing countries. On the other side, the management should strengthen forestry community participatory approach, and enlighten the public on the importance of forest areas through sensitisation campaigns.

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