Spatial and Temporal Changes in Land Use/Land Cover and their Driving Forces in Kahe Forest, Northern Tanzania

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ABSTRACT

Deforestation is one of the major changes in terrestrial landscapes that affect the environment. Deforestation is caused by anthropogenic activities and a myriad of natural factors which cause a global loss of natural biodiversity and alteration of ecological processes and services across different ecosystems. The analysis of the spatial-temporal changes in land use and land cover was done in Kahe Forest. Moderate resolution land satellite images were downloaded from the United States Geological Survey (USGS) archives and analysed using the random forest (RF) algorithm and mapped in ArcGIS 10 software to ascertain the changes that took place in land use and land cover in Kahe Forest from 1998 to 2018. A questionnaire and key informant interviews were used to collect data. Findings show that agricultural land and grassland increased by 7 and 14 per cent while the forest area decreased from 85 to 51 per cent in the same period due to the escalation of human activities. The changes are caused by rapid population growth, wild fires, climate change and variability as well as human activities. It is recommended that the adoption of sustainable forest-management strategies such as the enforcement of the existing conservation laws and regulations and alternative environment-friendly sources of livelihood mainly community-based forest management should be enhanced by all stakeholders including the government and the community.

Keywords: *Spatial-Temporal Change, Drivers of Land Cover Change, Kahe Forest*

1. INTRODUCTION

One of the major changes affecting terrestrial landscapes is deforestation, resulting from both natural causes such as pests and diseases, forest fires and occurrences of invasive species; and non-natural factors such as human activities and rapid population growth. The decline in forest cover causes the loss of biodiversity (both flora and fauna), increases soil degradation, disrupts water cycles and causes greenhouse emissions, which lead to climate change (Brambilla et al., 2010; FAO, 2010). Globally, about 8.3 million and 5.2 million hectares of forests are estimated to have been lost annually for the periods of 1990—2000 and 2000— 2010, respectively. This occurred in rich natural tropical forest areas (FAO, 2010; Kundilwa et al., 2016).

Understanding changes in land use/land cover is very important for sustainable forest management, especially in developing countries, where the majority of people in both rural and urban areas depend on forests for their livelihoods (Msofe et al., 2019).

Normally, a change in land use is associated with sustainable development in a certain geographical space and is influenced by the flow of energy, landscape conditions, and biotic conditions chemical and physical characteristics. In addition, the changes are associated with the intensification of natural factors and anthropogenic activities such as climate change and climatic variability and soil erosion. Land-use/land-cover changes have certain negative effects on the environment as they stimulate soil erosion, land and habitat degradation, and the loss of biological diversity species (Millennium Ecosystem Assessment, 2005; Msofe et al., 2019). In order to examine land-use / land-cover changes, it is imperative to look at both natural and human factors which have become focal points in research on all land-use/land-cover changes (Msofe et al., 2019).

Land-use/land-cover changes directly impact biodiversity biosphere-atmosphere interactions, the ecosystem and sustainable utilization of natural resources (Liu et al., 2014; Msofe et al., 2019). These effects have attracted research interest of a range of international organizations and scholars in the world of investigating the drivers of LULCC (Geist & Ambin, 2006; Msofe, et al., 2019). o achieve sustainable land-use management, it is necessary to understand the LULCC processes that happen in the use of land resources over time and to identify the major drivers of land use and cover change. This will increase efficiency in land- resource use, mitigation of the negative effects of changes on landscape associated with LULCC, as well as the promotion of sustainable landscape ecosystem-management practices. To make informed decisions at local and national levels on sustainable land use, facilitate environmental monitoring and support national reporting on global conventions and frameworks, it is vital to examine the spatial and temporal processes of LULCC and their drivers (Leemhuis et al., 2017; Msofe et al., 2019).

Globally, forests are among the endangered ecosystem species because of land-use/Cover changes as they occupy approximately 31 per cent of the earths surface. Forests are estimated to contain more than half of all the terrestrial plant species, the majority of which are in the tropics. At the national level, studies revealed that forests cover 39.9 per cent of total land area in Tanzania, 43% of Mozambique, 12.4% of Uganda, and 6.99 per cent of Kenya comprising montane, mangrove acacia coastal woodlands and miombo woodland (GOM 2018; MENR 2016). As one of the largest forest protected areas, Kahe Forest (KF) is home to terrestrial biodiversity and has social, cultural and spiritual significance. It provides important goods and services. For example, it is a source of energy, especially firewood and charcoal. It is also a source of construction materials and medicinal products (Milledge et al., 2015; Nahashon, 2013).

Examining the drivers of land-use/land-cover changes in Kahe Forest is important for ensuring sustainable land use. Several studies on land-use/land-cover changes used various mathematical models, statistical models and, recently, GIS and remote sensing data to examine the alteration of land use/land cover in various parts of the world (Msofe et al., 2019; Nzunda et al., 2013). However, in many cases, analyses of land-use changes do not use a mix of different methodologies. Thus, this study analysed spatial and temporal changes in land use and the driving forces concerning Kahe Forest by integrating geospatial data, population data and socio-economic data.

2. METHODOLOGY

Kahe Forest (Figure 1) is located in Moshi Rural District in Kilimanjaro Region at the northern tip of Tanzania. It lies between Latitudes 3o 15 and 3o 20 south of the Equator and Longitudes 37o 15 and 37o 30 east of Greenwich. The area is bordered by Hai District in the north, Same District in the south, Moshi Urban District in the west and Kenya in the east. The area is found between 1000-1200m above sea level with a mean annual rainfall of 700mm-900mm and the average temperature of 30o C (Mndeme, 2016). The area was selected because the dwellers relied on the forest as their main source of energy, which, in turn, causes much forest degradation (URT, 2003). The adjacent villages are Oria, Mwangaria, Mawala, Ngasinyi "A" and Ngasinyi "B."

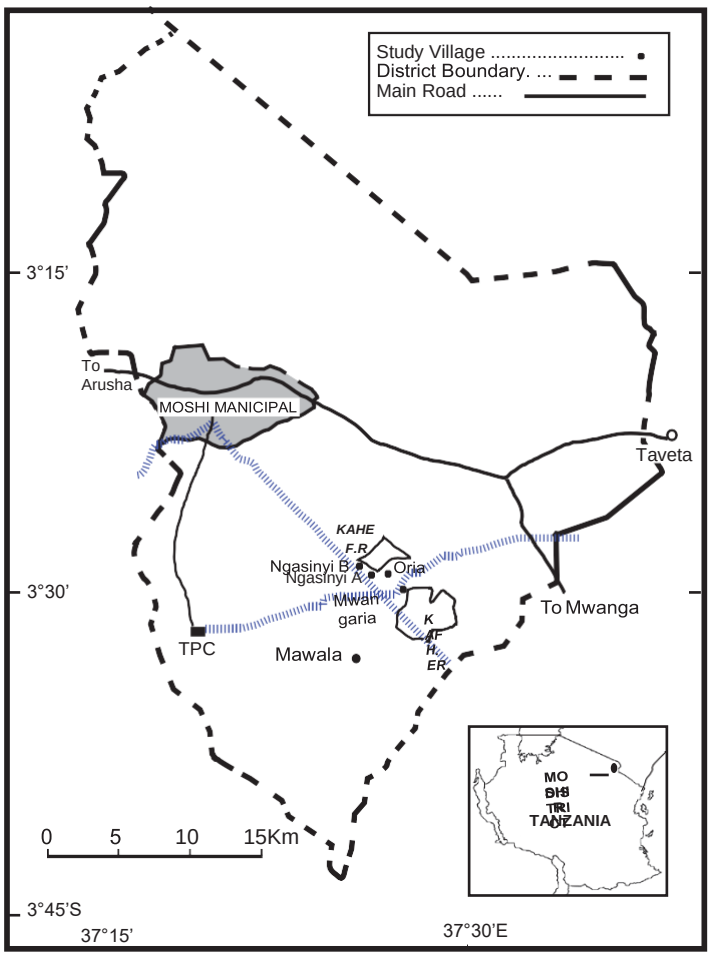

Figure 1: Moshi (R) District Showing the Study Area

Source: UDSMGeography Department, Cartographic Unit (2020)

About 150 out of 19,142 households in the five villages were involved in this study. Other informants were the Village and Ward Executive Officers. The sample size was obtained using the following formula suggested by Nassiuma (2000).

n= NC2C2+ (N-1)e2 $n= \frac{NC^2}{C^2+(N-1)e^2}$ ..... Equation 1

n= sample size

N= population size (19,142)

e= standard error/sampling error (1%)

C= variation coefficient (12.5%) -ranges from 10 to 20 per cent

From equation 1, the sample size for this study was obtained as follows;

N=19,142 12.5212.52+19,142-112= $N= \frac{19.142(12.5)^2}{12.5^2+(19.142-1)(1)^2}$ =150.24~150

150.24~150.....Equation 2

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Therefore, the sample size included 150 household heads and five key informants (see Table 1). Each village was represented by 30 households comprising the total sample size of 155 participants.

After determining the total sample size for this study as stipulated in equation 2, the next step was to obtain the study villages and specific individuals to respond to the questionnaires. This sampling process involved major two procedures. The first procedure was to identify the study villages. This was done through judgmental sampling where the villages were selected based on their proximity to the Kahe forest. The selection of study villages was done following the prior visitation in the study area by the researcher. Before the data collection, the researcher visited the buffer zone of Kahe forest and identified nine villages among which five were more proximal to the forest. The five sampled villages are Mawala, Mwangoria, Ngasinyi A, Ngasinyi B and Oria. Being close to the study forest, residents from the selected villages claimed to have direct contact with forest resources, a situation which is associated with the dynamics of the forest land cover in the study area.

The second activity during the sampling process involved the selection of specific individual household heads who are the unit of analysis in this study. This was done through systematic sampling where the total population (19,142 households) was divided by the sample size (150) and obtained 127, which was used as the sampling interval for selection. This sampling technique ensured that the population under study is sufficiently represented and thus the findings are realistic and convincing in concluding. Moreover, due to the nature of the study which intended to analyse the spatial and temporal changes in land use/land cover and the drivers in Kahe Forest as a complete ecological zone, , the researcher found worthy studying the surrounding sampled villages as a complete buffer zone.

Additionally, based on the similarities of the five study villages in both physical, geographical, economic and social characteristics and their relations with Kahe forest the researcher thought it wise to study all five sampled villages holistically. With this

regard, the names of household heads from all sampled villages were obtained from villages authorities and listed down following the villages alphabetical order. From the list of household heads every 127th name was picked for the questionnaire survey.

The study used spatial and non-spatial data. Spatial data comprised information obtained using satellite images produced from 1998 to 2018, which was used to detect changes in land use cover over time in the study area. The images were imported onto Arc GIS software to determine the changes in land use/land cover which happened over 20 years. The study also analysed non-spatial data, which were obtained using a socio-economic survey, meteorological data as well as population data to complement the information obtained from the spatial data.

Spatial data included satellite images produced at different times, which were downloaded from the United States Geological Surveys (USGS-GLOVIS) and Earth Explorer. The satellite images were used to map and explore changes in land use, determine the state of the forest, assess the rates and trends of deforestation and update the existing forest maps that could play a vital role in making decisions and making sustainable land-use plans. The land-use map of 2012, forest type maps, the population size, the forest boundaries and other socio- economic data that covered the whole study area were also used in doing a geospatial analysis of land-use/land- cover changes.

In order to detect the types of land use/cover changes and to determine the rate of changes, the study used satellite land sat images of 1998 and rapid eyes of 2018. The images were obtained from the Department of Urban Planning in Tanzania (DoSUP) downloaded Department of Survey and Urban Planning (DoSUP) Tanzania. Downloaded from Earth Resources Observation and Science (EROS) at (http:// glovis.usgs.gov) of the Geological Survey of the United States of America. Similarly, population data which were obtained from the National Bureau of Statistics in 2012 were used to assess the influence of population on land use change and resource use consumption.

The 150 household heads from the study area (Oria, Mwangana, Mawala, Ngasinyi A and Ngasinyi B) completed a semi-structured questionnaire, to get their perceptions of the drivers of land-use/land-cover changes and the natural reasons for the changes and to investigate the influence of human activities on the changes. Interviews were conducted with five local government officers who were believed to have much knowledge of and experience in the changes in land use/ land cover and the forces behind them.

All non-spatial data were carefully examined for consistency. The data were also edited to ensure that they were accurate, consistent and well-arranged so that they could be coded and entered into the data analysis software.

Data from the interviews were put into specific categories. All data were then carefully cross-checked to get rid of all unnecessary information.

As for the satellite data, image restoration, image enhancement and image classification were conducted. Image restoration involved correcting and calibrating the images to get high-quality images and remove degradation effects. Further radiometric restoration and geometric restoration were made.

The images were enhanced by optimizing their appearance. This involved contrast stretching, composite generating and digital filtering. Then, the images showing land-use/ land-cover changes were manually put into five groups, namely woodland, bushland, grassland and agricultural lands. A supervised classification method in Arc GIS was used to put the images into five classes. This technique was chosen because of its precision in land-cover categorization.

The first step was to select training sites; Arc G.I.S image classification software was used to identify the categories of land cover in all the images. The second step involved creating a signature file. The classification of land cover was based on the spectral signature defined in the training set and minimum-distance classification was used for classification logarithms. Finally, five categories of land cover which include forest (land covered by low-density trees, woodlands (land covered with low density and scattered trees as well as farms), Bushland Spatial and Temporal Changes in Land Use/Land Cover and their Driving Forces in Kahe Forest, Northern Tanzania (land covered with bushes and shrubs), Grassland (land covered by grass) and agricultural land (land on which farms are located were obtained.

The data obtained using the socio-economic survey were quantitatively analysed using the statistical package for the social sciences (SPSS) version 20 software to get the frequencies and percentages of responses. Qualitative information was analysed using content analysis techniques. The satellite images were analysed using Quantum GIS (Open-source software). Before a change was detected, the images which had been classified were checked for accuracy levels by doing post-processing.

Then, an error matrix table was produced to show a land-use /land-cover classification report and overall accuracy levels of the satellite images. The accuracy level accepted for this study was 80 Per cent. Then, a semi-auto classification plug-in was used to calculate the changes in land use.

The product of this process was a change trajectory map showing what has changed and what has not changed, and cross-tabulation statistics tables showing the extent of the changes and annual changes. The summation of loss and gain was used to calculate and identify the net changes of each type of land use. Overall changes were calculated by dividing the net changes by the number of years — from 1998 to 2018 — to get the annual land-use changes. The following formula was used to calculate the annual land-use changes:

$$r = \frac{[\ln(A_{t1}) - \ln(A_{tv})]}{t_1 - t_v} = 100$$

r = rate of annual change

A_{t1} = land use area in the initial

A_t = land use area in final year or time

t_1 = initial time (year)

t_v = final time (year)

ln = constant (Kashaigili and Majaliwa 2013)

The data obtained from the analysis of land use and satellite images were presented in tables and map formats, which show land-use/land-cover changes.

The data obtained using the questionnaire and interviews were presented as descriptive statistics which include frequencies, percentages and figures.

3. RESULTS AND DISCUSSION

3.1 Spatial and Temporal Changes in Land Use and Land Cover in Kahe Forest from 1998 to 2018

The maps on land use/land cover for 1998 and 2018 are presented in Figures 2 and 3. Generally, the maps show variations in Land use/land cover from 1998 to 2018. Table 4 presents the spatial distribution of five classes of land-use/land-cover for the period between 1998 and 2018.

The results in Table 1 and Figures 2 and 3 show that bushland and grassland are among the main types of land cover in Kahe Forest accounting for 85, 5 and 4 per cent of the total land cover in 1998 (Table 4). By 2018, agricultural land, grassland, bushland and woodland had increased by 18, 14, 10 and 7 per cent, respectively. However, the area occupied by Kahe Forest decreased by 34 per cent from 833 ha (85%) in 1988 to 507 ha (51%) in 2018.

The rapid decrease in the land size was caused by the conversion of the land to agricultural land, bushland, grassland and woodland. The conversion was mainly influenced by the expansion of agricultural land the rise in the demand for forest products such as timber, fuel wood and charcoal. These findings concur with the findings in a study by Msofe et al. (2019), who revealed that human activities and the rise in the demand for forest products such as fuel wood and logs were the primary drivers of deforestation in the Kilombero Valley.

Table 1: Estimated Area (ha) of LULCC in Kahe Forest from 1998 to 2018

LULC Type	1998 (ha)	%	2018 (ha)	%
Agricultural land	26	3	95	10
Bushland	50	5	136	14
Forestland	833	85	507	51
Grassland	41	4	177	18
Woodland	29	3	64	7
TOTAL	**979**	**100**	**979**	**100**

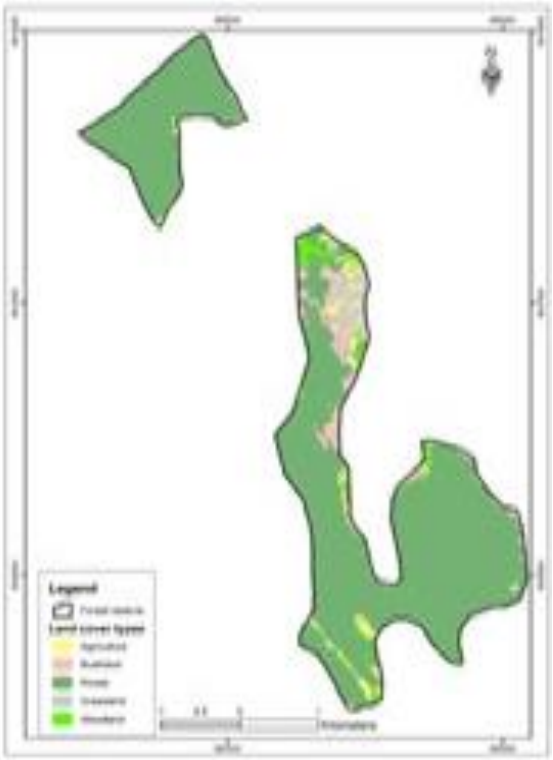

Figure 2: Land Use/Land Cover Map for Kahe Forest, 1998

Figure 3: Land Use/Land Cover Map for Kahe Forest, 2018

3.2 Land-Use/Land-Cover Changes from 1998 to 2018

The extent of the changes in land use/land cover including area change, percentage change and an annual rate of change are shown in Table 2. The increase and decrease of the land use/cover change categories are represented by negative and positive signs (-) and (+) respectively. The results indicate that grassland increased by 14 per cent, bushland by 9 per cent and agricultural land by 7 per cent.

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The increase of grassland was influenced by its suitability for being grazing land, as the communities were engaged in both farming and livestock keeping. Generally, the increase in agricultural land and grassland can be attributed to too much pressure on the land resources. On the other hand, the results show a decrease of forest land to -38 per cent because the land was converted to other uses to support the local communities livelihood (Table 2).

Table 2: Land-Use /Land-Cover Changes in Kahe Forest from 1998 to 2018

LULC Type	Area Change(ha)	Percentage of Change (%)	Annual Rate of Change (ha/year)
Agricultural land	-69	7	-6.3
Bushland	-86	9	-7.8
Forest	326	-38	29.6
Grassland	-136	14	-12.4
Woodland	-35	4	-3.2

3.3 Drivers of Land-Use / Land-Cover Changes in Kahe Forest (KF)

Community Members Perceptions on Land-Use/Land-Cover Changes at KF

The results in Table 6 show that 46.7 per cent of the informants noted that the state of Kahe Forest had fallen and 30.7 per cent noted that it had risen. These results imply that the informants have mixed perceptions towards the state of the forest, this could be because there is no clear management regime for Kahe Forest. The findings are similar to the findings of studies conducted by (Munthali, et al 2019 and Tanui 2015) as they observed that the local community had noted a rapid decline in forest cover as a result of severe deforestation and land degradation, caused by people's overexploitation of forest resources in Malawi and Nandi Kenya.

Contiguous Drivers of Land-Use Changes at KF

The results in Table 7 show that the leading cause of changes in land use in Kahe Forest was indirect consumption of forest resources (62.7%). This consumption of the resources was caused by agricultural expansion, free livestock keeping and the expansion of settlements. This was followed by direct consumption of forest resources such as the extraction of wood for fuel and charcoal-making, and the natural reasons which accounted for only 7.3 per cent These results imply that anthropogenic activities are the source of deforestation in all forests. Although Wubie et al. (2016) observed that direct consumption of forest resources such as direct extraction of forest resources for the wood used in cooking, heating and lighting accelerates land- use / land-cover changes in Ethiopia, this study notes that indirect causes such as agricultural expansion, free livestock keeping and the expansion of settlements also cause land-use/land-cover changes.

Human Activities that Contribute to Land-Use/Land-Cover Changes in Kahe Forest

The results in Table 3 show that firewood collection and the expansion of crop farming accounted for 38.7 per cent of the total responses and that the expansion of human settlements and grazing land accounted for 61.3 per cent of the total responses. These were followed by charcoal-making, which accounted for 54.7 per cent of the human

activities that cause deforestation in Kahe Forest. The results imply that cooking and warming energy are still a problem, although the government is installing electricity in the villages through the Rural Energy Agency (REA) programme.

In Kahe Forest, deforestation is attributed to the expansion of agricultural land, illegal logging as well as increased demand for such forest products as fuel wood and charcoal. Similarly, Msofe et al. (2019) and Geist and Lambin (2002) reported that human activities and increased demand for such forest products as fuel wood and logs were the primary drivers of deforestation. The results of this study also show that agricultural land, bushland and grassland have increased by 7, 9 and 14 per cent, respectively, mainly owing to high population growth (Table 2).

The increase in population has greatly increased pressure on land resources, as shown in Table 4. These findings are supported by the responses from the key informants, one of whom said,

> *… the state of Kahe Forest has greatly changed in recent years. Twenty years ago, the forest was thick and the trees were tall and had huge trunks. But the forest is no longer thick as the trees are scattered and are not very tall and thick. This situation is caused by the high demand for forest wood products, especially charcoal and timber…. (A Village Executive Officer aged 52)*

Table 3: Human Activities that Contribute to Land-Use/Land-Cover Changes in KF

Activity	Rank					Overall N=150
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	
Firewood collection	58 (38.7)	58 (38.7)	34 (22.6)	0 (0)	0 (0)	150 (100)
Charcoal-making	35 (23.3)	82 (54.7)	33 (22)	0 (0)	0 (0)	150 (100)
Timber-making	11 (7.3)	24 (16)	81 (54)	23 (15.3)	11 (7.3)	150 (100)
Building materials	12 (8)	35 (23.3)	92 (61.3)	0 (0)	11 (7.3)	150 (100)
Expansion of human settlements	0 (0)	92 (61.3)	47 (31.3)	11 (7.3)	0 (0)	150 (100)
Expansion of cultivation land	58 (38.7)	57 (38)	35 (23.3)	0 (0)	0 (0)	150 (100)
Expansion of grazing land	24 (16)	92 (61.3)	23 (15.3)	0 (0)	11 (7.3)	150 (100)

NOTE: Numbers in brackets are percentages

Human Population Growth Adjacent to KF

Kahe Forest is accessed and utilised directly and indirectly by the adjacent villages and districts which include Hai Same, and Moshi urban. Table 9 presents trends in population Spatial and Temporal Changes in Land Use/Land Cover and their Driving Forces in Kahe Forest, Northern Tanzania

growth in these districts. The number of people increased from about 538, 107 in 1967, to about 1,131,369 in 2012 and about 1,259,188 in 2018. This trend in population growth has produced an overall growth rate that ranges from 1 to 8.6 per cent from 1967 to 2018. This rapid population growth almost doubled the size of the population in every two decades. The increase in population increased the pressure on natural resources, thereby causing land scarcity and fragmentation. Generally, it could be argued that there is a relationship between population growth and changes in land use at KF, as indicated in Section 3.2.2.

Thus, population growth has increased the demand for arable land and caused much environmental degradation. The results are consistent with the results of other studies (i.e., Munthali et al., 2019; Kindu et al., 2015; Chowdhury, 2008). These studies revealed is a relationship between population growth and forest degradation. Population growth caused a decline of the forested area by 4.5 per cent between 1990 and 2016.

Generally, as the population grows, arable land becomes scarce, which makes it necessary for people to intensify agricultural production in Kahe Forest. The results from the data obtained using the questionnaire are supported by data from key informant as one of the key informants said,

> *… I have lived in this village for more than 40 years. When I was younger, the houses were scattered and very few people lived near the forest. But houses are many now and some of them are very near Kahe Forest.*
> *The increase in the number of people in our village has drastically intensified the exploitation of the forest resources…. (One Village Executive Officer aged 54)*

These findings are similar to the findings of a study by Mdemu et al. (2012), who observe that population growth in peri-urban areas is associated with the expansion of settlements and an increase in the demand for agricultural land. Similarly, Debel et al. (2014) reported that population growth has a huge impact on forestry since it increases the demand for forest products such as timber, firewood and charcoal.

Table 4: People Living Adjacent to KF by District for the Period 1967-2018

	District				Total
	Hai	Moshi Rural	Moshi Urban	Same	
1967	116, 974	242, 075	29, 423	149, 635	538, 107
1978	172, 444	312, 041	52, 066	133, 628	670, 179
1988	200, 136	342, 553	96, 838	170, 053	809, 580
2002	259, 958	402, 431	144, 836	211, 738	1,018, 963
2012	210, 533	466, 737	184, 292	269, 807	1, 131,369
EST. 2018	234, 318	519, 468	205, 113	300, 289	1, 259,188

Source: Human Population Censuses of 1967, 1988, 2002, and 2012

Natural Reasons for Land-Use Changes in Kahe Forest

The findings from the questionnaire survey indicate that the majority (62.7%) of the respondents strongly agreed that climate change and variability contributed to land-use changes in KF. They contend that weather changes were the main drivers of most human activities in developing countries. On the other hand, wildfires accounted for about 14.7 per cent of land use changes.

The analysis of time series (meteorological) data obtained from the Tanzania Metrological Agency, located at Moshi Airport, which is near KF, from 1987 to 2018, generally shows a slight decline in the total annual rainfall. The dependent variables were the parameters of weather and the independent variable was time.

The analysis showed a slight change in the pattern of annual rainfall at $R2 = 0.0523$, $p < 0.05$ ($y=897— 6.2089x$) (Figure 3). Similar results were reported by Lyimo and Kangalawe (2010) who observed that in Shinyanga Rural District, rainfall was decreasing although at a non-significant rate of $R2 = 0.18$, F probability > 0.47. Although the decrease was not statistically significant, the amount of rainfall was declining in the area where the study was conducted.

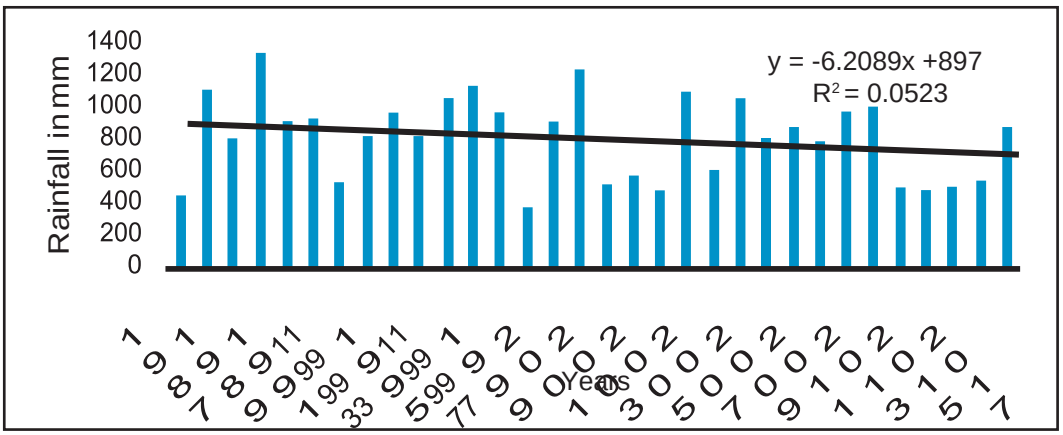

Figure 3: Total Annual Rainfall (in mm) Recorded by the Tanzania Metrological Agency at Moshi Airport

The analysis of time series data from TMA showed a statistically significant increase in maximum and minimum temperature (y = 29.472 + 0.0216x and y = 17.732 + 0.0268x, respectively). The minimum temperature was higher than the maximum temperature.

For the period 1987-2018, the maximum temperature increased by about 1.8oC, while the minimum temperature increased by 2.6oC (Figures 4). Generally, the minimum temperature increased at a higher rate than the maximum temperature.

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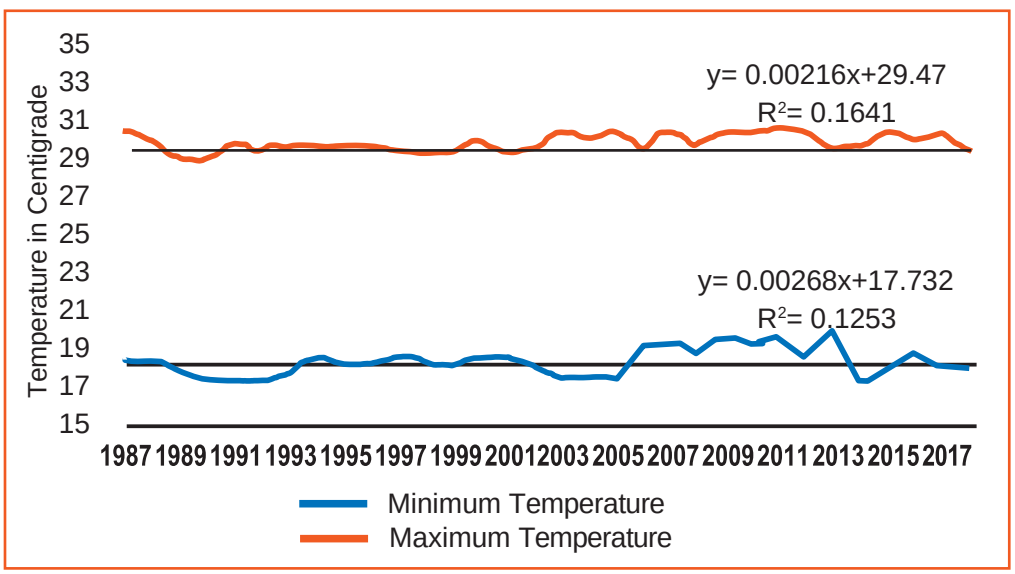

Figure 4: Minimum & Maximum Temperature Recorded by the Tanzania Metrological Station at Moshi Airport

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

This study revealed that Kahe Forest has experienced Spatio-temporal changes in LULCC mainly because of the conversion of land into anthropogenic activities. The activities include agriculture, collection of fuelwood, charcoal-making, and the harvest of timber and other building materials. These activities cause environmental degradation in Kahe Forest.

The changes in land use and land cover constitute a complex process that involves the interaction of various factors. Demographic pressure, the influence of markets, biophysical factors and policies are among the factors for the changes. However, the factors act simultaneously and separately at different magnitudes in terms of time and space to influence the changes in question. High demand and higher prices of forest products coupled with improved infrastructure influenced the overall process of socio-economic activities as most households depend on farming and livestock keeping as their main sources of livelihood. Furthermore, if the changes continue, they will adversely affect the ecosystem of the forest.

4.2 Recommendations

In order to ensure that Kahe Forest is sustainably managed and conserved, the changes must be monitored over a long period. In addition, land-use planners and decision-makers must properly implement their strategies. Therefore, future management and conservation strategies should include an introduction of alternative, environment-friendly sources of livelihood such as beekeeping. Other steps could be population growth control, intensification of agricultural land use, promotion of community participation in forest management and provision of education on the importance of conserving the forest. Affordable cooking and warming energy technologies must also be provided to safeguard the forest.

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