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Vegetation Land Cover/Use Dynamics and Their Effects in Mbulu and Karatu Districts in the North-Eastern Highlands of Tanzania

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Abstract

Vegetation Land Cover/Land Use dynamics (VLC/LU) are the result of complex and compound interactions between the human (cultural, socioeconomic, and political) and the physical environment at different spatial scales. The present study assesses the spatial distribution of VLC/LU dynamics from 1987 to 2015 in the North-Eastern highlands of Tanzania using both qualitative (in-depth interviews and focus group discussions) and quantitative techniques (spatio-temporal analysis through GIS). The qualitative approach was used to elicit information on the main drivers of VLC/LU changes by land users as transitions occurred with time. The spatio-temporal analysis was used to assess the systematic vegetation land losses, gains and persistence of the various land use categories with time. The results identified the presence of forest, woodland, bush land, grassland, wetland, cultivated land, bare soil, water, and settlements (built up area). Throughout the period 1987-2015, wetland, settlement (built-up area), cultivated land and bare soil expanded at an average rate of 42.15%, 15.66%, 12.09% and 6.41% per year at the expense of grassland, woodland, water, forest and bush land which declined by 2.68%, 2.5%, 2.04%, 1.36% and 0.12% per year, respectively. The vegetation land cover/use dynamics of 1987-2015 resulted in the reduction/loss of plant species, occurrence of soil erosion and ramification of gullies. The triggers for these changes were population growth, land cultivation, expansion of farmland, inappropriate land management and fuel wood demand. These led to further land degradation among many farming households. Land resources have to be used according to their suitability. Thus, the exposed and steep hills of the study area have to be protected from cultivation and should be re-afforested. The paper also discusses other implications for management and policy formulation in the study area.

Keywords

Vegetation, Land cover, Land use, Dynamics, Tanzania

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1 INTRODUCTION

Vegetation is important for people's well-being. For instance, the livelihoods of over 240 million of the people who live in or around the vegetation lands in the world depend on vegetation resources (Rickbeil et al. 2018; CIFOR 2014). Globally, vegetation provides about 30 million employment opportunities in the informal sector, whereas more than a quarter of all non-farm employment opportunities in the world depend on the vegetation resources (Harris and Feriz 2011). Vegetation plays diverse roles in improving livelihoods of local people in villages. It is important as homes of wildlife habitat and tourism; as a source of rainfall, water and medicines; for spiritual purposes; as a better place for carbon storage; for grazing livestock, and as a good source of fertile soil for crop production (Forkuo and Frimpong 2012). These uses and functions of land resources have triggered pressure on the existing vegetation, which has resulted in vegetation cover changes (Bonan 2008). Vegetation land cover/land use change is a function of interactions between and among humans and the natural environment such as population growth, urbanisation, drought and economic reform policies (Muna and Hussein 2017; FAO 2010; Tang and Heiling 2007). The interactions and feedback, arising from such linkages in an agro-pastoral community, are normally revealed in community livelihood adaptation strategies at the village level (Liu et al. 2014; Rounsevell et al. 2010).

Socio-economic practices such as over-cultivation, over-grazing and rapid population growth, extreme climatic conditions, poor policies and legislation are among the root causes of vegetation cover change (Rickbeil et al. 2018; Kangalawe et al. 2014; URT 2014). All these drivers in an area function in a system framework to enable human beings to earn livelihoods (Alo and Pontius 2008). Socio-economic practices and poor policies have accelerated the magnitude of vegetation cover change and affect the livelihoods of community living in the proximity of vegetation lands (John et al. 2014; Rounsevell et al. 2010; Mwalyosi 1992).

The global statistics of vegetation cover change shows that a total of seven countries in the world, which are leading in vegetation land cover change, have lost about 60% of the total vegetation to degradation in the period between the 1980s and 2010 (Gardner et al. 2012). These countries are Brazil, Canada, United States of America, Indonesia, China, Russia and the Democratic Republic of Congo. A similar observation was also made in the report by CIFOR (2014), which claims that the planet Earth has lost about 80% of its vegetation cover to deforestation in the period between the 1970s and 2010s. These global conversions of vegetation land cover to other land uses are reported to be mainly caused by subsistence farming (46%), commercial agriculture (32%), logging (14%), fuel energy (5%) and traditional medicine (3%) (Wang et al. 2012; Harris and Feriz 2011). Present global political, cultural and socio-economic development activities have changed vegetation cover patterns and species (Forkuo and Frimpong 2012). Prasad et al. (2010) observes that when the vegetation cover changes, the livelihoods of the surrounding communities depending on vegetation resources also change so as to adapt to the situation.

According to FAO (2010) Africa is losing almost 3.4 million hectares of vegetation cover per year to agriculture, wood fuel, charcoal-making and settlement establishment. The FAO (2010) further added that low technology in harnessing alternative resources like solar and water encouraged over-dependence on vegetation resources. With such activities (farming, wood fuel, charcoal-making), vegetation in Africa may come under enormous pressure (Hakansson et al. 2008; Lambin et al.

2003). This may create conflicts with vegetation-dependent people and jeopardise the provision of environmental services as well as affecting community livelihoods and their lifestyles (Raphael 2015; URT 2014; Alo and Pontius 2008).

Vegetation cover in East African countries, including Kenya, Tanzania and Uganda, is estimated at 85.6 million ha, which is about 21% of the total vegetated land in sub-Saharan Africa (FAO 2006). However, vegetation distribution is uneven, with Kenya and Uganda having very little, while Tanzania has about 44% of its land area under vegetation cover (URT 2014). The most widespread vegetation type in Tanzania is savannah/*miombo* woodland and thicket, which constitutes 85% of the area coverage (URT 2002). Woodland vegetation provides a wide range of vegetation products, including fuel wood, thatching grass, medicinal plants and food in terms of fruits and roots, as well as important environmental services (Rickbeil et al. 2018; URT 2014). Mountain forests amount to 13% of the country's vegetation cover, while plantations account for 1.5% and mangroves for another 0.5% of vegetation cover (URT 2002). Despite their importance, there has been a significant increase in vegetation loss over the recent years (Reed 1992). For instance, in the period between the 1980s and 1990s, about 40% of the vegetation in Tanzania was cleared to open new land for agricultural activities in both public and gazetted land (John et al. 2014; Shivji 1994; Reed 1992). In the period between the 1990s and 2000s, about 20% of the vegetation cover was degraded to other vegetation land cover for timber, fuel wood, charcoal, grazing and biomass in the North-Eastern Highlands of Tanzania (John et al. 2014, Kabonesa and Kindi 2013; Meindertsma and Kessler 1997).

Vegetation in Tanzania is divided into two broad categories, namely, reserved vegetation and non-reserved vegetation. Reserved vegetation accounts for about 39.7% (12.5 million ha) while non-reserved vegetation accounts for 60.3% (19 million ha) (URT 2002). Reserved vegetation is owned by the central and local governments. Non-reserved vegetation is on "public" or "village" lands where vegetation resources are free to be used by everyone in the village (URT 2001; URT 2000). Raphael (2015) has noted that vegetation land cover dynamics in Mbulu and Karatu Highlands are associated with the human population growth in both rural and urban areas. Rhode and Hilhorst (2001) has noted that the changes in vegetation land cover in the North-Eastern Highlands of Tanzania were triggered by the *Villagisation Programme* of the period between the 1960s and 1970s as well as the social, economic and Structural Adjustment Programmes (SAPs) of the early 1980s.

The main objective of this study is to determine the extent, nature and rate of vegetation land cover dynamics between 1987 and 2001, and between 2001 and 2015 in the agro-pastoral communities of Mbulu and Karatu Districts and their related effects on land resource management and policy formulation. The study answers the following questions: what is the extent and rate of vegetation land cover change in the study area in the periods 1987-2001 and 2001-2015? What are the main driving forces that have triggered such changes? What are the implications of vegetation land cover/use dynamics for land resource management and policy formulation? These questions are dealt with through the application of the conceptual framework and study methodology as described in the next sections.

2 CONCEPTUAL FRAMEWORK UNDERPINNING THE STUDY

The theory underpinning vegetation land cover/use change and their effects on community livelihoods is based on the Drivers-Pressure-State-Impact and Response (DPSIR) of humankind in ecosystem settings, developed by Rounsevell et al (2010). DPSIR seeks to show causes and to put in place agents that can reverse the processes that may lead to vegetation cover change. The reality is that the model explains how vegetation land cover change occurs, why it happens and its different types of impact on the community. The main constraint of this model is that it separates the underlying and immediate factors of vegetation cover change and considers them as different entities, while they are in fact two sides of the same coin. One cannot talk of vegetation cover change without mentioning dynamic forces (immediate factors) or underlying forces (root factors) as they are spatially distributed on the land, and are mostly triggered by human development processes (Raphael 2015; URT 2014). Based on these theories, a conceptual framework for the analysis of vegetation land cover/land use change has been developed (Figure 1).

The intra- and inter-relationship between and among those factors resulted in dynamic pressures within the vegetation ecosystem resource utilisation. Change in micro-climate aspects such as precipitation, temperature and water may lead to change in vegetation cover. These aspects directly influence the changes in vegetation-related goods and services, resulting in the mismatch between the Vegetation Ecosystem Service Beneficiaries (VESBs) and Vegetation Ecosystem Service Providers (VESPs). While nature and VESPs remain constant over time, there are variations in the group of VESBs, who want to gain a larger share over the others (Rounsevell et al. 2010). For example, the wealthy individuals demand recreational and aesthetic services while the less wealthy demand the supply of goods and services and other daily niches. The different types of impact of vegetation cover change are both positive as well as negative for VESBs. As noted by John et al. (2014), there is a need to learn new human behavioural changes in specific VESBs to better manage the environmental change variables.

3 MATERIALS AND METHODS

3.1 Description of the Study Area

Mbulu and Karatu Districts are located in the North-Eastern Highlands of Tanzania at the edge of the eastern arm of the East African Rift Valley in Tanzania. The study area is situated between Latitudes 3°05'S and 4°15'S and Longitudes 34°45'E and 36°00'E (Figure 2). The area was selected because, firstly, it is located just at the edge of the Eastern arm of the East African rift valley in Tanzania with some distinct volcanic features such as lakes, valleys, crater and conical hills (John et al. 2014). Being a fertile volcanic land, the area is endowed with natural vegetation land cover, which has attracted agro-pastoral communities from different parts of the country to engage in agricultural activities such as farming and livestock keeping. However, if not well managed, such activities may trigger vegetation land cover changes (Hambati 2013). Secondly, the landscape of the study area varies from valley bottoms, gentle slopes and steep slopes to interfluves. These highly dissected landscapes, endowed with different vegetation cover, are the home of gatherers, hunters, sedentary farmers and pastoral communities. The communities in the area have been utilising vegetation resources for their daily livelihoods over time. The utilisation of these resources in the area might have been influenced by the attitudes and activities of the community. The continuous use of vegetation resources may have some implications on their livelihoods when the vegetation cover deteriorates significantly. Based on the mentioned reasons, the study area ecosystem presents itself as an appropriate case study in view of the main drivers of vegetation land cover dynamics in Tanzania.

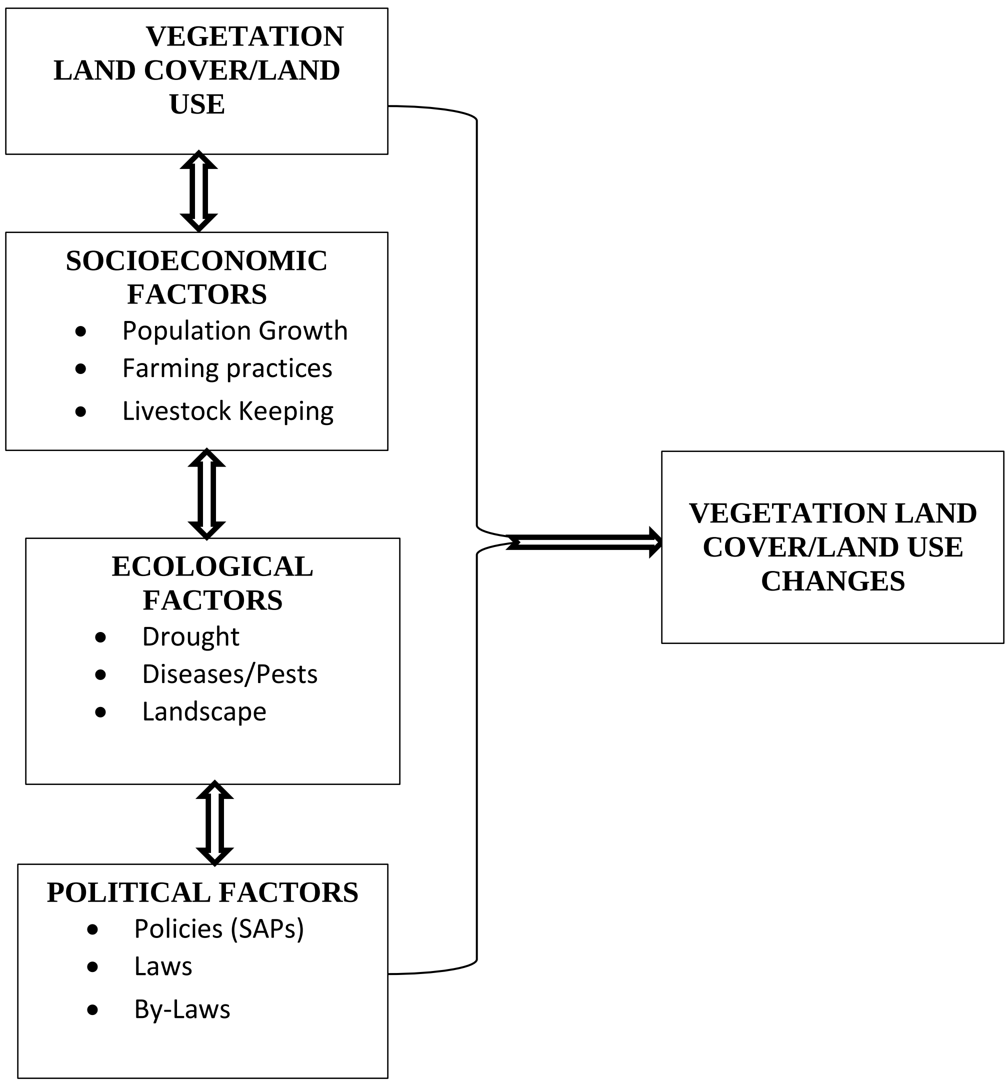

Figure 1. The intra- and inter-relationship between and among the drivers of vegetation land cover/use dynamics (Modified from Rounsevell et al. 2010).

Figure 2. The location of sampled wards in Karatu and Mbulu Districts, Tanzania
Source: Cartographic unit, University of Dar es Salaam.

3.2 Data Collection

Both qualitative and quantitative data were collected for this study. Qualitative data were collected through in-depth interviews (IDIs), field observation (FO) and focus group discussions (FGDs) that elicited information on community perceptions regarding the main drivers of vegetation land cover/land use in the study area. Quantitative data were collected through questionnaire surveys and spatial-temporal data analysis as described below.

3.2.1 In-depth Interviews (IDIs), Focus Group Discussions (FGDs) and Field Observation (FO)

IDIs, FGDs, and FO were carried out in the study areas in 2016. Questionnaire Interviews were conducted in 384 households in both Districts within the selected wards (Figure 2). In each ward, one FGD was formed comprised of seven members. The members included are: two village leaders (the Village Chairperson and Executive Officer), two farmers (one male and one female), one Extension Officer and two experienced and influential people in the ward (one male and one female). The information acquired through IDIs, FGDs and FO were institutional, individual perceptions and spatial-temporal data/information on vegetation cover changes. These techniques were useful in bringing to the fore the perceptions and lived experiences of community members concerning the vegetation land cover/land use changes that were not articulated in the questionnaire survey. The survey elicited household demographic and socio-economic information such as age, gender, occupation, education level, marital status and land tenure issues. Field observation involved ground verification of the information related to human activities in relation to vegetation land resource utilisation. This method was useful in providing the evidence for vegetation land cover/land use changes in the study area in order to confirm previous information obtained through the techniques mentioned earlier.

3.2.2 Geospatial Techniques for Land Cover Change Assessment

Landsat images for the years 1987, 2001 and 2015 were obtained from the data repository of the United States Geological Survey (USGS) Centre for Earth Resources Observation and Science (EROS) website (www.glovis.usgs.gov). These are multi-spectral data with a spatial resolution of 30m×30m. Landsat images have been extensively used for land cover change studies and natural resource assessment by many researchers (e.g. Rickbeil et al. 2018; Tang and Heiling 2007; Lambin et al. 2003).

Pre-processing of the images was done prior to classification. All images were radiometrically and atmospherically corrected using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) tool. LEDAPS is a NASA project to map disturbance, regrowth, and permanent vegetation conversion across the continent (John et al. 2014; Pontius et al. 2013). LEDAPS processes Landsat imagery to surface reflectance, using atmospheric correction routines developed for the Terra MODIS instrument (Figure 3). Digital image classification techniques are used to group pixels to represent land cover features (Liu et al. 2014). There are three main classification schemes: object-based image analysis which supports the use of multiple bands for multi-resolution segmentation and classification; supervised image classification, in which the classification of land cover is based on the spectral signature defined in the training set; and unsupervised image classification, in which pixels are grouped according to their reflectance properties (Muna and Hussein 2017; Wang et al. 2012). In this study, unsupervised classification was used to create thematic raster layers in Erdas Imagine 2014. Being an automated process, it allows users to specify parameters that the computer uses as guidelines to uncover statistical patterns in the data. This type of classification was opted for because of lack of enough pre-existing field data and detailed aerial photographs for the image area to be used to generate training samples for the supervised classification and for accuracy assessment of the classified image. As indicated in the study by Liu et al. (2015), this classification method is also convenient for a large-scale study area, and its time economy. The user generally determines the number of clusters to be generated and the bands to be used. The decision on the number of clusters was based on other classification efforts by natural resource departments of the Tanzanian government. The study used the ISODATA clustering algorithm to generate the clusters (Mather 2004; Erdas Field guide 2005; Memarsadeghi et al. 2007). This uses the minimum spectral distance formula to form clusters. The initial cluster option was set by specifying the number of clusters and iterations. In this case, 30 initial clusters, a maximum of 10 iterations, and a 0.95 convergence threshold were specified.

Due to the spatial complexity of biophysical environments this leads to spectral confusion among land cover classes. The classification resulted in data sets containing mixed pixels, i.e. pixels jointly occupied by more than a single land cover class. To overcome this, post classification was used where a majority filter was applied to reduce the noises in the classified image. The majority filter was used to smooth the classified output to show only the dominant (presumably correct) classification. The majority filters calculate the predominant value or class name and assign the predominant value or class name to the central pixel in the output map. This study opted for the 5×5 majority filter focal kernel. The classified image was later vectored and, using ArcGIS 10 software, an elimination process was conducted in order to remove tiny polygons (polygons with an area less than 3 pixels); this process merges the selected polygons with neighbouring polygons with the largest shared border or the largest area. Finally, the classified data was modified using ancillary data based on expert rules and knowledge of specific vegetation classes. All these were assigned to particular classes, ending consequently with 9 classes: i.e. forest, woodland, bush-land, grassland, wetland, cultivated land, bare soil, water, and settlements (built up areas). These classifications were also in line with the land cover/land use types determined during the FGDs. The main vegetation land cover/land use change types as mentioned by the FGDs and observed during the field survey include: forest, woodland, bush-land, grassland, wetland, cultivated land, water, settlement and bare soils. These vegetation land cover/land use categories were further described in order to explain their meaning in the study area community (Table 1).

Table 1. Main vegetation land cover/land use categories in the study area

Vegetation land cover/land use categories	**Description**
Forest	Areas predominantly covered both by planted and natural forests
Woodland	Tracts of land largely covered by medium height trees (with an average height of 5 to 10 meters) and relatively denser natural and/or planted trees
Bush-land	Areas covered by sparsely grown and short trees/bushes mixed with grasses
Grassland	Areas covered with grasses and some vegetation (between the cultivated lands and along the flood plains)
Wetland	Flat areas normally occupied by water seasonally or permanently with some water vegetation
Cultivated land	Areas used for rain-fed farming and for the dwellings of rural farming households
Bare soil	Areas with or without very little vegetation cover and characterised by shallow and rocky soils
Water	Areas covered with water bodies i.e. lakes, rivers or dams
Settlements (build up areas)	Areas covered with urban residential houses, buildings and rural settlements

Source: Field survey, 2016

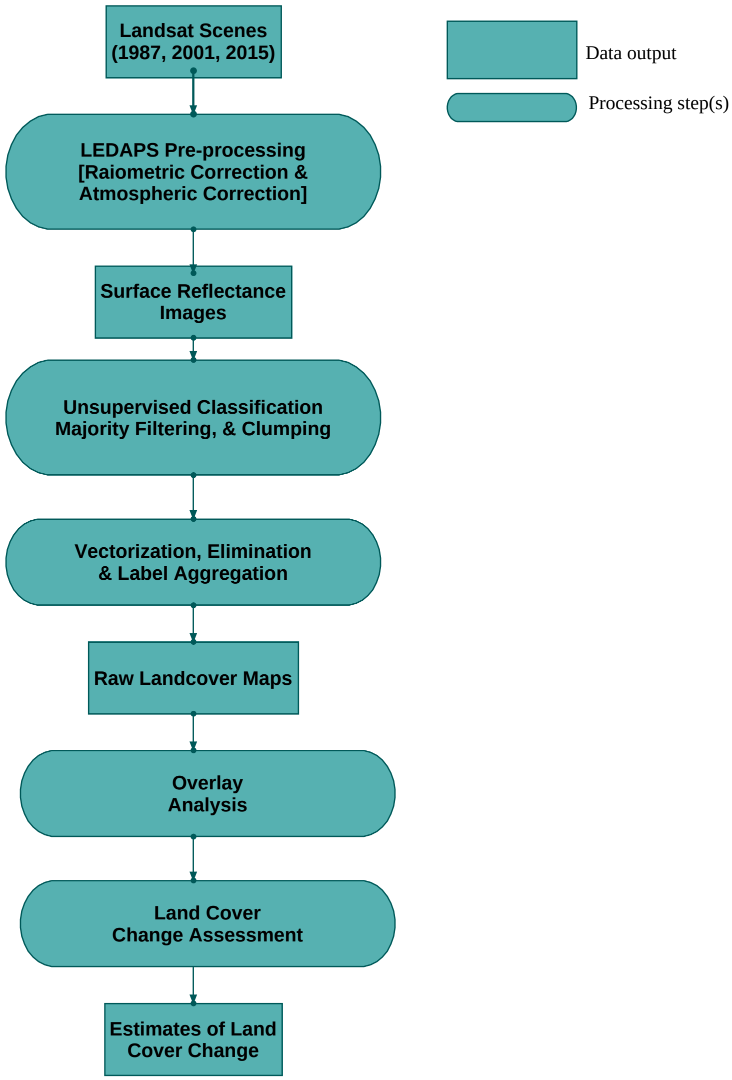

Figure 3. Work flow for processing remotely sensed data and undertaking land cover classification

3.3 Land Cover Change Detection

The detection of vegetation land cover change is one of the most important applications of remote sensing techniques due to its capacity for repetitive acquisition imagery with consistent image quality, at short intervals, on a global scale, and during complete seasonal cycles (Liu 2015). This study uses Landsat scenes from Landsat 5 and Landsat 7 sensors. The images used were those acquired in 1987 and 2015 (Landsat 5) and 2001 (Landsat 7) to detect land cover change. The land cover change detection was done using ArcGIS 10 software. The two classified land cover layers i.e. land cover 1987 and 2001 and land cover 2001 and 2015 were used. The spatial analysis tool using the zonal tabulated area function was used to generate a land cover change matrix. The function calculates cross-tabulated areas between two datasets and outputs a table. The table displays a record for each unique value of the zone dataset and a field for each unique value of the class dataset. Calculated geometry was used to calculate the areas (in hectares) of each land cover in the matrix.

4 RESULTS AND DISCUSSION

4.1 The Main Driving Forces and Vegetation Land Cover/Land Use Dynamics during the Period 1987-2001

The woodland and bush-land, which had occupied the largest part (more than 53%) of the total land in the study area (Table 2, Figure 4) gradually declined from 53% (431,133 ha) in 1987 to 44% (355,556 ha) in 2001, dropping sharply by –35.46% (–75,577 ha) throughout the first period (Table 3). The forest land and water bodies, which had occupied 8% (67582 ha) and 16% (126,564 ha) of the total land, respectively in 1987, slightly declined to 6% (46,424 ha) and 15% (120,817 ha) in 2001, respectively. They further declined by –31.31% (–21,158 ha) and –4.54% (–5747 ha), respectively (Tables 2 and 3). Three explanations are possible. First, in the study area there was a declaration of occupation of the most suitable farming areas for crop cultivation under what was called the *Villagisation Programme* between the early 1970s and 1980s. Secondly, the challenges of infestation by tsetse fly, an insect that attacked cattle, normally in *miombo* woodlands, which resulted in the massive clearance of vegetation in such areas. Thirdly, there was cultivation of highland areas, which resulted in the siltation of water bodies such as Lake Manyara in the East and Lake Eyasi in the West of the study area (Figure 4). Between 1987 and 2001, land cultivation had absorbed 18.49% (40,327 ha) of the bush- land, 28.75% (24,795 ha) of the grassland, 6.77% (14,426 ha) of the woodland, 0.89% (197 ha) of the bare land (due to slight regeneration and shortage of farmland), 9.24% (11 ha) of the settlement (abandoned settlement areas due to the *Villagisation Programme*), and 0.65% (439 ha) of the forest land (Table 4).

The bush-land was mainly located on steeper slopes of the mountains unsuitable for crop cultivation and formed the largest spatial extent. It is commonly composed of the following tree species with their botanical names in brackets: red stink-wood (*Prunusafricana*), Elgon olive (*Olea capensis*) and Julbernardia (*Julbernardiaglobira*) and varieties of grass species. The extent of the bush-land, however, continuously shrank from 27% (218,103 ha) in 1987 to slightly less than 27% (217,053 ha) in 2001, declining at an average rate of –0.04% (75 ha)/year (Tables 2 and 3). Table 4, indicates that, the bush-land cover was transformed into cultivated land (18.49%), grassland (17.52%), woodland (11.55%), bare land (6.3%), water bodies (0.45%), forest (0.41%) and settlements (0.1%). As indicated during the in-depth household interviews, the conversion of bush-land into bare land, cultivated land, settlement and grassland was associated with loss of soil, biodiversity and expansion of land degradation in the study area. Woodland, the second largest vegetation land cover/land use pattern from 1987 to 2001, occupied 26% (213,030 ha) in 1987, but had decreased to 17% (138,503 ha) in 2001. The woodland land cover/land use declined by 34.98% (74,527 ha) between 1987 and 2001 at the rate of 2.5% (5,323 ha)/year (Tables 2 and 3). The woodland vegetation land cover category was largely transformed into bush-land (36.46%), grassland (13.95%), cultivated land (6.77%), bare soil (3.57%) and forest (2.48%) in the first period (Table 4; Figure 4).

Table 2. The extent of vegetation land cover/use categories in the study area in the periods 1987, 2001 and 2015

Vegetation land cover/land use types	Vegetation land cover/ land use type in Ha and %					
	1987		2001		2015	
	Ha	**%**	**Ha**	**%**	**Ha**	**%**
Forest	67,582	8	46,424	6	41,800	5
Woodland	213,030	26	138,503	17	63,659	8
Bush-land	218,103	27	217,053	27	209,715	26
Grassland	86,243	11	105,796	13	21,445	3
Cultivated Land	73,492	9	123,592	15	322,301	40
Wetland	2,594	0	7,236	1	33,209	4
Water	126,564	16	120,817	15	54,206	7
Settlement	114	0	437	0	614	0
Bare Soil	22,728	3	50,592	6	63,501	8
Total	810,450	100	810,450	100	810,450	100

Source: Landsat imagery: 1987, 2001 and 2015.

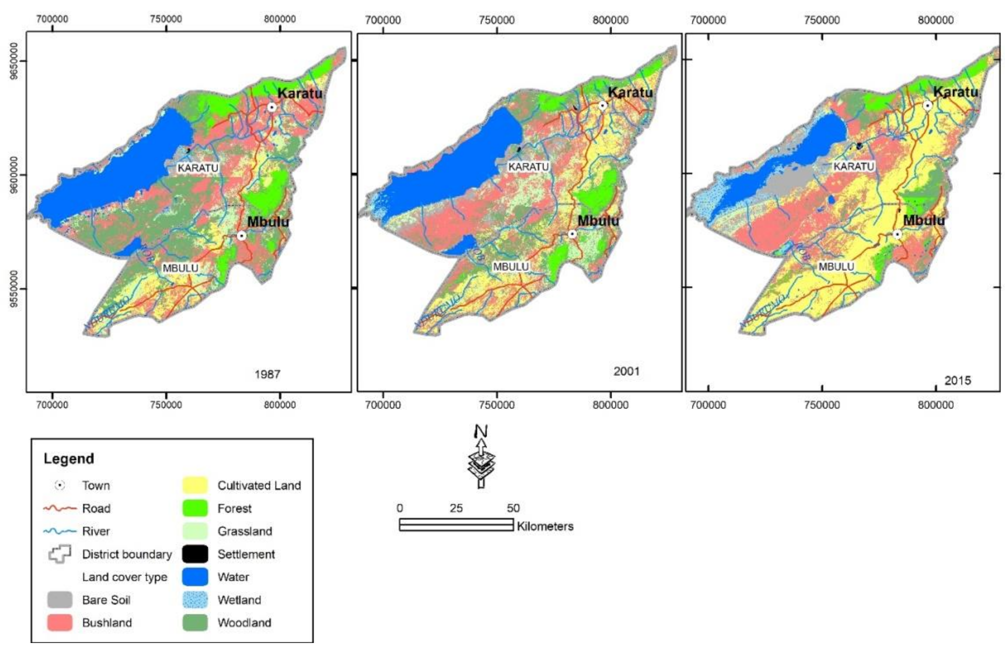

Figure 4. Vegetation land cover/land use dynamics in Mbulu and Karatu Districts.
Source: Landsat imagery: 1987, 2001 and 2015.

Table 3. The extent of vegetation land cover/land use categories in the study area in 1987-2001, 2001-2015 and 1987-2015.

Vegetation land cover/land use types	**1987-2001**			**2001-2015**			**1987-2015**		
	Change in ha	**% Change**	**Ave.Ann.rate of Change in %/Year**	**Change in ha**	**% Change**	**Ave.Ann.rate of Change in %/Year**	**Change in ha**	**% Change**	**Ave.Ann.rate of Change in %/Year**
Forest	-21158	-31.31	-2.24	-4624	-9.96	-0.71	-25782	-38.15	-1.36
Woodland	-74527	-34.98	-2.5	-74844	-54.04	-3.86	-149371	-70.12	-2.5
Bush-land	-1050	-0.48	-0.04	-7338	-3.38	0.24	-8388	-3.85	-0.12
Grassland	+19553	+22.67	+1.62	-84351	-79.73	-5.69	-64798	-75.13	-2.68
Cultivated Land	+50100	+68.17	+4.87	+198718	+160.79	+11.48	+248809	+338.55	+12.09
Wetland	+4642	+178.95	+12.78	+25973	+358.94	+25.64	+30615	+1180.22	+42.15
Water	-5747	-4.54	-0.32	-66611	-55.13	-3.94	-72358	-57.17	-2.04
Settlement	+323	+283.33	+20.24	+177	+40.5	+2.89	+500	+438.6	+15.66
Bare Soil	+27864	+122.6	+8.76	+12909	+25.52	+1.82	+40773	+179.4	+6.41

Source: Landsat imagery: 1987, 2001 and 2015.

Note: (+) Refers to Land gains from other vegetation land cover/land use while (–) indicates land loss to other vegetation land cover/land use.

Table 4. Vegetation land cover/land use class matrix between 1987 and 2001 in Mbulu and Karatu Districts

	From vegetation land cover/land use class in 1987																	
	Bare Soil		**Bush-land**		**Cultivated Land**		**Forest**		**Grassland**		**Settlement**		**Water**		**Wetland**		**Woodland**	
To Vegetation land cover/land use class in 2001	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Bare Soil	16,752	73.71	13,745	6.30	1,655	2.25	56	0.08	8,329	9.66	0	0.00	1,937	1.53	520	20.04	7,598	3.57
Bush-land	2,355	10.36	98,369	45.10	15,724	21.40	2,895	4.28	18,447	21.39	7	6.39	791	0.63	780	30.06	77,674	36.46
Cultivated Land	197	0.87	40,327	18.49	43581	59.30	439	0.65	24,795	28.75	11	9.24	89	0.07	0	0.00	14,426	6.77
Forest	0	0.00	885	0.41	32	0.04	40,091	59.32	85	0.10	0	0.00	5	0.00	0	0.00	5,291	2.48
Grassland	2,423	10.66	38,202	17.52	7,352	10.00	1,708	2.53	23,983	27.81	2	1.34	1,982	1.57	247	9.52	29,719	13.95
Settlement	0	0.00	211	0.10	100	0.14	0	0.00	18	0.02	93.6	82.11	0	0.00	0	0.00	15	0.01
Water	670	2.95	978	0.45	32	0.04	203	0.30	3,491	4.05	0	0.00	114,895	90.78	0	0.00	509	0.24
Wetland	43	0.19	185	0.08	112	0.15	2	0.00	230	0.27	0	0.00	6,513	5.15	17.1	0.66	147	0.07
Woodland	289	1.27	25,200	11.55	4,905	6.67	22,187	32.83	6,865	7.96	0	0.08	351	0.28	1,030	39.72	77,652	36.45
Total in year 1987	22,728	100	218,102	100	73,492	100	67,582	100	86,243	100	114	100	126,564	100	2,594	100	213,030	100

Source: Landsat imagery: 1987 and 2001.

During the period 1987-2001, grassland, the fourth largest vegetation land cover/land use pattern, occupied 11% (86,243 ha) in 1987, but gradually increased to 13% (105,796 ha) in 2001. The grassland land cover/land use grew by 22.67% (19,553 ha) between 1987 and 2001 at a rate of 1.62% (1397 ha)/year (Table 3; Figure 4). The grassland vegetation land cover/land use category gained largely from bush-land (17.52%), woodland (13.95%), bare soil and cultivated land (10.66%), wetland (9.52%), forest (2.52%) and water (1.57%) in the first period (Table 4). As noted during the in-depth interviews, the growth of grassland vegetation cover during 1987-2001 could be attributed by *villagisation* policy implementation in the 1970s, as well as the social, economic and Structural Adjustment Programmes of the 1980s, which encouraged agricultural production of export crops, with the consequent expansion of farms into vegetated lands.

The bare land use was commonly found along stream courses and mountain slopes, characterised by rock surfaces. The spatial coverage of bare land had doubled from 3.0% (22,728 ha) in 1987 to 6% (50,592 ha) by 2001. The conversion into bare land of 20.04% (520 ha) of wetland, 9.66% (8329 ha) of grassland, 6.30% (13745 ha) of bush-land, 3.57% (7598 ha) of woodland, and 2.25% (1655 ha) of cultivated land between 1987 and 2001 could indicate the expansion of bare land and hence the severity of land degradation in the study area (Tables 2 and 4). Moreover, the long, deep and wide gullies observed during field surveys in 2015 and 2016 in the various localities of the study area are further evidence of severe land degradation. From 1987 to 2001, bare land expanded at a higher rate (8.76%/year) than the expansion rate of the other vegetation land cover/land use categories (Table 3). This helps to explain the severity of vegetation land cover/land use change and land degradation in the study area in the first period. Urbanised, built up land expanded from 114 ha to 437 ha between 1987 and 2001. The increase in built up areas or settlement land is attributed to growth of the urban centres of Mbulu and Karatu as headquarters of the respective District (Table 3 and Figure 4).

4.2 The Main Driving Forces and Vegetation Land Cover /Land Use Dynamics during the Period 2001-2015

Cultivated land in the study area expanded from 15% (123,592 ha) in 2001 to 40% (322,301 ha) in 2015 at a rate of 11.48% (14,194 ha/year) (Tables 2 and 3). In both periods (1987-2001 and 2001-2015), cultivated land slowly but surely gained more land than it lost to other vegetation land cover/land use categories (Tables 2 and 3; Figure 4). For instance, over the 28-year period from 1987-2015, cultivated land grew by 338.55% (248,809 ha) at the expense of grassland (53.20%), bush-land (45.55%), bare soil (27.15%), settlements (26.88%), woodland (25.46%), wetland (8.82%), water 2.01%) and forest land (0.84%) (Table 5). In the period between 2001 and 2015, 207,732 ha of grass, bush, bare, settlement, wood, wetland, water and forest lands were totally converted to cultivated land (Table 5). As confirmed during the in-depth interviews and focus group discussions, population growth and the farmers' ability to pay for modern agricultural inputs largely contributed to the cultivated land expansion. As noted in John et al. (2014), suitable climatic conditions in tropical savannah similar to those of the rest of the Northern Highlands of Tanzania, favour crop cultivation on the high altitudes. Therefore, maximising crop production through farmland expansion cannot be a feasible strategy of farmer's development in the future. Farm land expansion to marginal areas exacerbates soil erosion, encounters constraints of soil moisture and hinders improvement of crop productivity. As noted by Hambati (2013), in the Northern Highlands of Tanzania agricultural suitability decreases with an increase in the slope gradient.

Bush-land, the largest vegetation land cover/land use in 1987 declined slightly from 27% (217,053 ha) in 2001 to 26% (209,715 ha) in 2015 (Tables 2 and 3; Figure 4), at an average rate of 0.24% (524.14 ha)/year from 2001 to 2015 and by 0.12% (299.57 ha)/year between 1987 and 2015 (Table 3). As indicated during the household interview and focus group discussion, the decline of bush-land has aggravated the loss of different plant species and pastures. Between 2001 and 2015, 45.55% (98,875 ha) of bush-land became cultivated land, 6.33% (13,741 ha) woodland, 2.63% (5,712 ha) grassland, 1.18% (2,552 ha) bare soil, 0.34% (744 ha) to wetland, 0.24% (516 ha) forest land, and 0.02% (50 ha) became settlement. The improvement of land management policies after the 2000s have significantly enhanced bush-lands into woodland cover. However, bush-lands themselves gained less from other vegetation land cover/land use categories. This led to the spatial-temporal decline of vegetation land cover/land use in the two analysis periods (Tables 4 and 5). Furthermore, as noted during the household interviews, selective bush cutting for firewood, logs, farm implements and farm plot expansion caused major bush-land decline. During the focus group discussion, elders reported that illegal cutting of bush plants for firewood to sell in Arusha, Karatu and Mbulu urban areas has resulted in bush-land degradation. Local elders relate this illegal bush cutting to the low level of income, shortage of firewood and food insecurity of the local agro-pastoral community. On the contrary, the conservation of the vegetated land ecosystems and education by development workers have made farmers aware of their role in enhancing bush-lands to become woodlands, minimising human interference. For instance, the patrol of vegetated land resources by assigned local guards to prevent illegal human interference has minimised the illegal harvesting of vegetation resources in Mbulu District. This helps to enhance vegetation on the land surrounding the hills, mountains and controls expansion of gullies on low lying agricultural lands.

Woodland cover retreated from 17% (138,503 ha) in 2001 to 8% (63,659 ha) in 2015 (Table 2), at the rate of 3.86% (5,346 ha)/year (Table 3). As observed during the household survey, most wood covers were composed of local plants such as (with botanical names in brackets) East African yellow wood (Podocarpusfalcatus), Wild date palm (Phoenix reclinata), Elgon olive (Olea capensis) and Julbernardia (Julbernardiaglobira) and grass plant species. The woodland vegetation land cover/land use declined by 54.04% (74,844 ha) between 2001 and 2015 (Table 3; Figure 4). The conversion of woodland to bush-land 43.23% (58,495 ha), cultivated land 25.46% (35,261 ha), grassland 1.38% (1,906 ha), wetland 0.22% (309 ha), water 0.19% (262 ha) and bare lands 0.16% (220 ha), led to the depletion of associated natural plant communities in the period 1987-2015, while its conversion into forest land by 7.54% (10,444 ha) is an indicator of sustainable vegetation management by the local community in the study area. During the focus group discussion, elders reported that the reduced area for mountain bushes and woody plants has accelerated the rate of runoff over steep slopes and resulted in water logging on the low-lying farming plots and grasslands. This has been justified by the increase in wetlands coverage by 42.15% (1,093 ha/year) between 1987-2015 (Table 3). As interviewees explained, flash flooding from mountains occasionally led to the displacement of the local people from the low lying and gently sloping areas in the Eastern (Lake Manyara) and Western (Lake Eyasi) parts of Karatu and Mbulu Districts, respectively.

Bare land cover/land use increased slightly by 6% (50,592 ha) in 2001 to 8% (63,501 ha) in 2015 (Table 2, Figure 4). From 1987 to 2015, bare land grew at an annual rate of 6.41% (1,456 ha/year) while wetlands expanded at a higher annual rate 42.15% (1,093 ha/year) than the rate for settlement 15.66% (17.86 ha/year) and cultivated land 12.09% (8,886 ha/year) (Table 3). About 40,773 ha of the other vegetation land cover/land use were transformed to bare soils. For instance, out of 40,773 ha; 29.05% (35,102 ha) were from water, wetland 10.56% (764 ha), grassland 4.49% (4753), bush-land 1.18% (2,552 ha) and woodland 0.16% (220 ha) (Tables 2 and 5). The increase in bare soil land cover/land use in the second period, therefore, demonstrates the degradation and deforestation of vegetation land cover in the study area.

As the vegetation cover declined the local people quarried some of the resulting bare lands and river valleys products for construction materials. Inappropriate quarrying, degradation and deforestation in the study area, disturbed the hydrological flow and ecosystem balance of the river and the downstream traditional irrigation practices. During focus group discussions, the elders pointed out that, out of the 14 permanent rivers in the study area, only 4 remained while 10 have become seasonal rivers (Figure 4). The local population suggested that there should be an environmental impact assessment of quarrying, and monitoring of its effects on other economic activities and the people's livelihood security. Quarrying and lumbering activity licences should require prior environmental impact assessment and the monitoring of social effects. Grasslands decreased from 13% (105,796 ha) in 2001 to 3% (21,445 ha) in 2015 at 5.69% (6,025 ha)/year. Thus, a large portion (79.73% or 84,351 ha) of the 2001 grasslands had declined in 2015. The drying of the valley wetlands shows that the water table in the study area fell during the period 2001-2015. The grasslands were transformed into cultivated and settlement lands, while the mountain grasslands became bush-lands and bare lands. There was a sharp decline in the spatial extent of grassland cover in 2015 in the study area (Tables 2 and 3).

The suitability of the grasslands for agricultural, decline of surface water, shortage of farming plots and growth of the population in the study area aggravated the rapid conversion of grasslands into cultivated and settlement lands in the second period (Table 3; Figure 4). The rapid conversion of grasslands into cultivated and settlement lands ultimately resulted in the shortage of animal feed and adversely affected the long-run integration of animal production and crop cultivation, as the mode of production in agro-pastoral communities. Therefore, unless appropriate management interventions occur, the continuity of population growth and overstocking will cause severe degradation of the existing grasslands and vegetation cover in the study area.

Table 5. Vegetation land cover/land use class matrix between 2001 and 2015 in Mbulu and Karatu Districts

	From vegetation land cover/land use class in 2001																	
	Bare Soil		**Bush-land**		**Cultivated Land**		**Forest**		**Grassland**		**Settlement**		**Water**		**Wetland**		**Woodland**	
To vegetation land cover/land use in 2015	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**
Bare Soil	19,404	38.35	2,552	1.18	422	0.34	195	0.42	4,753	4.49	90	20.52	35,102	29.05	764	10.56	220	0.16
Bush-land	9,587	18.95	94426	43.50	6,144	4.97	2,532	5.45	34,952	33.04	24	5.42	3,432	2.84	124	1.72	58,495	42.23
Cultivated Land	13,736	27.15	98,875	45.55	114,568	92.70	389	0.84	56,282	53.20	117	26.88	2,434	2.01	638	8.82	35,261	25.46
Forest	11	0.02	516	0.24	59	0.05	28,879	62.21	745	0.70	0	0.00	1,141	0.94	4	0.06	10,444	7.54
Grassland	6,946	13.73	5,712	2.63	1,838	1.49	6	0.01	3,578	3.38	0	0.00	1,191	0.99	268	3.71	1,906	1.38
Settlement	67	0.13	50	0.02	50	0.04	0	0.00	267	0.25	173	39.59	3	0.00	0	0.00	3	0.00
Water	7	0.01	437	0.20	10	0.01	45	0.10	333	0.31	0	0.00	53,011	43.88	102	1.41	262	0.19
Wetland	718	1.42	744	0.34	26	0.02	44	0.09	1,676	1.58	1	0.33	24,368	20.17	5,324	73.58	309	0.22
Woodland	117	0.23	13,741	6.33	475	0.38	14,336	30.88	3,211	3.03	32	7.27	135	0.11	10	0.14	31,602	22.82
Total in year 2001	50,592	100.00	217053	100.00	123,591	100.00	46,424	100.00	105,796	100.00	437	100.00	120,817	100.00	7,236	100.00	138,503	100.00

Source: Landsat imagery: 2001 and 2015

The built up urban areas (settlements) grew at a rather rapid rate (2.89% or 12.6 ha/year) between 2001 and 2015 (Table 3). As indicated during the interview and focus group discussion, the drastic increase of the population living in the small towns of Karatu and Mbulu since 1995 caused the transformation of large areas of bush-land, grassland and farmlands into built-up urban areas (Table 5; Figure 4). This partly indicates an increasing trend of urban population and associated demand for land for urban settlements that further aggravates the shortage of arable land. This also causes insecurity of food supplies as long as alternative sources of income are not available.

Since the 2000s, the forest cover in the study area has continued to be depleted at the decreasing rate of 0.71% (330 ha/year) in the second period between 2001 and 2015 as compared to 2.24% (1,511 ha/year) in the first period between 1987 and 2001 (Table 3; Figure 4). As observed during field surveys, *Eucalyptus globulous*, Cyprus and gravellier were the dominant forest species planted by the community in their areas. These new species of trees partly explain why there is decline in forest land deterioration in the second period (2001-2015). As noted during the interview and focus group discussions, the high demand for timber, construction materials and firewood caused by the urban population increase in Karatu and Mbulu towns stimulated tree planting activities and a significant expansion of forested lands in the study area. Large areas of wood, bushes, grass and cultivated lands became forest (Tables 4 and 5). Many rural residents in the study area sell *Eucalyptus globulous* as a source of firewood at the town centres. As pointed out in the study by Raphael (2015) and Pontius et al. (2013), this is a necessity if the population is to cope with food insecurity and to increase income for rural people who are poor and lack alternative sources of livelihoods. Furthermore, vegetated land cover enhances and balances ecological services by controlling soil erosion and reducing the expansion of gullies in the catchment areas.

5 IMPLICATIONS FOR LAND DEGRADATION, MANAGEMENT AND POLICY

5.1 Implications for Land Resource Degradation

Land degradation is a serious problem in agro-pastoral communities due to the sense of communal land resource utilisation. The study reveals various causes of land resource degradation, including: crop land expansion, population growth, overgrazing and extraction of logs for house construction as well as fuel wood materials. The dynamics of vegetation land cover/land use, therefore, profoundly aggravated soil erosion and loss of plant species. As a result, significant reduction of East African yellow wood (*Podocarpusfalcatus*), Wild date palm (*Phoenix reclinata*), Elgon olive (*Olea capensis*) and Julbernardia (*Julbernardiaglobira*) occurred over the study periods. These demonstrated the severity of the degradation of plant species in the study area.

The nature of the landscape, i.e. interlocking spurs, scanty vegetation cover, the steep slopes especially in the north, north-eastern and south-eastern parts of the study area led to the formation of long, deep and wide gullies. The gullying process was accentuated by the torrential nature of the local rainfall. The ramification of gullies could therefore result in erosion hazards and decline of soil fertility. The study also revealed that, the expansion of cultivated lands from 9% (73,492 ha) in 1987, to 15% (123,592 ha) in 2001, and to 40% (322,301 ha) in 2015 could increase the exposure of soils to erosion. Soil erosion would be more serious with the transformation of the bush and wood land covers into cultivated and bare lands. Analysis of the 3-year satellite image data to study 28 years (1987-2015) of vegetation land cover/land use changes has clearly shown that forest, wood-land, bush-land and grass-land covers have significantly declined. Thus, the severity of land degradation indicates the urgent need to improve the limited extent and quality of land management, as well as the need to choose suitable uses of vegetated land and integrated participation of the local farmers and livestock keepers in land management.

5.2 Implications for Land Resource Management

As revealed during the interviews and focus group discussions, deforestation of bush-land and wood land covers (Table 3) at the expense of farm land commonly resulted in the flooding of low lying areas as well as siltation of rivers and Lake Eyasi in the western part of the study area. Hence sediment accumulation from erosion occurred in the steep slopes and Oldeani mountain landscapes, leading to the decline of water bodies from 16% (126,564 ha) in 1987 to 7% (54,206 ha) in 2015. Similarly, research by Hambati and Rugumamu (2005) in Kainam Village in the Northern part of Tanzania indicates a similar observation: a high rate of soil erosion was seen on steeper slopes while alluvial sediments were observed on the flat valley bottoms. Thus, deforestation in the highlands accelerated the rate of run-off and soil erosion on steep slopes and mountains.

Therefore, to minimise the high rate of soil erosion, flooding and siltation, appropriate, participatory and integrated land management is necessary both on the low lying and steep slope ecosystems. The continuous expansion of farming plots to marginal areas and flat grasslands can be minimised through the use of intensive farming, the breeding of productive animals and choice of appropriate crops rather than by farmland expansion. In addition, government and development agencies should train local farmers about the multiplier effects of land management, land use suitability and breeding of limited but productive dairy and/or beef animals. For example, the soils on gentle slopes in the Northern Highlands of Tanzania may be suitable for upland annual crops while the valley bottom alluvial volcanic soils would probably be suitable for wheat, rice and onion cultivation. Hambati (2013) noted that steep slopes and mountain soils in Karatu District may be suitable for perennial tree crops, pasture or forest plantation while Adedeji and Adeofun (2014) records similar observations in South-West Nigeria. Muller-Samann and Kotschi (1994) elaborated that the more extensive root systems of trees and shrubs penetrate strata better than annual crops and may often be the best choice for a land use strategy in steep areas.

Furthermore, as pointed out in FAO (2012), the enclosure of bare lands and sustainable use of a natural vegetation ecosystem could restore degraded lands, control the expansion of gullies and the depletion of plant species. To satisfy the demand for wood by the local people and sustain the ecological health of the study area, the government and non-governmental organisations should encourage and support the planting of fast growing tree species such as eucalyptus and gravellier on the steep slopes and mountain environments. As noted by Zhang et al. (2000), in Southern China, tree plantations on the steep slopes could also check land resource degradation. During the field survey, the elders pointed out that, the youth in various villages can be organised as co-workers in environment management within their respective sub-villages under the guidance of experienced local elders, farmers and experts for sustainable agro-pastoral livelihood activities.

5.3 Implications for Policy Formulation

Agricultural policy and practices in Tanzania prohibit cultivation of steep slopes (over 30% gradients) and permits their use only for protective forestry (URT 2014). Cultivation of steep slopes, human and animal disturbance of the vegetation covers, quarrying of river valley bare lands, poverty and food insecurity have all featured in the degradation of the vegetation land cover in the study area. Therefore, the agricultural, forest, settlement and development policies of the country should appreciate and reward those farmers who practise effective land resource management. As indicated in FAO (1978), conservation of land use has to be positive, not merely prohibitive of certain bad community practices. A similar observation is also made by Cuervo et al. (2012) in Colombia, where incentives in afforestation have surprisingly led to vegetation land cover recovery in the period between 2001 and 2010.

For a sustainable management of land resources, various approaches are necessary, and policy and action by various Ministries, departments and agencies of government need to be co-ordinated and integrated. Furthermore, as noted in the country's human settlement and development policy of 2000, Tanzania must have an effective population policy that addresses population, quality and equal distribution of national resources against existing population. Over-population in a given area would lead to further resource pressure, shortage and fragmentation of farmlands and degradation of land resources. The policy of conserving steep slopes for vegetation should be reinforced by re-afforestation and the promotion of agri-silviculture in the study area. This can be done through the integration of local knowledge and skills in development plans and vegetation conservation measures at the individual and village levels.

6 CONCLUSIONS AND RECOMMENDATIONS

The study shows that the combination of socioeconomic, ecological and multi-temporal satellite, from different locations can potentially be used to monitor vegetated land cover degradation at the District level. As revealed in the study, the 3-year satellite image data analysis (1987, 2001 and 2015) provides the objective information on vegetated land cover/land use changes in Mbulu and Karatu Districts. The analysis has shown a significant dynamism of vegetated land cover/land use in the study area. The results identified the presence of forest, woodland, bush-land, grassland, wetland, cultivated land, bare soil, water, and settlements (built up areas).

Throughout the period 1987-2015, wetland, settlement (built-up area), cultivated land and bare soil expanded at an average rate of 42.15%, 15.66%, 12.09% and 6.41%/year, respectively, at the expense of grassland, woodland, water, forest and bush-land, which declined by 2.68%, 2.5%, 2.04%, 1.36% and 0.12%/year, respectively. The vegetated land cover /use dynamics of 1987-2015 resulted in the reduction/loss of plant species and occurrences of soil erosion. The continuous spatial-temporal decline of forest, wood, bush and grassland covers (from 1987 to 2015) has been accompanied by the expansion of urban settlement and prevalence of cultivated land. Should the continuous decline in the trend of vegetation land cover/land use persist, the future stability of agro-pastoral community livelihood and wellbeing will be further threatened, and hence may be susceptible to ecosystem imbalances.

These inequalities in ecosystems have severely aggravated soil erosion and the loss of plant species in the study area. For instance, the water runoff from the steep degraded interlocking spurs and mountains causes water logging in flatter lands. This inhibits crop cultivation and sometimes leads to the displacement of local people from their villages. In addition, the lack of appropriate agricultural practices on the highlands in the study area triggers severe water pollution and siltation of water bodies such as rivers and lakes.

The local community must be made liable for carrying out changes, with appropriate help from Government and development agencies. For example, to avoid soil erosion, expansion of gullies, food insecurity; and to satisfy the wood demand of the community, the practices of terracing and traditional land husbandry should be strengthened and integrated with the improvement of vegetation land cover/land use (grasslands, bush-lands, woodlands and forest lands). The vegetation land cover/land use can also serve as a supplementary source of income and livelihood to improve the living conditions and overcome food insecurity.

Above all, to augment the ecological balance in the study area, the grass resources of the bush-lands, wood covers and forests have to be used as a source of fodder. The wet season (February-May) crop cultivation of the flat valley areas has to be shifted to August and/or September-October planting so as to overcome the constraint of water logging. As an alternative measure, cereals that can resist water logging, such as rice can be tested, evaluated and, if proved appropriate, cultivated in the waterlogged parts of Lakes Manyara and Eyasi in the Eastern and Western parts of the study area, respectively. The limited but continuous expansion of cultivation into flat grasslands and/or marginal areas should be curtailed. Crop yields should be maximised per hectare of land, using appropriate soil management, improved seeds and land suitable for the crops. Animal husbandry needs to be modernised, making sensible choices of both the livestock suitable for that and for the land in which they are to be raised.

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