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LAND USE AND LAND-USE CHANGE DRIVERS AND THEIR INFLUENCE ON CARBON SINKS IN AGROFORESTRY AND MIOMBO WOODLAND AGRO-ECOSYSTEMS IN TANZANIA

Justinian M Bamanyisa[1], Pantaleo Munishi[2], Willy Makundi[3], Deo Shirima[4]

[1]Department of Co-operative Development and Management, Moshi Co-operative University, P. O. Box 474, Moshi, Tanzania
[2]Department of Ecosystems and Conservation, College of Forestry, Wildlife and Tourism, Sokoine University of Agriculture (SUA), PO Box 3010, Morogoro, Tanzania
[3]Visiting Lecturer, Directorate of Research and Postgraduate Studies, Moshi Co-operative University, P. O. Box 474, Moshi, Tanzania
[4]Department of Ecosystems and Conservation, College of Forestry, Wildlife and Tourism, Sokoine University of Agriculture (SUA), PO Box 3010, Morogoro, Tanzania

*Email of the corresponding author jbamanyisa@yahoo.com

ABSTRACT
Land use, land-use change and forestry (LULUCF) play a key role in terrestrial carbon stock changes. The contribution of LULUCF to greenhouse gas (GHG) emissions is approximately 20% of the total global GHG emissions. Activities in the LULUCF however, can provide effective ways in which GHGs removals from the atmosphere occurs. This paper examined the drivers of land use and land-use changes (LULUC) that reduce emission and enhance carbon sinks in Moshi and Urambo Districts. Specifically, the study sought to understand the nature and extent of land use changes as well as examining their drivers and implications on reducing emissions and increasing carbon stocks in different pools. A sample of 297 households was systematically selected from 16 villages. The study involved a questionnaire survey for collecting socio-economic data and satellite images for remote sensing data. Binary logistic regression analysis was used to assess factors which have influence on LULUC. Land-use change was analysed based on the interpretation of satellite images. Change Detection Matrix showed a replacement of tree crops by herbaceous crops (1995-2005) and an expansion of cultivation of tree crops at the expense of herbaceous crops (2005-2015) for Moshi District and an increase of land under closed vegetation in Urambo District (2010 – 2015). Intensive farming, establishment of woodlots, use of energy efficient stoves, agroforestry practices, population growth and tree planting were among the important drivers of land use and land-use change. The study concludes that drivers of land use and land use change in Moshi and Urambo districts are strongly related to GHG emissions and carbon sinks. Rigorous knowledge on agricultural practices that reduce emissions and enhance carbon stock should be encouraged.

Key words: *Land use, land-use change, land use change drivers, co-operatives, carbon emissions, carbon sinks and binary logistic regression.*

1.0 INTRODUCTION
The LULUCF sector plays a key role in limiting GHG concentration in the atmosphere. The contribution of LULUC to anthropogenic carbon emissions were about 33% of total emissions over the previous 150 years (Houghton, 1999), with a diminishing share as the emissions from the energy and industrial sectors grew, thus 20% of total emissions in the 1980s and 1990s (Denman *et al.*, 2007), 12.5 % of total emissions over 2000 to 2009 and 12% for the decade that ended 2010

(Houghton *et al*., 2012). According to the United Nations Intergovernmental Panel on Climate Change, the estimated global net flux due to land use change is approximately 20% of global CO_2 emissions in each year. Deforestation and forest use in the tropics such as conversion of forests to agricultural uses is responsible for 10 to 15% of the global carbon emissions each year (Denman *et al.*, 2007; Harris *et al*., 2012).

LULUCF affects the amount of carbon entering and leaving the atmosphere and, therefore, provide opportunities to reduce emissions and mitigate climate change (Sleeter *et al.,* 2012). Scientific literature has highlighted that LULUCF sector plays a key role in reducing emissions to the atmosphere by enhancing the sequestration of carbon in terrestrial reservoirs, substituting carbon intensive products and reducing emissions from deforestation and degradation (Cowie *et al.*, 2007; Forsell *et al.*, 2016). Thus, activities in LULUC provide effective ways in which greenhouse gas (GHG) removals from the atmosphere occur, via carbon sequestration during biomass growth (Schlamadinger *et al*., 2007). Studies show that with appropriate interventions such as long-term storage of carbon in wood products, expansion of forest carbon storage and substitutions in fuel woods, it is possible to reduce emissions from deforestation and forest degradation through LULUC (Cowie *et al*., 2007). Although it is widely accepted that LULUC is a potential source of carbon dioxide to the atmosphere (Noble *et al*., 2000), it is also established that there are drivers of LULUC that can enhance carbon pools (Lambin *et al*., 2001; Houghton, 2012; Meyfroidt *et al.*, 2013), the question of whether the LULUC drivers can be addressed in ways that will significantly enhance carbon pools in order to mitigate climate change is rarely acknowledged. Thus the objective of this paper was to examine the drivers of land use, land-use change and forestry that reduce GHG emissions and enhance carbon sinks. Specifically, the paper describes the extent of land use changes and the drivers of LULUC linked to co-operatives activities in agroforestry cropping systems and miombo woodland agro-ecosystems.

The results identify potential interventions and practices by co-operatives that reduce carbon emissions and enhance carbon sequestration in the LULUC sector. The findings are expected to guide decisions and to inform policy makers about the current status of LULUC and co-operative practices, which are very crucial in the global carbon cycle and resource management in the agroforestry ecosystems and the *miombo* woodland agro-ecosystems. Examining the drivers of land use, land-use changes associated with enhancing carbon pools in these ecosystems leads to a more robust understanding of the dynamics of land-use and land use changes and therefore, more appropriate policy interventions affecting carbon sinks. Improved understanding of drivers of LULUC is also required to assess and project the future role of land-use and land-use changes in the global campaign on reducing emissions from deforestation and forest degradation.

The paper used political ecology approach to examine drivers of land uses that reduce GHG emissions and increase carbon sinks. The political ecology approach engages with the social world and views the environment as not simply a stage or an arena in which struggles over resources access and control take place, but also consider nature or biophysical processes that play an active role in shaping human environmental dynamics. Under this approach the resource systems are typically viewed as utilized ecosystems that are, by nature in ever-changing interactions with human activities e.g. people – vegetation, people- wildlife, that are typically differentiated by power relations associated with gender, ethnicity, class or wealth categories (Zimmer and Basselt, 2003).

2.0 MATERIALS AND METHODS

2.1 Study Area Description

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The study was conducted in Moshi and Urambo Districts in Kilimanjaro and Tabora Regions respectively. The two districts were purposively selected due to the prevalence of agricultural marketing co-operatives. The districts provide a good case in identifying co-operatives' potential impacts on GHG emissions and carbon sinks. Moshi District is one of the seven districts of Kilimanjaro Region, it occupies an area of 1713 square kilometres on Southern slopes of Mount Kilimanjaro and according to 2012 National Census, the district has a human population of 466 737; of which 25 767 are males and 240 970 are females (URT, 2013). The district lies between longitudes 37° and 38° East and latitudes 2°30' and 50° South of the Equator at an elevation of 1200 m above sea level. The rainfall pattern is highly dependent on altitude, whereby the lowlands receive an average of 600 mm per year; the central part 1100 mm per year and the highlands 1600 mm per year. The district has an average daily temperature of 26ºC (URT, 2017). In Moshi District the study focused on the highland zone (coffee-banana belt and home-garden area) between 1200 and 1800 m above sea level and the midlands (maize-bean belt) between 900 and 1200 m above sea level.

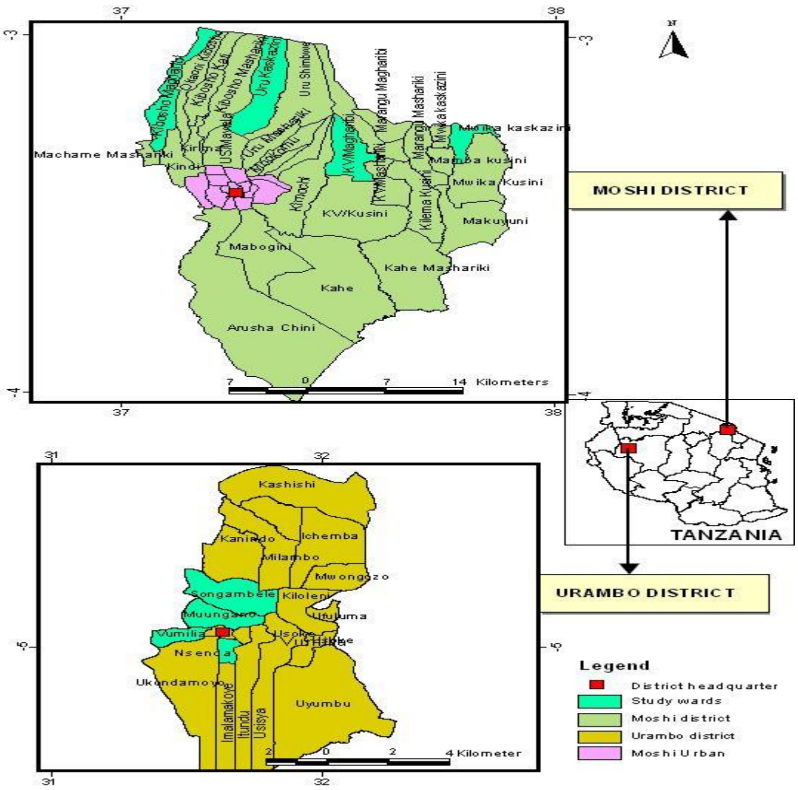

Figure 1: Study area map

Urambo District is located in the mid-western part of Mainland Tanzania on the central plateau between latitudes 4° and 5°55' South of the Equator and longitude 31° and 34° East of Greenwich Meridian. It has a total area of about 5 415.8 square kilometres and a human population of 192 781 of which 95,997are males and 96,784 are females. The district falls in the central plateau of Tanzania, an area of low relief lying between 1100 m and 1200 m above sea level, generally characterised by a flat land with small hills and scarce undulating landscapes with an annual rainfall range from 900 mm to 1200 mm and temperatures which range from 21 –33^{0}C. The dominant vegetation is *miombo* woodland with scattered bushes and thickets, mixed with wetland vegetation of *mbuga* wooded

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grassland and *mbuga* grassland. In Urambo District the focus was on *miombo* woodlands where shifting cultivation is the major farming system that exerts pressure on these woodlands. Miombo woodlands form an integral part to socio-economic and cultural aspects of local communities (Lupala *et al.*, 2014). In Tanzania, *miombo* woodlands support the livelihoods of estimated 87% of urban and rural population (Abdallah and Monela, 2007). The woodlands are also important for carbon storage and sequestration (Williams et *al.*, 2008).

2.2 Research Design and Sampling

The study adopted descriptive cross-section design in examining drivers of land use, land-use change associated with enhancement of carbon sinks. A socio-economic survey and remote sensing techniques were employed to generate data on drivers of carbon sinks and extent of land use land cover changes. The target population included all primary co-operatives in the two districts. Multistage sampling was adopted where the first stage represented administrative wards. Eight wards were selected, four wards from each district. The second stage represented the co-operative organisations and the third stage represented the households from villages in which co-operatives operate. Two primary agricultural marketing co-operative societies were chosen from each ward, making a total sample of 16 agricultural marketing primary co-operatives. Wards and farmer primary co-operatives were purposely selected with the assistance of District Co-operative Officers. Household's representatives were systematically selected from the village register. The sampling frame for social survey data was the list of all households in the village register. For villages where the list was not available it was generated by the help of leaders of villages and hamlets (*vitongoji*). The sample was calculated using Fisher *et al.* (1991) formula for population greater than 10 000. A total of 297 respondents were interviewed. The minimum age for the respondents was taken to be 18 years.

2.3 Data Collection Techniques

A questionnaire was administered to 297 household representatives. It was supplemented with remote sensing data. Freely downloaded Landsat TM (1995/2005) and ETM (2010/2015) images were used to examine changes in land use/cover. The main criteria for choosing images were availability, avoiding the peak of rain season (March/April) and avoiding images with cloud cover above 20%. To reflect changes in land use/cover in the two districts, the land sat scenes in Table 1 were used.

Table 1: Land sat scenes

District	**Scene**	**1995**	**2005**	**2015**
	168/62	30/01/1995	16/10/2005	14/01/2015
Moshi	168/63	27/09/1995	6/2/2005	6/2/2015
	167/63	1/7/1995	22/08/2005	1/4/2015
	Scene	**2005**	**2010**	**2015**
Urambo	1717/63	7/6/2005	14/12/2010	5/2/2015
	171/64	7/6/2005	14/12/2010	23/07/2015
	170/64	18/07/2005	11/4/2010	1/8/2015

Due to the high regenerative capacity of the *miombo* woodlands (Lupala *et al*., 2014), the study used an interval of five years between the land sat scenes. *Miombo* woodlands produce dense coppices in 2 to 5 years after clearing and become mature woodlands in 6 to 8 years (Frost, 1996). Tables 2 and 3

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present land use land-use change classes used in the study. Land use and land-use change classes were classified in accordance with Anderson's land use and land cover classification system for use with remote sensing data (Anderson, 1976). The difference in cover classes shown in Tables 2 and 3 is due to the fact that Moshi District is mainly a montane forest area while Urambo District is in Miombo woodlands.

Table 2 : Land use/cover types used for Moshi District

Land Use	Description
Bushed grassland	Land area dominated by grasses with seasonally cultivated crops, mainly maize, sunflower, and fodder
Bushed with scattered crop land	Medium height wooded grassland seasonally cultivated with crops mainly maize and sunflower
Cultivation with herbaceous crops	Mixture of non-woody crops with scattered perennial tree crops mainly banana and planted trees
Cultivation with tree crops	Mixture of annual crops with perennial tree crops such as coffee, banana planted trees and remnants of natural trees
Dense bush land	The vegetation is most woody plants with multiple stems and form bushes or small bush like trees with a few emergent trees of up to 20 m high.
Grassland with scattered cropland	Area of grasses mixed with shrubs, few trees and with some crops mainly maize, beans and sunflower
Inundated grassland	Land cover dominated by grass and herbs with scattered shrubs
Mixed cropland	Areas of farming where there is a mixture of annual crops with perennial tree crops
Natural forest	Multi-layered vegetation dominated by trees (largely evergreen montane forests)
Open woodland	Land covered with vegetation species (plants higher than 5 m to 20 m classified as woodland trees
Swamp	Areas inundated with water with some patches of cultivation mainly rice, and some vegetables
Urban area	Settlement area designated as town centres
Woodland with scattered cropland	Land covered with vegetation species (plants higher than 5 m to 20 m classified as woodland trees with patches of crops

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Table 3: Land use/cover types used for Urambo District

Land Use change	Description
Closed woodland	Closed *miombo* woodlands less disturbed
Open woodland	Woodland with trees higher than 5 meters and canopy covers between 10% – 40 or with a combined cover of shrubs, bushes and trees above 10%.
Woodland with scattered cropland	Woodland with patches of crops mainly tobacco and maize
Open bushland	Land composed of bush or shrubs (plants lower than 5 m are classified as bush land)
Bushland with scattered cropland	Land composed of bush or shrubs (plants lower than 5 m are classified as bush land) with patches of crops mainly tobacco, maize, potatoes and sunflower
Bushland with emergent trees	Land composed of bush or shrubs (plants lower than 5 m are classified as bush land)
Cultivation with herbaceous crops	Mixture of annual crops with perennial tree crops mainly mangoes
Mixed cropland	Crop fields with rural settlements; there is a mixture of annual crops with perennial tree crops
Wooded grassland	Land cover dominated by grass and herbs with scattered trees and shrubs (*mbuga* wooded grassland)
Open grassland seasonally inundated	Semi-permanent and seasonal waterlogged land dominated by grass and herbs with scattered trees and shrubs
Wooded grassland seasonally inundated	Seasonal waterlogged land dominated by grass and herbs with scattered trees and shrubs
Bushed grassland seasonally inundated	Semi-permanent and seasonal waterlogged land with less than 10% of vegetation cover (flood plains comprised of herbs, grass and dwarf bushes)
Urban area	Settlement area designated as town centres

2.4 Data Analysis

2.4.1 Theoretical and empirical model

In this paper, a logistic regression model was used to assess the factors contributing to land use and land-use changes in the study area. It was assumed that land use and land-use changes (binary choice: "Yes" = 1 if there was land-use change and "No" = 0 if there was no land-use change) were dependent variables Table 4.

That is:

$$L_i = ln\left(\frac{P_i}{1-P_i}\right) = \beta_1 + \beta_2 X_i + \varepsilon_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\ln(odds)ln = \ln(Y/(1-y)) = a + bX) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where P_i is the predicted probability of the event land use change which was coded with 1 (causing/influencing land use change) rather than with 0 otherwise. X_i is our predictor or explanatory variables. The binary logistic regression was used because the dependent variable was dichotomous and when compared to logistic models, they generate predicted probabilities that are almost identical. Aldrich and Nelson (1984) indicate that in practice the two models yield estimated choice probabilities that differ by less than 0.02. The social survey data was analysed using the statistical package for social sciences (SPSS) version 20.

Table 4: Description and Expected Sign of Variables Included in the Land-Use Change Model

Variable Name	Variable coding	Expectations: Land-use Change Models	Sign
Intensive farming	1, otherwise	Reduce GHG emissions and increase carbon sinks	+
Crop rotation	1, otherwise	Increases carbon sinks	+
Woodlots	1, otherwise	Enhances carbon sinks	+
Expanding farmlands	1, otherwise	Reduces carbon sinks	-
Soil conservation	1, otherwise	Enhances carbon sinks	+
Firewood collection	1, otherwise	Reduces carbon sinks	-
Timber and poles harvest	1, otherwise	Reduces carbon sinks	-
Migration	1, otherwise	Increases emissions, reduces carbon sinks	-
Conservation of natural forests	1, otherwise	Enhances carbon sinks	+
Energy saving stoves	1, otherwise	Enhances carbon sinks	+
Environmental pressure groups	1, otherwise	Enhances carbon sinks	+
Bylaws and regulations	1, otherwise	Reduce GHG emissions and increase carbon sinks	+
Population growth	1, otherwise	Increases emissions, reduces carbon sinks	-
Tree Planting	1, otherwise	Enhances carbon sinks	+
Planting fodder	1, otherwise	Enhances carbon sinks	+
Agroforestry	1, otherwise	Enhances carbon sinks	+

The empirical logit model for this study is specified as follows:

$$\log Y = bo + \sum_{i=1}^{16} \beta_i X_i + \epsilon_i \quad \text{.......3}$$

Where:

Y = Land use change
X_1 = Intensive farming
X_2 = Crop rotation
X_3 = Woodlots
X_4 = Expanding farmlands
X_5 = Soil conservation
X_6 = Firewood collection
X_7 = Timber and poles harvest
X_8 = Migration
X_9 = Conservation of natural forests
X_{10} = Energy saving stoves
X_{11} = Environmental pressure groups
X_{12} = Bylaws and regulations

X_{13} = Population
X_{14} = Tree planting
X_{15} = Planting fodder
X_{16}=Agroforestry

2.4.2 Interpretation of satellite images, images analysis and change detection

Satellite images were pre-processed using Erdas Imagen software. Since the images obtained were from different dates, the study areas (Moshi and Urambo Districts) scenes and pre-processing were crucial to rectify illumination within the images. The images were also geo-rectified using already existing datasets like roads and ground truth points. Rectified and geo-referenced images, were then processed in ArcGIS using on-screen classifier. Pre-processing was done using Erdas Imagen remote sensing software. Although it was time consuming, the on-screen interpretation and classification was opted over supervised or unsupervised machine classification due to high heterogeneous nature of the two districts and availability of personnel with good and reliable knowledge on land cover in the two districts. At first the major topographic features and other general/broad categories of land use/cover types/classes were identified and later verified in the field. Field data included GPS points taken in various locations, known road network within the two districts and detailed existing topographical maps.

3.0 FINDINGS AND DISCUSSIONS

3.1 Extent of land use, land-use changes

In Moshi District, drastic land use changes occurred between 1995 and 2015 (Fig. 2 and Tables 6 & 7). The major land use change observed in Moshi District between 1995 and 2005 was the replacement of tree crops (agroforestry) with herbaceous crops. The area under herbaceous crops expanded by 43 224.6 ha. Also, there was slight percentage increase in dense bush land and bushed grasslands for the same period (1995 to 2005). There was no change in the area under natural forests mostly due to gazetting, but according to the in-depth interviews the forest was very much degraded by illegal wood extraction.

Table 6: Land Use and Land-Use Coverage for 1995, 2005 and 2015 for Moshi District

Land Use/Cover Type	Hectares	1995 %	Hectares	2005 %	Hectares	2015 %
Bushed grassland	27.96	0.02	1649.58	1.18	6877.91	4.92
Bushed with scattered cropland	3872.32	2.77	3872.32	2.77	7339.24	5.25
Cultivation with herbaceous crops	27833.18	19.91	71057.80	50.83	29398.89	21.03
Cultivation with tree crops	33774.47	24.16	11001.87	7.87	33033.56	23.63
Dense bush land	4962.72	3.55	5116.50	3.66	4990.68	3.57
rassland with scattered cropland	5689.66	4.07	5074.56	3.63	2390.49	1.71
Inundated grassland	7632.81	5.46	12385.84	8.86	6598.32	4.72
Mixed cropland	29091.34	20.81	21738.12	15.55	12525.63	8.96
Natural forest	18061.51	12.92	15447.35	11.05	18089.47	12.94
Open woodland	97.86	0.07	4571.30	3.27	2865.80	2.05
Swamp	7674.75	5.49	13.98	0.01	1509.79	1.08
Urban area	391.43	0.28	1202.24	0.86	2082.95	1.49
Water	125.82	0.09	97.86	0.07	307.55	0.22
Woodland with scattered cropland	559.18	0.4	559.18	0.4	11784.72	8.43

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Table 7: Net Land use, land use Change 2005 – 2015 for Moshi District

	Net Change (Hectares)		
	1995-2005	**2005-2015**	**1995-2015**
Bushed grassland	1621.6	5228.3	6850.0
Bushed with scattered cropland	0.0	3466.9	3466.9
Cultivation with herbaceous crops	43224.6	-41658.9	1565.7
Cultivation with tree crops	-22772.6	22031.7	-740.9
Dense bushland	153.8	-125.8	28.0
Grassland with scattered cropland	-615.1	-2684.1	-3299.2
Inundated grassland	4753.0	-5787.5	-1034.5
Mixed cropland	-7353.2	-9212.5	-16565.7
Natural forest	-2614.2	2642.1	28.0
Open woodland	4473.4	-1705.5	2767.9
Swamp	-7660.8	1495.8	-6165.0
Urban area	810.8	880.7	1691.5
Water	-28.0	209.7	181.7
Woodland with scattered cropland	0.0	11225.5	11225.5

For the period between 2005 and 2015, informative changes occurred in land under cultivation with tree crops. There was a great increment in the 2015 map, and this is concurrent with an enormous decline in the land under herbaceous crops. Land under cultivation with tree crops increased by 22 031.7 ha (Fig. 2). In the 2015 map a slight increase was also noted on the proportion of lands with bushed grassland and bush land with scattered cropland. A decrease was noted on mixed cropland and woodland with scattered crops. The increase of land under cultivation with tree for the period between 2005 – 2015 is explained by farmers', thus, extensive efforts to plant new higher-yielding coffee plants and an emphasis on the benefits of shade, use of livestock manure and fodder crops were done. This is the period in which coffee started to fetch high price after the primary agricultural co-operatives became independent from Kilimanjaro Native Co-operative Union. Because of high prices farmers devoted to coffee production, the crop which was largely abandoned due to low prices in 1990s.

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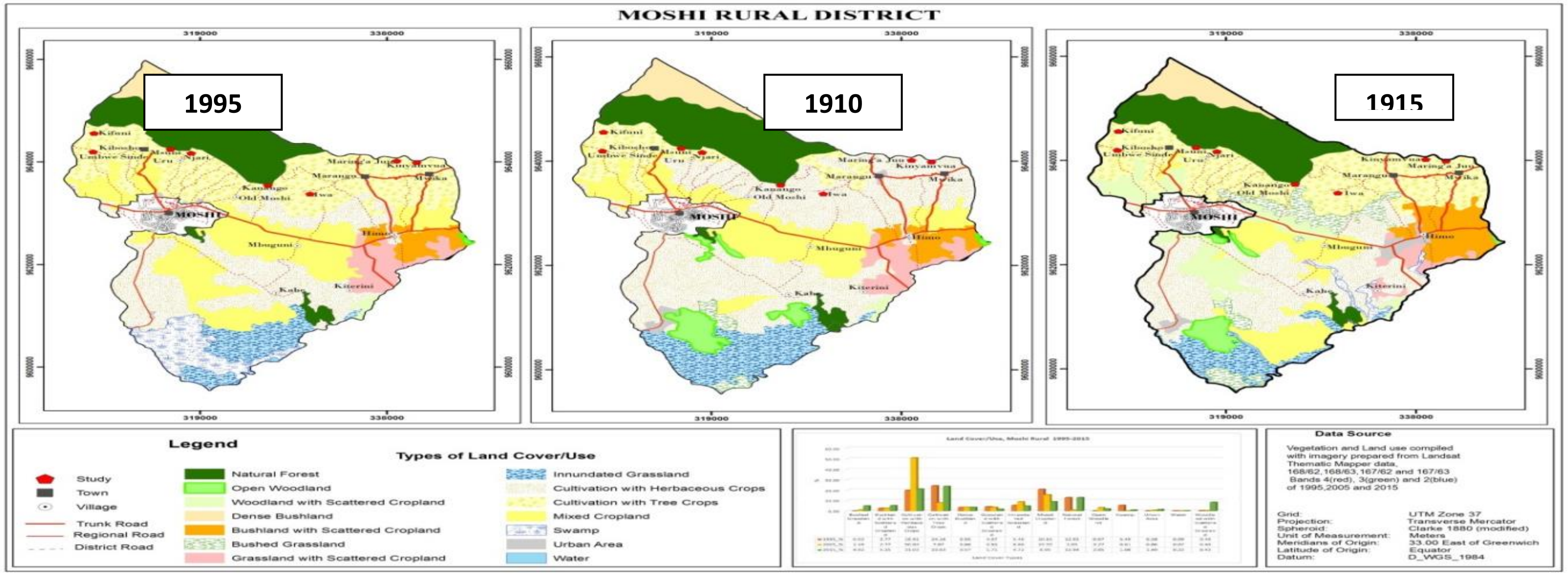

Figure 2: Land use and Land use change maps for Moshi district 1995 - 2015

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In Urambo District the results of the land use, land-use change generated for the three periods are presented in Tables 8 and Table 9 and Fig. 3. From 2005 to 2010 significant land-use changes occurred. In 2005 and 2010 maps the dominant land use type was woodland with scattered crops covering 50.08 and 36.21% of the total land area in 2005 and 2010 respectively. In 2010, map closed woodland almost doubled from 1644.15 hectares in 2005 to 3245.52 hectares. In 2015, the closed woodland further increased to 4339.58 hectares. A remarkable increase was also noted in the mixed crop land area; it increased by 5.20 and 14.04% in the two periods respectively. This increase is connected to a decrease of woodland with scattered crops.

Table 8: Urambo District Land use and land-use coverage for 2005-2010-2015

Land Use/Cover Type	2005		2010		2015	
	Hectares	%	Hectares	%	Hectares	%
Closed woodland	1644.2	0.3	3245.5	0.5	4339.6	0.7
Open woodland	73748.5	12.1	50809.8	8.3	46561.9	7.6
Woodland with scattered cropland	306062.9	50.1	221312.7	36.2	149599.5	24.5
Open bushland	1882.5	0.3	984.1	0.2	556.2	0.1
Bushland with scattered cropland	2127.0	0.3	2322.6	0.4	2292.0	0.4
Bushland with emergent trees	67.2	0.0	67.2	0.0	67.2	0.0
Cultivation with herbaceous crops	22565.8	3.7	44746.6	7.3	43481.4	7.1
Mixed cropland	89866.1	14.7	121630.6	19.9	207468.8	33.9
Wooded grassland	641.8	0.1	641.8	0.1	641.8	0.1
Open grassland seasonally inundated	537.9	0.1	11869.7	1.9	11869.7	1.9
Wooded grassland seasonally inundated	95788.7	15.7	125737.9	20.6	78577.0	12.9
Bushed grassland seasonally inundated	14870.7	2.4	24197.8	4.0	55076.0	9.0
Swamp	110.0	0.0	110.0	0.0	110.0	0.0
Urban area	1136.9	0.2	3056.1	0.5	10549.5	1.7

Table 9: Urambo District Net Land Use, Land Use Change 2005 – 2015

Land Use/Cover Type	Net Change		
	2005-2010	2010-2015	2005-2015
Closed woodland	1601.4	1094.1	2695.4
Open woodland	-22938.7	-4247.9	-27186.6
Woodland with scattered cropland	-84750.2	-71713.2	-156463.4
Open bushland	-898.5	-427.9	-1326.3
Bushland with scattered cropland	195.6	-30.6	165.0
Bushland with emergent trees	0.0	0.0	0.0
Cultivation with herbaceous crops	22180.8	-1265.2	20915.6
Mixed cropland	31764.5	85838.2	117602.7
Wooded grassland	0.0	0.0	0.0
Open grassland seasonally inundated	11331.8	0.0	11331.8
Wooded grassland seasonally inundated	29949.2	-47160.9	-17211.7
Bushed grassland seasonally inundated	9327.1	30878.3	40205.3
Swamp	0.0	0.0	0.0
Urban area	1919.2	7493.4	9412.6

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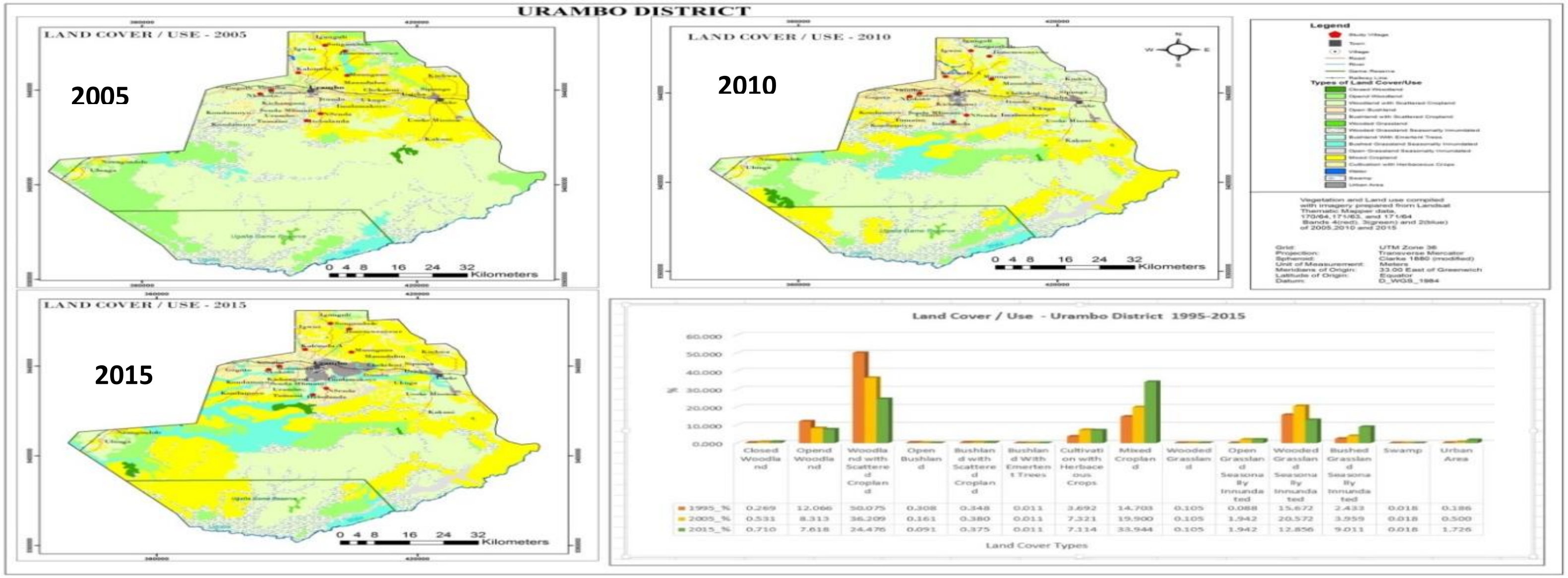

Figure 3: Land use and Land-use change maps for Urambo District 2005 – 2015

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The 2015 map presents the results of the land cover changes in 2010 – 2015 where closed woodland vegetation increased significantly (26 95.43 hectares). Additionally, fascinating changes occurred in land under mixed cropland where there was a big increment in 2015 map which is concurrent with an enormous decline in the land under woodland with scattered cropland (Fig. 3). According to the results, there was also an eminent decrease of open woodland by 3.75% in 2010 map and 0.45% in 2015 map. Moreover, the proportion of land under cultivation with herbaceous crops increased significantly (22 180.7 hectares) in the period between 2005 and 2010 but decreased by 1265 hectares in the period between 2010 and 2015. As it was detected in the analysis, the bushed grassland seasonally inundated increased in the 2015 map and this was connected to a decrease inland area under wooded grassland seasonally inundated vegetation.

The observed increase in closed woodland in Urambo district is due to introduction of village forest reserves, prohibitions on illegal harvest of poles and timber on forest reserves enforced by local government, use of energy efficiency tobacco curing kilns which, according to interviews with forest extension officer from Tanzania Leaf *Tobacco* Company Limited, reduces wood consumption by half. The big increment of land under mixed cropland in 2015 map (Fig. 3) is mainly due to population growth which leads to more land being converted from indigenous vegetation to cropland and income diversification at household level where a variety of crops are grown for cash. Moreover, the decrease of land under cultivation with herbaceous crops in the period between 2010 and 2015 can be explained by the re-growth of vegetation such as grass, herbs or shrubs in land left for fallow. From the analysis, the changes in land use and land use change varied across the study locations. The biggest change was the increase of agricultural land in proportion to other land use changes in all study areas. Mixed farming increased significantly in Urambo District.

3.2 Drivers of Land Use and Land-use Change

Outputs from binary regression are summarized in Tables 10, 11 and 12. A good number of the explanatory variables were found to have significant effect on land-use change. In pooled logit model the variables intensive farming ($p < 0.05$), establishment of woodlots ($p < 0.01$), tobacco curing ($p < 0.1$) migration ($p < 0.1$), bylaws and regulations ($p < 0.1$) and population growth ($p < 0.001$) were statistically significant.

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Table 10: Pooled Logistic Regression Model for Urambo and Moshi Districts LULUC

Dependent Variable (1=Use 0=no use)	**Coefficient**	**P-Value**	**Marginal Effects** Coefficient	P-Value
Intensive farming	0 .821	0.021**	0.123	0.017
Extending of farmlands	0 .032	0.935	0.004	0.935
Crop rotation	-0. 676	0.143	-0.101	0.137
Establishment of woodlots	1.740	0.000***	0.260	0.000
Soil conservation	0 .266	0.580	0.039	0.579
Tree planting	-0.188	0.608	-0.028	0.607
Firewood collection	0.519	0.135	0.077	0.130
Timber and poles harvest	0.182	0.607	0.027	0.606
Tobacco curing	0.864	0.052*	0.129	0.048
Immigration	0.635	0.061*	0.095	0.056
Overgrazing	0.422	0.281	0.063	0.278
Conservation of natural forests	-0.097	0.764	-0.014	0.764
Energy saving stoves	-0.056	0.885	-0.008	0.885
Environmental pressure groups	0.418	0.197	0.062	0.193
Bylaws and regulations	0.647	0.096*	0.096	0.091
Population	1.426	0.000***	0.213	0.000
Constant	-2.374	0.000		
Number of observations	297			
Pearson chi2(254)	285.63			
Prob> chi2	0.0003			
Pseudo R2	0.3042			
Log pseudo-likelihood	-136.21448			

*Note: p-value significance level *** refers to 1%, ** refers to 5% and * refers to 10%*

The explanatory variables which showed statistically significant effect on LULUC for Moshi and Urambo logit regression models were establishment of woodlots, migration, use of energy efficiency stoves, population growth, tree planting and agroforestry for Moshi; and intensive farming, establishment of woodlots, firewood collection, use of energy efficiency kilns/stoves, environmental pressure groups and population growth for Urambo (Tables 11 and 12).

Table 11: Logistic regression model for drivers of land use change in Moshi District

Dependent Variable (1=Use 0=no use)	**Coefficient**	**P-Value**	**Marginal Effects** Coefficient	P-Value
Intensive farming	0.654	0.229	0 .096	0.221
Crop rotation	-0.242	0.687	-0.035	0.687
Establishment of woodlots	1.825	0.003***	0.268	0.001
Agroforestry	-1.427	0.024**	-0.210	0.017
Farming land	-0.156	0.874	-0.023	0.874
Soil conservation	0.783	0.229	0.115	0.219
Firewood collection	0.118	0.823	0.017	0.823
Timber and poles harvest	0.660	0.162	0.097	0.152
Immigration	1.287	0.012**	0.189	0.007
Conservation of _natural forests	0.472	0.335	0.069	0.329
Energy saving stoves	-0.994	0.080*	-0.146	0.070
Environmental groups	0.189	0.707	0.027	0.707
Bylaws and regulations	0.134	0.830	0.019	0.830
Tree planting	1.548	0.029**	0.227	0.021
Population	1.699	0.002***	0.250	0.000
Constant	-1.921	0.026		
Number of observations	148			
Pearson chi2(124)	131.13			
Prob> chi2	0.0001			
Pseudo R2	0.3389			
Log pseudo-likelihood	-66.925345			

*Note: p-value significance level *** refers to 1%, ** refers to 5% and * refers to 10%*

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Table 12: Logistic regression model for drivers of land use change in Urambo District

Dependent Variable (1=Use 0=no use)	Coefficient	P-Value	Marginal Effects Coefficient	Marginal Effects P-Value
intensive farming	1.702	0.013**	0.177	0.007
crop rotation	-1.093	0.237	-0.114	0.231
Establishment of woodlots	2.251	0.009***	0.235	0.005
Farming land	0.975	0.227	0.101	0.217
soil conservation	-1.297	0.239	-0.135	0.228
firewood collection	1.617	0.021**	0.168	0.014
Timber and poles harvest	0.747	0.525	0.078	0.524
Tobacco curing	0.832	0.145	0.086	0.134
Immigration	-0.491	0.426	-0.051	0.422
Overgrazing	-0.328	0.562	-0.034	0.560
Conservation _natural forests	-0.344	0.556	-0.036	0.553
Energy saving stoves	1.696	0.014**	0.177	0.007
Environmental groups	1.138	0.054*	0.118	0.047
Bylaws and regulations	0.938	0.214	0.097	0.203
Population	2.121	0.002***	0.221	0.000
Constant	-3.346	0.001		
Number of observations	148			
Hosmer-Lemeshow chi2(8)	2.16			
Prob> chi2	0.9755			
Pseudo R2	0.3389			
Log pseudo-likelihood	-49.56965			

3.2.1 Intensive farming

Specifically, all other variables being equal, the odds that intensive farming influences LULUC was 3 times more likely than the perception that intensive farming has no influence on LULUC. Similarly, for Moshi and Urambo districts, the odds of the perception that intensive farming influences LULUC were 2.5 and 8 times more than the perceptions that it has no relationship to LULUC respectively. Intensive farming was found to increase the probability of land use change significantly at 1% level in Moshi District, 0.2% in Urambo District and at 8% in pooled logit regression. An increased practice of intensive farming reduces forest land cleared for agriculture, thereby sparing more forest lands from being converted into crop fields. Intensive farming practices were observed in both study sites. In Moshi the study witnessed use of organic and chemical fertilizer in crop production and raising of cows, pigs and chickens and in Urambo, chemical fertilizer use was observed to be common in tobacco, maize and sunflower farming. Faced by similar findings Wu (2013) concluded that land use and land use changes such as agricultural intensification play a significant role in the global carbon cycle; it increases carbon sequestration in agricultural land uses. Similarly, Paustin *et al*. (2000) report that greater cropping intensity, i.e. reducing the frequency of bare fallow in crop rotations and increasing the use of perennial vegetation increases water and nutrient use efficiency by plants, thereby increasing carbon inputs to the soil and reducing organic matter decomposition rates.

3.2.2 Establishment of woodlots

Additionally, key findings were that with all other variables kept constant, the perception that establishment of woodlots induces LULUC was statistically significant at 1%. As it was expected, woodlots had high probability of influencing land-use change at the 0.1% level of significant in Moshi

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District and 5% in Urambo District. Pooled together, woodlots increased the probability of land-use change significantly at 1% level of significance ($p < 0.01$). The logistic regression results further showed that there was significant relationship between firewood collection and LULUC for Urambo District. The results were statistically significant at 5% ($p < 0.05$).

Apart from satisfying fuel wood demand, woodlots offset carbon emissions through alleviating harvesting pressure on native forests. In Urambo near to two-thirds (65.8%) of the respondents owned woodlots varying between 2 to 10 acres. The woodlots also have immense effect on carbon sequestration; they are said to have a large contribution to carbon sequestration. This observation is in line with those by Barrow and Shah (2012), who found that an estimated 23.2 million tons of carbon were sequestered on woodlots restoration project in Shinyanga Region, Tanzania. Similarly, Ngazi (2011) found out that rotational woodlots and *ngitiri* have the potential for carbon storage and soil fertility improvement. According to Makundi and Okiting'ati (1995), establishing woodlots is one of the options for mitigating climate change.

3.2.3 Migration

Furthermore, all other variables held constant, the perception that migration influences LULUC was statistically significant at 1% and 5% levels in pooled and Moshi regression models respectively. Migration in this context means internal migration from one region to another region or from one district to another district in the same region. The study observed that internal migration as a driver of land use, land use change was very pronounced in Urambo District where focus group discussion and in-depth interviews with key informants revealed in-migration into Urambo District which involved herdsmen who went there with their livestock from neighbouring districts of Shinyanga Region. This was reported to exert pressure on the *miombo* woodlands through overgrazing and extensive and unsustainable agricultural practices that led to the encroachment and degradation of the woodlands. These findings are supported by Sunderlin and Pokam (2002) who claim that migrants have shorter planning horizons, which cause them to be more destructive than host populations.

3.2.4 Population growth

With regard to population growth pooled, logit regression models indicated that, holding all other variables constant, an increase in the number of human populations contributed to LULUC at 1%. Pooled logistic regression analysis showed that population growth increased chance of land use change at $p < 0.01$ and for Moshi and in Urambo districts population growth was found to increase the probability of land-use change significantly at $p < 0.01$ in each district. Population growth in Moshi District is attributed to natural increase whereas in Urambo District population growth is due to immigration. In Moshi District, population increased from 342 891 in 1988 to 466 737 in 2012and population density was 358.9 inhabitants per square kilometre. In Urambo District, on the other hand, the population was 192 781 with a population density of 35.6 inhabitants per square kilometre (URT, 2012). Higher population density increase the share of agricultural land, hence, higher demand for agricultural products and thus more pressure on the land and forests as investment in capital-intensive technologies is minimal to reduce the pressure on the land through improved productivity.

3.2.5 Tree planting

Findings also revealed that tree planting significantly influenced LULUC at 5% ($p < 0.01$) in Moshi District. In Moshi tree planting is done in bare land in the upper belt and lands left by owners who migrated to towns. In Urambo, tree planting is done in degraded croplands and is a requirement for one to enter into tobacco contract farming. Trees mostly planted in Urambo District are *Albizia* species, *Cassia siamea* (mijohoro) and Eucalyptus species. The study observed that 96% of those who planted trees reported to plant trees to meet fuel wood demand; 33.7% did so for timber and construction poles, 34% for fodder and 35.2% for tobacco curing. Many studies consider trees to be a terrestrial carbon sink (Schroeder, 1992; Schroeder; Makundi and Sathaye, 2004); tree planting presents an opportunity to increase the terrestrial carbon sinks and slow increase in atmospheric CO_2 concentration. Carbon is stored in trees (stem, branches, leaves and root), understory, litter and soils (Sharrow and Ismail, 2004). Trees present an important opportunity for carbon emissions mitigation because of their carbon storage capacity, (van Kooten, *et al.*, 1999).

3.2.6 Use of energy efficient stoves

The use of energy saving stoves showed high probability of influencing land use change at 10% ($p < 0.1$) and 5% ($p < 0.05$) significant level for Moshi and Urambo respectively. The study observed a switch from the use of traditional burns to modern burns in tobacco curing. As explained by the extension officer, the use of modern burns reduces firewood consumption considerably from 15 tons to as little as 7 tons of firewood for curing one acre of tobacco. Further analysis showed that modern burns, unlike traditional burns, use branches and therefore leaving tree stems to regenerate. This suggests that more use of energy efficiency stoves offsets carbon through relieving pressure on the forests and other woody vegetation. Barnes *et al.* (1993) reported that the use of energy efficiency stoves from the point of view of greenhouse effects contribute to increasing the efficiency of combustion while promoting sustainable biomass harvesting, lessening the pressure on biomass resources and reducing the emissions of carbon dioxide to the atmosphere. Similarly, the benefits of improved cooking stoves, according to García-Frapolli *et al.* (2010), include fuel wood savings, income generation, environmental conservation and reduction in greenhouse gas emissions.

3.2.7 Agroforestry

As would be expected, agroforestry practices were more likely to influence land-use change. Results indicated that agroforestry increased chances of land-use change at 5% significant level for Moshi District. In these agro-ecosystems, trees (some over 50 years old) are grown in mixed banana coffee farms where shade trees, fodder, tree fruits and maize are also grown. The agroforestry ecosystems also include windbreaks and live boundary plantings. Agroforestry has importance as a carbon sequestration strategy because of carbon storage potential in its multiple plant species and soil as well as its applicability in agricultural lands and in reforestation. A variety of environmental benefits found in this study are also similar to those found in other studies, although in this particular study farmers put more emphasis on the benefits of shade, livestock fodders, fruits and wood products. Souza *et al.* (2011) quoted in Richard *et al.* (2013), argue that the major role of agroforestry in adaptation to changing environmental conditions was through supporting the production of a wide range of products including food, fuel wood, fodder and forage, timber, shade, gardening material, medicine and ecological services. Similarly, according to Mutuo *et al.* (2005) in their study on the potential of agroforestry for carbon sequestration and mitigation of GHG emissions from soils in the tropics, agroforestry systems are promising management practices that increase above ground and soil carbon stocks, reduce soil degradation and mitigate GHG emissions. They reported that in the humid tropics, the potential of agroforestry tree-based systems to sequester carbon in vegetation can be over 70 Mg C ha^{-1}, and up to 25 Mg ha^{-1} in the top 20 cm of soil, and that in degraded soils of the sub-humid tropics, improved fallow agroforestry practices have been found to increase top soil carbon stocks up to 1.6 Mg C ha^{-1} y^{-1} above continuous maize cropping.

Although agroforestry may involve practices that favour the emission of GHGs including shifting cultivation, pasture maintenance by burning, paddy cultivation (Le Mer and Roger, 2001), inclusion of trees in the agricultural landscapes often improves the productivity of systems while providing opportunities to create carbon sinks (Montagnini and Nair 2004). Integrating trees on farms and landscapes contributes to reducing emissions from deforestation and forests and relieves pressure off the forests arising from demand for fuel-wood, charcoal, and timber and improves soil fertility and boost productivity through nitrogen fixing trees, thus enabling farmers to maximize yields in available plots of land without the pressure to deforest more farmland (Mutuo *et al.*, 2005; Minang *et al.*, 2014).

Although not statistically significant, four variables; firewood collection, timber and poles harvest, environmental pressure groups and by-laws and regulations were mentioned by most of the respondents as important drivers of LULUC.

4.0 CONCLUSION AND RECOMMENDATIONS

The drivers of LULUC presented here are a generalised interpretation of the farmers' responses as extracted from the field survey. Major changes in land use have occurred on both ecosystems and they vary overtime. Intensive farming, establishment of woodlots, use of energy efficiency stoves, agroforestry practices, migration, population growth, tree planting, crop rotation and conservation of natural forests were important drivers of land use and land use changes.

Education on agricultural practices that reduce emissions and enhance carbon pools should be enhanced and where possible extension services should be provided. Demographic policies that halt population growth should be enacted.

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