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The dynamics of land use-land cover changes for the years 1984, 1992, 2001 and 2014 in Mutasa district, Zimbabwe.

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Abstract

Tropical woodlands in southern Africa are a primary focus of conservation efforts because they are currently under threat from rapid clearing for agriculture and human settlements. A study was carried out in Mutasa district (18°35′0″S and 32°45′0″E) in northern Eastern Zimbabwe using data that spanned the period 1984 to 2014 in order to quantify the spatial and following the conversion to agricultural lands. The land cover changes analysis for the district showed a marked decline in land areas under woodland and considerable increase in area devoted to cultivation. Temporal land-use and land cover changes in Mutasa district on the woodland and plantation forests cover.

The annual rate of net cover change from natural woodland to cropland in the district was 0.8% and this was generally higher than the annual rate of net cover changes in tropical Africa which averages 0.36%. The period from 1992 to witnessed the highest daily conversion rate of commercial farm land under woodland (miombo) and forest plantations to cropland of about 3 ha per day and this also coincided with the Fast Track Land Reform Programme which started in 2000.

Keywords: land cover change; deforestation; environment; resettlement.

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1. Introduction

Land use and land cover changes are a global concern because of the negative impacts that they have on the environment (Ademiluyi, 2008; Getahun and Van Lanen, 2015). Land cover is generally described as the observed bio-physical cover of the Earth's surface that includes vegetation, inland water surfaces, bare soil, bare rock as well as man-made features (Awotwi, 2009; Mwangi et al., 2016b). On a fundamental level, land cover is the most important element for description of the study of the environment (Malmer et al., 2010; Bodart et al., 2013). Land use, by contrast, describes activities that take place on the land and represent the current use of the land resource (Fonji and Taff, 2014). Land use and land cover (LULC) change has been recognized as an important driver of global environmental change at spatial and temporal scales (Varkonyi-Koczy, 2010; Zewdie and Csaplovies, 2015). Land use and land cover changes are intertwined in many ways with other environmental issues, such as climate change, carbon cycle, loss of biodiversity, sustainability of agriculture and provision of safe drinking water (Ademiluyi, 2008; Lambin and Meyfroidt, 2011). The recently adopted implementation plan of the Group on Earth Observation (Craglia et al., 2017) highlights the importance of land cover for all areas of societal benefits. In this context, the United Nation's Conference on Environment and Development's Agenda 21, the World Summit on Sustainable Development (WCCD) in Johannesburg 2002, and previous UN conventions, most prominently the United Nations Framework Convention on Climate Change (UNFCCC), have further emphasised the importance of LULC and change dynamics as key variables in global change phenomenon (Guo et al., 2010; Vittek et al., 2014).

Land cover changes rapidly over time and is a good proxy for dynamics of Earth surface resulting from the variety of drivers and factors (Kashaigili and Majaliwa, 2010; Malmer et al., 2010). Land cover change is the most obvious and detectable indicator of human interventions on the environment (Ademiluyi, 2008; Getahun and Van Lanen, 2015). Land cover change can either be in form of substitution of, for example, forest land by agriculture or in other cases land cover changes involve small changes of land cover type while retaining the primary status, such as bush land to exotic forest (Zewdie and Csaplovies, 2015). Land use land cover changes in forest biomes are known to negatively impact on species diversity as well as leading to forest degradation and deforestation (Malmer et al., 2010; Salemi et al., 2013; Zewdie and Csaplovies, 2015). Empirical studies have established the positive relationship that often exists between habitat area and species richness (Salami et al., 2013; Pimm et al., 2014). A commonly accepted definition of forest is the one from the United Nations Food and Agriculture Organization (FAO), which includes natural forests and forest plantations (FAO, 2010; O'Connor et al., 2013). According to the FAO (2010) deforestation occurs when forest is converted to another land cover or when the tree canopy cover falls below a minimum percentage threshold of 10%. Forest degradation is defined as a process leading to a temporary or permanent deterioration in the density or structure of vegetation cover or its species composition (Salemi et al., 2013; O'Connor et al., 2014), and thus lowering the productive capacity of the forest (Gibbs et al., 2007; Bodart et al., 2013).

In Zimbabwe it is estimated that about 30 000 hectares of forest land is converted to agriculture every year (FAO, 2010). The root causes behind land use land cover changes in various countries differ, although their impacts on forest cover and species diversity are almost similar (Pimm et al., 2014). The main causes of forest loss include demographic and institutional changes, adopted development policies, political and social-cultural forces, war and development of infrastructure (Martson, 2010; Getahun and Lanen, 2015). Rapid depletion of forests in the country has been associated with increase in population, intensification of agricultural activities and increased demand for forests products (Malmer et al., 2010; Mwangi et al., 2016b).

In situations of rapid land cover land use change, earth observations provide objective information of human utilization of the landscape (Vittek et al., 2014). Remote sensing is a useful tool for monitoring the environment and has had an important contribution in documenting land cover change on regional and global spatial scales since the early 70's when the Landsat Multi-Spectral Scanner (MSS) provided the first commercial satellite images (Lambin and Meyfroidt, 2011; Redo et al., 2011; Getahun et al., 2015). Viewing the Earth from space is crucial in understanding of the influence of human activities on forest resources over time (Lambin and Meyfroidt, 2011; Zewdie and Csaplovies, 2015). Data from Earth sensing satellites has become vital in mapping the Earth’s features and infrastructure, managing natural resources and studying environmental change (Awotwi, 2009; FAO, 2010; Lambin and Meyfroidt, 2011; Gessner et al., 2013).

In the past three decades, the satellite earth observation has witnessed remarkable improvements in satellite image quality in terms of spectral and spatial resolution (Whiteside et al., 2011; Zewdie and Csaplovies, 2015) as well as in digital data processing algorithms, analyses and interpretation (Kashaigili and Majaliwa, 2010). The improvements in satellite images, along with the progress in the integration of Earth observation and geographical information systems (GIS), has vastly increased opportunities for environmental quantitative analysis (Zewdie and Csaplovies, 2015). The collection of remotely sensed data facilitates the synoptic analyses of Earth-system function, partitioning, and change at local, regional and global scales over time (Ademiluyi, 2008). Such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Awotwi, 2009; Pimm et al., 2014; Zewdie and Csaplovies, 2015).

Despite the growth in earth observation and GIS technologies, spatially explicit information on forest cover conversion throughout the sub-tropics has not previously been available to identify locations of most rapid change and in Mutasa district this information is not available. This study, therefore sought to examine the spatial and temporal land use land cover changes in Mutasa district in Zimbabwe over three decades from 1984 to 2014. The study also evaluated the effects of the government initiated resettlement exercises in Mutasa district on land use and land cover changes over the 30-year period.

2. Materials and methods

2.1 Description of study area

The study was conducted in Mutasa district (18°35′0″S and 32°45′0″E), in the eastern highlands of Zimbabwe (Figure 1). The district lies in Agro-Ecological Region II of the country which experiences an annual total rainfall that ranges between 800 to 1000 mm (Mugandani et al., 2012). Most of the rainfall is received in the summer season which is from November to March. The mean annual temperature is around 20°C although high temperatures of up to 35°C can be recorded during the hot months of October to December. Winter seasons can be extreme in some years recording temperatures as low as –3°C between May and July (Mugandani et al., 2012).

The economy of Mutasa district is mainly dependent on large scale commercial plantations and farms that produce timber, coffee and tea. Since the early 1980s,
Mutasa district has been characterised by a shift in land use systems as a result of the land resettlement programmes initiated by the Government of Zimbabwe aimed at decongesting communal areas and redistributing land to landless natives. The resettlement programmes

saw some commercial farming areas being converted to resettlement areas. Commercial farming areas in Zimbabwe at independence in 1980 were generally natural woodlands and forest areas of the commercial farmland. The district has also experienced a significant increase in population from the early 1980s. In 1982 the district had a total population of 118 002 which significantly grew to 168 747 by 2012 (ZimStats, 2012) (Table 1).

2.2. Establishment of land use/land cover changes between 1984 and 2014. Four Landsat images acquired during the month of August in 1984; 1992; 2001 and 2014 were used in the study. Satellite images during the dry season month of August for each year were used in order to avoid the negative influence of cloud cover on image clarity. The four satellite images were used to produce land use land cover classification maps of Mutasa district. The Landsat satellite images were downloaded from Global Land Cover Facility of the University of

characterised by well vegetated farmlands. The onset of the resettlement exercises marked the beginning of a rapid encroachment of crop cultivation activities into the Maryland, USA (http://glcf.umd.edu/data/landsat/). Table 2 shows the actual dates, the spatial resolution and the path and row of the Landsat images used in the study. The Landsat image for 1984 was chosen as the starting point because it marked the beginning of the resettlement programme by the Government of Zimbabwe. The 1992 Landsat image was selected for land cover and land use changes analysis in Mutasa district because it marked the onset of Phase 1 and II of the resettlement program which was operational until 1999. In a bid to speed up the process of land acquisition and resettlement, the government passed the Land Acquisition Act of 1992, following the introduction in 1990 of Constitutional Amendment Number 11.

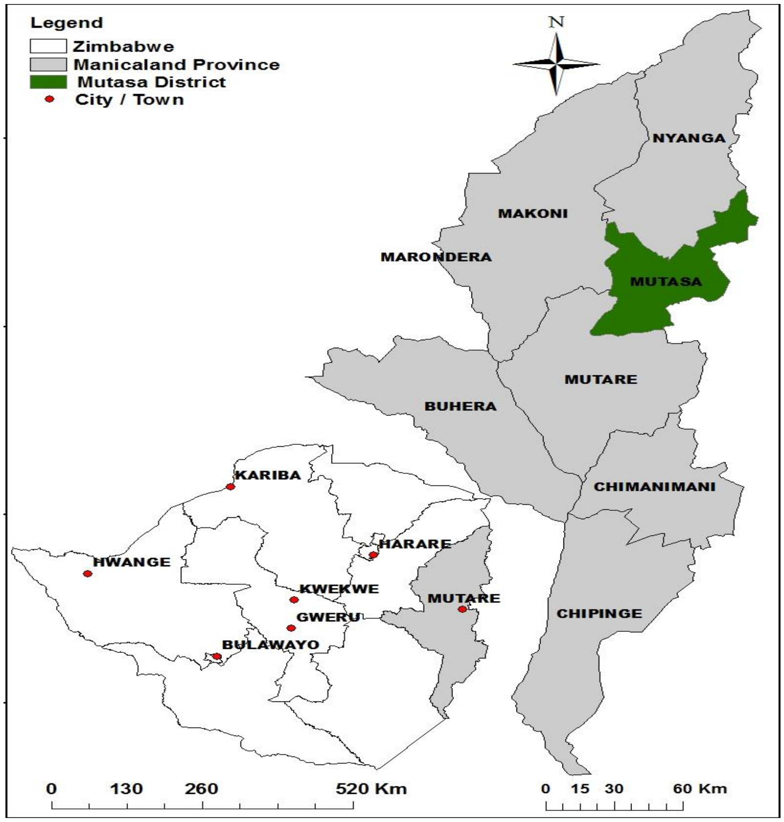

Figure 1: Location map of Mutasa district

Table 1: Population figures for Mutasa district (1982, 2002 and 2012).

Year	Male	Female	Total Population
1982	54 546	63 456	118 002
2002	78 470	88 176	166 646
2012	79 548	89 199	168 747

Source: ZimStas, 2012

This period witnessed a further conversion of the generally well vegetated commercial farmland into resettlement areas in which the smallholder farmers are more inclined to dry land cultivation of the staple maize crop after clearing the land. A further decline in the area under natural woodlands in response to the increase in the land under resettlement was anticipated during this period. This1992 period is also of particular importance for the fact that it witnessed the completion of the Osborne dam that flooded an area of 2600 ha under smallholder farming. This necessitated an involuntary relocation of smallholder communities to commercial farming areas of the district. During the period from 2000 to 2003 the government of Zimbabwe again initiated the Fast Track Land Redistribution Programme (FTLRP) in response to the slow pace of land redistribution under

Phase 1 and Phase II of the resettlement program. The program was characterized by massive land occupations of commercial farming areas as well as in previously ecologically preserved areas. The program saw large tracts of land being converted to communal settlements and small farming plots under the A1 and A2 models. It has been reported that the fast track land reform program has left most of the country's forests facing a serious threat of deforestation, increasing from 1.41% (1990–2000) to 16.4% (2000–2005) (Dalu et al., 2013).

2.3 Image Pre-processing

Remotely sensed raw images from satellites are full of geometric and radiometric flaws caused commonly by the curved shape of the earth, the imperfectly transparent atmosphere, daily and seasonal variations in the amount of solar radiation received at the surface, and imperfections in scanning instruments, among other things. While the 1984, 1992, 2001 and 2014, Landsat images were initially corrected by USGS Earth Resource Observation Systems Data Centre to a quality level of 1G (Jolla, 2010), the images were further radiometrically and geometrically corrected to enhance comparability of images from different years at pixel level. Digital numbers in individual bands were converted to radiance using the Gain and Bias method in ENVI. The Gain and Bias method uses the following formula:

$$\boldsymbol{L = gain * DN + bias} \qquad (1)$$

Where **L** is the cell value as radiance; **DN** is the cell value digital number; **gain** is the gain value for a specific band; **bias** is the bias value for a specific band. After converting the digital numbers to radiance, the bands were atmospherically corrected using Quick Atmospheric Correction (QUAC) procedure in ENVI 4.7. The three bands were then combined to create colour composite images through layer staking. A 1:25000 vector layer with administrative boundaries was used to geo-reference and subset the images. Geo-referencing was done using the nearest neighbour re-sampling method employing at least 15 ground control points for each image. Geo-referencing was based on the Universal Transverse Mercator zone 36 south projection and the WGS84 datum. A root mean square error of less than 0.2 pixels was achieved for all *the images. After geo-referencing, the administrative boundaries layer was used to subset the images corresponding to the extent of Mutasa district using masking in ENVI (Jolla, 2010).*

Table 2: Satellite images used in the study

Sensor type	Date	Path – Row	Spatial resolution
Landsat TM	27 August1984	168-073	30m
Landsat ETM +	25 August 1992	168-073	30m
Landsat ETM+	17August 2001	168-073	30m
Landsat ETM+	06 August 2014	168-073	30m

2.4 Image classification

Landsat bands 3, 4 and 5 representing visible red, near infrared, mid infrared respectively were used for LULC classification in this study. These bands have been shown to provide good results in many land cover investigations as they provide the most relevant and contrasting information for land cover discrimination (Whiteside et al., 2011; Zewdie and Csaplovies, 2015). Maximum likelihood supervised image classification in ENVI 4.7 software was used to determine the LULC classes for the different years. A false colour composite with band combination (Awotwi, 2009; Guo et al., 2010; Varkonyi-Koczy, 2010) in the Red; Green; Blue format was used for the classification. Accuracy assessment of the classified maps was evaluated using at least 100 sample points randomly spread around the study area for each image by computing an Error Matrix. Error matrix compares, on a pixel-by-pixel basis, the relationship between known referenced data and the corresponding results of an automated classification. Such matrices are square; with the number of rows and columns equal to the number of land cover classes obtained in the classification. Overall accuracy assessment of at least 82% was achieved for the classified images.

After classification, change detection analysis in ENVI 4.7 was applied to determine the spatial and temporal changes in land use and land cover between 1984 and 2014 in the study area. Overlay analysis of land use/ land cover maps with population data for 2001 and 2007 was carried out in Arc GIS 10.1.

3. Results

3.1 Land use land cover changes

The broad geographic patterns of land cover changes in Mutasa district were inferred from the 1984; 1992; 2001 and 2014 Landsat images. Natural forest cover changes were much more frequent and pronounced in the study area than the other forms of land cover change. Seven land cover categories were identified in this study (Table 3). The land cover classification (Table 3) for 1984 from the Landsat TM satellite image showed that the area under cultivation accounted for the largest part (98350.78 ha or 38.79%) of the study area. Smaller areas were occupied by grassland (2213.67 ha or 0.87%) and water body (146.8 ha or 0.06%). The area under woodland accounted for 64675.76 ha (25.51%), bush land 51324.67 ha (20.24%) and rock outcrop and mine dumps occupied 8608.36 ha, (3.40%). The land cover classification on satellite images for 1992 showed that comparatively larger portions were occupied by opened up arable lands (105909.61 ha, ~41.77% of land area) and woodland which occupied 64010.39 ha, (~25.25%). Smaller areas were covered by the grasslands which occupied 2246.96 ha, (~0.89%) as well as rock outcrop and mine dumps which occupied 8192.72 ha (~3.23%).

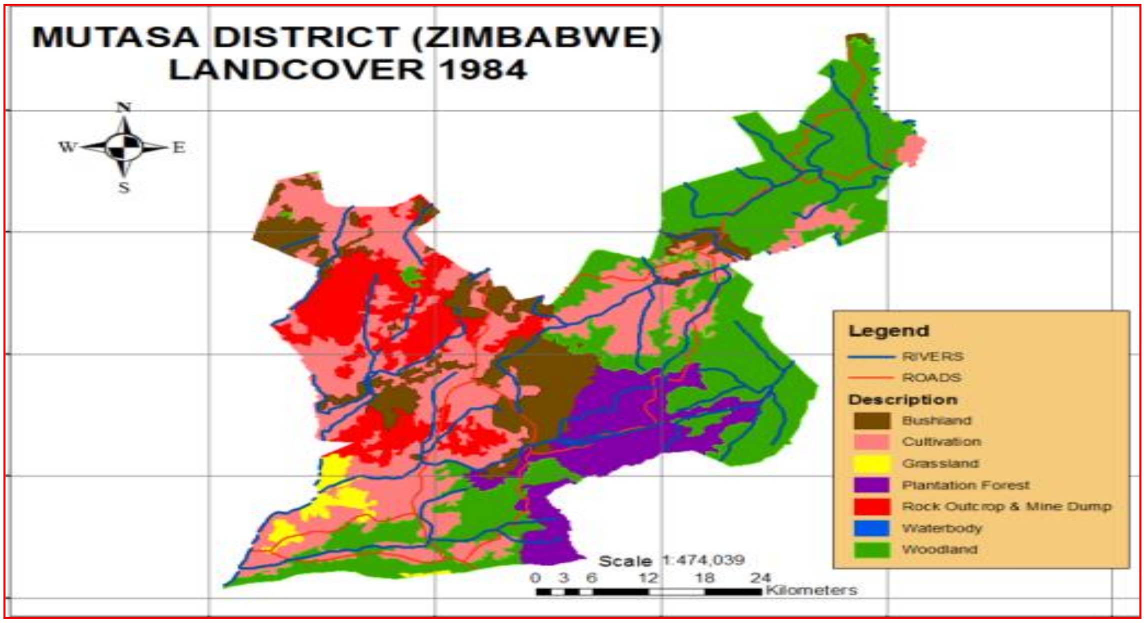

Figure 2: Land cover map for Mutasa district for 1984

Table 3: Land Cover classes and their corresponding areas for 1984 – 2014

	Bush lar	Cultivation	Forest plantations	Water boc	Woodland (Miombo)	Grassland	Rock outcrop ε mine dum	Wooded grassland	Total area, ha
1984 area, l	51324.6'	98350.78	28234.01	146.80	64675.76	2213.67	8608.36	-	**253554.05**
% land co 1984	20.24	38.79	11.14	0.06	25.51	0.87	3.40	-	**100**
1992 area, l	49125.7(	103662.70	26168.80	146.80	64010.39	2246.96	8192.72	-	**253554.05**
%land co 1992	19.37	40.88	10.32	0.06	25.25	0.89	3.23	-	**100**
2001 area, l	4221.40	113626.20	24325.60	1876.0	63278.90	6033.60	2201.30	-	**25355.0**
%land co 2001	16.65	44.81	9.59	0.74	24.96	2.38	0.87	-	**100**
2014 area, l	39675.3	12121.33	22975.56	1967.0	56234.45	7763.11	2156.45	1564.78	**253554.02**
%land co 2014	**15.65**	**47.81**	**9.06**	**0.78**	**22.19**	**3.06**	**0.85**	**0.62**	**100**

A comparative analysis of the 1984 and 1992 Landsat satellite imagery (Figure 2 and Table 3) has shown definitively that the area under bush land, woodland and forest plantations decreased by 0.87%, 0.26% and 0.82%, respectively. In contrast, the area under cultivation increased by 2.09% in response to conversion of land under natural vegetation and plantations to agricultural activities. Generally, the areas devoted to water bodies remained constant, while areas under grassland increased marginally by 0.02% in response to a reduction in forest land. Results of the study have demonstrated that the area under cultivation increased by 5311.9 ha over a period of eight years. This increase in the area devoted to cultivation resulted in-a decrease of 2730.6 ha of the area under forest plantations and natural woodland over the same period. On average, about 664 ha of woodland, forest plantations and grassland were converted to cultivated land annually between 1984 and 1992 in the district. This period represented an era before the Government of Zimbabwe passed the Land Acquisition Act of 1992. When the 1992 and the 2001 Landsat images were compared in terms of the total area of each land cover category, substantial quantitative spatial changes were established. As shown in Table 3 and Figure 3, the land cover class that increased considerably in area is that under cultivation, while areas under grassland and water bodies expanded marginally. The area covered by forest plantations and woodland declined as a consequence of an expansion in areas under cropland over the same period. The construction of Osborne dam from 1992 to 1994 contributed to an increase in the area under water bodies in the district for the period under consideration. About 9964 ha under forest plantations and natural woodland were converted into cultivated land between 1992 and 2001 with an annual increase in cropland extent of 1107 ha and corresponding decline in the area under natural woodland, forest plantations and grassland of 2620 ha for the same period. This period coincided with the introduction of the Fast Track Land Reform Program by the Government of Zimbabwe. The 1992 to 2001 period exceeded the 1984 to 1992 period in the conversion of area under natural vegetation and forest plantations into cropland by 4653 ha. The trends in land cover changes identified in the period 1984 to 1992 and 1992 to 2001 were generally maintained in the period between 2001 and 2014 (Table 3, Figure 4). Areas under woodland, bush land and forest plantations decreased considerably while the areas under cultivation, water bodies and rock outcrops and mine dumps recorded increased for the 2001 to 2014 period. The increase in the extent of cropland occurred concurrently with the largest reduction in the area covered by woodland and forest plantations for the same period. Land cover data presented in Table 3 show that the cropland extent increased by 7591 ha between 2001 and 2014. On average, the land cover under cropland increased by 584 ha annually from the conversion of woodland and forest plantations into cropland after the resettlement of smallholder farmers in the formerly commercial farm land. The annual rate of conversion of forest land into cropland-was highest during the period 1992 to 2001 (1107 ha year^{-1}). The periods 1984 to 1992 (664 ha year^{-1}) and 2001 to 2014 (584 ha year^{-1}) had comparatively similar annual rates of conversion of woodland into cropland.

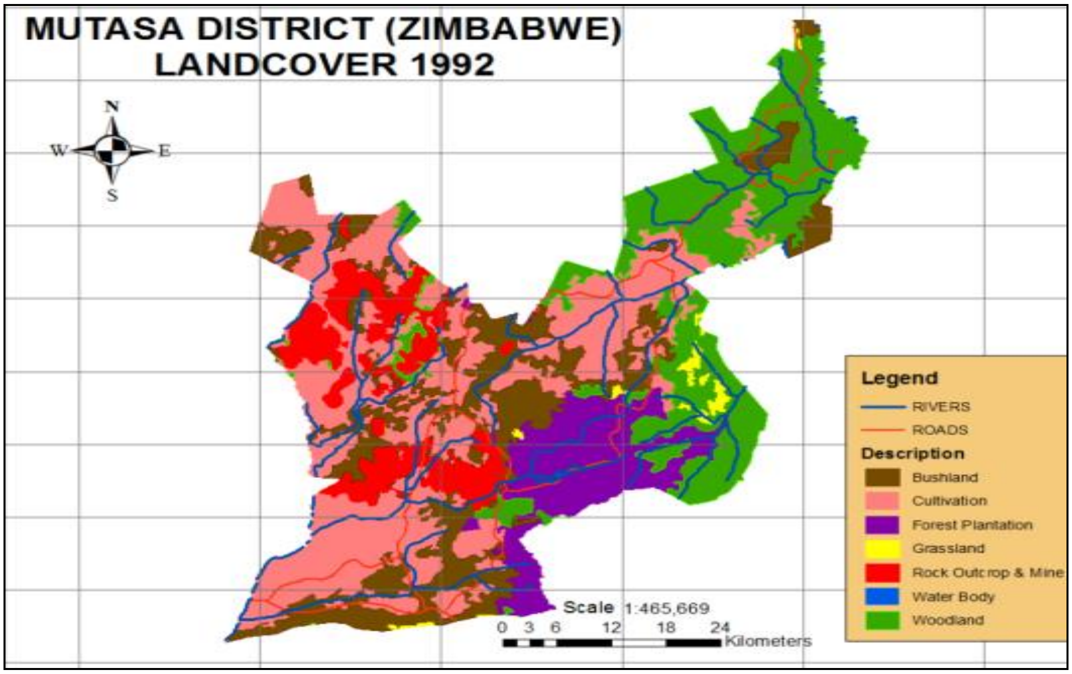

Figure 3: Land cover map for Mutasa district for 1992

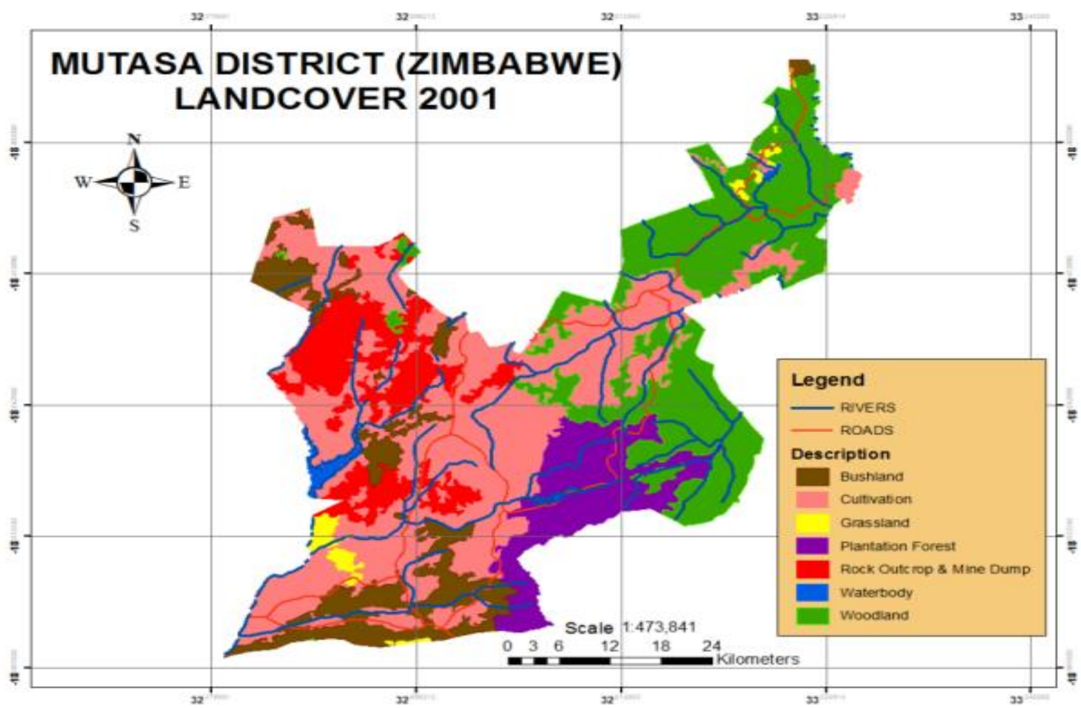

Figure 4: Land cover map for Mutasa district for 2001

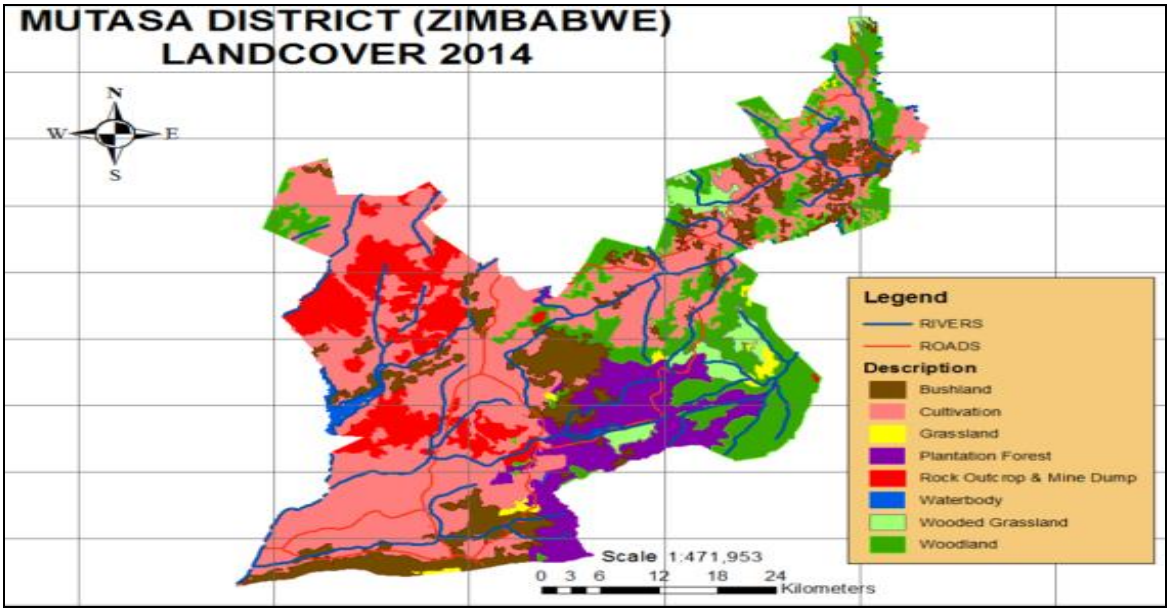

Figure 5: Land cover map for Mutasa district for 2014

In Figure 5, shows a substantial decline in forest and woodland areas over the 1984 to 2014 period while areas under cropland increased considerably in the district. Specifically, the woodland and forested areas converted into cultivation were increased by 22866 ha. The area under wood land, bush land and forest decreased by 8441; 11650 and 5259 ha, respectively, over a period of 30 years (1984 to 2014) in the district. Trends depicted in Figure 5 indicate that the area devoted to cultivation in the district increased annually by 762 ha with a corresponding annual decline of 388 ha of areas under bushland; 281 ha of woodland and 175 ha of forest plantations. This translates to a net cover change of 0.8% for the conversion of woodland area into cropland in the district.

3.2 Land cover and Population

Figure 6 shows an overlay of population data for the year 2012 (CSO, 2012) with woody species land cover map (woodland and plantation forests) extracted from the 2014 classification map. The population map is based on ward boundaries. The ward with the highest population has 16518 people while the least populated had 958 people. The densely populated wards are mainly on the north eastern side of the district in Honde communal lands (Figure 6). The western and central parts of the district are also highly populated with the highest ward having a population of 10 596. The areas which are densely populated have less vegetation cover as compared to those with smaller populations. This demographic change, particularly population growth, may form the basis for explaining the land use changes observed in the study area and the resultant negative changes in forest cover.

4. Discussion

4.1 Land use/ land cover changes and deforestation

Deforestation is the most measured process of land-cover change at a regional and local scale (Lambin and Meyfroidt, 2011). Deforestation as a result of resettlement of smallholder communities in Mutasa district was recognized as the most important driver of land cover changes for the thirty-year period under consideration (1984 to 2014).

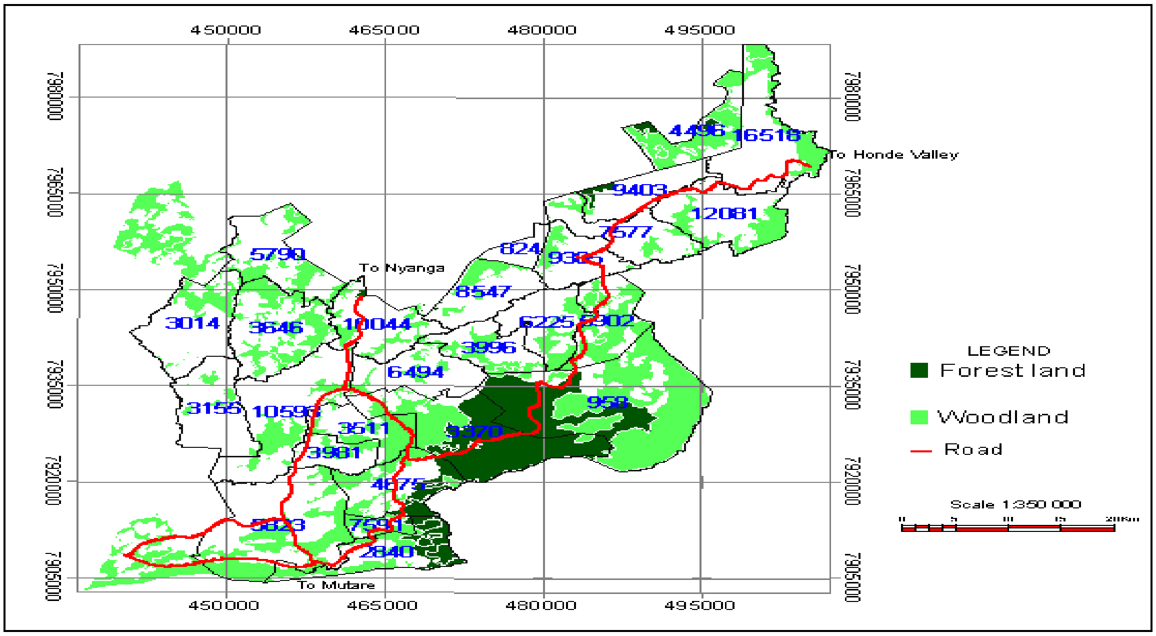

Figure 6: Overlay of land cover and population data

Deforestation occurred in the district when natural woodland and forest plantation were converted to cropland. It has been established that the annual rate of conversion of woodland into arable crop land in Mutasa district was highest during the period 1992 to 2001 (1107 ha year^{-1}).

Knowledge about the causes of land-use change in sub-tropical Africa has moved from simplistic representations of two or three driving forces to a much more profound understanding that involves situation-specific interactions among a large number of factors at different spatial and temporal scales (Porter-Bolland et al., 2012; Fonji and Taff, 2014; Mwangi et al., 2016b). Specifically, the trends in deforestation processes identified in this study were mostly related to decreasing opportunities for non-farm employment over the years for farmers in marginal lands and the redistribution of commercial farm land and previously protected areas to the smallholder farmers. Zimbabwe inherited a racially skewed system of ownership of agricultural land at independence in 1980 in which indigenous populations were located in marginal lands in the predominantly low-potential agricultural zones (United Nations Environment Program, 2002). Coupled with the rising population growth rates (until recently above 3 percent per annum (Zimstats, 2012), rural communities were thrown into increasing poverty due to the inadequate and poor-quality land for subsistence farming hence the farmers depended heavily on forest resources. In an effort to decongest densely populated rural areas, the Government-led resettlement programmes relocated smallholder farmers on commercial farms and some protected areas leading to extensive land clearing exercises in order to create arable land for cropping. Inevitably, the dry sub-tropical natural forest (miombo) and commercial forest plantations in the affected commercial farms suffered extensive and permanent deforestation recorded by the Landsat images for the periods 1984 to 1992; 1992 to 2001 and 2001 to 2014 in this study. The forest areas converted to cropland reached 22866 ha over a period of 30 years (1984 to 2014) in the district. In a related study on African forests by Malhi et al. (2013) a similar trend was reported. It was established that tropical regions lost 15.2 million ha of forests per year during the 1990s. Generally, the annual rate of net cover change from woodland and forest plantations into cropland for the period 1984 to 2014 in the district was 0.8%. In a related study, Bodart et al. (2013) reported an annual net cover change in Africa of 0.36%, which is much lower than the annual net cover change in Mutasa district and most probably in many other districts of Zimbabwe. This high land cover change was attributed to the resettlement programs by the government of Zimbabwe and the increase in population.

Land use land cover changes and the resettlement programs

The results of images classification of the three periods under consideration in the study show that the annual rate of conversion of forest land into cropland in Mutasa district was highest during the period 1992 to 2001 (1107 ha year^{-1}). Comparatively similar annual rates of conversion of woodland into dry land cropping were recorded for the periods 1984 to 1992 (664 ha year^{-1}) and 2001 to 2014 (584 ha year^{-1}). The period 1992 to 2001 coincided with time when the Government of Zimbabwe, resolved to implement "Fast Track" resettlement program. The objective was to accelerate the process of land acquisition of 5 million ha from the commercial farming sector for resettlement purposes by December 2001 (United Nations Environment Programme, 2002).

The government-initiated resettlement exercise, the construction and subsequent completion of the Osborne dam in the 1990s was followed by a massive relocation of smallholder households in the dam basin to the commercial farming areas. The commercial farming areas, which had greater ecological integrity covered by natural woodland and forest plantations of the district, were not spared from this concerted government drive to resettle smallholder communities from densely populated areas The period from 1992 witnessed the highest daily conversion rate of commercial farm land under woodland (miombo) and forest plantations to cropland of about 3 ha per day and this also coincided with the Fast Track Land Reform Program which started in 2000.

The resettlement of poor rural communities from densely populated smallholder areas of the district to ecologically more secure large scale commercial areas between 1984 and 2014 may have had immediate positive impacts on reducing population densities, but in the long term the program had deleterious impacts on the global atmospheric environment if it is adopted as a solution to reducing the effects of increased population densities in rural communities at regional and continental levels. The conversion of wooded land into cultivated areas reduces the capacity of the woodland areas to sequestrate carbon dioxide from the atmosphere in photosynthesis.

4.2 Environmental implications of land use land cover changes

Terrestrial ecosystems of the sub-tropical regions have been recognized as important sources and sinks of carbon and this has underscored the impact of land use/ land cover change on the global climate via the carbon cycle. The uncertainty of these terrestrial sources and sinks of carbon remains a serious challenge today not only at subcontinental level but globally (Guo et al., 2010; Bodart et al., 2013). The impact of cropping on soil organic carbon has been extensively investigated, with long-term cultivation trials indicating a steady loss of soil carbon with cultivation (Malmer et al., 2010). In a related study on soil carbon stocks and land use change, Malmer et al. (2010) concluded that changes in land use can cause significant changes to soil organic carbon (SOC) stocks. Specifically, the change from natural vegetation to cultivation in the converted may have caused significant disturbances to the soil, leading to a higher outflow of carbon without sufficient inflow to counter-balance soil carbon losses (Reitjes et al., 2011a) due to the low efficiency of smallholder farming activities in Zimbabwe generally. In this respect, the land cover changes from woodland to cropland had negative consequences as it reduced the carbon sequestration capacity of the land and increases the possibility of soil organic carbon losses to the atmosphere.

5 Conclusions

The Land cover changes analysis for Mutasa district for the periods1984 to 1992, 1992 to 2001 and 2001 to 2014 has shown significant decline in land areas under woody species (woodland and plantation forests) and considerable increase in area devoted to cultivation. The annual rate of net cover change from woodland and forest plantations into cropland in the district (0.8%) was higher than the average annual net cover changes for tropical Africa (0.36%). The Land Reform Program coincided with the highest daily conversion rate of commercial farm land under woodland (miombo) and forest plantations to cropland of about 3 hectares per day by the resettled farmers for a period of nine years (1992 to 2001). While the redistribution of land to the landless was effective in settling a political disparity on the land question, the exercise became a source of environmental degradation through deforestation and cultivation of virgin arable land.

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Conflict of interest

The authors confirm that they have read and understood the contents of the section on compliance with the statement of disclosure of the journal. In the disclosure of potential conflicts of interest, we can confirm that the authors have no conflicts of interest (either real or perceived) in the processes of data collection and analysis that led to the compilation of the results and the conclusions derived from these results. The authors unreservedly acknowledge the assistance from the Midlands State University grants and have disclosed all relationships or interests that could have direct or potential influence or impart bias on the work.

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