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Land Use and Land Cover Changes at Hova Farm in Bindura District, Zimbabwe

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Abstract

Land use and land cover (LULC) change analyses are critical for the sustainable planning and management of natural resources in the face of rapid population growth across the globe. It is believed that LULC changes cause severe environmental challenges such as climate change, biodiversity loss, pollution, alteration to the physical and chemical properties of the soil as well as the destruction of the ozone layer. The main objective of the study was to assess the LULC changes at Hova Farm from 1992 to 2011 using geospatial technologies. Three Landsat images for 1992, 2001, and EMT+ for 2011 were used. The Landsat images had a resolution of 30m by 30m. Five LULC classes of woodland, wooded grassland, cultivated land, bushland and water body were created using the supervised classification maximum likelihood in ENVI 5.0. Field observation and measurements were also used to validate remotely sensed data. The accuracy assessment for the classified maps for 1992, 2001 and 2011 was 88.74%, 86, 67% and 87% respectively. The results indicated that the greatest LULC changes occurred between 1992 and 2001 and was attributed to the fast-track land reform programme and illegal mining activities on the farm. The study recommends the creation of a LULC database for the periodic monitoring and sustainable management of natural resources at both local and national levels in Zimbabwean.

Keywords: land use, land cover, Hova farm, change detection, sustainable management, natural resources

1. Introduction

Zimbabwe gained its independence in 1980 after a protracted struggle against the British colonialists. One of the key objectives of the liberation struggle was to emancipate native Zimbabweans from land-use oppression as the bulk of fertile and productive land occupation was skewed in favour of the white minority race. As such, after the country successfully gained independence, white commercial farmers were obligated to return part of the land to the black majority as agreed at the Lancaster House Conference, but on a willing buyer willing seller basis. However, this did not happen as per expectation and the scenario prompted the government of Zimbabwe to engage in a chaotic fast-track land reform programme between 2000 and 2009 (Rukuni, Taonezvi, Munyuki-Hungwe & Matondi, 2006; Scoones et al., 2010; Chirara, 2011). Thus, fragmentation of the natural resources across the country became a common resource. There was a sporadic land invasion and the Zimbabweans targeted white-owned farms (Chirara, 2011). Resultantly, some properly managed farms became heavily fragmented as most of them became common property. This prompted the scholarly community in Zimbabwe to engage in empirical research into the status of LULC on formerly white-owned farms at both district and national level.

The studies carried out in Zimbabwe on the LULC changes were particularly conducted in Shurugwi District (Matsa & Muringaniza, 2010, 2011), Bindiru District (Kamusoko & Aniya, 2006; Kamusoko, Aniya, Adi & Manjoro, 2009) and Driefontein Grasslands (Fakarayi, Mashapa, Gandiwa & Kativu, 2015) among other studies. The results revealed that most of the LULC classes were converted to cultivated land and that it was mainly caused by rapid population growth coupled with poverty intensification, the land tenure system, agriculture intensification, poor planning, poor monitoring mechanisms and the government policy such as unplanned fast track land reform programme. However, there is little that is known about the status of LULC changes at a micro level, that is, farm or village level. Most of these studies focused on LULC changes at the macro level, that is, district, province, and national level, thus failing to take into account the need to consider studies at the farm level. The impression this creates is that the assessment of LULC is only critical at a macro scale, when in fact, the micro-level provides an ideal platform for sustainable management of natural resources. Therefore, the lack of knowledge on the status of LULC changes at the farm level in Zimbabwe, especially after the attainment of its independence and the subsequent fast-track land reform programme, prompted the undertaking of this research. The research was guided by the following objectives: 1) to generate the LULC maps and classes of Hova Farm for 1992, 2001, and 2011; 2) to assess the LULC changes at Hova Farm and 3) to determine the rate at which LULC changes are occurring at Hova Farm. This article fills the void in empirical research literature available on LULC changes at the farm and village level. Consequently, the recommendations made in this report should be of great value and benefit to the government, policymakers, and farm owners as they will assist them in the monitoring and management of natural resources for sustainable management on farms and villages.

2. Literature Review

The study of land use and land cover (LULC) change is critical in the sustainable planning and management of natural resources in the face of rapid population growth across the breadth and depth of the globe. Land cover refers to both the biological and physical cover of the earth's surface (Lambin, 2006; Erle & Pontius, 2007; Arsanjani, 2011; McConnell, 2015). Examples of land cover features include forests, grasslands, water bodies, wetlands, and soil (Fonji & Taff, 2014). Land use refers to the modification of the land by humans for socioeconomic purposes (Lambin, 2006; Arsanjani, 2011; McConnell, 2015). Modification of the land by humans arises from socioeconomic activities such as building construction, forestry, and agriculture among others (Erle & Potius, 2007). Land cover change describes the human modification of the earth's terrestrial surface as well as the study of land surface change (Ellis, 2010).

Several studies have indicated that LULC changes are responsible for the environmental challenges that are being experienced globally (Garede & Minale, 2014; Fonji & Taff, 2014; McConnell, 2015). Some of the environmental challenges include climate change, biodiversity loss, pollution, deterioration in the physical, and chemical properties of soil among others (Erle & Potius, 2007; Emadodin, Reiss & Bork, 2009). The main drivers of LULC changes are attributed to human actions such as land tenure insecurity, poverty, land reform programmes, lack of land, and poor planning, particularly in developing countries (Amare & Kameswara, 2012; Garede & Minale, 2014). In developed countries, large scale commercial farming and urban development are the main drivers of LULC changes (Bouma, Varallyay & Batjes, 1998; Tendaupenyu, Magadza & Murwira, 2017). Ultimately, this results in unplanned LULC, hence, there is a need to continuously monitor the changes that occur in an area for sustainable management of natural resources.

The monitoring of LULC changes was found to be effective through the use of remote sensing (RS) (Fonji & Taff, 2014). Literature has shown that remote sensing is a critical tool used to effectively monitor and manage the LULC changes in a particular area at low cost, in less time and with reliable accuracy (Kachhwala 1985, Herold et al., 2006). Furthermore, remote sensing also has the advantage of reaching areas that are inaccessible to obtain data through traditional means, such as mountainous regions (Roberts, Keller & Vianei, 2003; Cingolani, Renison, Zak & Cabido, 2004). However, the major disadvantages of remote sensing include the inability of many sensors to obtain data and information through cloud cover, difficulty to separate distinct phenomena if their reflectance is the same, for instance, bare ground and cultivated land. The resolution of the satellite imagery may be too coarse for detailed mapping and for distinguishing small contrasting areas and satellite imagery with very high resolution is very expensive (Fonji & Taffi, 2014). Nevertheless, it remains the only tool that provides vital information on resource inventory and land use, the identification, monitoring and quantification of changing patterns on the earth's surface (Fonji & Taffi, 2014).

Remote sensing (RS) has been used in the study of LULC changes in several countries. It has been used to analyse LULC and landscape fragmentation in Bindura District (Kamusoko & Aniya, 2006). They discovered that deforestation and cultivation in woodland areas was the continuous trend across all land tenure systems. Fonji & Taffi (2014) used RS for monitoring LULC in the north-eastern part of Latvia and discovered that areas along the roads experienced major LULC changes than areas that were far from the road. Matsa & Muringaniza (2011) assessed LULC changes in Shurugwi District using RS tools and revealed that there had been considerable LULC changes in the area particularly, on the vegetation cover. Shiferaw (2011) evaluated LULC dynamics in Borena Woreda of south Wollo Highlands, Ethiopia, and showed that there was a dramatic expansion in agriculture and this was caused by a high demand for farming land. Balaji, Geeth & Soman (2016) also used RS for change detection of forest vegetation in Kalakkad Mundanthurai Tiger Reserve and discovered that there were significant changes in forest cover in the area. Tizora, Roux, Mans & Cooper (2016) used RS for the quantification of LULC in the Western Cape Province and revealed that there was a decline in forest plantations, grasslands, wetlands and barren lands. Noor, Abdallah & Manzahari (2013) considered RS for analysing land cover change detection on the urban green area in Kuala Lumpur, Malaysia, and discovered that green areas were fast depleting.

The aforementioned importance of remote sensing and its related applications has prompted its use in assessing the LULC changes at Hova Farm with the view to enhance the sustainable management of natural resources at the micro-level. The reason for the choice of the study area is that the farm is found in Bindura District that receives normal to above normal rainfall of 700-1000mm per annum (Kamusoko & Aniya, 2006) and it is endowed with gold deposits. In addition, the farm is surrounded by small scale farmers who depend mostly on tobacco farming for their survival. This place the farm in danger as most communal farmers invade the farm every season in search of firewood to cure tobacco. Firewood is used to dry tobacco after harvesting, hence communal farmers take turns in destroying the vegetation at the farm. As a result, the fauna and flora in the farm either become extinct or migrate due to the loss of their habitats. Besides, the farm was also invaded by illegal gold miners (*Makorokoza*) which further plunged the farm into severe land degradation. The main farming activities at Hova farm are banana plantation, maize, and livestock production. The farm was also not spared from the fast track land reform programme of 2000 to 2009 (Matsa & Muringaniza, 2011) and the indigenisation policy which sought to empower the indigenous citizens which led to an influx of illegal gold miners. Thus, it was critical to carry out this study to help policymakers develop an understanding of the impact some of the policies they adopt and implement have on the sustainable management of natural resources. The study should be an eye-opener to policymakers so that they appreciate that there is a need for a pragmatic and holistic approach to natural resources management if future generations are to benefit from the current resources at the farm in particular and Zimbabwe in general. Similarly, it helps the government and farm management to use geospatial technology to come up with a natural resources database which they can periodically use to assess the status of natural resources in their respective areas of jurisdiction.

Failure to monitor the LULC patterns leads to severe land fragmentation that is most likely to cause climate change, biodiversity loss, and pollution among other environmental challenges. LULC changes cause climate change in that once the vegetation is cleared, greenhouse gases are released into the atmosphere causing global warming that eventually leads to climate change (Erle & Potius, 2007). Vegetation acts as a carbon sink, as a result, it absorbs carbon dioxide that is caused by both natural and anthropogenic activities. Climate change is detrimental to both terrestrial and aquatic ecosystems. Most species become either extinct or migrate to other areas as they would have lost their habitats. This also leads to poverty intensification as climate change causes seasonal changes. For example, the rainfall season has been shortened and is unpredictable in Zimbabwe (Zimbabwe Human Development Report, 2017) and that severely affects the country's economy as more funds are channelled towards poverty alleviation at the expense of other developmental projects (Nangombe, 2014). Therefore, it is critical to assess the LULC changes at a micro-level (farm or village) to reduce the effects of poor land-use practices.

3. Methodology

3.1 Study Area

Hova is a large scale commercial farm located in Bindura Rural District, Mashonaland Central Province of Zimbabwe. It is about 20 km northeast of Bindura City along Shamva Road. The farm covers approximately 13.1 km^2. Bindura Rural District in which Hova Farm is located falls within the 940 to 1580m altitude range (Kamusoko et al., 2009). In summer (September to March), the area experiences a temperature range of 26^0-35^0C. Conversely, in winter (May-July), the mean annual temperature of 16.5^0C prevails. Hova Farm also receives 700-1000mm of rainfall per annum which is average to above-average rainfall according to Zimbabwean standards (Kamusoko & Aniya, 2006). Due to climatic, geomorphologic, and geological conditions prevailing in the area, red and reddish to brown clay soils dominate the farm (Nyamapfene, 1991). Deciduous woodland (Miombo), woodland, wooded grassland, bushland, and grassland vegetation are predominant in the area (Kamusoko et al., 2009). Generally, Bindura District has a population of approximately 168894 (Zimbabwe National Statistical Agency, 2012). The farm management seasonally employs about 200 workers from the nearby community to assist with tilling, planting, weeding and harvesting of the crops. The main farming activities are banana plantation, maize, and livestock production. The farm management, apart from farming, has to cope with hundreds of illegal gold miners who occasionally occupy the farm. Such conflict of interest at the farm necessitated the need to closely assess the LULC changes that have occurred at the farm so that there is sustainable management of its natural resources. Thus, the study area was chosen for LULC analysis because of its contrasting activities, typically experienced in Zimbabwe and other developing countries such as Malawi, Zambia, and Kenya.

3.2 Datasets

Data for this study were obtained from both primary and secondary sources. While primary data were obtained from field observation and measurement, secondary data were obtained from the satellite images and topographic maps of the study area. The three Landsat satellite images for the study years (1992-2011) were downloaded from the Global Land Cover Facility's (GLCF) website-http://glcf.umiacs.umd.edu/index.shtm (Table 1). These images were selected based on cost, date of acquisition, spatial resolution, availability and percentage of cloud cover (Lu, Mausel, Brondizio & Moran, 2004). Image acquisition dates are critical as they enable the comparison of images obtained in different years (El-Hattab, 2016). Besides, it averts variations in reflectance caused by seasonal vegetation fluxes and solar angle differences (Bottomely, 2008). Such considerations improve the accuracy and the potential to discern land cover changes (Lunetta & Elvidge, 1999) by allowing the comparison of images with almost similar vegetation conditions.

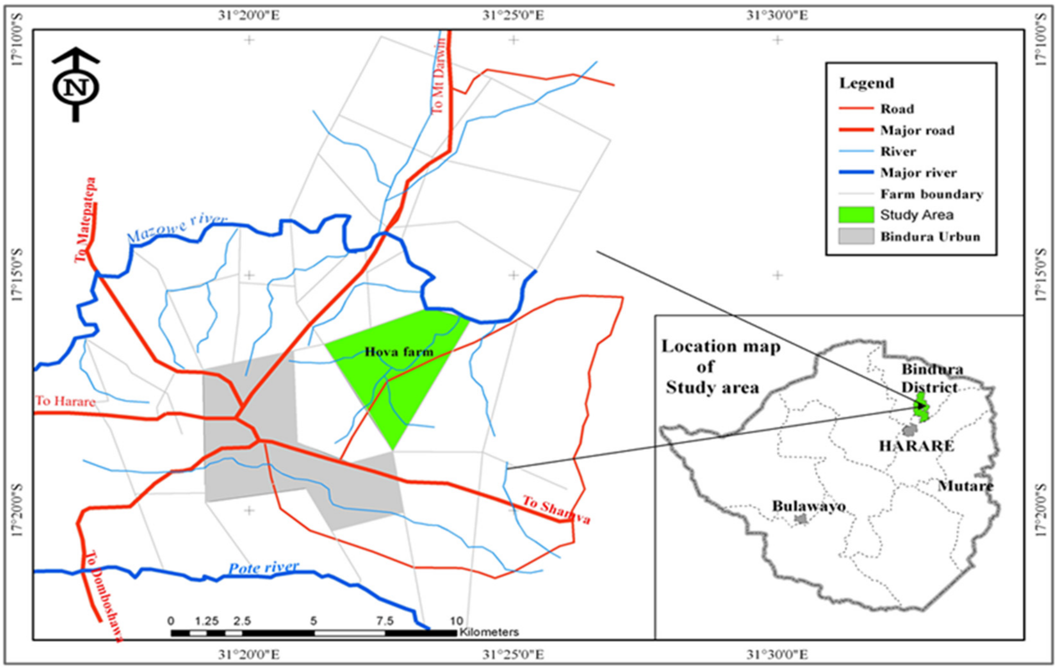

Figure 1. Location of the study area

Source: Authors, 2019

Table 1. Characteristics of Landsat Thematic Mapper (LTM) imagery used in the study

Satellite	Path row	Resolution	Acquisition Date	Source	Remarks
Landsat 7TM	169/72	30mx30m	1 September 1992	GLCF	Dry season
Landsat 7TM	169/72	30mx30m	9 September 2001	GLCF	Dry season
Landsat 7ETM+	169/72	30mx30m	21 September 2011	GLCF	Dry season
Topo Map	1: 50 000			DSG	

Landsat used in this study is vital for detailed mapping of land use and land cover of Hova Farm (Jensen, 1996; Sisay, Soromessa & Teketay, 2016). Dry season and cloud-free images were used for easy analysis (Molla, Ikporukpo & Olatubara, 2018). The satellite images for LULC analysis for Hova Farm had a spatial resolution of 30m. This means each pixel in the image represents 30 by 30m on the ground. The acquisition dates were from the same month (September) of different years. This makes it easy to compare the LULC changes at the farm. The reason for selecting the post-rainfall season was to get accurate information on the status of the land use and cover of the farm. ENVI 5.0 and ArcGIS 9.2 were the software used for the production of land use and land cover change maps. Ground control points (GCPs) data used for accuracy assessment were obtained from field observations using a hand-held GPS.

3.2.1 Topographic Map

A topographic map of Bindura District was used in this study. The map was obtained from the Department of the Surveyor-General (DSG). It has a scale of 1: 50 000 and it covers the study area among other areas. The topographical map was used to verify the study area's boundary and the annotation of the key features of the farm. However, the map could not be used to validate the final classification maps as they were created earlier than the date of the acquisition of the Landsat satellite images.

3.2.2 Field Surveys

Field visits were done in the study area to authenticate the LULC change thematic maps that were created. It was also during these visits that different environmental challenges such as land degradation and non-reclaimed pits were observed. The field visits were meant to gather data used for both image classification and accuracy assessment processes. All the field surveys were achieved through the use of a hand-held Garmin 12X Global Positioning System (GPS) tool, topographic map, satellite image printouts and a digital camera. The survey helped in the identification of the exact positions representing different LULC patterns of the study area. Collectively, these are known as training sites that are used for both satellite image classification and accuracy assessment.

3.3 Image Processing

Landsat TM images 1992, 2001and ETM+ of 2011 were used for the study. The raw satellite images were converted from Tag Image file format (Tiff) to image format using ArcGis 9.2. This was meant to make the satellite images compatible with ENVI image files. The data corresponding to the farm area was cropped and mosaiced. The UTM Zone 36S coordinate on the WGS 84 was used to geo-code the imported image. The band combination of red, blue, and green was used to display the raw images in standard colour composites. The spectral band combination is necessary for visual interpretation. In this study, the Landsat TM images were displayed in a band combination of RBG 123 which is standard for visual interpretation of vegetation mapping in the tropics (Prakash & Gupta, 1998).

3.4 Image Classification

Image classification involves the creation of thematic maps from satellite imagery and it automatically categorises all pixels based on their spectral properties into land cover classes (Lillesand & Kiefer, 2004; Palaniswami, Upadhyaya & Maheswarappa., 2006; Navalgund, Jayaraman & Roy, 2007). There are two methods of image classification: supervised and unsupervised. In this study, supervised classification was adopted to extract five different land use and land cover classes**.** Supervised classification is known for producing accurate classification than the unsupervised technique (Peacock, 2014), hence its use in this study. To verify the classification, 300 ground control points collected from the field using hand-held Garmin 12X Global Positioning Systems (GPS) were used. Knowledge of the study area was also used. The ground control points were then overlaid using ArcGIS 9.2 on the satellite images. The 300 points were, however, not equally distributed within each land use and land cover due to the stratified sampling procedure that was applied. The field surveys aimed at determining the LULC types, associating the field data of specific land cover types with their image characteristics and collecting sufficient field data for validation land cover maps derived from the Landsat ETM+ image.

With a supervised approach, calibration pixels are selected and statistics are produced for the classes of interest. There are three calibration strategies used for supervised classification: single pixel, seed, and polygon (Chen & Stow, 2002). As such, the seed calibration was chosen in this study, because it selects spectrally similar pixels and is an effective way of selecting homogeneous data. As for algorithms, parallelepiped classification, minimum distance classification, and maximum likelihood classification are commonly used. This study used maximum likelihood classification because it classifies data according to the highest probability (Franklin, Phinn, Woodcock & Rogan, 2003). In addition, maximum likelihood classification enables the validation of classified images through ground-truthing. Thus, based on the supervised classification methods, five major land uses and land cover types were identified at Hova Farm (Table 2). These include waterbody, bushland, cultivated land, woodland, and wooded grassland based on the characteristics of Landsat satellite images of the year 1992, 2001, and 2011.

Table 2. Description of land use and land cover classes at Hova Farm

Class	Description
Woodland	Scattered trees greater than 5m high with canopies less than 40% cover
Wooded grassland	A mixture of grass and trees with height (1-15m) and a canopy cover of (2-20%)
Cultivated land	Area covered by different crops e.g. banana and maize plantations
Bushland	The area with a high percentage of shrub cover of between 2-5m high
Waterbody	Land submerged by water e.g. dams, streams, and rivers

3.4.1 Accuracy Assessment

Accuracy assessment is critical as it measures the number of ground truth pixels classified correctly (Bottomley, 2008). To determine the correctness of the classification, error matrix tabulation was done. In this study, accuracy assessment was only done for the 2011 classification map since it was current during the study. Further, accuracy was determined by superimposing the points on a classified image and obtaining the kappa coefficient. The recommended standard accuracy in the identification of the LULC mapping from the remote sensor data should be between 85% and 95% (Congalton, 1996). Molla et al. (2018) note that the kappa coefficient which is an estimate of the overall agreement between image data and ground truth data is a piece of important information in accuracy assessment. Kappa values are classified into three groups, namely: a value greater than 0.80 representing a strong agreement, a value between 0.40-0.80 representing a good agreement and a value below 0.4 representing a poor agreement (Aynekulu, 2007, Melaku, 2008).

The producer's accuracy is described as the total number of correct pixels in a class divided by the total number of pixels of that class as derived from the reference data. The kappa factor is given by the following formula:

$$K_a \frac{=[n * \sum_{i}^{r}=1 \; x_{ij} - \sum_{i}^{r}=1(x_i * \; x_j \;)]}{[n^2 - \sum_{i}^{r}=1 \; (x_i \; * \; x_j)]} \tag{1}$$

Where K_a = Kappa coefficient, N = total number of samples, x_{ij} = sum of correctly classified pixel, r = the number of rows in the matrix, x_{i} = the marginal totals of row i and j respectively.

On the other hand, the user's accuracy or reliability is the probability that a pixel classified on the map represents that class on the ground (Andualem, Belay & Guadie, 2018). User's accuracy is described as the total number of correct pixels in a class divided by the total number of pixels that were classified in the class (row total); the result is a measure of commission error (Andualem et al., 2018). Overall accuracy can be obtained by dividing the total number of correct pixels (diagonal) by the total number of pixels in the error matrix.

3.4.2 Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different periods (Singh, 1989b). It is useful in many applications such as LULC changes, habitat fragmentation, the rate of deforestation, coastal change, urban sprawl, and other changes that may occur within the environment (Noor et al., 2013). MacLeod & Congalton (1998) came up with the following four aspects of change detection which are pertinent when monitoring natural resources: 1) detecting the changes that have occurred; 2) identifying the nature of change; 3) measuring the areal extent of change, and 4) assessing the spatial pattern of the change. In this study, change detection was based on the satellite imageries for the years 1992, 2001 and 2011. The choice of these years was based on the availability of satellite images and the free cost associated with them. Many change detection techniques are used in the monitoring of natural resources, namely: image regression, spectral mixture analysis, hybrid change detection, and post-classification comparison among others (Lu et al., 2004). For this study, post-classification was used because it classifies date 1 and date 2 images separately and compares class values on a pixel-by-pixel basis between the dates (Ernani & Gabriels, 2006). The post-classification technique is a comparative analysis of independently produced classification for dates (Alagu Raja, Anand, S. Kumar, A. Kumar & Maithani, 2013). It is the most common approach used for monitoring land cover changes as it provides detailed information on the initial and final land cover types in a complete matrix of change direction (Foody, 2002b).

3.4.3 Rate of LULC Change Assessment

The rate of LULC change was calculated for each land use and cover using the following formula:

$$\Delta\ (\text{km}^2/\text{year}) = \frac{(A-B)}{C} \tag{2}$$

Where Δ = Annual rate of change, A = Recent area of land use and land cover in km^2; B = Previous area of land use and land cover in km^2, and C = Time interval between A and B in years.

4. Results and Discussion

4.1 Accuracy Assessment

The classification accuracy assessment results of the land use and cover classes for 1992, 2001 and 2011were derived from a computed confusion matrix. The confusion matrix is used to calculate overall accuracy, producer and user accuracy, and kappa coefficient. Appropriately classified values are indicated diagonally on the matrix and inappropriately classified values are at variance with the diagonals. Accordingly, the overall accuracy for 1992, 2001 and 2011 images were 88.74%, 86.56% and 87% respectively. The kappa coefficient values for the same images was 0.85, 0.82 and 0.84 (Table 3). The overall accuracy statistics fell between 85% and 95% which is the recommended standard accuracy in the identification of the LULC mapping from the remote sensor (Congalton, 1996). Overall, these results indicate that the method of classification and ground control (truth) points collected and used were correct.

Table 3. Accuracy assessment results for 1992, 2001 and 2011 land use and cover classification

Years	1992		2001		2011	
Land use and land cover	Pc (%)	Uc (%)	Pc (%)	Uc (%)	Pc (%)	Uc (%)
Waterbody	92.00	95.84	83.23	83.00	100.00	100.00
Bushland	80.11	76.20	75.10	75.10	100.00	57.15
Cultivated land	92.22	95.29	86. 14	91.14	83.00	100.00
Wooded grassland	86.00	82.34	70.32	70.32	89.00	89.23
Woodland	87.56	87.56	96.00	91.12	75.00	100.00
Overall accuracy	88.74		86.67		87	
Kappa coefficient	0.85		0.82		0.84	

Pc = Producer accuracy, Uc = User accuracy

4.2 Land Use and Land Cover Change Detection Analysis

The results of change detection analysis imply that Hova farm has been exposed to severe land fragmentation for the past three decades. Land use and land cover changes between 1992, 2001 and 2011indicated that the vegetation (woodland, wooded grassland and bushland) was converted to agricultural land (Table 4 and Figure 2). The conversion of vegetated land to agricultural land was predominant in 2001 (Figure 2). This coincided with the land reform programme that was carried out in 2000. The purpose of the land reform programme was to equitably distribute the land so that every Zimbabwean could have access to arable land (Cliffe, Alexander, Cousins & Gaidzanwa, 2011). However, the programme was hijacked and became politicised to such an extent that the study area experienced the convergence of people from different geographical locations. Resultantly, the farm became common property and it was subdivided into small pieces of farming land. Ironically, in 1992, vegetation was the main land use and land cover (Figure 2). By then, the farm was under the stewardship of one farmer who could monitor and manage the farm.

4.2.1 LULC changes for Hova between 1992 and 2001

Table 4 and Figure 2 shows the land use and land cover changes in the Hova farm between 1992 and 2001. Between 1992 and 2001, the cultivated land increased by 41% from 12% to 53%. Wooded grassland increased by 14% from 10% in 1992 to 24% in 2001. Furthermore, the water body increased by 2 % in 2001. The reductions in LULC categories were experienced in bushland that sharply dropped by 47% from 50% in 1992 to 3% in 2001. This was followed by woodland that decreased by 10% from 28% in 1992 to 18% in 2001. These results are similar to a study conducted by Kiunsi & Meadows (2006) in Tanzania in the Monduli district in which the researchers discovered that agricultural areas increased by 75% from 1% to 76% between the years 1960 to 1991. In the same vein, Soini (2005) discovered that bushland was replaced by cultivated land in Kirua Vunjo in Tanzania. Similar findings were made by Vagen (2006) in the eastern highlands of Madagascar between 1992 and 1999. Kuinsi & Meadows also revealed that in Monduli District, Tanzania, the waterbody increased by 2% from 3% in 1960 to 5% in 1999.

4.2.2 LULC changes between 2001 and 2011

Wooded grassland marginally increased by 4% from 24% in 2001 to 28% in 2011 (Table 4 and Figure 2). This was followed by woodland that slightly increased by 6% from 18% in 2001 to 24% in 2011. The waterbody gradually increased by 5% from 2% in 2001 to 7% in 2011. Similar results were noted in Kieni, Central Kenya where the waterbody increased significantly (Maina, Wandiga, Gympoh & Charles, 2020). The bushland steadily increased by 12% from 3% in 2001 to 15% in 2011. However, this observation is in sharp contrast to the results studied in Kieni, Central Kenya where the bushland decreased from 24.5% in 1987 to 15.01 in 2017 (Maina et al., 2020). The cultivated land sharply decreased by 27% from 53% in 2001 to 26% in 2011. A decrease in the cultivated area was also witnessed in the Monduli District of Tanzania (Kiunsi & Meadows, 2006).

4.2.3 LULC changes between 1992 and 2011

Overall, from 1992 to 2011 (Table 4 and Figure 2), waterbody increased by 7% from 0% in 1992 to 7% in 2011. A study by Maina et al. (2020) in Kieni, Central Kenya revealed that overall, the waterbodies increased by 300% in over four decades (1987, 1995, 2002, 2010 and 2017). The bushland sharply dropped by 35% from 50% in 1992 to 15% in 2011. As for Kieni, Central Kenya, the bushland dropped by 46% from 1987 to 2017. The cultivated land increased by 14% from 12 % in 1992 to 26% in 2011. The cultivated lands in Kenya increased by 160% (Maina et al., 2020). Wooded grassland also increased by 18% from 10% in 1992 to 28% in 2011. However, the grassland decreased by 4% from the initial 28% in 1992 to 24% in 2011.

Table 4: Percentage of land use and land cover changes from 1992-2011

LULC Class (%)	1992	2001	2011
Waterbody	0	2	7
Bushland	50	3	15
Cultivated land	12	53	26
Wooded grassland	10	24	28
Woodland	28	18	24
Total	100	100	100

4.3 The Rate of Land Use and Land Cover Changes in Hova Farm from 1992-2011

Analysis of the rate of land use and land cover changes revealed that between 1992 and 2001, cultivated land increased at a rate of 0.5 km^2/year and sharply decreased to 0.35 km^2/year between 2001 and 2011 (Table 5 and Figure 3). Between 1992 and 2011, the cultivated land increased at a rate of 0.09 km^2/year. An increase in the rate of cultivated land was a result of the conversion of both bushland and woodland to farming activities (Figures 2). This shows that there was a dramatic expansion of cultivated land between 1992 and 2001. These results were also confirmed in the Shenkolla Watershed in Ethiopia (Bufebo & Elias, 2021). Bufebo & Elias (2021) discovered that between 1995and 2017 the agricultural land increased by approximately 3%. This land use and/or cover change was positive as it showed that most farmers engaged in farming thereby boosting food production in the country.

The water body increased in size by a rate of 0.03 km^2/year between 1992 and 2001 and further increased in size by 0.06 km^2/year. Generally, between 1992 and 2011, the waterbody increased by a rate of 0.05 km^2/year (Figure 2). The reason why the waterbody constantly increased over the study period is attributed to good rainfall patterns that were experienced between 1992 and 2011. In 2000, the area received above-normal rainfall (750-1000mm) due to Cyclone Eline and it was followed by Cyclone Japhet that occurred in 2003 (Reason, 2004). Besides, the farm falls in farming region 2 that receives between 700-1000mm of rainfall per annum (Kamusoko & Aniya, 2006). However, in 1992 the waterbody was almost invisible due to the severe drought that was experienced in Zimbabwe as a whole and at Hova Farm in particular. These results from the waterbody indicate that the farm seasonally receives good rains and that the area is good for agricultural activities.

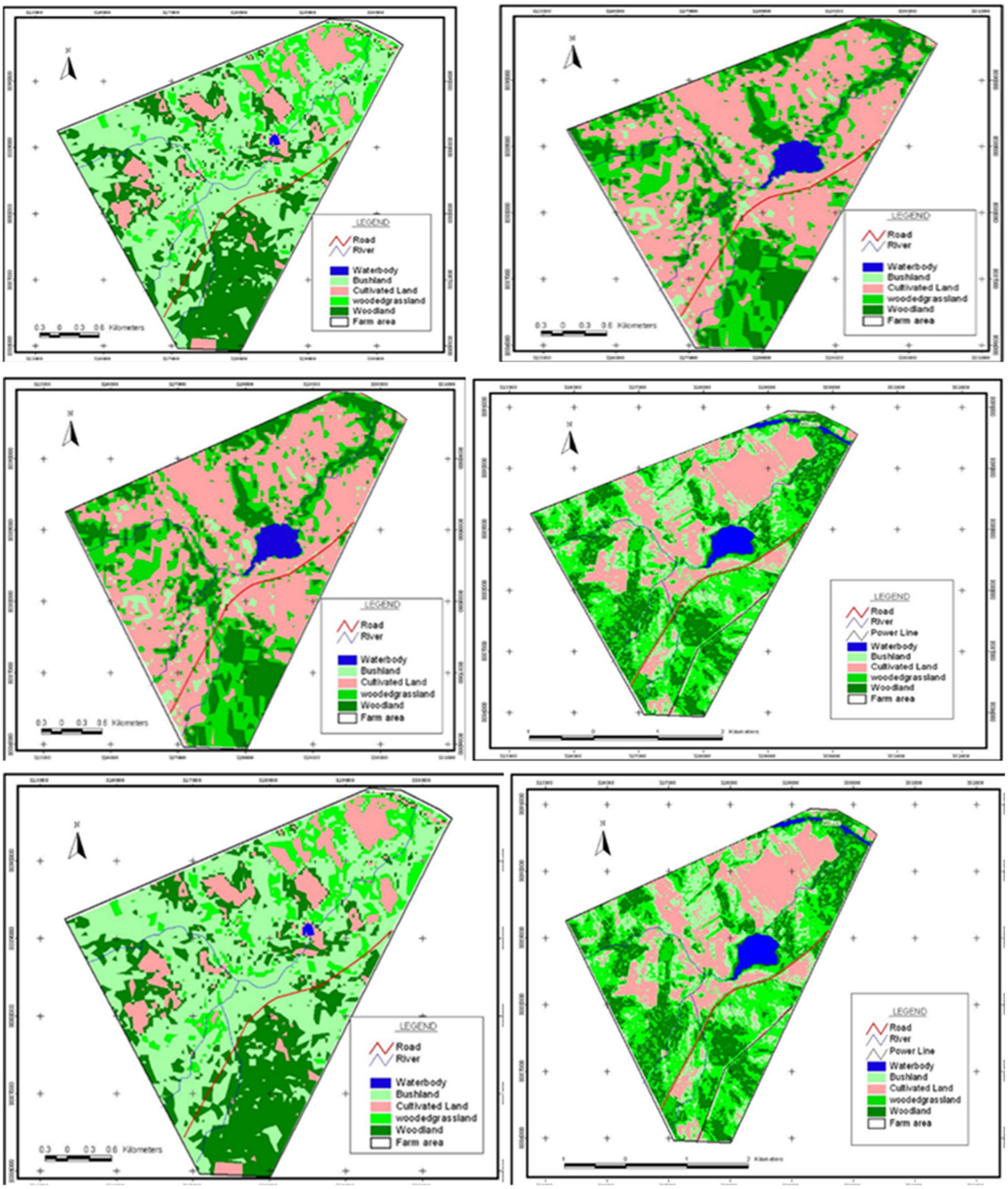

Figure 2. Land use and cover changes (1992-2001, 2001-2011 and 1992-2011) in Hova farm

Table 5. Rate of land use and land cover changes (1992-2011)

LULC Class (km^2/year)	1992-2001	2001-2011	1992-2011
Waterbody	+0.03	+0.06	+0.05
Bushland	-0.68	+0.16	-0.24
Cultivated land	+0.59	-0.35	+0.09
Wooded grassland	+0.20	+0.06	+0.13
Woodland	-0.14	+0.07	-0.03

Wooded grassland increased at a rate of 0.2 km^2/year between 1992 and 2001 and slightly decreased to the rate of 0.06 km^2/ year between 2001 and 2011. Generally, between 1992 and 2011, wooded grassland slightly increased at a rate of 0.13 km^2/year (Table 5 and Figure 3). This shows that the wooded grassland's rate of change was not severely affected. Such a result was also positive as it improved the ecological balance of the study area. The fauna and flora species benefited from this land use and land cover change. The major land uses that were affected and that had fluctuation tendencies were the woodland, bushland, and cultivated land. In most cases, whenever the woodland was converted to any other land use, the resultant landform became wooded grassland. The same applies to the cultivated land; whenever it was abandoned, the resultant land use and land cover easily became the wooded grassland, hence it is a class that is not severely affected.

The rate of bushland and woodland decreased by 0.68 km^2/year and 0.14 km^2/year between 1992 and 2001 respectively. Such a decrease in bushland and woodland affected the terrestrial ecosystem. Species either become extinct or migrate due to the loss of their habitat. However, between 2001 and 2011, both bushland and woodland respectively increased by a rate of 0.16 km^2/year and 0,07 km^2/year (Table 5 and Figure 3). This was positive as the fauna and flora in the study area had their habitats restored. Gold panning enabled the bushland and woodland to replenish as people preferred mining the precious mineral for agricultural activities. Worth noting, from 1992 to 2011 bushland and woodland respectively decreased by a rate of 0.24 km^2/year and 0.03 km^2/year. This was attributed to the high demand for land for cultivation by farm management and those who just entered the farm without permission. Also, deforestation mainly caused by the need to process the harvested tobacco by the local community means more land was either converted to cultivated land. Tobacco is dried using firewood in and around the Hova Farm, hence the severe destruction of vegetation in the study area.

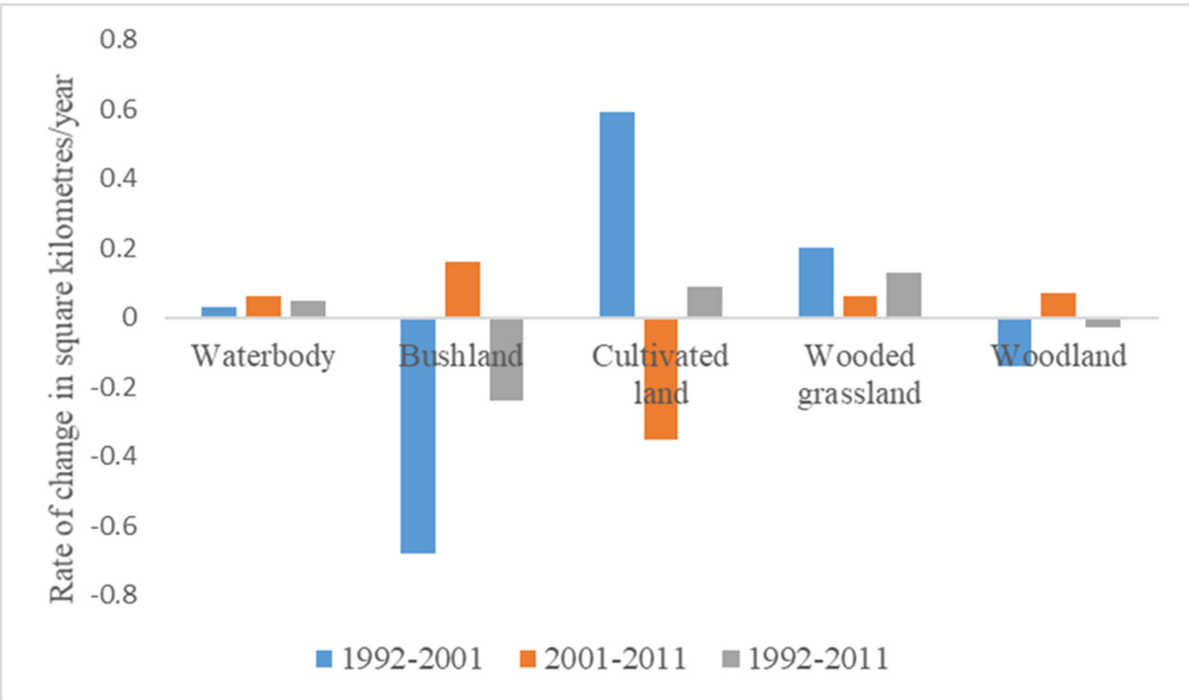

Figure 3. Rate of LULC changes (1992, 2001 and 2011)

Overall, the results show that LULC changes in the study area fluctuate in terms of usage. Over a long period, that is, from 1992-2011, there is no LULC that was more dominant than the other. Woodland, wooded grassland, bushland, and cultivated land are almost uniform in terms of quantity and the rate of change. Worth noting is that in-between years distinct LULC changes were observed (Figure 2). For example, in 2001 cultivated land was dominant owing to the land reform programme, poor planning, lack of property rights, and the land tenure system (Chirara, 2011), but in 2011 the expansion of cultivated land decreased due to a shift from agricultural activities to mining activities because of gold deposits found on the farm. Most researches that have been conducted in developing countries such as Zimbabwe, Zambia, South Africa, Madagascar, and Ethiopia among others indicate that major LULC is cultivated land and that has been caused by population growth. Such an observation resonates well with the studies carried out in Ethiopia (Agldew & Singh, 2017; Andualem, Belay & Guadie, 2018).

The results also indicate that the assessment of LULC dynamics at short time intervals is very critical for the sustainable management of natural resources. For instance, in Canada, LULC changes are done every five years (Latifovic, Pouliot & Olthof, 2010). Assessing LULC changes over a long period gives a wrong impression about the status of natural resources in an area. This calls for the creation of LULC databases for effectively monitoring the negative changes that occur on natural resources. Moreover, the results show that it is vital to consider evaluating the status of LULC changes at a micro-level such as a farm or village. This is a pragmatic approach that makes sure that everyone is involved and is accountable for the changes that would take place in his or her area of residence and jurisdiction. The literature shows that the majority of studies have been carried out at a macro level such as district, province and national. These results from such studies tend to generalise the outlook of the LULC changes in the whole district yet at the micro-level, the results would be dire. Thus, considering studies at the micro-level is important as this gives the specific area that needs urgent attention.

The major contribution of this study is that of the need to periodically assess the LULC changes even at a small-scale level as the results showed that studying land cover changes over time gives a false impression in terms of the quantity and rate of change. For example, the overall results over nineteen years (1992-2011) indicated a slight change in LULC changes, but the results of the changes that occurred over a short period (1992-2001) at the farm indicate a huge change (Figure 2). The other contribution made by this study is the strengthening of the use of geospatial technologies in the monitoring of LULC changes for sustainable land use management. It also gives the policymakers, government authorities, and natural resources managers including farm owners the chance to reflect on their practices so that future generations also benefit.

However, the major limitation of the study was the use of 30m x 30 m resolution on a small scale such as a farm. For example, the statistics of the waterbody for 1992 (Figure 2) shows that water was nonexistent, yet the visual interpretation shows that it is visible. The other weakness is that interviews could not be conducted to verify some of the results due to the politically volatile situation that was prevailing in the area during the study period. There was a lot of political turmoil and a lack of political will to cooperate by key informants during the study. As a result, the study heavily relied on literature review and field observation.

Nevertheless, the results present an opportunity for further studies using another resolution as well as a different algorithm so that the status of the LULC changes at the farm is clear. The study used maximum likelihood classification and a resolution of 30m by 30m. Therefore, using another resolution and classifier can either buttress or refute the results of this study. Besides, since the interviews were not done to comprehend the results from geospatial technologies, particularly on the possible drivers of LULC changes, further researches infusing statistical analysis with interviews are recommended.

5. Conclusion

This research, which intended to assess the LULC changes at Hova Farm in Bindura District, revealed that there were substantial land-use changes in the area during the 1992, 2001, and 2011 reference years. The most interesting finding that emerged from the results was the huge change that occurred between 1992 and 2001. During this period, there was a huge change in the cultivated land, but between 2001 and 2011, the change was not as great as for 1992 and 2001. The cultivated land increased in magnitude because of the onset of the fast track land reform programme that was instituted by the government. The other reason why the cultivated land decreased in magnitude between 2001 and 2012 could be ascribed to the abandonment of agricultural activities for gold panning. The farm is endowed with gold deposits and, as such, gold panners invaded the farm, making it extremely difficult for the farmer to engage in farming activities. The invasion was triggered by the government's indigenisation policy that allowed small scale miners to operate in gold-rich areas with minimum restrictions. This resulted in the conversion of cultivated land to bushland. The waterbody was ever-increasing in capacity since 1992 on the farm. This was attributed to cyclones Eline of 2000, Japhet of 2003, and Flavio of 2007. The area annually receives normal to above normal rainfall, hence, its expansion. The results also show a peculiar scenario in that when considering results, say for nineteen years (1992-2011), a false picture that LULC changes were not taking place at an alarming rate. If one considers the period between 1992 and 2001, the land fragmentation that occurred is so alarming. Therefore, there is a need to periodically assess the LULC changes for sustainable management of natural resources even at the farm level. The results are critical to both farm managers and the government as they show that natural resource fragmentation starts at a micro-level, such as the farm level. Monitoring resources at the district level gives the impression that either resource is well conserved or vice versa, yet that should be looked at on a small scale such as a farm. At the district level, a lot of natural resource depletion is neglected. Therefore, for sustainable management of natural resources, both the government and farmers need to closely monitor the situation at the farm level using geospatial technologies. Finally, the study has contributed to the body of knowledge on the importance of using geospatial technology in the creation of a natural resource database for monitoring LULC changes for sustainable management.

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