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RATE OF LAND-USE/ LAND-COVER CHANGES IN SHURUGWI DISTRICT, ZIMBABWE: DRIVERS FOR CHANGE.

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ABSTRACT

Shurugwi district lies around the mineral-rich geological formation commonly referred to as the Great Dyke. The formation also has fertile soils ideal for agriculture. The district has been experiencing a lot of land-use and land-cover changes induced both by the people and machinery in recent years following the government's Fast-Track Land Reform and Resettlement Program and the exploitation of different minerals, including gold and platinum. This study sought to determine the rate of land-cover change that has occurred in Shurugwi district since 1990. This was achieved through the use of Geographic Information Systems (GIS) and remote sensing techniques. The study also attempted to establish the factors contributing to land-use and land-cover changes and this was achieved through semi-structured interviews with key respondents. Field observations and measurements were also employed to validate results from remotely sensed data. Results show that the rate of land-cover and land-use change has been significant in Shurugwi district and that the greatest change occurred in 2000-2009. This accelerated change is mainly attributable to cultivation(and related activities) linked to the Fast-Track Land Reform and Resettlement Program, as well as mining and gold panning activities. The study recommends that the Environmental Management Agency (EMA) monitor the cutting down of trees in newly resettled areas through the promotion of tree alternatives for fuel and construction purposes. EMA should also stop panning activities, as well as ensure that all new mines undergo full environmental impact assessments as per EMA statutes in order to reduce land degradation in the district.

Keywords: Geographic Information System, Remote Sensing, Land use, Land cover

BACKGROUND INFORMATION

Since early 1980s, vast transformations have occurred in the land-use and land-cover patterns as evidenced by persistent expansion in cultivated land, decrease in natural woodland, and grassland in the world (Xiaomei & Ronqing, 1999). These transformations have also been experienced in the semi-arid catchments, including Zimbabwe (Lambin, Turner, Agbola & Angelsen, 2001). It is crucial to quantify such changes and assess their effects on natural and human processes alike, which are all so important to natural resources management and sustainable development at district.

The land-use and land-cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure in Zimbabwe (Tomlinson, 2006). Land-use and land-cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land-use and land-cover change, thus providing an accurate evaluation of the spread and health of the world’s forest, grassland, and agricultural resources (Vescovi, Park, & Vlek 2000); (Symeonakis,Koukoulas, S, Calvo-Cases,& Makris, 2004)

Viewing the Earth from space is now crucial to the understanding of the influence of man’s activities on his natural resource base over time. In situations of rapid and often undocumented and unrecorded land-use change, observations of the earth from space provide objective information of human activities and utilization of the landscape.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management, land-use mapping, and planning. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system functions, patterning, and change at local, regional, as well as at global scales over time (Lambin, et al., 2001).

Satellite imagery is particularly a valuable tool for African environments in which historical land-use change records are either not available or out-dated (Lunetta & Elvidge, 1998). The usefulness of these techniques has already been demonstrated in Africa by the increasing number of researches that have incorporated the use of GIS and remotely sensed data.

Vescovi, et al. (2000) detected the human induced land-cover changes in Ghana applying principal components analysis and vector analysis techniques to provide information on the change type and intensities. Similarly in Zimbabwe, Murwira (2003) assessed natural resources distribution employing Remote Sensing and GIS. Studies now need to incorporate and synthesize the GIS and Remote Sensing techniques with the conventional field surveys in order to generate a nationwide land-use and land-cover scheme and inventory the national resource base.

Shurugwi district is experiencing considerable growth and developmental activities, such as infrastructural development, mining, land reform (resettlement), and deforestation, among other anthropogenic activities (Chenje, Sola, & Paleczny, 1998) Madebwe & Madebwe, 2005). These human activities have resulted in increased land consumption, modification, and alteration of the status of the land-use and land-cover over time. This situation is of concern in that these changes have and are still occurring without a detailed and comprehensive attempt to determine, keep track of, and evaluate their status.

This study seeks to determine the rate of land-cover change in Shurugwi district from 1990 to 2009, as well as to account for the inherent spatial changes, extent of change, and identifying the responsible factors the changes. The information will be useful in providing a more informed and well structured land-use plan for the district and provide a basis for more effective natural resources management. It will also assist in monitoring the dynamics of land-use emanating from the changing demands of the district's increasing population. These results are especially useful to the district authorities, natural resources managers, and other principal authorities to manage and conserve the natural resources and plan effectively land-uses in the district.

The study provides a new dimension to land-use and land-cover studies in Shurugwi district, establishing the extent of the changes. This is because the few attempts to document the dynamics of land-use and land-cover using GIS and remote sensing for the district have been made with reference to the nature, magnitude, rate, and extent of land-use and land-cover changes (Miller, 1996; Briney, 2008). The use of remote sensing and GIS in this research provides a general extensive synoptic coverage of large areas and possesses powerful capabilities with evaluation techniques for detected changes.

Description of the Study Area

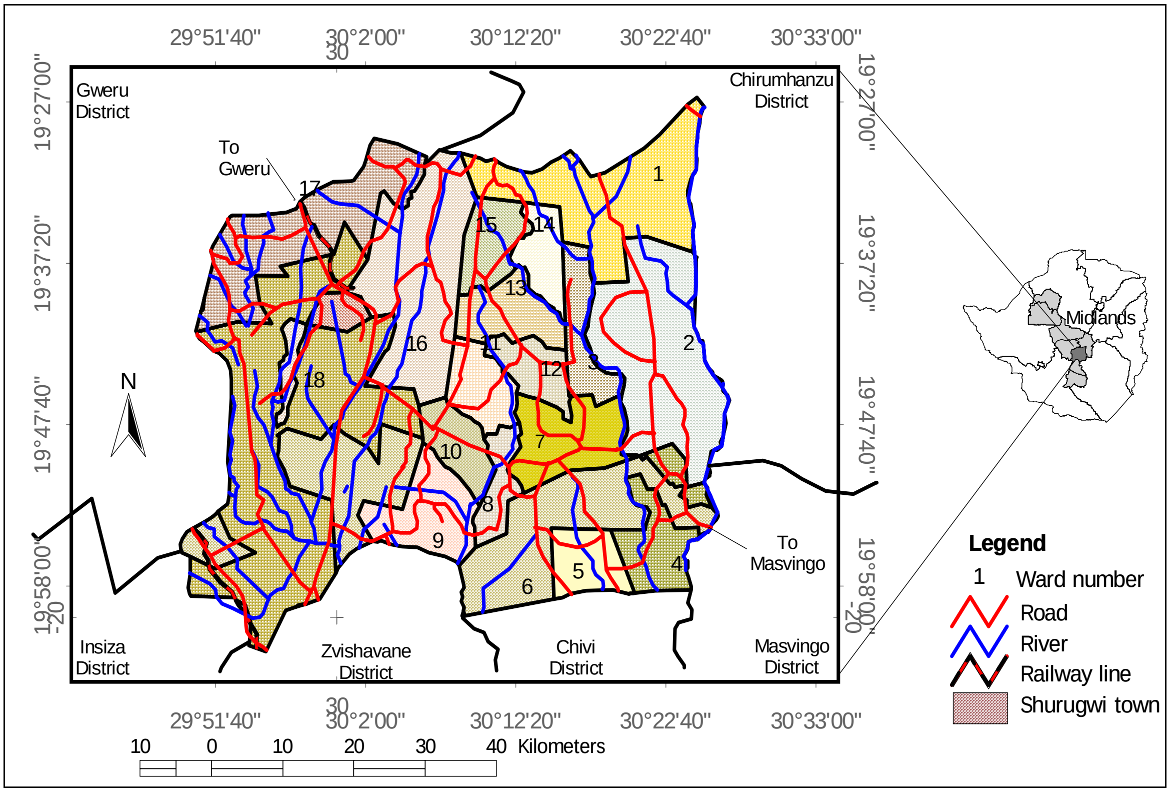

Figure 1: Map of Shurugwi district.

Source: Primary data

Shurugwi district is situated about 30 km to the southeast of the city of Gweru in the Midlands Province of Zimbabwe (Figure 1). It lies in the time zone of approximately Universal Time Zone (UTZ) +2. The district's main town, also called Shurugwi, was established in 1899 as a mining town. The district remains an important mining center for gold, nickel, chrome, and, recently, platinum. Shurugwi town is located on the mineral rich belt, commonly known as the Great Dyke in Zimbabwe. The district lies in agro-ecological region 3 and receives an average rainfall between 650-800 mm. Major land uses in the district include residential (settlement), agricultural, mining, industrial, and forest areas. Subsistence crop and livestock farming are the dominant human activities in the rural areas.

Table 1: Population and household figures for Shurugwi district (1992 and 2002)

Ward Name	***Males 1992***	***Females 1992***	***Total 1992***	***Males 2002***	***Females 2002***	***Total 2002***	***Households 1992***	***Household 2002***	***Household Size(2002)***
Shurugwi Town	10149	8164	18313	8518	8348	16866	1593	4285	3.9
Tokwe II	1268	1304	2572	1285	1368	2653	734	446	5.9
Tokwe I	1416	1524	2940	1155	1283	2438	429	430	5.7
Jobolingo	441	478	919	996	812	608	146	99	6.1
Gamwa	801	783	1584	1373	1387	760	237	112	6.8
Mufiri	1714	1944	3658	1663	1855	3518	701	720	4.9
Zvamatenga	1165	1898	3063	1506	1535	1041	774	176	5.9
Chikato	2058	2362	4420	2390	2753	5143	1186	1188	4.3
Shamba	1356	1619	2975	1560	1826	3386	555	730	4.6
Chanaiwa	2342	2673	5015	2120	2532	4652	944	1003	4.6
Donga	1467	935	2402	2740	3208	5948	1083	1313	4.5
Gundura	2263	2688	4951	2866	2337	4203	931	923	4.6
Tongogara	1649	1957	3606	1620	1865	3485	747	786	4.4
Hanke	2581	1937	4518	2046	2347	4393	1020	956	4.6
Svika	1718	2049	3767	1676	2073	3749	706	743	5.0
Dombwe	2066	2409	4475	1279	1705	3184	837	728	4.4
Chironde	1751	1719	3470	1523	1007	2030	591	353	5.8
Valley Mine	1507	2018	3525	3009	2851	2443	2155	747	3.3
Gwenoro	1478	2112	3590	3595	2808	6403	1531	1740	3.7
Grand Total	30190	33573	79763	42920	43900	86820	16900	17478	5

Source: CSO, 2002

In 1992, Shurugwi district had a population of 79,763, which grew significantly to 86,820 in 2002 (CSO, 1992; CSO, 2002). The district is experiencing significant change in land-use and land-cover due to the increasing demand for land intended for food and industrial production associated with the mining of gold, platinum, and chrome.

The various activities that ensued in the period from 2000 to present have effected spatial changes in land-use and land-cover in the area. Evidence of the extent of change can be found in satellite imagery of the area over different years and can be documented using various change detection and analysis techniques.

MATERIALS AND METHODS

The study used three satellite images of different years to come up with the land-use/land-cover map and classification of Shurugwi district. The two Landsat TM satellite images of the district for the years 1991 and 2000 (path/row 170/74; captured on April 17, 1991 and April 23, 2000, respectively) were obtained from the Global Land-cover Facility (GLCF) on Earth Science Data Interface (http://glcf.umiacs.umd.edu.8080/esdi/index/jsp), while the third image (October 2009) was obtained from the Google Earth Image Domain.

Establishing the land-use and land-cover status for Shurugwi district.

Image pre-processing

To estimate the current land-use and land-cover status for the district, a satellite image, which was obtained from the Google Earth Image domain, was captured as a set (series) of screen by screen images; each covering a relatively small area of the district. This was performed in order to capture as much detail as possible relating to fields, streams, roads, vegetated areas, degraded, and bare land. A total of 80 images were captured screen by screen and were saved in JPEG file format.

On completion, each scene was imported and geo-referenced in Integrated Land and Water Information System (ILWIS) 3.4 and Earth Resources Data Analysis System (ERDAS) Imagine 9.1. The geo-rectification was performed according to the Geographic (Latitude/Longitude) projection system (WGS84) on each single image, after which all 80 scenes were combined into a mosaic in ERDAS Imagine 9.1.

Image classification

The image classification process involved both supervised and unsupervised classification in order to come up with a current depiction of the state of land-use and land-cover in the district.

Five vector layers of vegetation areas (forest areas, grasslands, water bodies, cultivated (farming) land, bare areas and degraded land (wasted)) were digitized as training sites for the supervised classification. These provided spectral signatures which guided the classification process as all pixels were assigned to a class in which they fitted into the range of an identified (training site) land-use type. The supervised classification process was verified by the field data (ground truthing) and was clearly discernible from the images, with the assistance of the Google Earth images Domain, which provided the opportunity to manipulate scale and view unclear features much easily.

Land-use/land-cover changes in Shurugwi district from 1990 to 2009.

The downloaded Landsat images were obtained in Tiff picture format, thus required spatial reference (coordinates), known as geo-referencing (geo-rectification). This was done in ERDAS Imagine 9.1 software, in which they were imported and recognized as 'imagine' files. The two Landsat images were geo-referenced by the process of co-registration. The 2009 geo-referenced image was assumed as the master image from which the two other Landsat images were co-registered in order to minimize the geometric errors. Since the study involves multitemporal analysis performed on a pixel-by pixel basis, any mis-registration would provide erroneous results. The average error was 0.032 per pixel on all the images.

On completion, the geo-referenced images were stacked. That is, the bands for each Landsat image were stacked together into a single image having been imported into ENVI 4.2 software. A shapefile (thematic layer) of Shurugwi district that was imported from ArcView 3.2a software was then used to mask and subset the study area of the district from the overall Landsat scene image, which covered a much larger area stretching as far off as Insiza district in Matebeleland province. Normalization of the image was undertaken with respect to the other images and the topographic correction.

Conversion of digital numbers (DN) to reflectance

Exactitude of the image was improved through calibration, a process in which the top-of-atmosphere (TOP) signals are converted to band-wise spectral surface reflectance. This process was done because the research was using three multivariate (and multitemporal) images spread over 18 years; hence these had to be independent of all atmospheric variables. Consequently, the images were converted from digital numbers to spectral radiance from which they were converted into feature reflectance, which recognizes terrestrial reflectance.

Change detection

The images were analyzed using change detection techniques along with the Google Earth screen to screen images to come up with the extent of the changes that have occurred. Image differencing of each image's bands (Landsat bands 1, 2, 3, 4, 5, and 7) was done so as to analyze and compare the different images pixel by pixel in order to identify and establish the changes per pixel (being representative of the area as a land unit comprised of homogenous biophysical properties). Prominent changes in the land-use/land-cover, which were observed, were zoomed in in order to clearly discern the extent. In this case, the classified digital layers' statistics were analyzed facilitating comparative analysis of the image along with statistical comparison of the pixel-to-pixel figures. This brought about the direction of change, nature, and magnitude of change detected in the three images of the district.

The rate of land-cover change over the 18 years in Shurugwi district

The rate of land-cover change was obtained through determining the proportion of change that occurred in each land-use/land-cover in between the given three time periods. This gross rate in km^2 was averaged over the three years to come up with a general rate of change for Shurugwi district.

Drivers for land-use/land-cover changes

Interviews

Semi structured interviews were used to gather data on the drivers of land-use/ land-cover change in Shurugwi district. The questions mostly focused on the socio-economic activities that are undertaken in the district by the different groups of people along the social divide and administrative community of the district.

Key respondents and sampling procedure

Interviews were carried out with the goal of unearthing the major causes of land-use/land-cover change in the district. Key respondents included 5 prominent (leading) commercial farmers (Mr. Ransburg, Mr. Millan, Mr. Ganyani, Mr. Chademana, and Mr. Mabonga) 2 EMA officials (Mr. Berekwa and Miss Simbiso), 1 AREX official (Mr. Mangisi), and one other official from the Department of Lands. The farmers, together with the AREX official, provided information on the farming practices in the district, soil quality, status of fields, production trends, and general livestock data. EMA officials, as an environmental management organ, provided information on present land-uses and causes of land-cover and land-use change. Most importantly, the official from the Department of Lands provided information on the resettlement activities in the district and land-use planning. A general land-use classification was drawn up from the information obtained depicting the resettlement schemes in terms of A1 and A2, according to the Fast-Track Land Reform and Resettlement Program.

Observations and Measurements

To complement the other data collection techniques and to verify the responses provided, image differencing was done in which the analyst assessed the images and referred back to the field observations obtained in ground truthing for more concise answers.

RESULTS AND DISCUSSION

The rate of land-cover change over the 18 years in Shurugwi district

The rate of land-use/land-cover change has been separated to cover two intervals for the five classes. These periods are from 1991 to 2000 and from 2000 to 2009. The rate of change in Shurugwi district generally has been significant with discernible changes clearly observable, especially in the central regions of the district in which Shurugwi town lies. Generally, it is evident that the greatest change in the land-use and land-cover in Shurugwi district occurred during the 2000 – 2009 period as illustrated in Figure 2. Cultivated land and vegetation land have registered the greatest rate of change over the years. Cropland cover, for example, increased in extent by 52.6% in the period 2000 – 2009 as compared to 35.3% in 1991 – 2000. The vegetated land has registered the most significant rate of change over the whole period, as illustrated by table 4.3 in which vegetated land was reduced by 20.9% (773.71 km^2)

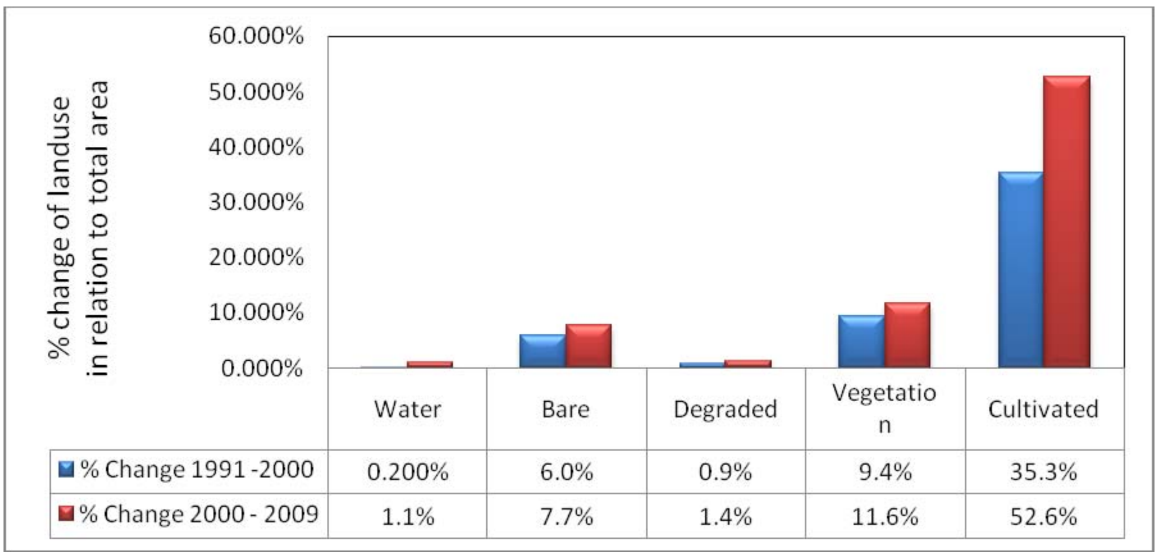

Figure 2: The rate of land-use/land-cover change between 1991-2000 and 2000-2009.

Source: Primary data

Drivers to the land-use/land-cover changes in Shurugwi district

Agriculture

On the classified images in Figure 3, increases in area under cultivation can be noticed with corresponding decreases in vegetation areas. Agriculture is responsible for most of the land-use/ land-cover changes that have occurred in the central and eastern regions of the district. Figure 4.8 illustrates the extent of change that has occurred in Zvamatenga (Ward 6) in the southwestern region of the district, where it was mostly dominated by commercial farms before 1999. After the Fast-track Land Reform

Program, which commenced in 1999, cropland and bare surfaces have significantly increased, replacing the commercial farms and vegetation. Examples of such settlements include Beacon Kop, Safago, Mambava Woodlands, Outward Bound, and Circle V, just to mention a few.

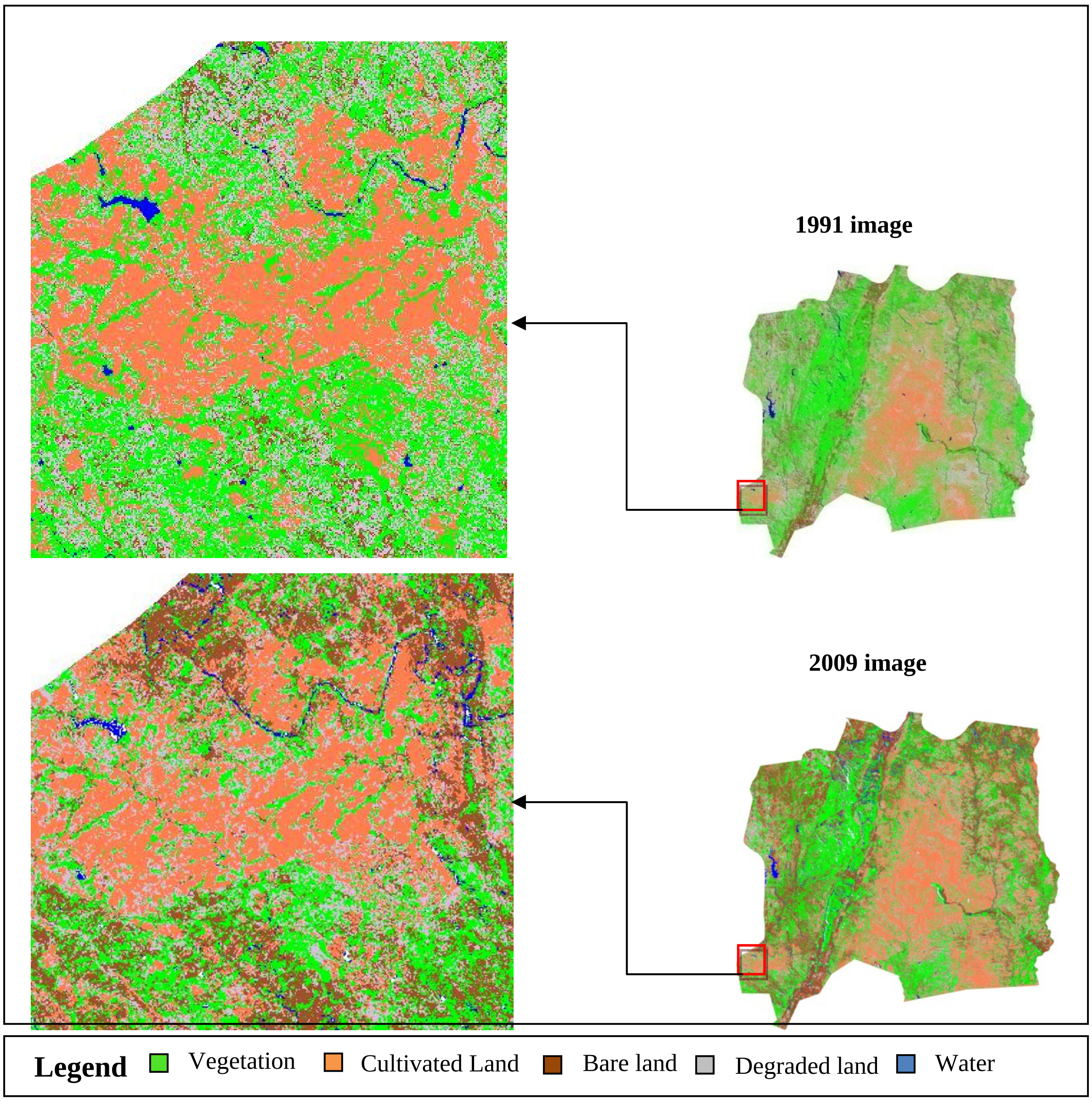

Figure 3: The extent of change in the south-western area of the district (1991 - 2009).
Source: Primary data.

It is significant to note, in the case of Figure 3, that areas initially under cultivation (cropland) has been degraded to such levels that it has been marginalized as indicated by the upper-most section of the enlarged area. The increase in the area classified as bare surfaces suggests extension of cropland into marginal land and general deterioration of the condition of soil. There is a corresponding relationship between increase in agriculture and demand for agricultural land due to population increase.

Mining

There are quite a number of mines located in Shurugwi district, which include Unki, Kironde, Bougei, and ZIMASCO mines along with sporadic panning activities. Figure 4 indicates the general distribution of the mines along the Great Dyke. Establishment of mining activities along the Great Dyke initiated land-use conversions as forests were replaced by new settlements and agriculture. There are also gold panning activities spread across the district which are also impacting significantly on the vegetation as indicated by the degraded areas.

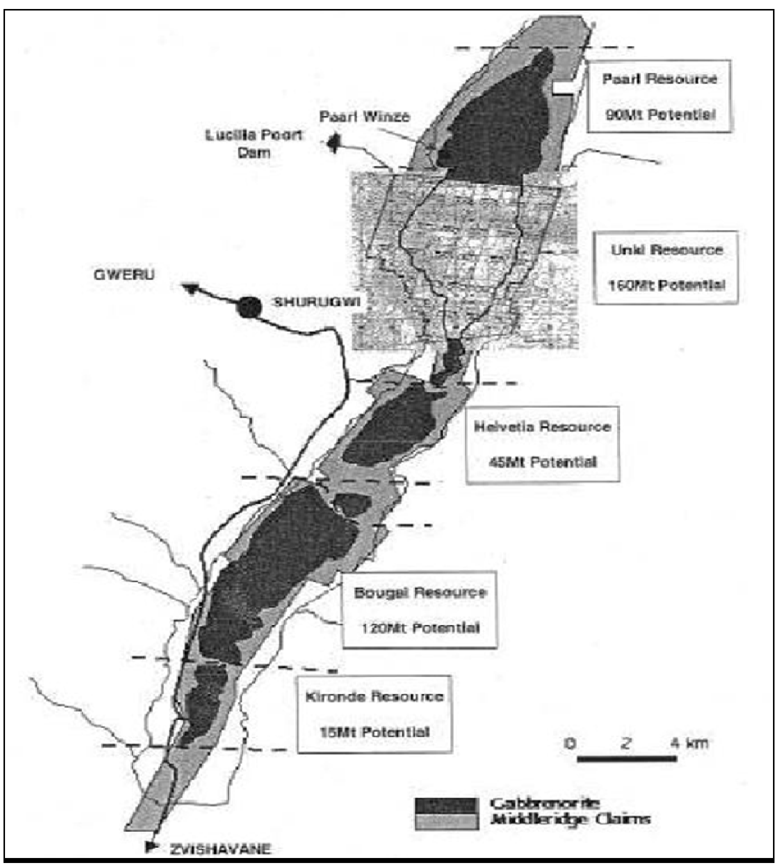

Figure 4: Location of the major mines in Shurugwi district along the Great Dyke

Source: EIA report of Bougei mine (2008)

Unki mine, which began its exploration in 1996, has had significant impacts on the land-cover, as observed by the changes indicated in Figure 5. This emanated from the drilling, trenching, and blasting processes involved in the exploration and surveying of the mine. The areas in and around the mine (bigger circle in red in Figure 5) shows an increase in degraded areas and corresponding reduction of cultivated land in the area where the mine is now located, implying contribution of the mine to the degraded areas. There is need, however, to acknowledge the fact that, in spite of the increase in the area covered by degraded areas, there are also improved areas in Shurugwi district as indicated in Figure 5(smaller circle in yellow). The vegetation indicates improved health as shown by the much brighter green color. This is attributed to re-vegetation practices associated with reclamation measures adopted by various stakeholders, including the Unki mine.

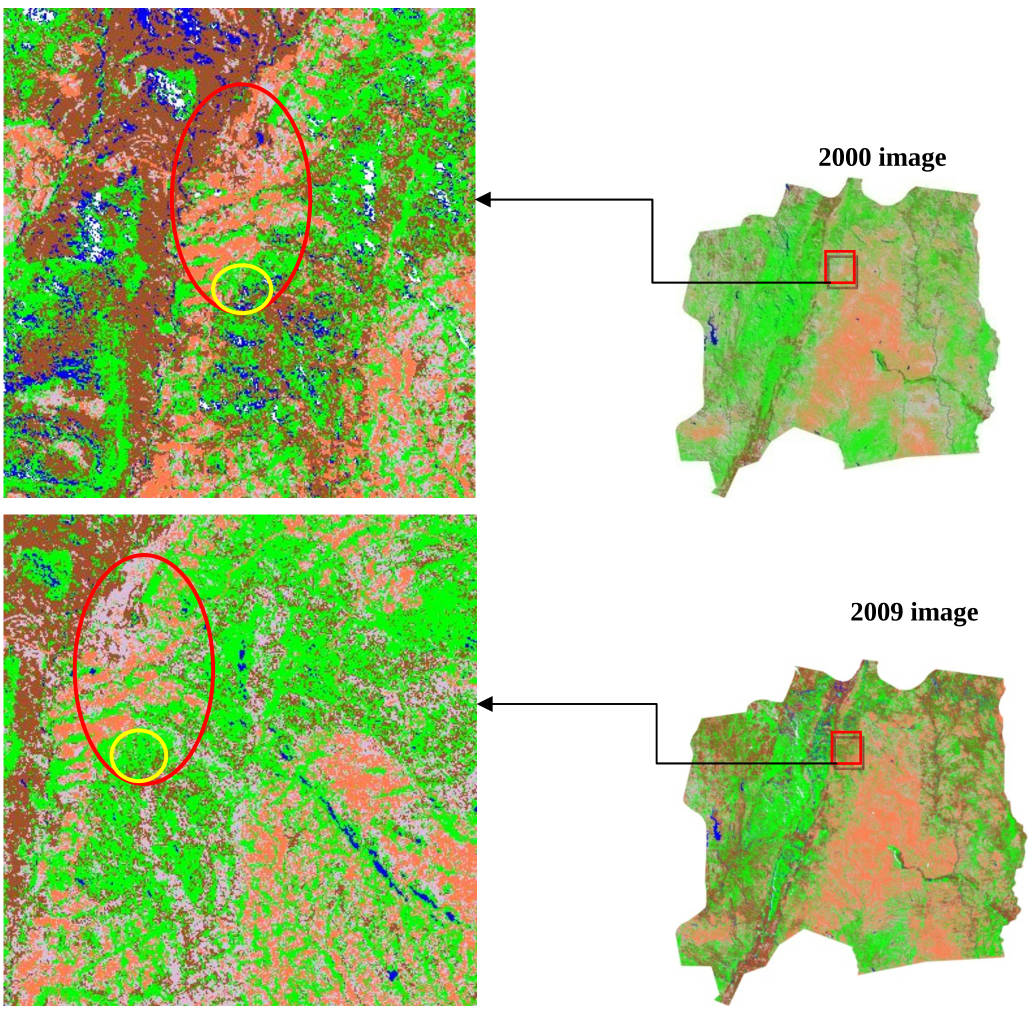

Figure 5: Extent of change around Unki mine.

Source: Primary data.

Tree cutting (Firewood collection)

Firewood was identified as the main source of fuel for most of the homesteads in rural Shurugwi district. The indiscriminate cutting of trees by villagers for such domestic uses as construction of structures, fence lines, and as firewood accounts for the change in land-use/land-cover. Firewood is also exported to Shurugwi business center from the busy Masvingo-Shurugwi road, which is traversed by haulage trucks. This has become an important source of income for quite a number of villagers in the district. This selling, however, is illegal as it is not sanctioned by any of the traditional leaders or by EMA officials. EMA officials are aware of this wood smuggling, but do not have enough resources to deal with the problem given the large number of culprits involved and also the fact that so many poor people rely on forest resources for their livelihood.

Population and livestock growth

Table 2: Livestock statistics in Shurugwi district (1992)

Sector	Cattle	Sheep	Goats	Pigs	Donkeys	Ostriches	Horses
Commercial	14606	204	127	29	0	0	37
Communal	37696	831	6426	46	1329	0	0
Resettlement	34492	484	4401	168	1615	0	0
Small Scale	12914	135	2639	0	85	0	0
Total	99708	1654	13593	243	3029	0	37

Source: Ministry of Lands and Agriculture, 2004.

Table 2 indicates trends of livestock growth in Shurugwi district, which are generally increasing just as much as population (Table 1). The combination of these two variables has considerably affected the land-use/land-cover of the district. The Fast Track land Reform, which ensued in the year 1999 in Shurugwi district, accounts for part of both the population increase and livestock increase as resettlement occurred in most of the former commercial farming areas. Cattle, goats, and donkeys account for the greatest proportion of livestock in the district (Tables 2 and 3).

Table 3: Livestock statistics in Shurugwi district (2000)

Sector	Cattle	Sheep	Goats	Pigs	Donkeys	Ostriches	Horses
Commercial	9318	98	86	46	0	0	12
Communal	40271	1702	8673	22	1617	0	0
Resettlement	56639	493	6891	176	2436	0	0
Small Scale	14826	206	3145	12	238	0	0
Total	124054	2499	18795	256	4291	0	12

Source: Ministry of Lands and Agriculture, 2004.

Signs of rangeland degradation in the district can therefore be accounted for by the increased number of livestock as shown in Table 3.

CONCLUSIONS AND RECOMMENDATIONS

Shurugwi district has experienced significant change in land-use and land-cover between 1991 and 2009. The greatest changes occurred between 2000 and 2009 in the central regions of the district around the mining town of Shurugwi. The major cause of change was agriculture, which saw cropland cover increasing in extent by 52.6% between 2000 and 2009 compared to 35.3% in the period of 1991-2000. This accelerated increase was mainly as a result of the Fast-Track Land Reform and Resettlement Program, which saw a large influx of new farmers occupying large areas of former white-owned commercial farms, and in the process clearing large areas of forests for different farm-related activities like opening new farming plots, wood for fuel, poles for building both homes and cattle pens, among other activities. Mining also contributed significantly to the rate of land-cover and land-use change in Shurugwi district as the establishment of both mining and panning activities initiated land-use conversions as forests were replaced by mines and gold panning sites. The Fast-Track Land Reform and Resettlement Program also led to an increase in the number of livestock like cattle, goats, and donkeys into formerly well-managed former commercial farmers pastures. These were quickly depleted by the introduced freely-managed livestock as most former private land suddenly became common property.

In light of the findings from this research it is recommended that:

- The Ministry of Environment through the Environmental Management Agency (EMA) monitor the cutting down of trees in newly resettled areas through the promotion of alternatives to tree resources, like still poles.
- The government should resuscitate electricity supply points vandalized during the occupation period in most of the newly resettled commercial farms so that new farmers get electricity from Zimbabwe Electricity Supply Authority (ZESA) in line with the Rural Electrification Program. This will significantly reduce the rate of deforestation in these areas.
- EMA should also stop panning activities rampant in the district as these have caused serious degradation in this mineral rich district. EMA must also ensure that all new mines undergo full Environmental Impact Assessments as per EMA statutes.
- Chiefs, headmen with the help of EMA, and the Ministry of Agriculture must designate properly managed paddocks in the newly resettled areas in order to control grazing and reduce the rate of land degradation in these areas.

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