ASSESSING SPATIAL-TEMPORAL CHANGES OF LAND USE: CASE STUDY IN RUNDA SECTOR

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Abstract

Nowadays, urban development causes many negative impacts to the agricultural production. Agriculture is the main economic activity for the people of Rwanda, providing employment about 86% of the total population. The sector contributes 47% of Rwanda's gross domestic product and accounts for about 80% of the foreign earnings from the exports of the primary products of coffee, tea, hides and skins, pyrethrum and horticulture. Over 80% of the population depends on agriculture for subsistence. Every year, built-up area increases and challenge agricultural production.

Multi-temporal Landsat ETM2001, TM2008 and OLI/TIRS2017 images were acquired. Digital orthophoto, Google earth maps, direct field observation and interview using questionnaires were used as data sources. More than 200 training samples were selected for classification of the Landsat images using supervised method, maximum likelihood in ERDAS Imagine 2014, and in ArcGIS 10.2 land cover maps were produced and change detection analysis was performed.

Runda sector changes have occurred on the land use/land cover. Built up areas increased from 177.5ha (3.5%) to 641.7ha (12.7%) while agricultural areas decreased from 3436.2ha (68%) to 3059.6ha (60.5%) from 2001-2017. Built up surface expansion followed certain pattern depending on the increasing of infrastructure development and population growth. By considering results of spatial analysis of change detection and pattern, within 16 years the most cell which show the increase of built-up area is Ruyenzi cell. With referring to the soil types, large part of Ruyenzi covered by fertile soil which is cambisols and this fertile soil are almost covered by built-up, the same case in Runda land use master plan. Mapping of the spatial temporal land use/land cover changes in an accessible GIS platform can be used by land planner to look after this agriculture sector or by improving other sector for more social economics with positive impact to productivity.

Keywords; Land use, land cover, spatial temporal, Runda, built up, Ruyenzi, agricultural land.

Introduction

The world's urban population grew from 200 million in 1990 to about 290 million in 2000, and it is expected to be about 500 million by 2030 (Estoque & Murayama, 2011). Such high growth rate will certainly make worst the existing environmental consequences of urban expansion, especially in the absence of intervention. Hence studying the spatial and temporal LU/LC changes might provide a significant basis for more effective land use planning that would eventually mitigate the negative consequences of urban growth, and keep the ecosystem in balance (Estoque & Murayama, 2011).

The impact of urban growth on agriculture was considered to come from the growing urban demand for food and agricultural raw materials and for labor provided by rural urban migrants. A city's impact on agricultural, nonfarm and total income growth in a village will not only depend on the growth of light intensities of cities, but also on the distance of the city to the village.

Taking into account the way the government of Rwanda is implementing group settlements in rural area in order to avoid living in high-risk zone and accessing social infrastructures easily. This policy of group settlement is good, however it causes another problem where fertilized land, which could be used to produce harvest is at risk of becoming land for residential.

With population on a rapid increase, the city of Kigali is fast becoming one of the most densely populated cities in Africa. The city has a total area of 730 square kilometers with the average population density at 1556 persons per Square kilometer (Collins, 2013). According to the fourth Population and Housing Census, Rwanda, 2012, Runda sector is one of sectors in Kamonyi district with a high population of 680 inhabitants per km^2 with a population of 34839 (NISR, 2012).

Our case study Runda sector is also facing the problem of increasing population and is one of the sector neighboring of Kigali city. Here there is influx of people from Kigali City to this sector looking for new settlement that is why the land use planning must be carefully assessed by preserving enough suitable land for agriculture but at the same time maintaining area for population growth.

In order to monitor urban land use change and development in the region, a change detection analysis was performed to determine the nature, extent and rate of land cover change and destruction over time and space. The results quantify the land cover change patterns in Runda sector area and demonstrate the potential of multitemporal Landsat data to provide an accurate, economical means to map and analyze changes in land cover in a spatial temporal framework that can be used as inputs to land type for management and policy decisions with regard to varied themes that has link with space such as urban growth, agriculture land decreases, impact on local society food security.

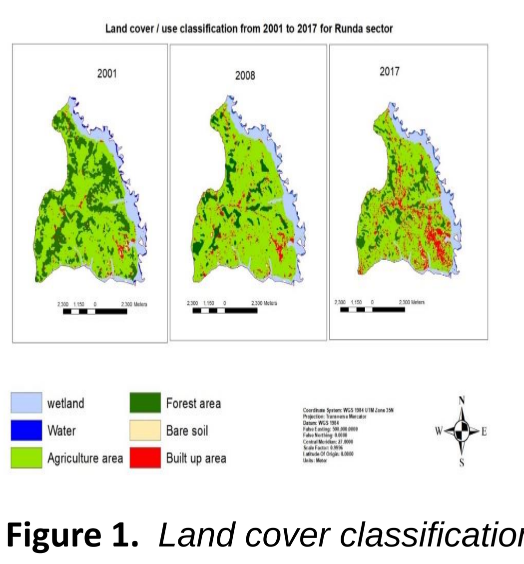

Figure 1. *Land cover classification from 2001 to 2017 for Runda sector*
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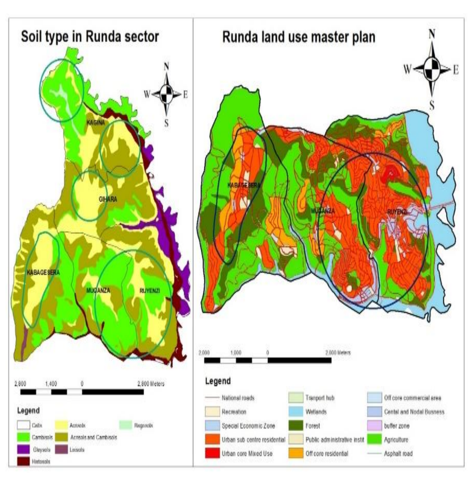

Figure 2. Soil analysis with master plan.

Methods and Materials

This section describes the data and methods that were applied in data acquisition, processing Analysis and presentation of data in order to achieve the designed objectives and the research questions posed. This allowed us to analyse change and to draw conclusion on the spatial-temporal land use land cover change in Runda sector.

It was noted that there is a competition of land use especially between agriculture and housing sector. By conducting our research, basic information relating to existing land use, population distribution, population movement and population need socially and economically were gathered through interviews to the local people and local leaders.

The way land cover changes over time was analyzed by using satellite images of different time from 2001 to 2017 and orthophoto to see changes in land use/land cover. For more accurate we was conducted ground truthing in enhancing maps with precise information. All data were analyzed by using Software such as ArcGIS and ERDAS.

The data that has been used for studying Runda sector spatial-temporal land use/land cover change include three historical Landsat satellite images covering this sector for the past 16 years (2001-2017). These images included one 15 m resolution Landsat 8 image (2017) and two 30m resolution Landsat 7 and Landsat 5 for 2001 and 2008, respectively.

Land use/land cover maps derived from classification of images usually contain some type of errors due to several factors that range from classification techniques to methods of satellite data capture. Hence, evaluation of classification results is an important process in the classification procedure. The reference data that were collected from field work.

The land cover classification accuracy assessment was based on 200 random sampling points (reference point), comparison between each classified images and its extracted Landsat gave us accuracy assessment. And also with referring to the orthophoto, Google Earth Images and field observation improve high level of accuracy.

Results

Classification of results is an important process in satellite image classification procedure. The accuracy was assessed with corresponding Google Earth Imageries and orthophoto. Using these reference data and the classified maps, accuracy was assessed for the three periods by using ERDAS Imagine 2014 software.
The resulting classification land use/land cover maps of the three periods of 2001, 2008 and 2017 had an overall classification accuracy of 90.00%, 93.00% and 95.00% respectively. This was reasonably good overall accuracy and accepted for the following analysis and change detection.

Landsat ETM image (2001) was classified into six land cover classes successfully. However, built-up area were classified with a smaller producer accuracy (50%) than other classes. This is due to the combination of omission and commission errors particularly mixing with agricultural class. Lower producer's accuracy was also observed for bare soil due to the omission and misclassification to built-up. Accuracy of the ETM Landsat image is lower because it has lower spatial resolution. It was common to find mixed land use in urban areas within this 30m spatial resolution image. Overall classification (90.0%), it was acceptable as good classification.

Landsat TM image (2008) was classified into six classes. However, also built up area were classified with the smallest producer accuracy (75.0%) compared to other classes. This is due to the combination of omission and commission errors particularly mixing with agricultural class. Lower producer's accuracy was also observed for bare soil due to the omission and misclassification to built-up. Accuracy of the TM Landsat image is lower because it has lower spatial resolution. It was common to find mixed land use in urban areas within this 30m spatial resolution image. Overall classification (93.0%), it was acceptable as good.

Landsat OLI/TIRS image (2017), much better overall classification accuracy (95.00%) was achieved. The higher accuracy was achieved due to the utilization of more ancillary data in collecting training samples for classification and the image spatial resolution of 15m. In general, there was some evidence for both systematic commission and omission errors resulting from the classifier side as incorrectly commits pixel of the class being sought to other classes as well when some class on the ground were misidentified as another class by the classifier.

Table 1: *Area, extent and rate of land cover change (2001-2017)*

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Land Cover Type	**2001-2008**			**2008-2017**		
	Change area (ha)	Change extent (%)	Annual rate of Δ (%/yr)	Change area (ha)	Change extent (%)	Annual rate of Δ (%/yr)
Built up	142.74	80.38	11.48	321.4	100.3	11.1
Agriculture	-60.09	-1.74	-0.24	-316.4	-9.3	-1.04
Forest	-104.12	-11.4	-1.6	38.7	4.81	0.53
wetland	-5.53	-1.3	-0.19	-5.008	-1.236	-0.137
Bare soil	35.28	101.8	14.54	-26.2	-37.4	-4.16
Water	5.53	6.5	0.92	5.19	5.738	0.637

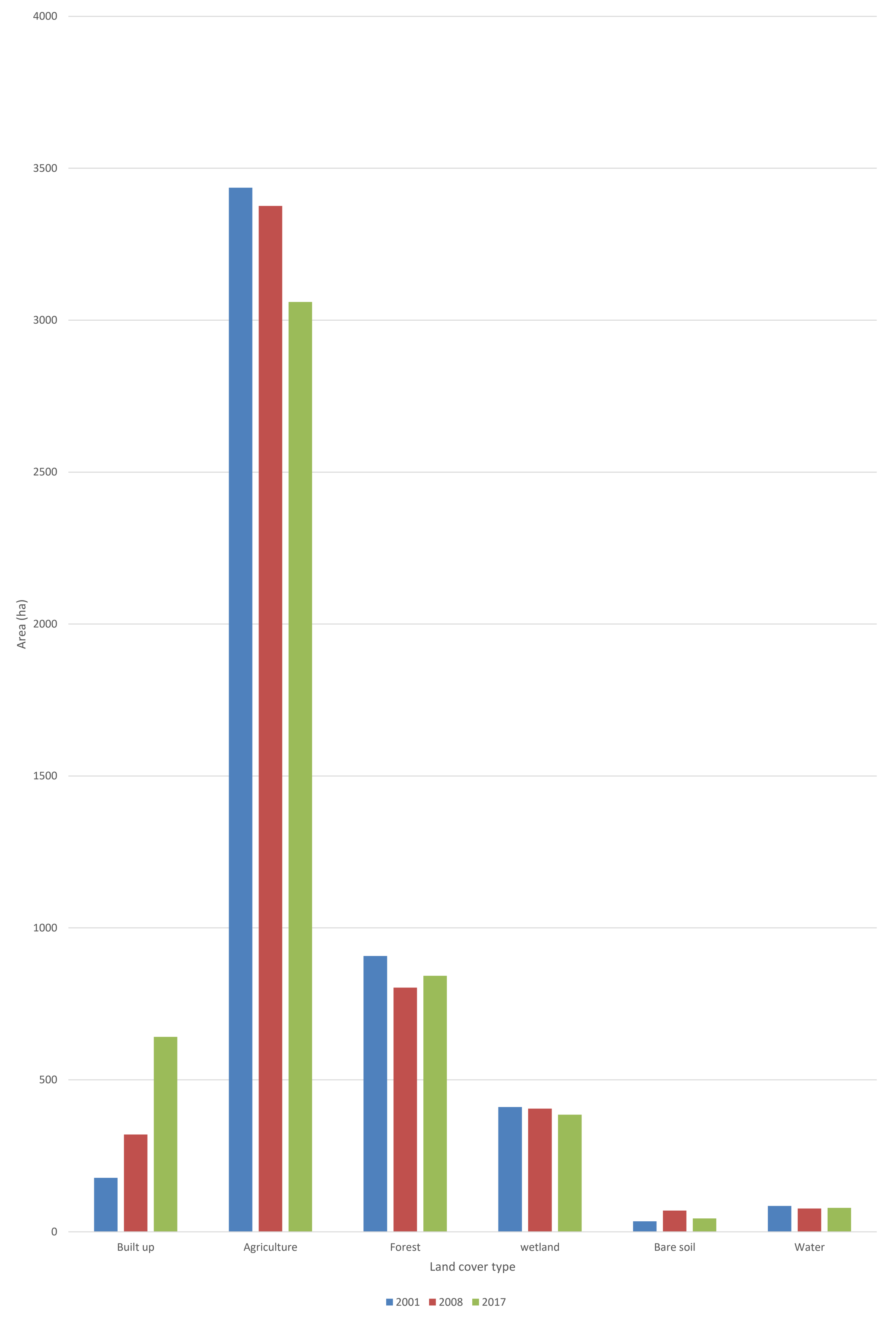

Chart 1. Bar chart showing Land Cover Change 2001 to 2017

Discussion

Using the approaches adopted in the methodology, land cover maps were generated in ArcGIS 10.2 software for all the three period (2001, 2008 and 2017). Area estimates and change statistics are computed as the individual class area and change statistics for the three period were shown. In the study periods covered, the major land cover classes identified includes agriculture, built-up, water, forest, wetland, and bare soil.

The trends of change between the seven years from 2001 to 2008 were computed, the built up area increased approximately 316.7ha (178.4%) while agricultural land decreased 60.9ha (1.7%), forests areas decreased 104.1ha (11.4%), wetlands decreased 5ha (1.3%), bare soil increased 35.2ha (101.8%) and water decreased 8.2ha(9.7%). During the second period between 2008 to 2017, the built up environment increased drastically by 321.4ha (100.3%) while agricultural land continuously converted and decreased 3016.4ha (9.3%), forests increased 38.7ha (4.8%), wetlands decreased 20ha (4.9%), bare soil decreased 26.2ha (37.4%).

Figure 13 represent the comparative land cover change trends from 2001-2017 in Runda sector. The major land use of urban-built up surface had an increasing positive trend of change in its areal extent while agricultural lands decreased continuously in the three periods.

In general, the change values iindicated that increase in built-up mainly originated from conversion of other land covers in particular agriculture to urban land uses during the past 16 years (2001-2017) following increasing development pressure within the Runda. Besides the summary of above statistics, graphical representations of the classification and visual comparison offer a general insight into the relative amounts of the defined classes across the landscape and the changes observed.

Conclusions

This study has shown that information from satellite remote sensing and integrated with GIS can play a useful role in understanding the nature and extent of changes in land use/ land cover, where they are occurring and monitoring these changes at local scale. The change detection analysis performed in this research allowed for the monitoring of land use/ land cover changes overtime and space. The analyses provide valuable insight into the extent and nature of changes that has taken place in Runda sector from 2001 to 2017.

Land use/land cover change have been identified by analyzing satellite images of 2001, 2008 and 2017 in a GIS platform and remote sensing. The evidences of land use change is growth of built-up area. Conversions of land from agriculture to urban land represent the most land cover change. Where 9.20 % of land was the increase of built-up while agricultural area decreased 7.44% from 2001 to 2017. Extent of urban change is likely to continue with the rapid development of infrastructure and increasing of population. The majority of changes in urban built-up area happened in most nearest side closer to Kigali city especially in Ruyenzi cell because people like to live near their job and also accessibility of need in the city, that causes land for agriculture decreases and converted into plots for buildings and other urban development infrastructures.

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