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Study on Changes of Land Use impacting the Process of Urbanization, by Using Landsat Data in African Regions: A Case Study in Kigali, Rwanda

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***Abstract*—**Human activities on land use make the land-cover gradually change or transit. In this study, we examined the use of Landsat TM data to detect the land use change of Kigali between 1987 and 2009 using remote sensing techniques and analysis of data using ENVI and ArcGIS, a GIS software. Six different categories of land use were distinguished: bare soil, built up land, wetland, water, vegetation, and others. With remote sensing techniques, we analyzed land use data in 1987, 1999 and 2009, changed areas were found and a dynamic situation of land use in Kigali city was found during the 22 years studied. According to relevant Landsat data, the research focused on land use change in accordance with the role of remote sensing in the process of urbanization. The result of the work has shown the rapid increase of built up land between 1987 and 1999 and a big decrease of vegetation caused by the rebuild of the city after the 1994 genocide, while in the period of 1999 to 2009 there was a reduction in built up land and vegetation, after the authority of Kigali city established, a Master Plan where all constructions which were not in the range of the master Plan were destroyed. Rwanda's capital, Kigali City, through the expansion of the urban area, it is increasing the internal employment rate and attracts business investors and the service sector to improve their economy, which will increase the population growth and provide a better life. The overall planning of the city of Kigali considers the environment, land use, infrastructure, cultural and socio-economic factors, the economic development and population forecast, urban development, and constraints specification. To achieve the above purpose, the Government has set for the overall planning of city Kigali, different stages of the detailed description of the design, strategy and action plan that would guide Kigali planners and members of the public in the future to have more detailed regional plans and practical measures. Thus, land use change is significantly the performance of Kigali active human area, which plays an important role for the country to take certain decisions. Another area to take into account is the natural situation of Kigali city. Agriculture in the region does not occupy a dominant position, and with the population growth and socio-economic development, the construction area will gradually rise and speed up the process of urbanization. Thus, as a developing country, Rwanda's population continues to grow and there is low rate of utilization of land, where urbanization remains low. As mentioned earlier, the 1994 genocide massacres, population growth and urbanization processes, have been the factors driving the dramatic changes in land use. The focus on further research would be on analysis of Rwanda's natural resources, social and economic factors that could be, the driving force of land use change.

***Keywords*—**Land use change, urbanization, Kigali City, Landsat.

I. Introduction

LAND use is one of the main factors affecting the national environment and human life. Land use change is mankind's activities of the Earth's surface that reflects important changes in the ecological environment [1] in addition to climate change, but also the main factors for the purposes of the human environment [2]. Human transformation of the Earth's surface has an impact on all aspects of biological systems, including urban, the heat island effect [3], the river flow change [4], [5], changes in the global atmospheric circulation patterns [6] and the extinction of species [7]. Land use changes have a significant impact on the global ecosystem, studies have pointed out that the consequences of land use change may exceed the impacts of climate change arising from land use influences [8], [9]. Land use and land cover changes can be divided into two major categories of conversion and transformation. Conversion refers to a land-use type into another land use patterns; and the transformation means to retain the existing land use patterns that changed with the land attributes [10], [11]. The United States Environmental Protection Agency Studies show that [12], the main causes of land use and land cover change are:

(1) Natural processes such as climate change, natural fires and pests; (2) a direct impact caused by human activities such as deforestation and road construction; (3) the indirect impact caused by human activities, such as water diversion leading to reduction. These factors are divided into two categories: direct and indirect causes. The direct cause refers to the direct land use change caused by certain reasons; the indirect cause refers to the follow-up of a direct cause and its result after classification.

UNEP [13] pointed out that land degradation and desertification in Africa, as well as deforestation related to human activity, is leading to soil degradation. That is the main reason to use and study land cover change, since the African desertification process affects 46% of the African continent.

Land in Africa is seriously threatened; large-scale land degradation has been reported, whereby more than 43% of the area of land degradation can be defined as extreme desertification. The cause of desertification is not only due to natural Influencing factors, but also socio-economic factors,

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such as land use rights, marketing, policies and regulations, labor income, human health, policy incentives and political stability, etc. [14]. If people do not have land and water use rights and accessibility, it is difficult consciously for conservation and management of land and water resources. They will focus on meeting short-term needs of economic development, and thereby cause damage to the ecological environment [15].

Urbanization is a complex process; its impact on human life extends from rural to urban [16]. Due to the natural conditions of control, urbanized region in a presentation space star pattern and the process of urbanization is traceable [17], [18]. Urbanization process in Rwanda with the increase of population and the development of social economy continues to accelerate. Mainly for the following aspects: the urban population is growing, land for construction and urbanization has improved rapidly, urban land significant change. This is because only the transformation or change land use patterns, human economic needs can be met.

Remote sensing images have macroscopic features such as real-time, in the monitoring of land use change has been widely used, for trend analysis of land use change and urbanization providing data and technical support [19]-[21]. This article aims to apply Landsat TM/ETM + Data Research urbanization Kigali Rwanda land use change characteristics in order to provide decision-making basis for regional sustainable development.

II. Regional Urbanization Kigali City

The Study area for the capital city of Rwanda is Kigali. The city is located 1.95°S and 30.06°E, with a total area of about 730 km2, it is a city almost surrounded by mountains. The highest mountain is Kigali Mountain, altitude 1539 m. The annual water drop area is 900 mm, with an average annual temperature of 20°C-21.6°C. There are four seasons: from mid-March to mid-May for the long rainy season; from mid-May to mid-October for the long dry season; from mid-October to mid-December short rainy season; and from mid-December to mid-March is the short dry season.

Population pressures lead to lower utilization of land, pastures and fallow periods shortened and natural woodland into farmland; these three phenomena have led to land degradation, further increasing the impact of population pressure on natural resources and leading to another cycle of environmental degradation.

As of January 1, 2011, the population of Kigali city was about 1,019,862 people, a nearly two-fold increase over the 1999 population of 604,966 people, which greatly promoted the growth of housing and other urban land demand. The Kigali population continued to grow during the past four decades and after the 1994 war and genocide and then presents a new growth trend, coupled with world trends.

Rwandan immigrants from around the region returned, leading to a further sharp increase in the population. Due to the relative safety of the capital of Rwanda, most people tend to stay in the capital, which contributed to the change in land use in some way.

III. Methods

A. Data Preprocessing

Institute data of Landsat TM/ETM + data acquisition time three-scene data are February 5, 1987 (TM), 1999 June 8th (ETM +) and June 5, 2009 (TM), both sources were collected from USGS open source data, and the geometry has been corrected.

By using ENVI software, TM images were radio metrically calibrated to link pixels intensities to physical parameters. Images were also atmospherically corrected to retrieve the surface reflectance from the image by removing the atmospheric effects to improve the significant accuracy of image classification. The relevant atmospheric correction parameters in practice are often difficult to determine correctly, usually approximate solution is obtained [22].

Chavez cost method is an image-based atmospheric correction method that uses only cosine values of solar zenith as parameters [22], which is used to correct the effects of atmospheric gas absorption and Rayleigh scattering. Using this method, the DN value of the image is converted to radiance and reflectivity [23].

$$L_\lambda = GAIN_\lambda \times DN_\lambda + BIAS_\lambda \quad (1)$$

$$\rho_\lambda = \frac{\pi \times L_\lambda \times d^2}{ESUN_\lambda \times cos\theta} \quad (2)$$

where, Lλ is the cell value as radiance, DN is the cell value digital number, GAIN is the gain value for a specific band, and BIAS is the bias value for a specific band. Where, ρλ is unit less planetary reflectance, d is Earth-Sun distance in astronomical units, ESUNλ is mean solar exoatmospheric irradiance, and θ is solar zenith angle. These parameters are derived from the literature [23].

The land use type is divided into six types: bare land (not reclaimed or idle land), construction land (residential, roads, bridges, industrial land and buildings, etc.), and wetlands, water bodies (rivers and lakes, etc.), vegetation cover (Including vegetation, including meadows, forests, farmland and paddy fields, etc.) and other land (bare sand, rock). ENVI software provides a parallel hexahedron, the minimum distance, Mahalanobis distance, maximum likelihood method and other supervision classification.

In this study, the maximum likelihood method was selected, and the spectral characteristics of some known land use types were extracted. Take them as a "training sample"; then calculate the statistical eigenvalues of the various types according to the training samples, and establish the classification discriminant function; and finally, the pixel feature vector is substituted into the discriminant function by pixel to find the probability of belonging to each class, and the pixel to be discriminated belongs to a group with the largest probability of discriminating the function. The accuracy of the classification results was evaluated, and the Kappa system was found. The number is greater than 0.8.

To determine the classification results of the three images,

the land use of Kigali City was analyzed using pixel-by-pixel statistics and comparative methods; changes in characteristics, by analyzing the driving factors of land use change, to explain the process of urbanization in Kigali and the relationship between land uses.

IV. Results and Analysis

A. Characteristics and Analysis of Land Use Change in Kigali City

The changes in land use in Kigali City from 1987, 1999 and 2009 are shown in Table I. The results show that from 1987 to 1999 and from 1999 to 2009 land use types have undergone great changes. From 1987 to 1999, bare soil area fell 11.40%, representing a reduction of 199.05 km^2, which concluded that the 1994 genocide may be was the cause of the reduction of bare soils from 1987 to 1999. The urban development of Kigali in these years was at a standstill.

From 1999 to 2009, the area of bare soils increased by 18.82%. The reason for this change was that, after genocide, settlements and various industries disappear, the government was consciously re-planning the city of Kigali. During this period a large number of forests were cut down and vegetation cover reduced by 1.06%, as the government re-allocated these lands to local people so that they can continue to develop in the future.

Construction land growth of 11.82% in the 12 years between 1987 and 1999 resulted in a large expansion of the government's residential plans after the 1994 genocide. However, construction land in Kigali decreased by 16.61% between 1999 and 2009, due to the government's re-planning of urbanization processes and decentralized of settlements in line with overall urban planning policy. The 1994 genocide, however, did not significantly prevent the growth of urbanization or construction land, since the number of settlements had been increasing before, during and after the 1994 genocide.

TABLE I
Land Use Distribution (Years 1987, 1999, 2009)

Land use type	1987		1999		2009	
	Area/km^2	%	Area/km^2	%	Area/km^2	%
Bare soil	955.13	54.67	756.08	43.27	1084.66	62.09
Built up land	229.23	13.12	435.61	24.94	145.39	8.32
Wetland	48.13	2.76	35.29	2.02	32.30	1.85
Water	19.06	1.09	18.89	1.08	22.56	1.29
Vegetation	494.70	28.32	480.25	27.49	461.67	26.43
Others	0.74	0.042	20.88	1.20	0.24	0.01

Vegetation area fell 0.82% between 1987 and 1999, due to the increase in construction area over the same period. Similarly, between 1999 and 2009, the area of vegetation fell by 1.06%; this is due to the 1994 war, when a large number of immigrants from other countries came to the Kigali City and settled. The deforestation caused by increased construction land has a significant impact on vegetation, which is also an important reason for the decrease in the vegetation area during this period.

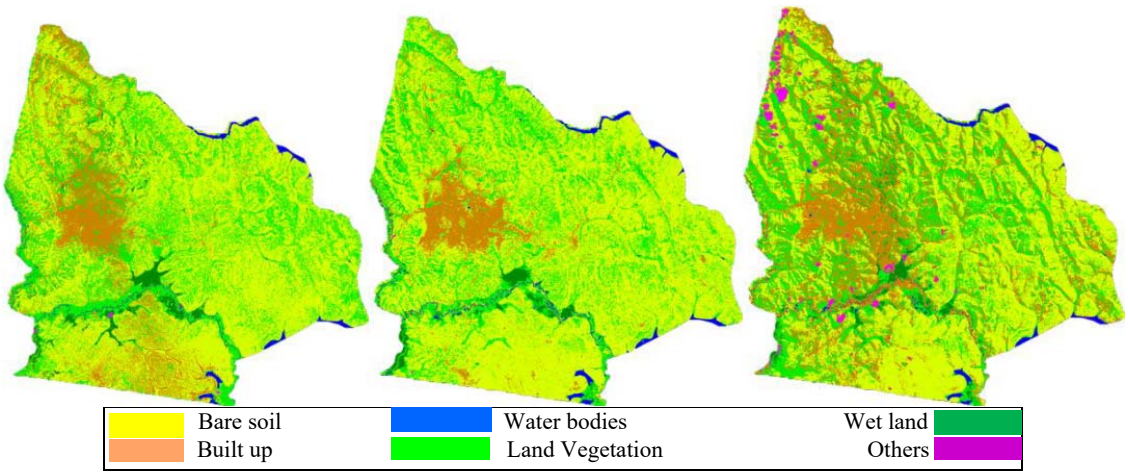

Fig. 1 Classification results

From 1987 to 1999, 23.31% of the bare soil was changed to construction land due to the needs of urban construction, while 23.10% of the bare soil was changed to vegetation (Table II) with the aim to keep green land in Kigali City to attract tourists and keep the city clean and tidy, and 37.99% of the construction land changed to bare soil to meet the need to further build residences.

Wetland area declined, with 45.91% of wetlands changing to vegetation. After the 1994 massacre, 34.83% of the vegetation was degraded to bare soil; 20.43% of the vegetation was changed to construction land due to the subsequent reconstruction. In some parts of the city, the growth of the rainy season plants changed 34.23% of the other types to vegetation, and 30.93% changed to wetlands.

TABLE II
CHANGE DETECTION OF LAND USE FROM 1987 TO 2009

	Bare soil	Built up land	Wetland	Water	Vegetation	Others
Bare soil	51.71%	23.31%	0.87%	0.08%	23.10%	0.94%
Built up land	37.99%	44.59%	0.87%	0.36%	14.96%	1.22%
Wetland	4.99%	15.37%	29.20%	0.74%	45.91%	3.79%
Water	1.26%	11.83%	1.00%	74.60%	11.08%	50.24%
Vegetation	34.83%	20.43%	2.13%	0.53%	40.60%	1.47%
Others	11.74%	3.18%	30.93%	19.68%	34.23%	0.24%

TABLE III
LAND USE CHANGE FROM YEAR 1999 TO 2009

	Bare soil	Built up land	Wetland	Water	Vegetation	Others
Bare soil	78.68%	4.86%	0.02%	0.03%	16.41%	0.00%
Built up land	58.59%	20.38%	0.96%	0.72%	19.32%	0.02%
Wetland	20.46%	2.95%	31.88%	0.87%	43.53%	0.01%
Water	4.19%	3.08%	2.14%	80.31%	10.24%	0.04%
Vegetation	45.12%	3.52%	3.05%	0.73%	47.55%	0.03%
Others	46.45%	6.07%	8.80%	0.51%	38.12%	0.05%

TABLE IV
LAND USE CHANGE FROM YEAR 1987 TO 2009

Bare soil	Built up land	Wetland	Water	Vegetation	Others	
Bare soil	76.42%	4.19%	0.67%	0.14%	18.56%	0.01%
Built up land	51.77%	33.98%	0.36%	0.51%	13.37%	0.00%
Wetland	28.90%	1.41%	31.94%	1.24%	36.38%	0.13%
Water	2.75%	2.35%	1.02%	80.91%	12.92%	0.05%
Vegetation	44.78%	5.32%	1.88%	0.81%	47.19%	0.01%
Others	12.22%	0.86%	24.45%	5.01%	57.33%	0.12%

From 1999 to 2009, 58.59% of construction land changed to bare soil; this is due to the introduction of the Kigali city planning, the planning redesign and reorganization of scattered settlements, to a certain extent to curb the process of urbanization. Decrease in construction land from 2009 to 2009, 43.53% of the wetlands and 38.12% of the other sites were changed to vegetation. In addition, grazing and vegetation growth replaced some unused land. It is also because the Kigali municipal government had to find the right place to reorganize the scattered settlements, 46.45% of the other land changed to bare soil.

Overall, the results from 1987 to 2009 (Table II) show that 51.77% of construction land and 44.78% of the vegetation are changed to bare soil, the leading cause of this change is due to the 1994 genocide when a large number of houses, roads and bridges in Kigali were destroyed. In 2009, due to the implementation of the urban planning policy introduced by the government, redesigned and reorganized scattered settlements, as well as the planning process of urbanization, and thus curbing the increase in bare soil.

V. DISCUSSIONS AND CONCLUSION

The Driving Factors of Land Use Change: As the capital of Rwanda, Kigali must experience an expansion of the city area, increase the internal employment rate and attract international investment in commercial, industrial and service sectors, to enhance their economy, but also must make prevision for present and future residents, which will continue to rise as the population grows, increasing the need to provide accommodation and activities. The overall planning of Kigali City takes into account environment, land use, infrastructure, cultural and socio-economic factors, and predicts economic and demographic development and provides opportunities and constraints for urban development. To achieve the above objectives, the government has set different stages for the Kigali City Master Plan and described in detail the design, strategy and action programs that will guide the planners and citizens of Kigali City to have more detailed areas in the future planning and practical measures [24]. Thus, changes in land use significantly represent the important role that human activities play in the Kigali region. In addition, taking into account the natural situation of the city of Kigali, agriculture in the region does not occupy a dominant position, and with the population growth and socio-economic development, construction land area will gradually increase, and the process of urbanization will accelerate.

From 1999 to 2009, the Kigali City, after the 1994 genocide, led to a shift in land use due to factors such as urban renewal and population movements. Our findings show a significant increase in construction land between 1987 and 1999, and the reduction in green area due to the implementation of urban renewal after the 1994 genocide. Between 1999 and 2009, as the Kigali government developed a city master plan, the demolition of all buildings outside the planning area resulted in a reduction in construction land. It can be seen that as a developing country, Rwanda's population continues to grow and land use is low and urbanization is still at a low level. As mentioned earlier, factors such as genocide,

population growth and urbanization have led to drastic changes in land use; thus, future research focuses on further collecting data on the natural, social and economic data of the Rwandan region and the driving force analysis of land use change.

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