

GIS-Based Monitoring of Forest Changes for Sustainable Management in Rwanda

Jean Paul Muzezayo, Lamek Nahayo*, Egide Hakorimana

Faculty of Environmental Studies, University of Lay Adventists of Kigali, Kigali, Rwanda

Abstract

The use of Geographic Information System (GIS) is important, almost in every field since it enables users to efficiently and accurately collect the spatial data and ensure their monitoring. The Bugesera district similar to other parts of the eastern Rwanda suffered the impact of serious prolonged drought from 1999 to 2000, and such famous disasters are mostly provoked by climate change triggered by forests degradation as one of the most causes. This raised the concern of community forestry management through afforestation and re-afforestation in Bugesera district. The authors recognized this fact and then chose to assess the benefits and challenges associated with GIS application in forest management mainly in Bugesera district as the case study. The results approved the potentiality of GIS in the monitoring and management of forest since it helped the authors to detect change on forest cover which was recorded from 2000 to 2020. The recorded change on forest cover was mainly attributed to rapid growth of human population and development of infrastructures. From the findings of this research, it can be noted that GIS helps to analyze the change detection of forest cover, monitoring of the available forest resources. The technology also, can help policy makers to understand local communities' contribution to forest degradation and best ways of involving them (its local knowledge) in the planning and management of how to exploit forest resources.

Keywords

Bugesera District, Forests Sustainable Management, Monitoring, Rwanda

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1. Introduction

The Geographic Information technology (GIS) and its associated techniques can be approached by users in order to ensure smooth planning, management and decision making processes as well. The management of forest resources due to multiple uses of forest and related challenge in their management. This expresses the need of applying appropriate technology mainly GIS, which can help in the formulation of policies of forest conservation and management processes [1, 2]. The GIS can help to obtain accurate information which helps forest users and managers to record updates on planting, inventories, harvest record and future planning as well. In addition, GIS can help its users to create regular

databases which facilitate preparing the work plan, conservation of the wildlife and conservation of the soil as well [3, 4].

The study of Sherrouse et al. [5] and Karisa Kane [6] suggested that GIS can be used to provide a wildfire management probability model by utilizing the data layers including not limited to the availability of water, topography and weather, forest ecology and access route. Accordingly, with popular computer access, GIS is increasingly facilitating the management of natural resources including forests [5, 6]. This can result from the fact that forest owners consider different aspects from plantation to harvest which GIS application can make the task more easy and successful. These include the biodiversity, water and soil conservation.

* Corresponding author
E-mail address: lameknahayo@gmail.com (L. Nahayo)

[6].

In Rwanda, a forest cover mapping exercise done in 2012 with intervention of GIS technologies illustrates the spatial distribution of forests among provinces and their categorization by forest types [7]. Forests covered an area of 673,516.80 ha equivalent to 28.28% of the total land area, where the Eastern province has the largest share of Shrubland (258,403 ha) comprising Bugesera District as the area under consideration by this research [8, 9]. In the beginning of 1980, rapid population growth put pressure on marginal forests in terms of encroachment and deforestation. This was associated with poor management of forests and land conflicts, which 1990s led to forest reduction. And high reliance (about 0 percent) on forest resource products for cooking; wood construction; handcraft and clearing forest for agricultural activity lead to deforestation [10, 11].

Sustainable Forest Management concept has been initiated to address many problems relating to deforestation, especially those in developing countries. In the exercise of protecting forests, either from fire, diseases and pests, or other human actions, availability of spatial information is useful in the

design and implementation routines [12-14]. This thus, expresses how much GIS application in forest management is general prerequisite in the collection/gathering, analysis, presentation/interpretation and sharing of information on forest cover and forest management [14, 15]. Therefore, the researcher chose to apply GIS in monitoring forest change for sustainable forest management in Bugesera district of Rwanda.

2. Methods and Materials

2.1. Description of the Study Area

This research was conducted in Bugesera district which is one of districts of the Eastern Rwanda. The northern part of the district borders with Nyarugenge and Kicukiro Districts of Kigali city. It borders in West by Kamonyi, Ruhango and Nyanza districts of Southern province, Ngoma and Rwamagana in the East and also Republic of Burundi in the South of Bugesera. In this district, both the savannas densely shrubs and grassy savannas dominate the hills, dry and trays of the hills in the study area [16, 17].

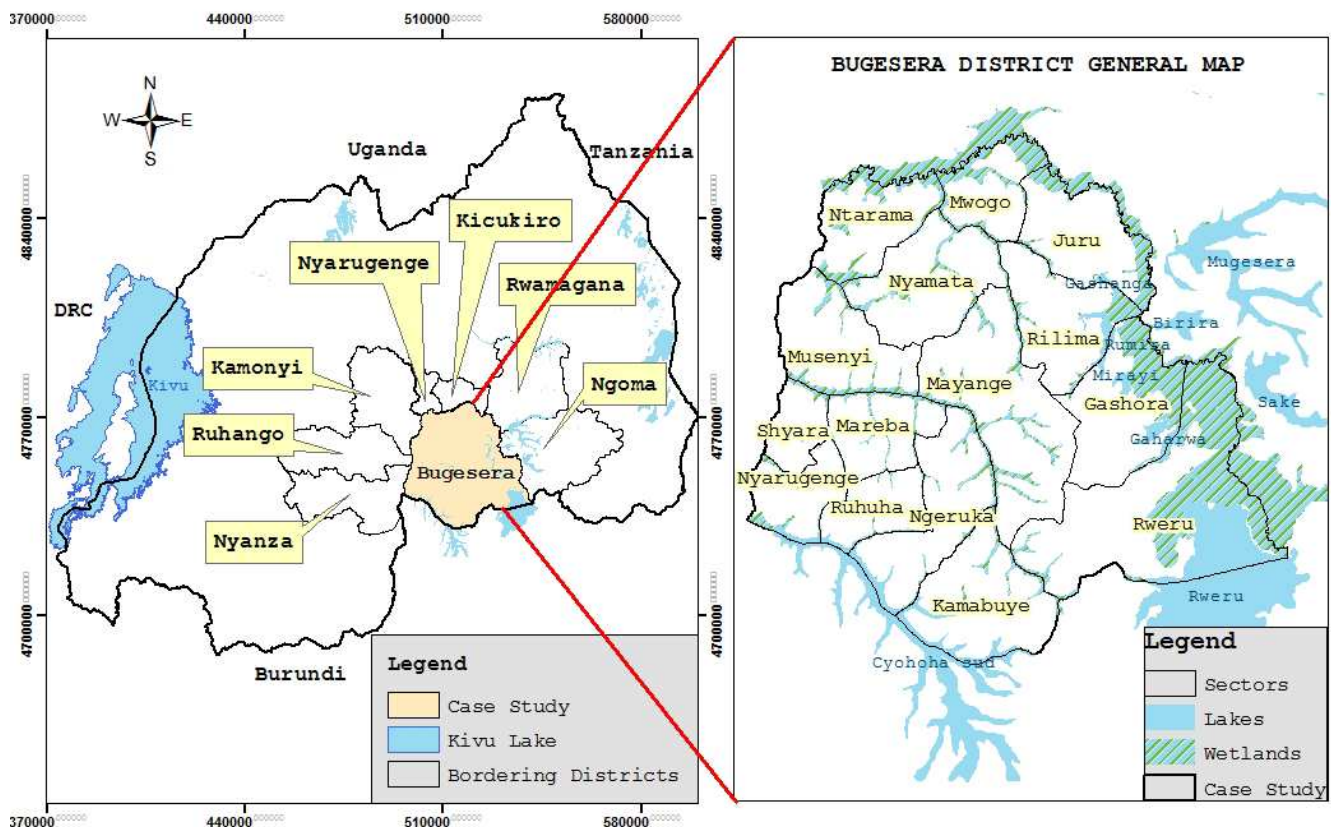


Figure 1. Map indicating the location of the study area.

The mixture of plateau and an altitude varying between 1,100 and 1,780 m characterize the topography of Bugesera district. The area is featured by dry savannas of shrubs, short grasses and trees under arid and semi-arid conditions

[16, 17].

2.2. Types And Sources of Data

In this research, geoprocessing tools have been performed on

Another part of data used by this study were collected from different websites in charge of forests management in Rwanda, including, not limited to the former Ministry of Land and Forests (MINILAF), Rwanda Environment Management Authority (REMA) and Bugesera district' website.

2.3. Data Analysis

Data analysis was completed by using qualitative data through GIS technologies. This analysis helped the authors to identify changes in forests of Bugesera district from 2000 up to 2020. This analysis has been initially computerized and processed by using ArcGIS 10.7.1 version.



3.2. GIS in Monitoring Forest Resource

By using the ArcGIS software, version 10.7.1, through image classification of the different periods, it was noted that forest cover in Bugesera district has been changed. The results in Figures 3 indicated that the largest forestland in Bugesera district was distributed in Mayange, Kamabuye and Gashora sectors.

The remaining sectors recorded low forest cover, and this be attributed to the fact that as long as people have been coming to settle in Bugesera district the forest was cut off in search

for cropland and areas to settle in which led to this reduction in forest cover.

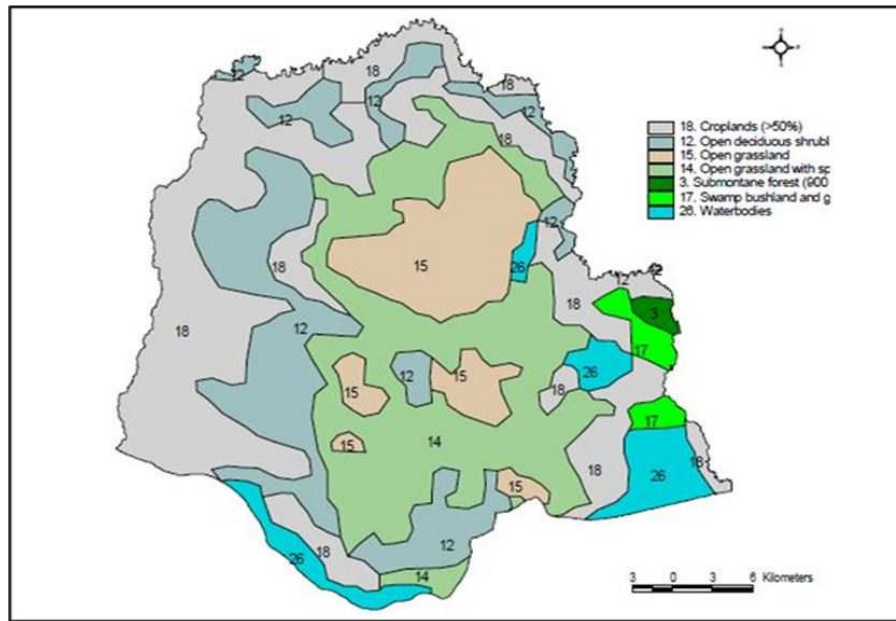


Figure 3. Bugesera Forest Cover type in 2000.

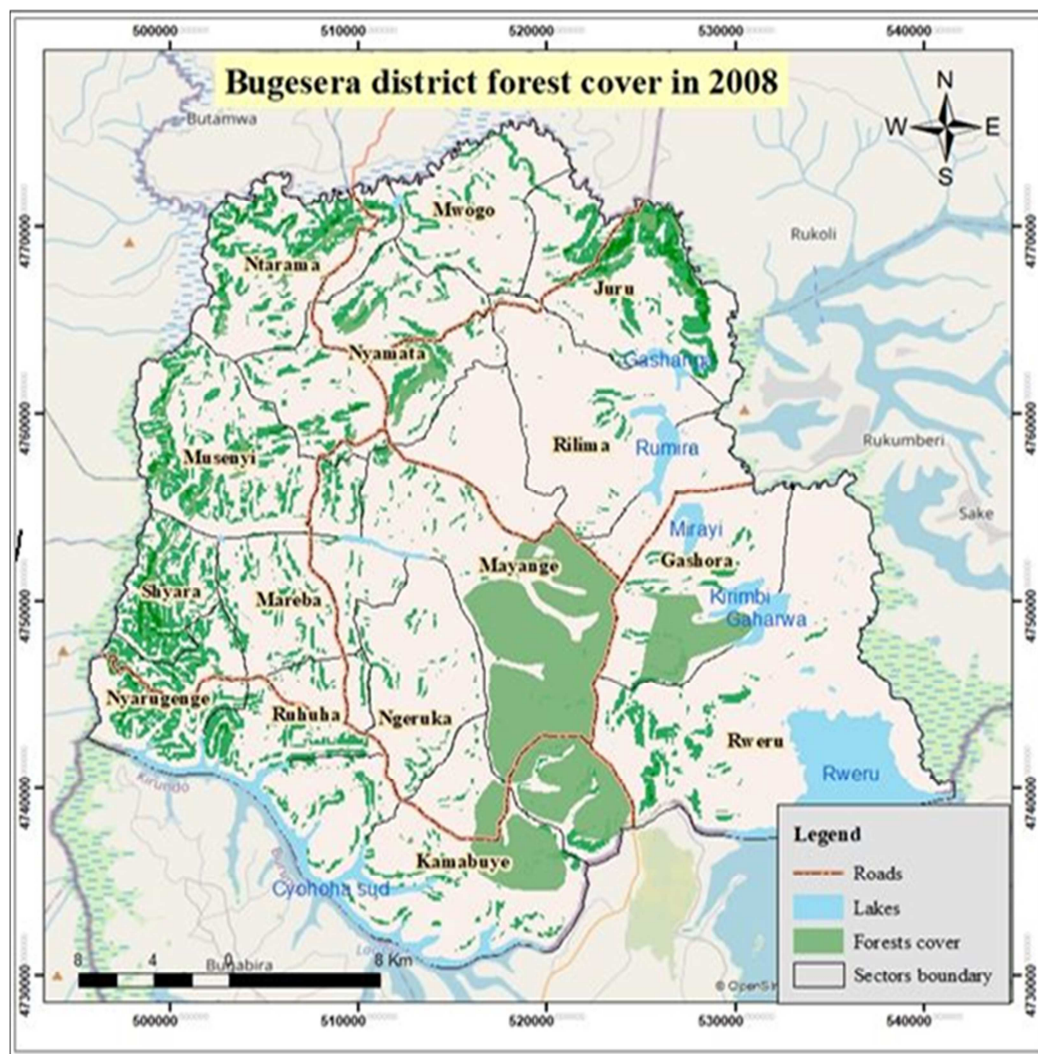


Figure 4. Bugesera Forest Cover in 2008.

However, the results in Figure 4 indicated that forest cover increased at large extent compared to that of 2000. This was mainly resulting from the Government initiatives of restoring forests in Rwanda. The policy aimed to enlarge forest cover by planting new trees, conserving existing forest, empowering agroforestry and afforestation policies.

The results in Figure 4 showed that Gashora, Mayange and Kamubuye sectors remained the largely forested sectors of Bugesera district. However, sectors like Ntarama, Mwogo, Gasenyi, Nyarugenge and Shyara which were under very low forest cover in 2000 (Figure 3) recorded very large increase in forest cover. Nevertheless, sectors of Ngeruka and Rilima which registered low forest in 2000 remained under forest as well in 2008. This again can be attributed to the local weather of Bugesera district (high temperature talking too long over the year), thus not allowing trees to grow in some areas of the district since some parts of the district are still facing water

shortage and crop failure as well.

Finally, as indicated in Figure 5, the forest cover reduced from 2008 to 2020 at high speed. This can be mainly attributed to reason that within these 12 years, the district has recorded rapid growth and high number of migrants from different district came to locate within the district looking for better place to settle in.

This can be associated with the fact that forests are important natural resources for human life and environment in general. For this reason, the forests should be well managed and protected in way that they provide their useful functions to humans and biodiversity. Therefore, as shown in Figure 5, it is good to mention that forest management in Bugesera has been challenged by many factors including human factors and lack of enhancement of forest regulation which lead to forest degradation.

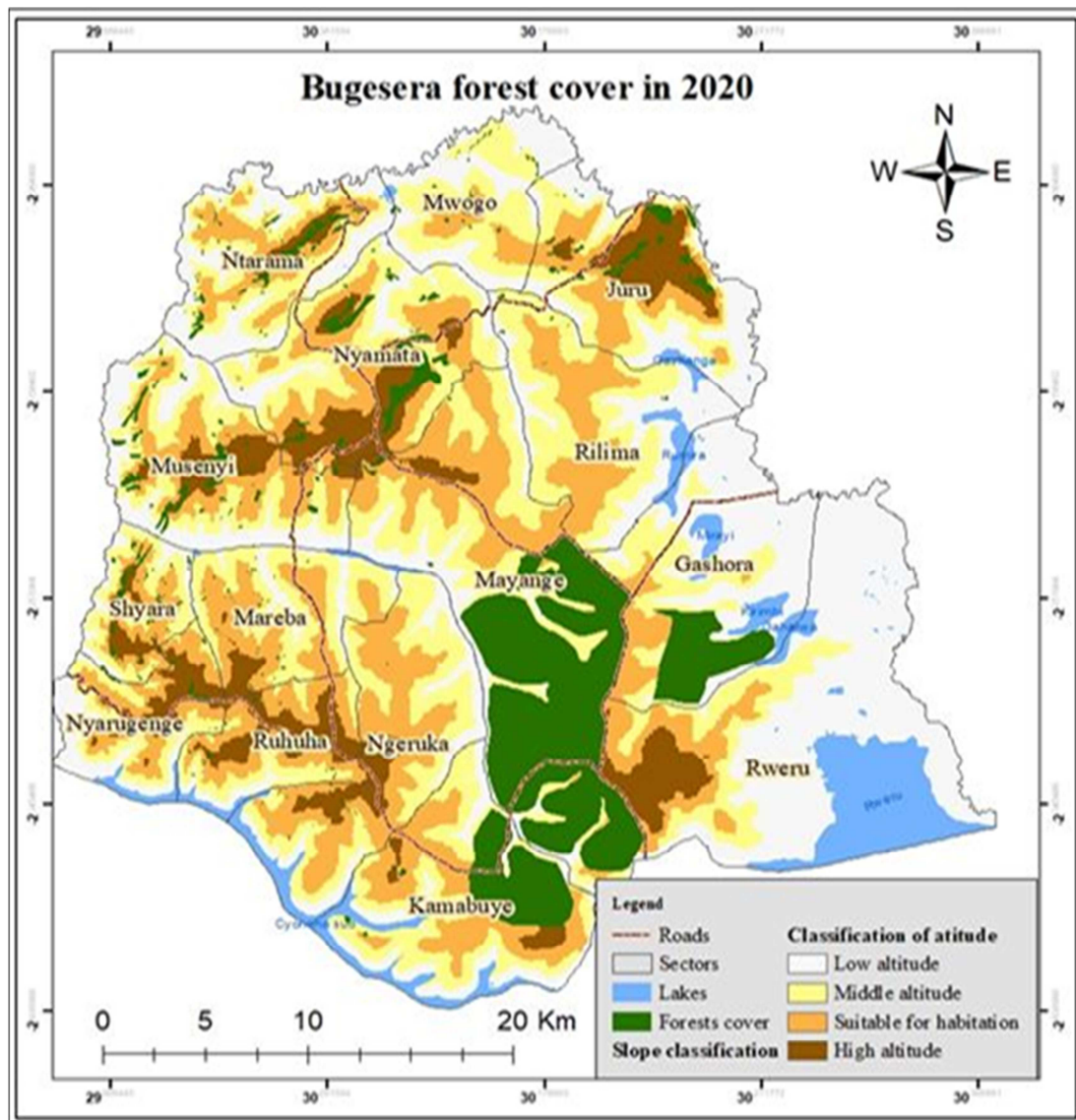


Figure 5. 2020 Bugesera forest cover.

3.3. Forest Suitability Analysis in Bugesera District

The district of Bugesera records varied biodiversity and ecosystem formed by forest, wetlands, lakes and rivers. The district's inhabitants merely depend on these ecosystem and biodiversity for daily survival primarily farming, crafting making and fishing [16].

Nevertheless, this region registered drought and famine

which led to poverty among people as a result of ecosystem degradation and the declining ecosystem services [16].

The authors took into consideration the facts mentioned above and then after mapping forest cover from 2000 to 2020, they judged it necessary to indicate forest suitability in Bugesera. As shown in Figure 6, it was noted that Juru, Musenyi, Ruhuha, Nyarugenge and part of Rweru sector are the best suitable areas in which forest can be planted.

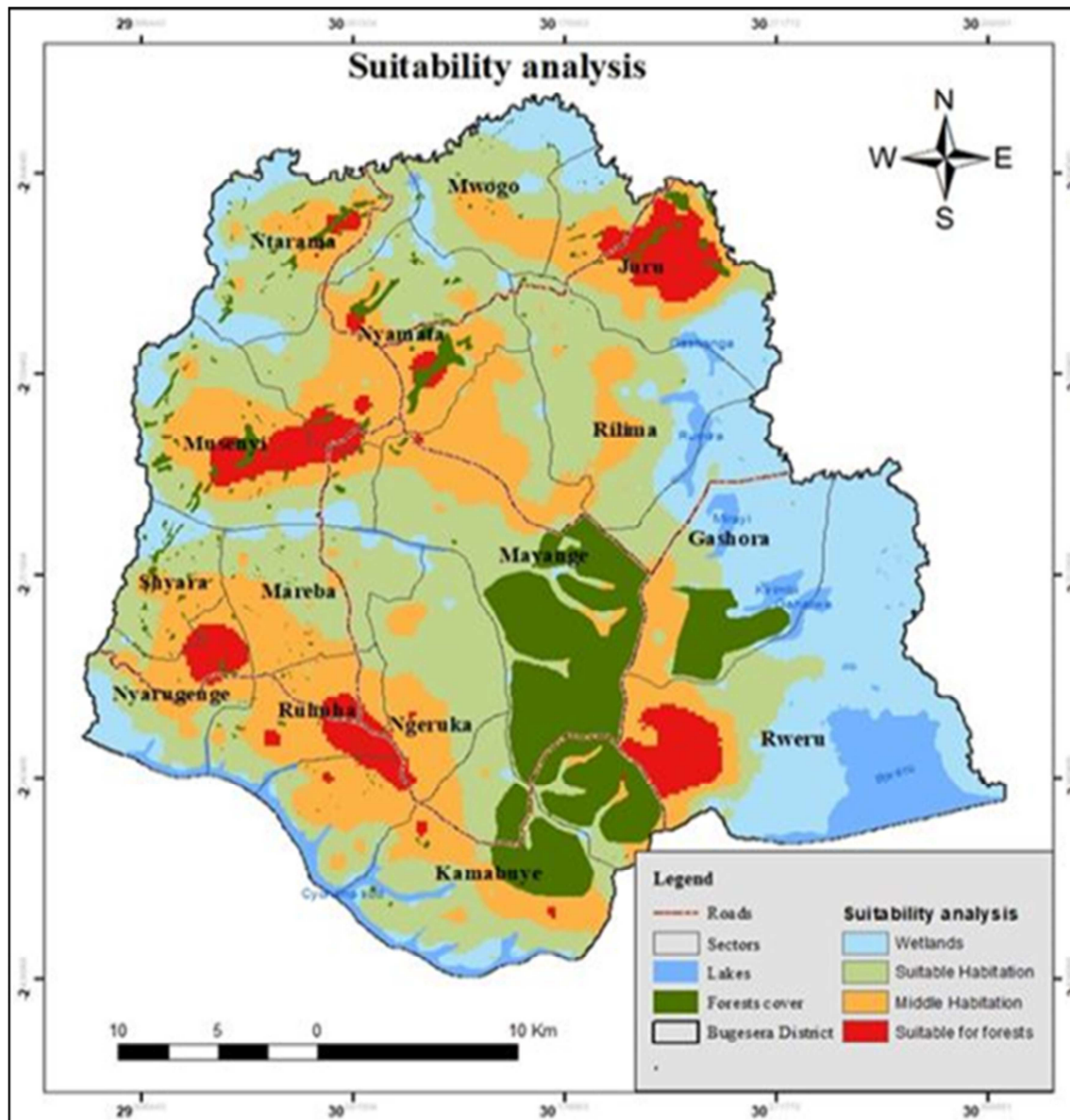


Figure 6. GIS based in mapping forest cover and suitability analysis.

4. Conclusion

This study applied the Geographic Information System (GIS) to map forest cover change in Bugesera district of the Eastern Rwanda from 2000 to 2020. The results indicated that in 2000 the forest cover was low compared to that of 2008

where almost all sectors of Bugesera recorded increased forest cover. However, in 2020, the forest cover dramatically reduced compared to that of 2018. Thus, within the last 12 years, forest registered decrease in forest which was mainly attributed to high population growth recorded by Bugesera district in association with migrants from others parts of the

country in search for areas to settle in and cropland as well. Although GIS can be used for forest management in Bugesera, there is need of integrating other policies to solve the problem of deforestation in this area. The policies include laws and regulations enforcement, strong community engagement, mobilization and capacity building, alternating ecosystem management strategies, and sharing the resulting revenues to motivate the conservation and management.

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