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Hydro-Geospatial Characteristics of Potential Irrigable Lands of Bugesera Region, Eastern Rwanda

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A B S T R A C T

Climate change constitutes a significant constraint to agricultural development and fruition through perturbation of rainfall. Areas located in the eastern part of Rwanda are more vulnerable than other regions of the country, owing to their topography, geology and climatology. Comprehensive hydro-geospatial information will unveil its potential irrigation capacity and further suitable irrigation solutions for the region. This study aimed at mapping the hydrological and geological characteristics and other geospatial features of irrigable lands of Bugesera region, in the Eastern Province of Rwanda, using remote sensing and geographic information system's tools. The methodological approach consisted of processing Aster radar satellite image of 2006 and a topographic map of 1998 to enable designing a Digital Elevation Model (DEM) and producing different types of map layers using appropriate software packages (ILWIS 3.3, Erdas 8.7 and ArcGIS 9.2). These maps were interpreted to describe and classify lands by slope, water proximity, percentage of clay and sand in the soil, and land use/ cover types. This will further assist to determine the most suitable areas for irrigation and derive the characteristics of potential irrigation methods for each land. This is a useful planning tool for optimizing agriculture development in the Eastern Region of Rwanda

Keywords: *Spatial information, Aster Image, Digital Elevation Model, irrigation.*

INTRODUCTION

Evaluation of the impact of land use and land cover change on the hydrology, and thus irrigation, in tropical catchments has gained much interest since the last century. Researchers are mapping selected land use types using classified satellite images to understand the nexus between land use/ cover change and surface/ atmospheric water cycle processes and their parameterization in the management of irrigation schemes, agriculture and ecosystems (Forrester, 2007; Maeda, 2010; Luwesi, 2011; Getachew and Melesse, 2012; Ngonzo, 2013; Akombo, 2014). Vegetation vigour is generally quantified by the trends of Normalized Difference Vegetative Index (NDVI) to assess the impact of land use/cover change on sediment yield, surface runoff and streamflow within the catchment area (Mango, 2011; Maeda, 2012; Ike and Eludoyin, 2013; Mkaya . 2013). This hydrological effect of land use/cover change has been further linked to the impacts of climate change, which sometimes is evidenced by the cycle of El Niño (flooding) and La Niña (drought), and in the unpredictability of rainfall patterns in many areas (Crowley and Kim, 1996, Mann, 1998; Crowley, 2000; Ngonzo, 2010). This perturbation of rainfall constitutes a significant constraint to water security and agricultural development and fruition (Mathenge, 2014). It increases farmers' vulnerability to drought in some areas

(Luwesi ., 2012). The Republic of Rwanda is among such vulnerable countries of the globe due to its topography and agro-climatology (FAO, 1995; Mann, 1998; O'Brien and Leichenko, 2000).

Rwanda is Africa’s most densely populated country, with roughly 80% of its population (8.0 out of 9.9 million in 2008) living in rural areas (Mushinzimana, 2012). Furthermore, demographic growth puts pressure on food security, natural resources and adaptation to the effects of climate change. The Eastern region of Rwanda has been more vulnerable to drought over the last three decades as witnessed by Verdoodt and Van Ranst (2003). The region is recognized as the hottest and driest of Rwanda. Its agro-climatic patterns range from very poor to fairly moderate suitable agricultural lands due to annual rainfall limitations. Consequently, the agricultural development of this region is generally low and is substituted by dominant pastoral activities. Irrigation being the most feasible alternative to rainfed agriculture, it is adequate to interrogate the hydro-geospatial characteristics of the lands of the eastern region of Rwanda (Bathgate and Duram, 2003). This hydro-geospatial information will enable comprehending soil water holding capacity and its irrigation potential and suitability for feeding the whole region (Dobos ., 2000). In addition, hydro-geospatial information will also enable determine opportunities and threats for irrigation decision-making, and thus channel new strategies in support to the Rwandan Vision 2020, Economic Development and Poverty Reduction Strategy (EDPRS) and National Agricultural Policy (FAO, 1992; MINECOFIN, 2002; MINAGRI, 2008).

This paper presents topographic, geological and agronomic patterns of irrigable lands of the Bugesera region of Eastern Rwanda. Prior to presenting and discussing these findings, a short description of the materials and methods used to that effect is provided below, followed by a conclusion and recommendations.

MATERIALS AND METHODS

Study area

Geographical Characteristics

Bugesera region is located in the south-eastern plains of the Eastern Province of Rwanda. The region covers a total area of 1,303 Km^2 represented by latitudes 2°01’55’’ S and 2°24’45’’ S, and longitudes 29°56’50’’ E and 30°23’19’’ E (Figure 1).

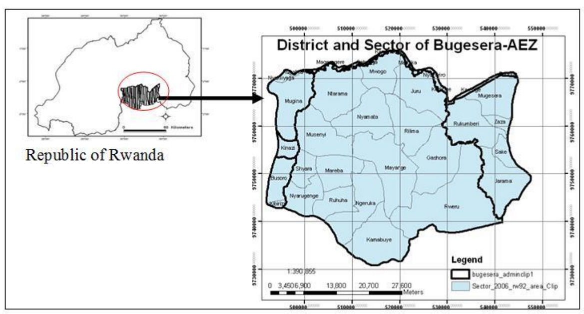

Figure 1. Bugesera District from the map of Rwanda (Adapted after CGIS)

It is sandwiched between the Republic of Burundi to the south, Lake Rweru to the south-east, Lake Cyohoha to the south-west, Nyabarongo River to the North-East, and Akanyaru River to the west (Haboubacar, 2006). The Bugesera region neighbours Nyamata region to north, Gashora region to the east, and the regions of Ngenda, Nyamure and Ntongwe regions of the southern province to the west.

The Bugesera region is largely a plateau rising at an altitude ranging from 1,323 to 1,544 m. The landscape consists of a very broken relief consisting of a range of hills and borders the fluvial depositions of the Nyabarongo. However, just like in any area of Rwanda, the climate may be hotter and drier depending on the region’s rainfall limitations. The eastern region receives average annual rainfall of about 850 to 1,000 mm, falling in a bi-modal rainy season. The region experiences 7 months of drought and average temperatures of 21°C. This climate is acknowledged as to be too dry for optimal plant growth and agriculture suitability for development (Verdoodt and Van Ranst, 2003).

Population and Human Development

The population of Bugesera region is mainly constituted by the Hutu and Tutsi tribal groups. This population amounted to 266,775 people in 2006, with an average household’s size of 5 people (District de Bugesera, 2006). The population density ranged from densely populated in rural areas of Ruhuha (a cross-border trade centre shared with the Republic of Burundi), to fairly populated in urban areas of Nyamata. Most of the people are agriculturalists and livestock keepers, even though nearly 60% of households own less than 1 hectare of land (FEDRA, 1994). A majority of people earn their living through exchange of their unskilled labour with food, either directly (through food for work) or through a remuneration that enables just purchasing foodstuffs from the market (IRIN, 2003). The most vulnerable groups are female and child headed households, elderly and lonely people, who usually depend on food aids (UNEP, 2007).

Finally, Bugesera region disposes of widespread road network that connects all the sectors and villages ("Imidugudu"). Though most of sectors and cells do not have tarmac roads, they are however accessible and well maintained by the local administrations (Mushinzimana, 2012). The main centres are regularly supplied with electricity, tap water and telecommunication, the big centre of Ruhuha having both landlines and mobile telephones. National and private schools, a referral Hospital situated in Nyamata town and small health centres registered in different sectors provide education and healthcare to the whole region. These institutions have sustained human development in this region (Bizimana, 2007).

Data Sources and Processing

Topographic data for mapping the irrigable lands of Bugesera region were gathered from ASTER Radar Satellite Images of 2006 and the 1988 topographic map of Eastern Rwanda (scale = 1:150,000). These data were obtained from the Centre of GIS of the National University of Rwanda (CGIS -NUR). The image was already geo-referenced and corrected for sensor irregularities, while the toposheet needed to undergo such a process to enable digitization of land use/ cover types found in the region. This particular aspect required the generation of slope gradient terrain parameters from topographic information. ILWIS Academic 3.3 was thus utilized alongside ERDAS Imagine 8.7. Thereafter, ArcGIS 9.2 software enabled the overall mapping process (Figure 2).

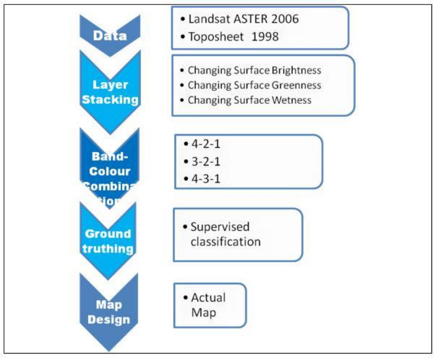

Figure 2. Flow chart for the mapping process (Adapted after Getachew and Melesse, 2012)

Digital Elevation Model (DEM) was derived from the Shuttle Radar Topography Mission (SRTM). This encompassed high-resolution radar elevation data from a global digital topographic database. The SRTM generates consistent, comprehensive topographic data and radar images to model the terrain and map the land of most of the inhabited surface of the Earth (Dobos ., 2000; Bathgate and Duram, 2003). The SRTM used in this study was still acquired from the CGIS- NUR.

RESULTS AND DISCUSSION

Topographic Characteristics

As said above, the Bugesera region is a large plateau located at an altitude of 1,323 to 1,544 m. It borders the fluvial depositions of the Nyabarongo. The topography is not very broken, half of the surface having very gentle slopes, the steepest ones ranging between 25 to 55% (Figure 3).

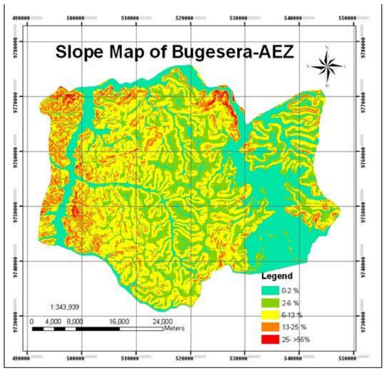

Figure 3. Slope map of Bugesera region

Altitudes rise from East to the West. The landscape consists of 3 types of hills: (1) hills with tops more or less rounded in the shape of dome; (2) hills with long and steep slopes; and (3) acute tops and hills that are like croups rounded of small tops out of sugar loaf. These hills often have the pace of peak and culminate at variable altitudes (Figure 4).

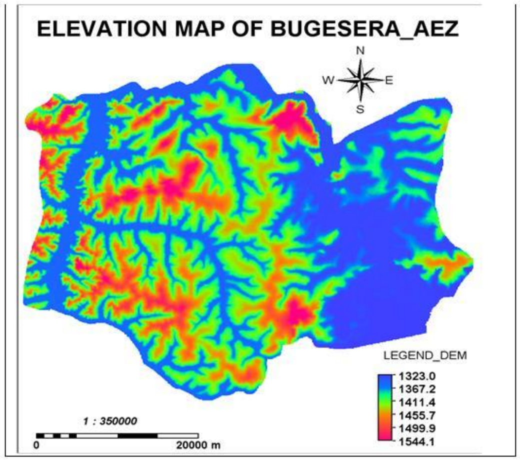

Figure 4. Elevation map of Bugesera region

Geological Characteristics

Dark schist intercalated by quartzite features the geology of Bugesera region. There are granites level on the slopes of the tabular hills covered by materials drifted from schist and quartzite. Figure 5 and 6 show that the soils in Bugesera region are generally little or fairly deep, well drained, clayey, sandy clay or sandy silt.

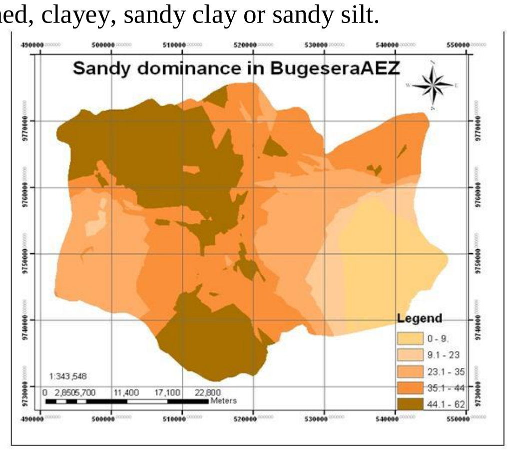

Figure 5. Soil texture map of Bugesera region with sand dominance

Figure 5 indicates that the bottom of the slopes have mixed clayey and sandy texture underground. In such conditions, land degradation is inevitable. Soil erosion is severe in the west highlands and moderate to low in the central plateau and eastern plains, respectively. Farmland status ranges from advanced to very advanced degraded lands.

Moreover, the underground rocks are characterized by accumulation of iron oxides in the hard layer. This is explained by the succession of wet periods by dry ones during which occur high evaporations that lead to cementing. During the wet seasons several components are carried deeper underground by several meters, while high evaporations occur during dry periods thus leading to cementing of boggy and argillaceous soils in deep valleys.

Figure 5 displays vertisols, which are featured by high mineral nutrients' content and very low organic compounds. They are hard when dried up and melt and become muddy during the rainy season. Sand-clay soils, which are suitable for construction and manufacturing of bricks are found at the edge of lakes, swamps and marshes. They are rich in humus and fruitful for agricultural production. This zone belongs to the basin of Akagera, relatively imperfect flattening, whose landscape is alike to an undulated plate with steep slopes towards the North-West. The slopes of the downhill are generally low and lie between 10 and 20%. The cashing of the largely widened valleys does not exceed 50 m.

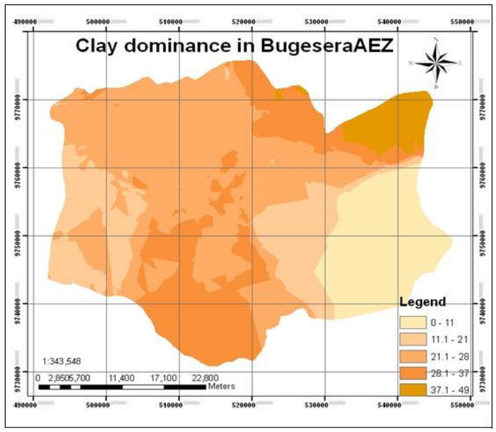

Figure 6. Soil texture map of Bugesera region with clay dominance

Hydrology

The Eastern region of Rwanda possesses abundant surface water, Nyabugogo River of Kigali and the Akanyaru River from the North-West environs discharging their waters into the Nyabarongo River. The latter flows towards the east in a deep valley broad of about 2 to 3 km. It forks then towards South-East then the South and shrinks back to 500 m towards the northern end of Bugesera (Rwinzoka), before widening up again into the depression of Bugesera. The latter forms the complex of lakes and marshes of Bugesera-Kisaka (Gashanga, Rumira, Mirayi, Kirimbi, Gaharwa, Mugesera, Bilira, Sake and Rweru) (Figure 7).

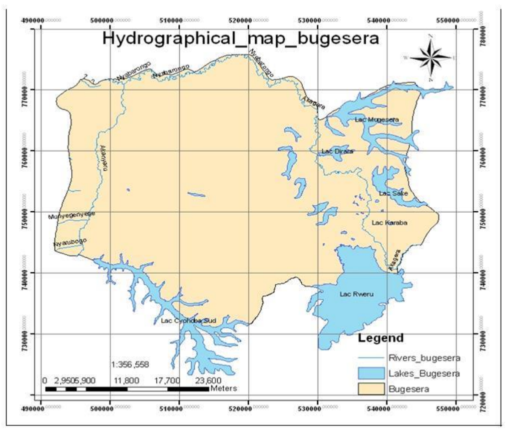

Figure 7. Hydrographical map of Bugesera region

Vegetation and Agricultural Land Use

Vegetation and agriculture suitability highly depend on the relief and the distribution of the rainfall. Just like any other agro-ecological zone of Rwanda, the eastern region experiences hot and dry climates due to its rainfall limitations (Figure 8).

The region experiences 7 months of drought and is too dry for optimal plant growth. The land is also strongly threatened by erosion leading to high depletion of soil fertility. In such agro-ecological conditions, agriculture development ranges from very poor to moderately suitable (Verdoodt and Van Ranst, 2003).

In general, Figure 9 shows that vegetation cover in Bugesera varies from poor to good (30 - 50%) in the valleys and on the hilltops, and very poor (< 30%) on hillsides, mainly due to soil erosion. However, there is vast vegetation diversity from the dense forests in the west to the semi-arid savanna in the east through assorted types and varieties of healthy wood and fruit trees in the central plateau.

Owing to its increasing population pressure on the natural vegetation, most of forests in the Bugesera region have been converted into agricultural lands. Hence, the natural vegetation that found in the region has been depleting over years. It mainly comprises of drought resistant plants and specific grassy species such as Asparagus falcatus, Aloe dawei, Rhynchaosia minima among others and of woody dominated by Acacia spp., Euphorbia spp., Cactus, Cyperus papyrus, Grevillea robusta, Pinus (Bizimana, 2007).

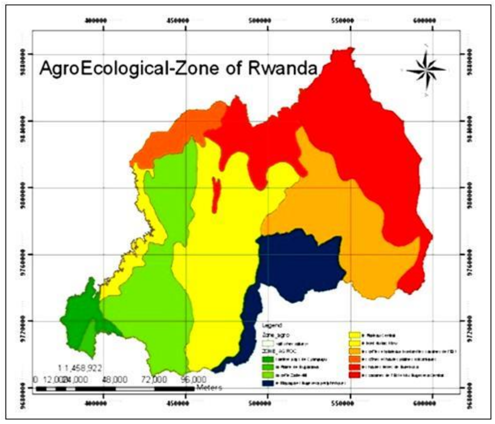

Figure 8. Agro ecological Zones of Rwanda

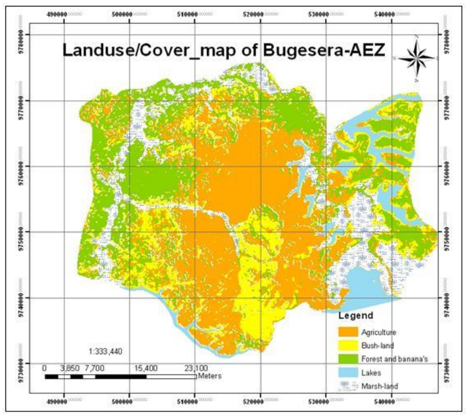

Figure 9. Land-use land cover map of Bugesera region

The region is dominated by savannas in the lowlands, grasslands in the dry valleys and the plates of hills, and shrublands covering the hills. In addition to the savanna graminaceous and thorny bushes, a vegetation of steppe type grows in the region and mainly encompasses acacias, euphorbia, and cactus. Galleria forest covers alluvia plains at the edges of lakes, swamps and marshes, which are stagnant waters of the puddle pools. It is represented by association of Acacia siberiana (“umunyinya”) and other species such as “umuko”, “umuvumu”, “umusave”, “umusasa”, and papyrus (“urufunzo”). These vegetations are rich in humus and strongly desired by pastoralists in search of better pastures. The grassy savannas found in the dry valleys and plates of hills are predominantly made of botriochlora, hyparrhenia filipendula, sporubulus pyramidalis, themeda triandria species. Shrubby savannas are scattered among the above vegetations and include various types of strewn shrubs and grasses of the meadows.

Major crops practiced in the region compound of maize, sorghum, sweet potato, bean, manioc, groundnut, pineapple and banana. The farming system is mainly of traditional type and offers very little profitability. It is an extensive agriculture without rationalization, though new farming methods are gradually being introduced through vulgarization, field demonstrations and diffusion of selected varieties

CONCLUSIONS

This study was a methodological research for gathering, presenting and interpreting hydro-geospatial information that can be used to derive the characteristics of the most suitable lands for irrigation in Bugesera region of eastern Rwanda. It has given insight on the type of information needed by agriculture developers and political decision makers to determine and map the most suitable areas for irrigation within Bugesera region. This information includes a classification of slope from which different classes of irrigation may be derived, including surface irrigation (0-2%), sprinkler and drip irrigation (2-4 %), pressure irrigation (6-25%) and marginal irrigation (25- 55 %). The same process can be done for classifying soils (into clayey and sandy soils) and land use/ cover found in the region.

We wish that this hydro-geospatial information will assist agriculture developers and political decision makers to develop an integrated approach to create buffer zones for slope gentleness, water and road proximity, and soil fertility, which will generate critical information on the most suitable areas for irrigation in Bugesera region. By overlaying different kind of layers, it may be possible to detect and calculate areas of irrigable lands as well as the type of irrigation. That is why authors of this paper recommend further studies in that direction to produce a design model that can help Bugesera and other regions of Rwanda to adapt to rainfall fluctuation and aridity occurring in the course of climate change.

They also recommend participatory researches that include local populations and NGOs operating in Bugesera to achieve critical thinking during field data collection, generation and validation of results and enable their use at local level.

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