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Spatial information for determination of irrigable lands in Eastern Rwanda

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ABSTRACT
The present study aimed to map irrigable lands in Bugesera Agro Ecological Zone (AEZ) in the Eastern Province of Rwanda, using spatial information's. The related Concerns were to determine the suitable area for irrigation that can include all different parameters which influence irrigation. The methodological approach consisted of processing Aster Landsat and DEM; gathered by Radar Satellite acquired at CGIS/NUR, using appropriate packages-software ILWIS 3.3, Erdas8.7 and ArcGIS 9.2. Satellite image was used to determine land use and land cover classification of the study area and the DEM to determine slope classification. The results showed maps that are describing different type of layers classified according to purpose of irrigation, slope, water proximity, percentage of clay and sand and type of land use. Those maps helped to produce a model design that conducts us to determine the most suitable area for irrigation. The model designed would be used as a planning tool to optimize agriculture in the Eastern Region of Rwanda.

Introduction

Background

During recent years there has been much progress in understanding land surface-atmosphere processes and their parameterization in the management of land and water resources. This knowledge can be combined with the potentiality of Earth Observation observation techniques from space, which are able today to provide detailed information for monitoring agriculture and ecosystems.

In several countries, the lack of sufficient rainfall constitutes a significant constraint to sustainable of agriculture. One example could beof this situation concerns the Eastern region of Rwanda which has faced several periods of drought. In fact, Verdooth Verdoodt and van Ranst (2003) described the eastern agro-climatic region, including Bugesera included, as very poor to moderately suitable for agriculture due to annual rainfall limitations. It is recognized as the , like hottest and driest region of the countryRwanda.

The drought occurring from of 1998 to 2000 required emergency plans and strategies, among others, the development of an irrigation master plan. Irrigation is considered as the only mean of ensuring a constant source of water supply for agricultural needs. From a climatic point of view, this agricultural zone is dry and warm, characterized by an annual rainfall varying between 850 and 1,000 mm, a dry season lasting for three months and an average temperature of about 21 °C. Consequently, the agricultural potential of this region is generally low and pastoral activities are dominantthe region mainly has a pastoral use.

Despite many constraints to its development, agricultural sector has a number of potentials which, if adequately tapped, should lead to production intensification and improved value addeda better development. Such potentials include the favorable climatic conditions that are conductive to agricultural activities in Bugesera and thanks to which a wide variety of food, tree, cash crops, etc. (food crops, tree crops, cash crops, etc.) can be produced all the year round, even as and food stocks can be raised. The political will to modernize and professionalize agriculture as clearly expressed in the Vision 2020 document, the EDPRS and the Rwanda National Agricultural Policy, encourages the private sector to invest in agriculture, the modernized agricultural sector would occupy only 50% of the population of the country, so Irrigation takes a predominance place for the transformation of the agriculture and to achieve 2020 vision of the country.

Research Problem

Rwanda is an Africa's most densely populated country. Of its population of 9.9 million, approximately 8.0 million people are located in rural areas, and 1.4 million people are located in semi-rural and urban areas. Rwanda's policymakers are challenged by issues such as a lack of food security, demographic pressure, pressure on natural resources, and a concern for the effects of climate.

These issues have led policy-makers to search for strategy to improve food security and improve aggregate economic growth, while optimizing the use of natural resources.

The Eastern part of Rwanda in general and particularly the agro-ecological zone (AEZ) of Bugesera has a serious problems of dryness in general, but, agriculture in Bugesera agro-ecological zone is particularly affected by this problem ofrelated to drought.

Under the guidance of the 2020 Vision, Rwanda is adopting strategies to promote food and cash crop intensification and is investing in to support infrastructure. Irrigation was identified as one of the strategic actions to support intensification of crop production intensification. According to FAO (1995), the intensification of irrigation is one of the most important tools that Africans should give priority to over the next few decades.

Spatial information will help us to determine threats of obvious importance for decision makers. However those processes of determination and quantification take usually long-time and require an important investment in human resources and materials.

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In order to address this important issue, this study attempt to demonstrate the use of geographical (GIS) and remote sensing (RS) techniquesologies in handling several problems in relation with management of Lland and wWater resources. This implies management to identification of the most favourable areas to establish irrigation water infrastructure. GIS & RSThese spatial information techniques have got lot applicationsbeen largely applied in agriculture agricultural domain fields such as irrigation, and drainage, fertilization and in other related fields such as groundwater investigations, pumping, erosion, soil fertility, forestry, etc. These GIS and RS tools have a high advantage of being very cost- effective, they are and very efficient in time- and, energy- servingsaving.

Research objectives

Global objective:

The present study aims at identifyingto identify irrigable lands in Bugesera AgroAEZ-ecological Zone using spatial information techniques and suggesting for a type of irrigation with regard to physical environment of Bugesera region.

Specific objectives:

To do this, this study will:

1. To determine suitable irrigable lands based on combination of different layers that factor driven to specific irrigation type ;
2. To equip Eastern Rwanda with a spatial planning tool/model to optimize agriculture production ;

Research questions

1. To what extent the topography, soil type, land use can help to determine potential irrigable areas within the Bugesera AEZ?
2. Where are the most suitable areas for irrigation located in the Bugesera agro-ecological zoneAEZ of Eastern Rwanda?
3. Which type of irrigation should be used for each irrigation site identified?

Research hypotheses

1. Determination of each type of slope can conduct to determine irrigable area in Bugesera agro-ecological ZoneAEZ?
2. A Spatial model that matches the environmental structures such as soil, rainfall, topography to delineate the areas of potential irrigation possibilities, is be most appropriate for Eastern Rwandan prediction irrigable land.

Research approach

In Order to map the irrigable land in Eastern Rwanda, topographic information (DEM) gathered by Radar Satellite was taken at CGIS/NUR, processed using appropriate packages-software (ILWIS 3.3 and ArcGIS 9.2). Many layers (topography, hydrology soil, etc.) ware put into a spatial combination in GIS, to be able to describe and determine potential irrigable lands as well as type of irrigation, in Bugesera AEZ of Eastern Rwanda.

Material And Methods

Study area

Location

Bugesera Agroecological Zone is located in the south-east of the Eastern province of Rwanda (Figure 1). This area is delimitated in the North-East by the Nyabarongo River, in the west by the Akanyaru River. In the south, it makes border with Republic of Burundi from which it is separate in south-east by the Lake Rweru and south-west by the Lake Cyohoha (Haboubacar M, 2006). The study area lies between latitude 2°01'55'' S and 2°24'45'' S and between longitude 29°56'50'' E and 30°23'19'' E.

Climate

The climate in the Eastern region of Rwanda area is recognized as too dry for optimal development of agriculture. Verdooth Verdoodt et al.l (2003) describes the eastern agro-ecological zone, Bugesera included, as very poor to moderately suitable for agriculture due to annual rainfall limitations, like hottest and driest of the country. The annual average rainfall oscillates around 850 mm and 1,000 mm of which 7 months of the dry season left again over two seasons of rain and an average temperature of about 21 °C.

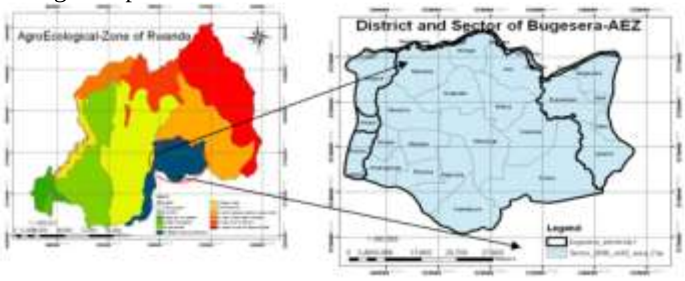

Figure 1: Map showing Bugesera Agro Ecological Zone

Topography

The topography is not very broken; half of the surface has very gentle slopes, the strongest slopes lie between 25 and 55% (Figure 2).

Figure 2: Slope map of Bugesera Agro ecological Zone

The hills often have the pace of peak and culminate at variable altitudes. Altitudes rise from East to the West. The landscape consists of a very broken relief, and includes 3 types of hills: hills at tops more or less rounded in the shape of dome, hills with long and strong slopes and acute tops and the some hills with overcome croups rounded of small tops out of sugar loaf.

The Bugesera is a large plateau located at an altitude of 1,323 to 1,544 m and bordered by the fluvial depositions of the Nyabarongo (Figure 3).

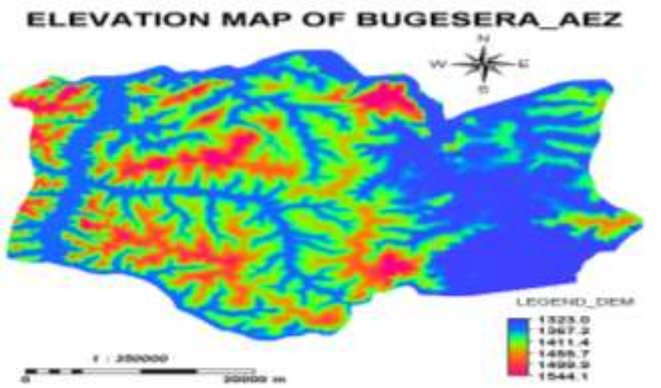

Figure 3: Elevation map of Bugesera Agro Ecological Zone

Soils

This area consists of subbasement with predominance of granite and gneiss; but we can observe there sometimes the influence of other rocks such as schist and quartzite (Neel, 1968). Soil degradation is from severe in the high hill ranges in the West (it is mostly due to severe soil erosion) to moderate in Central plateau and low in the eastern plains of the basin.

In the zone of Bugesera, there are granites level on the slopes of the tabular hills covered by materials drifts of schist's and quartzite. These grounds are generally little or fairly deep, well drain, clayey, sandy clay or silty sandy, presenting an advanced deterioration has very advanced . On the bottom of the slopes, deeper grounds meet, with clayey texture and sandy texture (Figure 4).

This zone belongs to the basin of Aakagera, relatively imperfect flattening whose landscape is that of a plate undulated with slope towards the North-West. The slopes of the downhill generally low and lie between 10 and 20%. The cashing of the largely widened valleys does not exceed 50m.

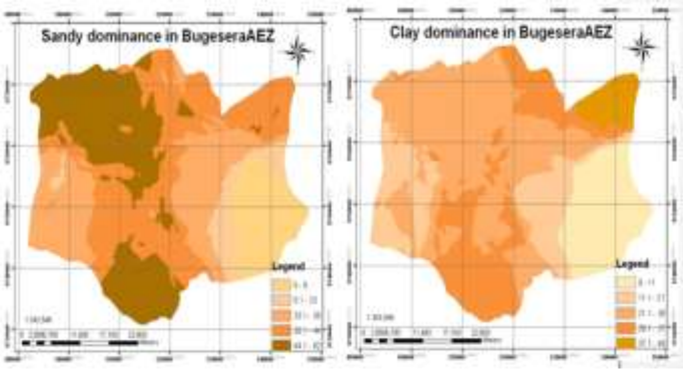

Figure 4: Soil texture (Sand and clay) map of Bugesera Agro Ecological Zone

Hydrology

The Eastern region of Rwanda possesses surface water in abundance, Nyabarongo River receives water of Nyabugogo upstream of Kigali. It receives then water of Akanyaru, surrounding the district of Bugesera on its western limit in the North-West of the district. It runs out then towards the East in a valley from 2 to 3 km broad. It forks then towards South-east East then the South via shrinking of 500 m has the northern end is of Bugesera (Rwinzoka) , before widening has new in the depression of Bugesera , forming the complex of lakes and marsh of Bugesera-Kisaka (Gashanga, Rumira, Mirayi, Kirimbi, Gaharwa, Mugesera, Bilira, Sake and Rweru) (Figure 5).

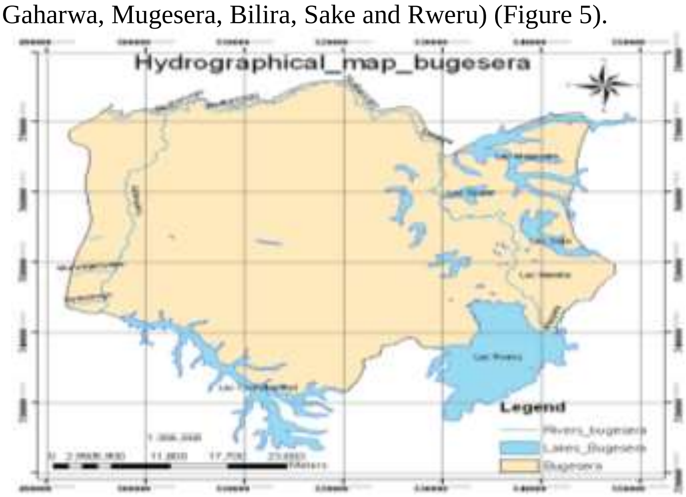

Figure 5: Hydrographical map of Bugesera Agro Ecological Zone

Agriculture and Vegetation and Agriculture

The vegetation varies with the relief and the distribution of the rainfall. In general, the vegetation covers are from poor to good (30 - 50%) in valleys and on hilltops and very poor (< 30%) on hillsides 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 (Figure 6).

The farming system is of traditional type offering a minimum of profitability. It is about an extensive agriculture without rationalization of the exploitation. However, the new farming methods are gradually introduced through vulgarization with model demonstration fields and diffusion of the selected seedsvarieties. The land is also strongly threatened by erosion. This erosion led, indeed, with the to strong depletion of soil fertility and to a degraded land.

Figure 6: Land-use land cover map of Bugesera Agro ecological Zone

The principal cultures practiced in Bugesera-AEZ are: the maize, sorghum, sweet potato, bean, manioc, groundnut, pineapple and the banana tree.

The natural vegetation found in the area is mainly made up of the formations tolerating the drynessplants tolerant to drought in particular the grassy species grassy likesuch as Asparagus falcatus, Aloe dawei, Rhynchaosia minima… among others and of woody dominated by Accacia spp., Euphorbia spp., Cactus, Cyperus papyrus, Grevillea robusta, pinusPinus. (Bizimana. A, 2007).

Inputs data and GIS and &RS packages

In order to map the irrigable land in Eastern Rwanda, topographic information with digital elevation models (DEM) gathered by Radar Satellite was taken at CGIS/NUR , processed using appropriate packages-software (ILWIS 3.3 and ArcGIS 9.2). Many layers (topography, hydrology, soil, etc.) were put into a spatial combination in GIS, to be able to describe and determine potential irrigable lands as well as type of irrigation, in Bugesera AEZ of Eastern Rwanda.

Digital Elevation Model (DEM)

The SRTM (Shuttle Radar Topography Mission) obtained elevation radar data in high-resolution digital topographic database of the earth. The SRTM generated consistent, comprehensive topographic data and radar images to model the terrain and map the land of most of the inhabited surface of the Earth.

For this study the SRTM of our area of interest was acquired at CGIS/NUR.

Satellite images

ASTER images of 2006 which completely cover the watershed were obtained for this study at CGIS/NUR. The table bellow gives the details of this image. This image has already been geo-referenced and corrected for any sensor irregularities.

Topographic map of 1988

The topographic map of 1988 (1/150.000) was also obtained at CGIS/NUR. This map provided the land use/land cover on that year whichwitch helped us to classify the land use and land cover of our study area.

Software used

ILWIS Academic 3.3

The particular aspect in this work was the generation of slope gradient terrain parameters map from topographic information. ILWIS Academy 3.3 contain a specific module, DEM Hydro-processing, which is related to terrain parameterization. For more information, (refer to ILWIS 3.3.'s User user guide.

ERDAS IMAGINE 8.7

ASTER imagery of 2006 and the topographic map of 1988 (1/150.000) were used as input data for land use and land cover change analysis. The analyses were done by image processing for the ASTER image and by digitalization for the topographic map using Erdas IMAGINE 8.7 and ArcGIS 9.2 software.

ArcGIS 9.2

This software was used for overlaying process. After acquiring slope classification from Ilwis 3.3 and land use land cover classification, those maps were combined into Arcmap with others maps.

Research Methodology

Flowchart of the research

A flow chart explaining the different steps of the research is displayed in Figure 7

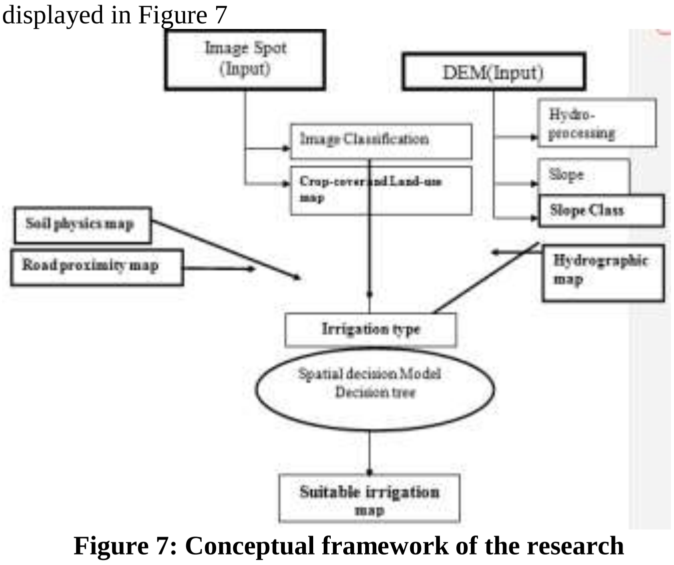

Figure 7: Conceptual framework of the research

Selection of suitable irrigation areas

To fulfill the task of building a database, a methodology was developed that is supported by GIS. A multi – thematic geo-database was compiled for Bugesera agro-ecological zone, with the following main layers (soil types, digital elevation modelDEM, topographical map, Hhydrographical layer, and land use and- land cover layers).

Once the geo-database is compiled, each of the layers can be used as decision variables. Next, a sequential of GIS intersections between the layers, desired areas (polygons) was selected and non-relevant areas were filtered out.

To select the optional irrigable land, which obey the conditions, a sequence of GIS intersections between the layers was performed in Arc GIS, and the suitable polygons was were depicted.

Digital Elevation Model Hydro-processing

The DEM is essentially a regularly-spaced matrix of altitude data. It is an essential layer for many GIS analyses and can be used to derive important characteristics of the land surface such a slopes, aspects and watersheds.

For this study, the DEM will be obtained from CGIS/NUR to provide elevation data. The Elevation contours map will come from DEM and the contour interval will be known for this study. Hydrological analysis method of the image processing techniques will be performed in ILWIS, ; the key input is basically digital elevation map (DEM) that is used to generate both slope gradient (in percentage).

Using linear filtering procedure, the first derivatives (DEM_dx, DEM_dy) respectively in X, Y directions per pixel were will be calculated.

• Positive values of DEM_dx in the output map mean that the terrain goes up from left to right;

• Negative values of DEM_dx in the output map mean the terrain goes down.

The slope gradient is then calculated using the formula in ILWIS command line as follow:

100 * HYP (DEM_dx, DEM_dy)/PIXSIZE(DEM)

Topographical data

The contour data of 25 m equidistance was acquired to generate different terrain parameters. This contour map was created in the same project as soil map. This map contained contour lines at an equidistance of 25 m. Digitalization of the topographic map data was realized by Arc GIS.

Decision support by overlaying function (Model Design)

This will be the logical framework that use different types of overlaying layers used to produce model design.

Land use and land cover change data

The method of land use and land cover detection by comparing classification was applied to identify land use/land cover changes using satellite image and topographic map. The analysis was done using Erdas 8.7 and ArcGIS 9.2 software.

Satellite image was classified using supervised classification and the topographic map was digitizing digitized using ArcGIS. Those maps were compared with each other using the identical or same classes:

1. Forest and banana (or other trees crops);
2. Lakes;
3. Marshland;
4. Bush land
5. Agriculture

The difference map was then generated using matrix (intersection) which is a default in ArcGIS enables to create an output file that contains classes that indicate how the class values of the input overlapped. Area of each class was calculated to determine the percentage change.

Results and Discussion

Determination of type of irrigation by layers used as Decision variables

Determination of each type of irrigation according to slope classification

According to slope classification, we defined four classes of irrigation:

• 0-2 % : Surface irrigation

• 2-6 % : All type of irrigation

• 6-25 % : Pressure Irrigation
• 25-65 % : Marginal irrigation

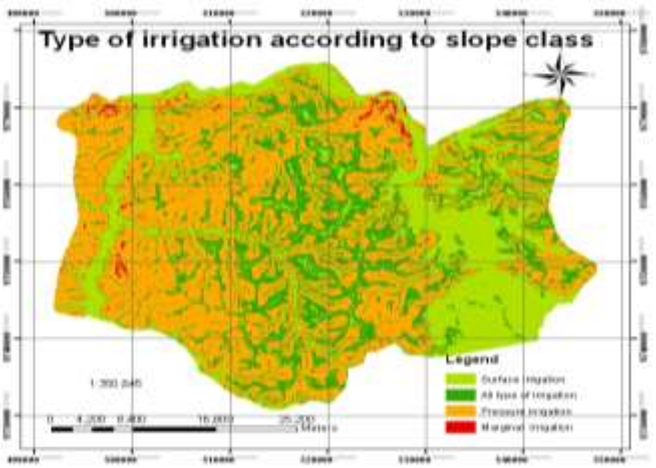

Figure 7: Type of irrigation according to different slope in Bugesera-AEZ

We calculated also area than that can be occupied by each class of irrigation we proposed in Bugesera Agro Ecological Zone :

• Surface irrigation : 421 358 780.83 m2
• All type of irrigation : 423 628 895.99 m2
• Pressure Irrigation : 864 795 800.82 m2
• Marginal irrigation : 12 717 811.43 m2

At For the first class of surface irrigation, we can suggest three types of surface irrigation like :

• Border irrigation
• Furrow irrigation
• Basin irrigation

To use slope as a decision variable for determination of the most suitable area in Bugesera AEZ, we considered only two classes of slope for irrigation:

• 0-2 % : Surface irrigation
• 2-6 % : All types of irrigation

We used those two classes because we wanted to have a suitable area that can be also the most economically suitable as possible. But for other decision makers, we give them all possibility of type of irrigation for Pressure pressure irrigation and marginal irrigation. At For those slopes, according to ideas of using all land the first thing to do is to establish radical terraces at for slopes between 13 to 25 % and progressive terrace at slope between 6 to 12 %. After those leveling, those areas can be used for purpose of irrigation

So in this map below we defined map with class of suitability for irrigation according to our classification (Figure 8).

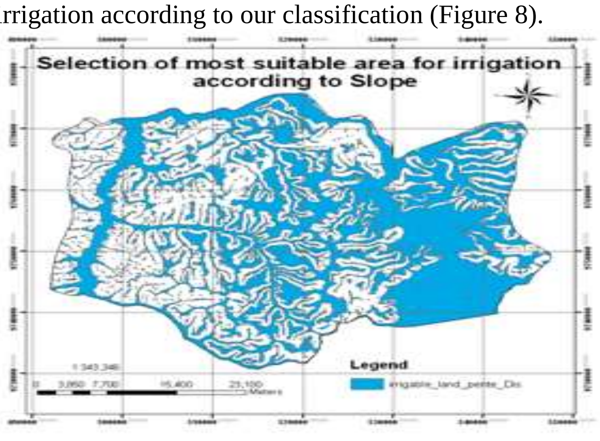

Figure 8: Most suitable are for irrigation according to slope in Bugesera-AEZ

In Bugesera AEZ, the most suitable area for irrigation is presented in blue in this map and those areas are suitable for all types of surface irrigation and pressure irrigation., in In pressure irrigation, we include sprinklers irrigation and drip irrigation.

To produce suitable irrigable area, we did not took take into account areas in white in this map .

Determination of each type of irrigation according to clay characteristics

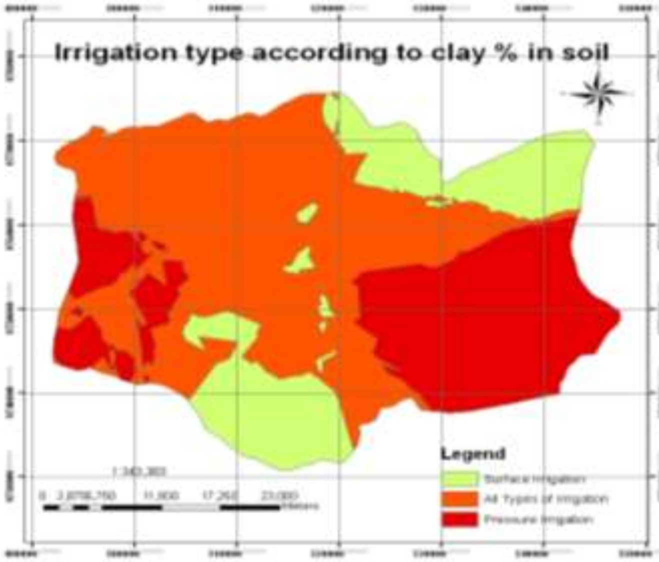

Figure 9: Type of irrigation according to clay % in the soil

This map shows us the possibility to irrigate in Bugesera-AEZ according to clay characteristic in the soil (Figure 9). We defined three clay classes according to percentage of clay in the soil. First we had 5 clay classes in our study area and than then with these classes, we defined 3 irrigation type classes:

• 0-20% of clay : Pressure Irrigation
• 20-30% of clay : All types possible
• 30-50% of clay : Surface irrigation

The areas were then, calculated for each class of irrigation in Bugesera Agro EcologicalAEZ.

• Surface irrigation : 357 020 198.58 m2
• All types of irrigation : 868 928 266.64 m2
• Pressure Irrigation : 504 003 879.42 m2

So to produce the most suitable area for irrigation, we used two classes of clay, those with surface irrigation and the other one of all types of irrigation. Like As we said for the first map, we considered only those two classes because of their high consideration in determining the slope.

Determination of each type of irrigation according to sandy characteristics

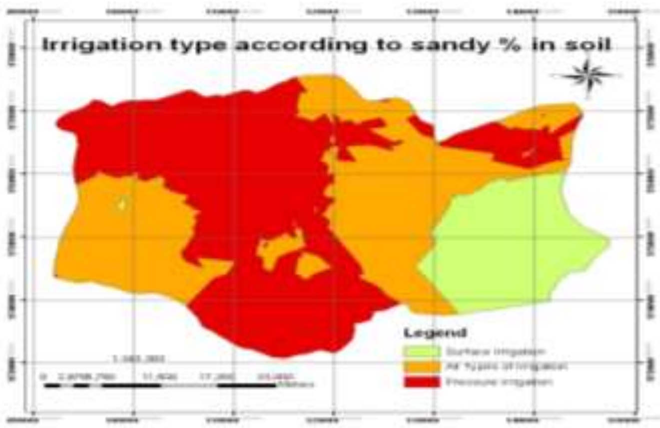

Figure 10: Type of irrigation according to sandy (%) in the soil

This map shows us the possibility to irrigate in Bugesera-AEZ according to sandy characteristic in the soil (Figure 10). We defined three irrigation classes according to percentage of sandy in the soil. First we had 4 sandy classes in our study area and than then with these classes we defined 3 irrigation type classes:

- 0-20% of sandy : Surface Irrigation
- 20-40% of sandy : All types possible
- 40-60% of sandy : Pressure irrigation

We also calculated also the area than that was occupied by each class of irrigation in Bugesera Agro Ecological Zone:

- Surface irrigation : 276 591 301.306 m2
- All type of irrigation : 639 144 662.49 m2
- Pressure Irrigation : 816 948 456.544 m2

So to produce the most suitable area for irrigation, we used two classes of clay, those with surface irrigation and the other one of all types of irrigation. Like we said for the first map, we considered only those two classes because of their high consideration in determining the slope.

Determination of each type of irrigation according to Road network

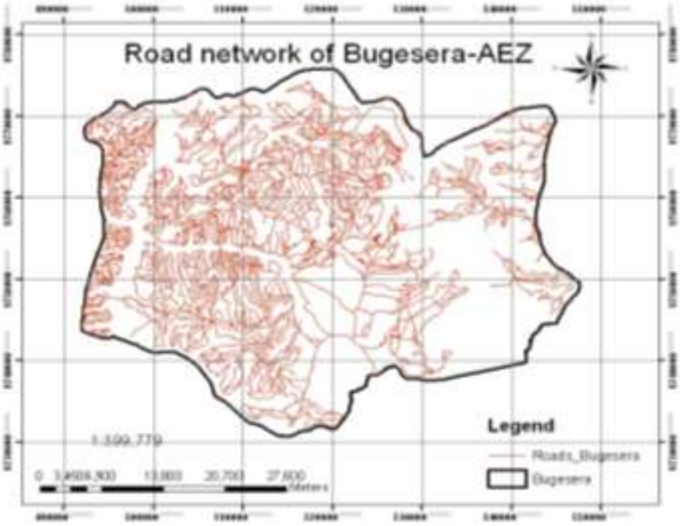

Figure 11: Road network of the study Area

The use information of Road network for the determination of irrigable land was important for our study area. The determination of irrigable land is very important by the impact of proximity to communication infrastructure. However, as the map shows, in Bugesera AEZ, there are no problem of proximity to transport network (Figure 11), so it can be possible to irrigate every where there is any constraint of evacuation of material and products .

Determination of suitable area for irrigation according to water body proximity

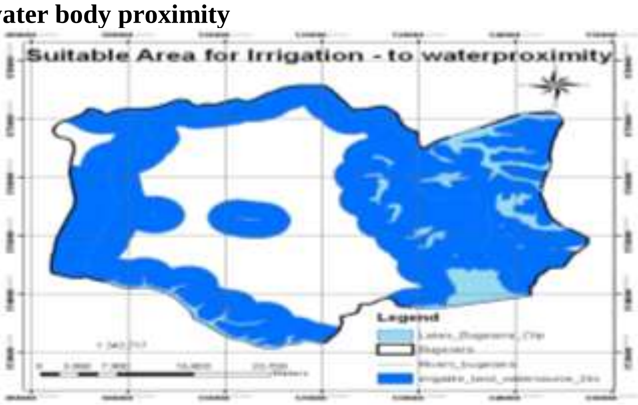

Figure 12: suitable area for irrigation according to water proximity

To determine irrigable land, we must be able to know the proximity of the water that we can use as input for irrigation purposes. This map is showing the area that can be irrigated by the availability of water that we dispose at a distance of 3 Kmthree kilometers to the place at witch wewhere must applicant the irrigation must be applied (Figure 12).

Determination of suitable area for irrigation according to Land Use/Land Cover

Figure 13: Land Use to Irrigation

To determine suitable area for irrigation, we made consideration to considered different classes of land use.

We decided that, if we must irrigate, considerations will be taken to class at in witch which there are agriculture and marshland.

For now, it is not relevant to irrigate forest and bush in case of on- farm irrigation, until the use is converted to crop lands.

We wanted also to determine areas that can be occupied by every type of land use and land cover: Those maps were compared with each other using the identical or same classes:

- Forest and banana : 565 289 400 m2
- Lakes : 152 699940 m2
- Marshland : 206 793 200 m2
- Bush land : 193 690 020 m2
- Agriculture : 624 550 600 m2

Model design by overlaying function

Irrigable land according to two overlaying

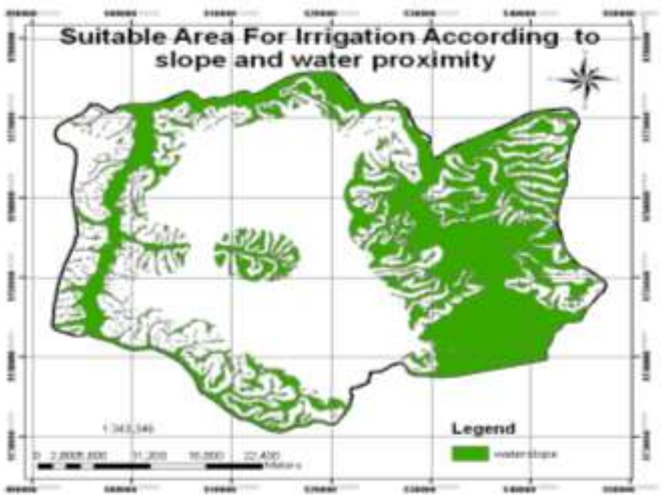

Figure 14: Suitable area for irrigation according to slope and water proximity

This map is showing areas that can be irrigated for projects of irrigation that can consider only two types parameters for the determination of irrigable lands (Figure 14).

Irrigable land according to three overlaying

Matching three factors (soil type,

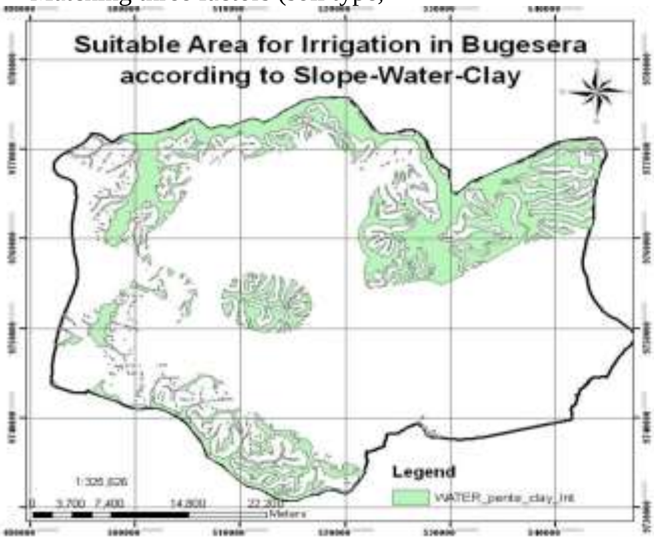

Figure 15: Suitable area considering slope, water proximity and clay

This map (Figure 15) is showing suitable area for irrigation purposes according to overlay of three layers,

• we used layer of suitable slope that take to account two classes of slope ,the first class of surface irrigation and the second class of all type of irrigation;

• the second layer used in this part was the layer of water proximity with a buffer zone of three kilometers;

• The last layer used was of clay % in the soil.

We calculated also suitable area for irrigation if we take into account for soil characteristic, only sandy, slope and water proximity (Figure 16).

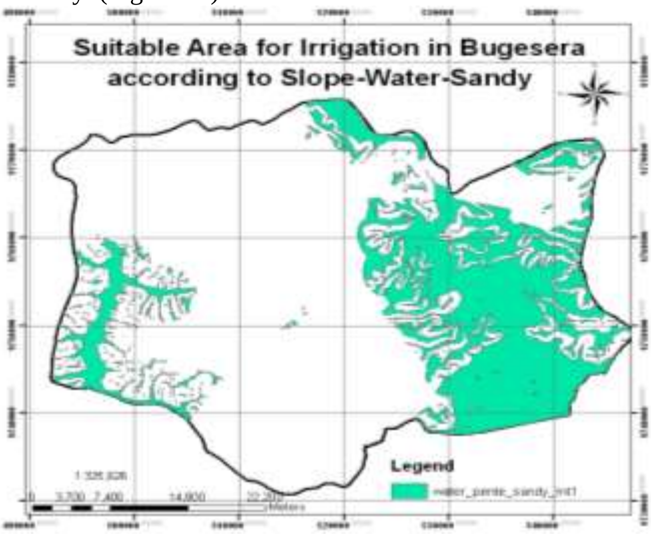

Figure 16: Suitable area considering slope, water proximity and sandy

As seen, this table shows us some sites witch which are most suitable for both of surface irrigation and all type of irrigation, this means surface irrigation, sprinkler irrigation and drip irrigation

Suitable Irrigable land according overlaying functions

This map gives us the most suitable area for purpose of irrigation if we must consider all conditions matched (i.e. sSoil texture: (clay and Sand sand content), slope gradient, and water source). It resulted that, the most suitable area for irrigation in Bugesera AEZ is located to 15, 0 35.5 Ha (Figure 17).

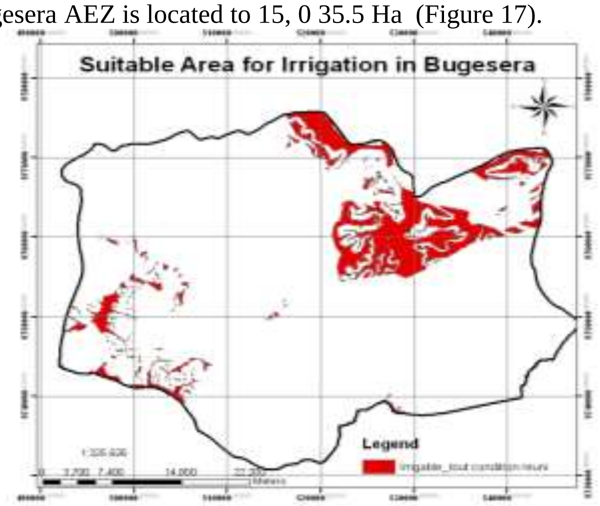

Figure 17: Suitable area considering all parameter

Conclusions and recommendations

Conclusion

The objective of this study was to map the suitable area for irrigation within Bugesera AEZ using spatial information. We integrated several methodological steps to provide a logical framework that can be used to map and locate irrigable land in Eastern-Rwanda and therefore potential suitable area to help decision makers.

We classified slope according to fourth classes of irrigation,: first class of surface irrigation (0-2 %), second class of all types of irrigation (surface, sprinkler and drip irrigation, 2-4 %), the third of pressure irrigation (6-25 %) and the fourth class of marginal irrigation (25- > 55 %) and with those values, we depicted irrigable lands, that was the answers to our first questions if each type of slope would conduct to determine irrigable areas. The same process was done also for clay, sandy and land use map.

Next, we create buffer zone for water proximity up to 3 Kmthree kilometers and this map helped us to match with other maps of slope, land use, clay and sandy class to generate the most suitable area for irrigation in Bugesera AEZ. This was the explication to our second research questions.

By overlaying different kind of layers like we did, we introduced a new kind of thinking to produce a design model that can help other first Eastern of RwandaBugesera and other Agro Ecological ZoneAEZ in Rwanda to detect and calculate areas of irrigable lands as well as the type of irrigation, so we think that to have answered our third question of model design.

Recommendations

This study was considered as a methodological study to demonstrate how spatial information can be used to derive most suitable lands to irrigation in Bugesera Agro Ecological Zone.

However, we recommend that if the study can be continued with field data to confirm those results and to use validation of results with local population and local NGO witch are operating in the Agro Ecological Zone of Bugesera.

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