Journal of Geography and Regional Planning Vol. 4(9), pp. 525-532, 4 September, 2011
Available online at http://www.academicjournals.org/JGRP
ISSN 2070-1845 ©2011 Academic Journals

Full Length Research Paper

Using geographic information systems (GIS) to determine land suitability for rice crop growing in the Tana delta

David KURIA[1]*, Douglas NGARI[2] and Edward WAITHAKA[2]

[1]Department of Geomatic Engineering and Geospatial Information Science, Kimathi University College of Technology, P. O. Box 657-10100, Nyeri, Kenya.
[2]Department of Geomatic Engineering and Geospatial Information Systems, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 6200-00200, Nairobi, Kenya.

Accepted 27 July, 2011

This research gives an evaluation of Tana delta with regard to areas that are suitable for rice growing. The study area lies on the Eastern delta area of the Tana river of which 16000 hectares have been earmarked for commercial rice farming. The evaluation of land in terms of the suitability classes was based on the method as described in FAO guideline for land evaluation for rain fed agriculture. A land unit resulting from the overlay process of the selected theme layers has unique information of land qualities for which the suitability was based on. The selected theme layers include landforms, agricultural lands, soil texture, soil sodicity and salinization of the soils. Soil texture, soil sodicity, soil salinity, were formulated using soil maps from Kenya soil survey. Landforms of the area were prepared from Landsat TM data. Overlay operations on the layers were done on these layers according to weighted significance of each of the factors. A land suitability rating model was developed using model building techniques in ArcGIS. From the results of this research, a rice suitability map was prepared identifying the various areas as four classes: most suitable, suitable, less suitable and unsuitable.

Key words: Geographic information systems (GIS), land evaluation, land suitability, land use, model building.

INTRODUCTION

Rice is the most important food source for half of the world's population. Rice is equally an important food crop for Kenya. Rice crop area is not extensive in Kenya thus giving a low produce leading to importation of the commodity to satisfy the market demand. A number of organizations are interested in the suitability area for rice so as to estimate the production and expand the extent of rice farming such as the Tana and Athi river development authority (TARDA). It is therefore necessary to develop a systematic approach to facilitate the production of land suitability information. The information can be separated into layers to model suitable area as a set condition.

Food and agriculture organization (FAO) guideline on the land evaluation system is widely used. The system is based on defined land qualities as related to landuse requirement. In Kenya land classification activities have been conducted since post independence. Two land classification systems are used: land capability for field crops and land suitability for rice. Landuse planning requires dynamic land evaluation system. The conventional map production is not such a dynamic tool. Recently with the advent of satellite remote sensing and geographic information systems (GIS), a number of pilot projects have been undertaken to test the capability of this new technology. So far the spatial database of land resources is being established by digitally encoding the existing maps. In an effort to apply this technology, this research proposes to model land suitability for rice using GIS. This can provide the key in improving yield to feed an expanding world population at a time of increasing restraints on agriculture.

The Tana river is the longest in Kenya being over 1000 km long and it has a catchment area of 95,000 km² (or 120,000 km² according to other estimates), starting on Mount Kenya and entering the Indian ocean in north

*Corresponding author. E-mail: dn.kuria@gmail.com or david.kuria@kuct.ac.ke.

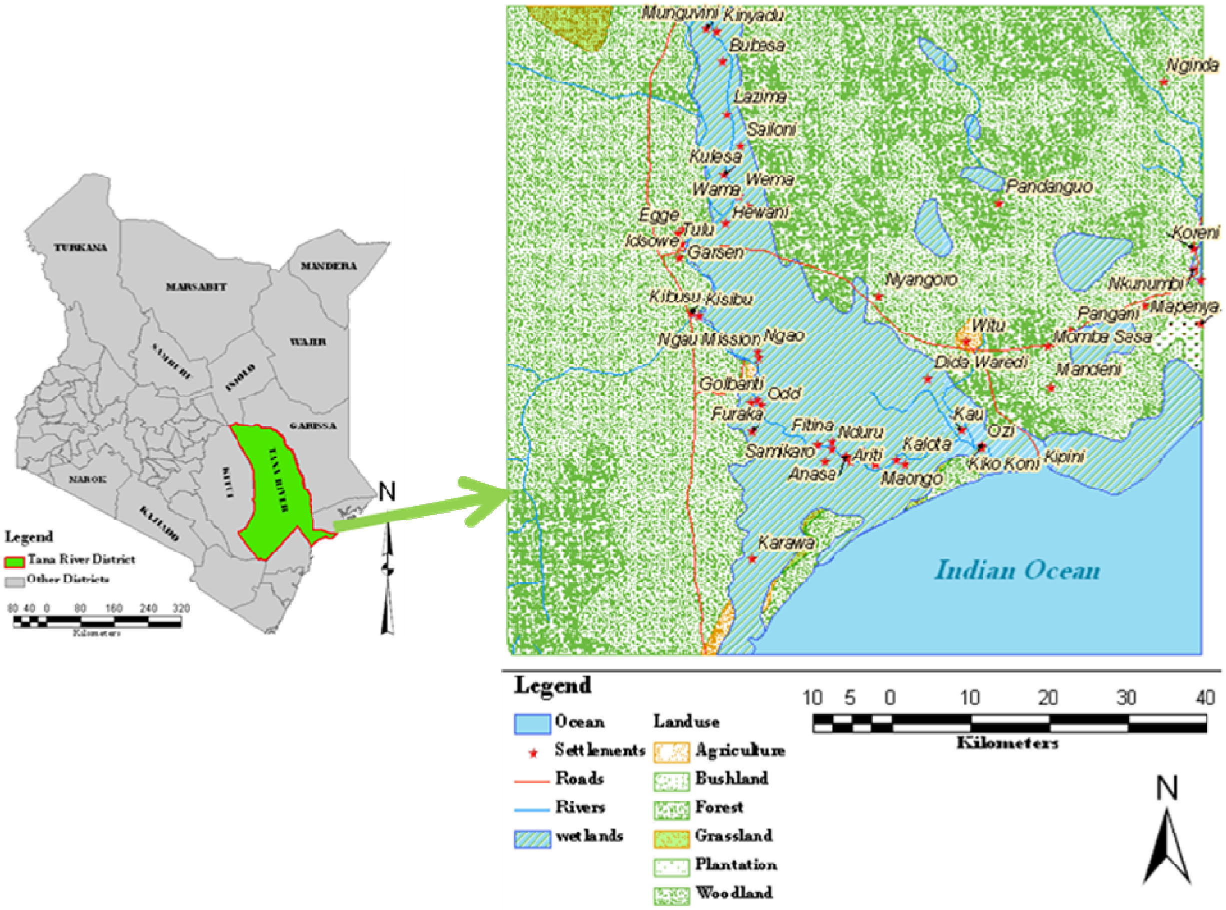

Figure 1. Tana river delta rice suitability study area.

eastern Kenya near Kipini, The river provides a good platform for irrigation. Increased usage of land resources in terms of production has led to soil degradation through loss of plant nutrients and organic matter, erosion, buildup of salinity and damage to soil structure. There is an urgent need for the evaluation of land resources in the context of their usability as well as sustainability for a crop landuse in the light of the needs of that crop. This process is technically known as land suitability evaluation and a detailed methodology has been laid down by the food and agriculture organization (FAO, 1978). The current study aims to assess the suitability of the land in Tana for the cultivation of rice.

Lack of information in Kenya, especially in terms of socio-economic issues for decision making, makes both the development and application of a government policy difficult. Ideally, informed decision-making at all levels should be based on a knowledge system incorporating both bio-physical and socio-economic factors as they influence land use systems. A GIS can help to improve the understanding of the processes of land evaluation and decision-making. It can improve the efficiency of data processing, can help to solve data integration problems and can support spatial analysis. Moreover it can help to improve the description of land utilization types required for land evaluation.

This research effort seeks too establish a prototype spatial model in land evaluation for rice growing using GIS. To accomplish this broad objective, the following sub-objectives are pursued: (1) establish suitable rice growing sites within the area of study, (2) provide a preliminary planning information for the Tana rice irrigation project, and (3) establish the areal extent of rice growing suitable areas in the proposed scheme.

Study area

It borders Lamu to the south east and Malindi to the southwest. It also borders the Indian ocean to the south with a coastal strip of 35 km. The major physical feature in Tana river district is an undulating plain which is interrupted in a few places by low hills. The expansive delta created by the river is characterized by wetlands, presenting great potential for agriculture. It provides grazing area during the dry season and is a tourist attraction. Figure 1 shows this delta region with the entire Tana river district highlighted in the inset.

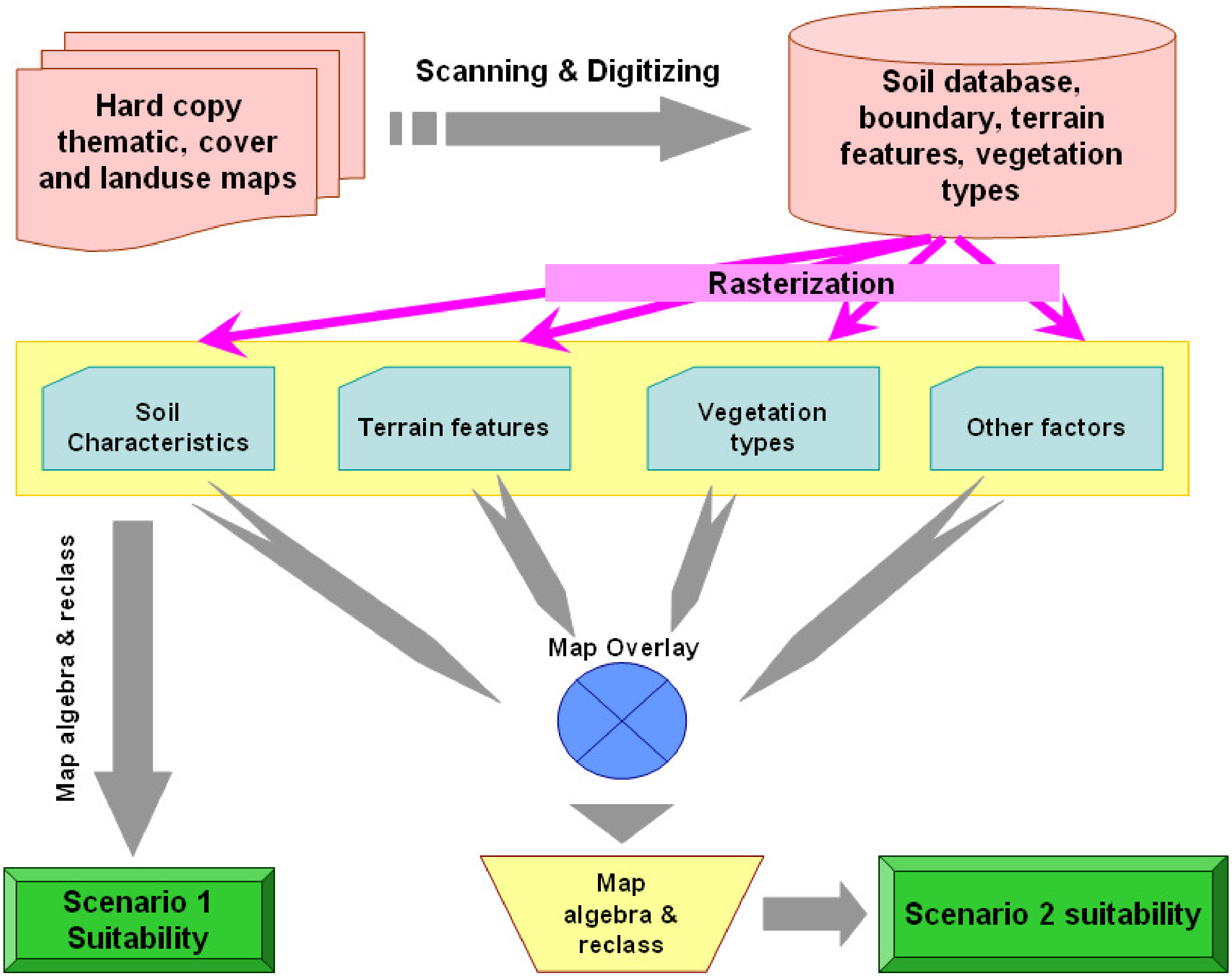

Figure 2. Methodology and workflow adopted in this research.

The district is generally sparsely populated mainly due to harsh climatic conditions like low and erratic rainfall and high temperatures. In 2002, the projected population was 5 person/km^2. Insecurity has forced most communities in the district to live together for protection. Rainfall is low, bimodal, and erratic with mean annual ranging between 300 to 500 mm. Long rains occur in the months of April and May while short rains occur in the months of October and November. The average annual temperatures are about 30°C and along the coast humid conditions are prevalent.

MATERIALS AND METHODS

Figure 2 shows the methodology that was employed to meet the objectives of this research. The complete methodology includes identification of the spatial characteristics of the study area, conversion of information into digital form, suitability analysis within the GIS environment and presenting the outputs using a thematic map.

The processes

Step 01

Gather data to assist in classifying the land according to their use called land suitability. Land capability, which is also considered as land suitability (FAO, 1978) is primarily the potential biological productivity of land.

Productivity of land can be determined by four main components of the environment namely; climate, local topography, soil and existing vegetation. Land suitability evaluation involves identifying land use patterns and the economic and environmental feasibility of its current use.

Step 02

Land suitability mapping with GIS. Traditionally, spatial data has been acquired and rendered into pictorial or map form to accomplish variety of activities related to land resource management. Presently, almost any project aimed at land resources planning may be greatly facilitated by the use of an efficient GIS. Useful land suitability assessments cannot solely be based upon biophysical resource information.

	Calcareousness Soil reaction Sodicity	Additional features (see below) - relevant for parts of the soil unit			Classification FAO/UNESCO (1974)
		Relief class	Salinity profile	Vegetation type	
n stratified, sand to ained	- usually non-calcareous - neutral to moderately alkaline - predominantly non-sodic	I	S0, S2, S4	b, f	eutric and vertic FLUVISOLS, partly saline phase
ay over clay; rich l drained	- non-calcareous - neutral - non-sodic	I	S0	b	eutric and vertic FLUVISOLS
layloam, in places fine textured,	- non-calcareous - neutral to moderately alkaline - non-sodic	I	S0, S4	b, f	vertic FLUVISOLS, partly saline phase
grayish brown clay drained	- non-calcareous - neutral to moderately alkaline - predominantly non-sodic	I	S0, S1	b	vertic FLUVISOLS, partly saline phase,

Figure 2. Scanned sample attribute data.

Transportation networks, scale dependent localised economies and social factors such as education and demographics dealing with large number of spatially related information also have to be considered in this process (ESRI, 2002). The surface and overlay analysis capabilities in GIS can effectively facilitate in handling this vast amount of spatial information. Today,remote sensing and GIS are playing a very significant role in land evaluation systems such as production of land suitability maps (Perera and Tateishi, 1994).

Data collection

Soil thematic maps, salinity, soils classification (according to certain soil characteristics), land uses and topographical maps were obtained from Kenya soil survey and TARDA. These analog datasets were scanned with a high-resolution scanner to convert them from analogue form to digital form.

Attribute data for soil classification from FAO guidelines was also obtained, the data was used to delianate soil suitability according to following soil characteristics: (1) soil reaction, (2) soil sodicity, (3) soil salinity and (4) soil texture. Figure 3 shows these attribute data.

RESULTS AND DISCUSSION

Weighted overlay is a technique for applying a common scale of values to diverse and dissimilar input to create an integrated analysis. The geographic problem required the analysis of many different factors. This information exists in different rasters with different value scales: pH, distances, degrees of slopes, etc. In this research each of the contributing factors was given, its commensurate weight-soil characteristics were considered to have more significance, that is, the distance to a road.

Figure 4 shows a suitability map after performing map algebra operations using only soil characteristics and digital elevation model (DEM) generated slope. In this case, the soil properties considered were all given an equal weight. These factors were generated in conformity with soil and Terrain database developed for Kenya (KENSOTER) guidelines for rice crop growing. This database was developed by the Kenya soil survey (KSS) and the international soils reference and information centre (ISRIC) (Jacobs et al., 2007). In this classification, a value of 3 signifies an unsuitable area and 1 the most suitable area.

This classification was further refined by considering these features: (1) gullies, (2) ridges, (3) former river courses, (4) tracks and (5) villages. Buffers were created around these features.

Figure 5 shows the combined buffers generated for refining the suitability analysis. To come up with the final suitability map, each of these buffers was weighted (percentage influence). The total influence for all considered rasters tallies to 100%. Table 1 lists the weights used in the map algebra operations.

After running the model the final suitability map shown in Figure 6 was obtained. Compared to Figure 4, there are observable differences which are quantified during subsequent analysis. This analysis was undertaken by comparing areal extents of the final four classes in each case as shown in Table 2. Case 1 represents the scenario considering only soil characteristics and case 2 represents the scenario that considers other factors in addition to soil characteristics.

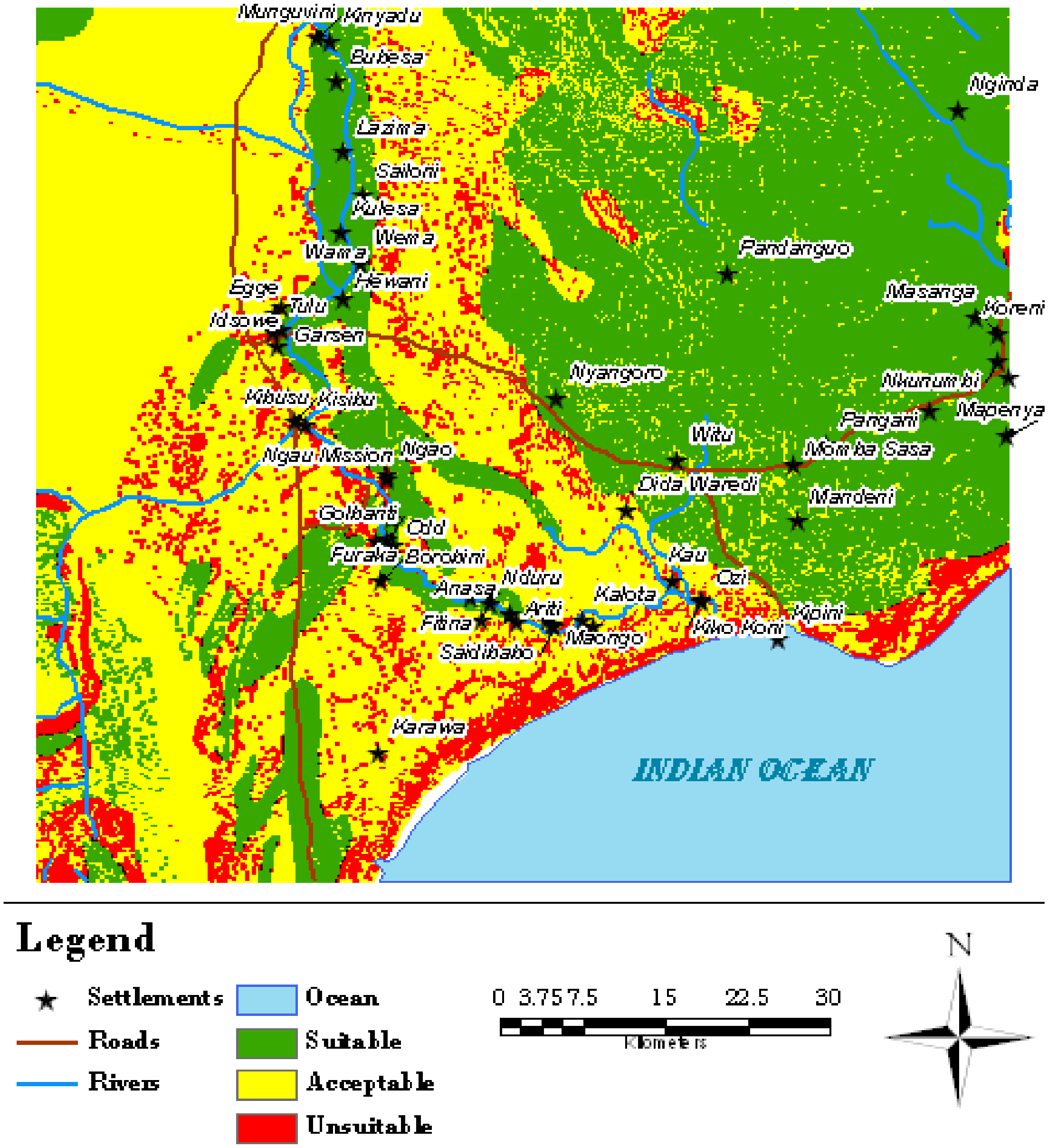

Figure 3. Preliminary suitability map using soil characteristics and slope.

From case 1, the most suitable areas for growing rice have the following soil characteristics: neutral to moderately alkaline, non sodic, imperfectly drained and usually the very dark gray clay. These characteristics were found to occur together and they prevalently occupy 67% of the study area.

Moderately suitable soils for growing rice are vertisols with the following characteristics: neutral to slightly acidic, predominantly sodic, poorly drained and usually humic cracking clay. These soils occupy 14% of the total study area.

Marginally suitable soil types are vertic flusivol (partly saline) which are predominantly fine textured, neutral to moderately alkaline, non sodic, moderately well drained and usually the dark brown to brown clay loam. These soils occupy about 10% of the total research area.

The unsuitable soil types are eutric fluvisol (partly saline), that are predominantly non sodic, moderately alkaline, often well stratified and are usually sandy clay.

The overall suitability (case 2) produced a more refined suitability results with the most suitable areas extent reducing from 67 to 48% at the expense of increase of both the areas of moderately and marginally suitable areas, the rise was by 18 and 1%, respectively,this may be attributed to the presence of many gully's and ridges in the areas that were found to be most suitable following

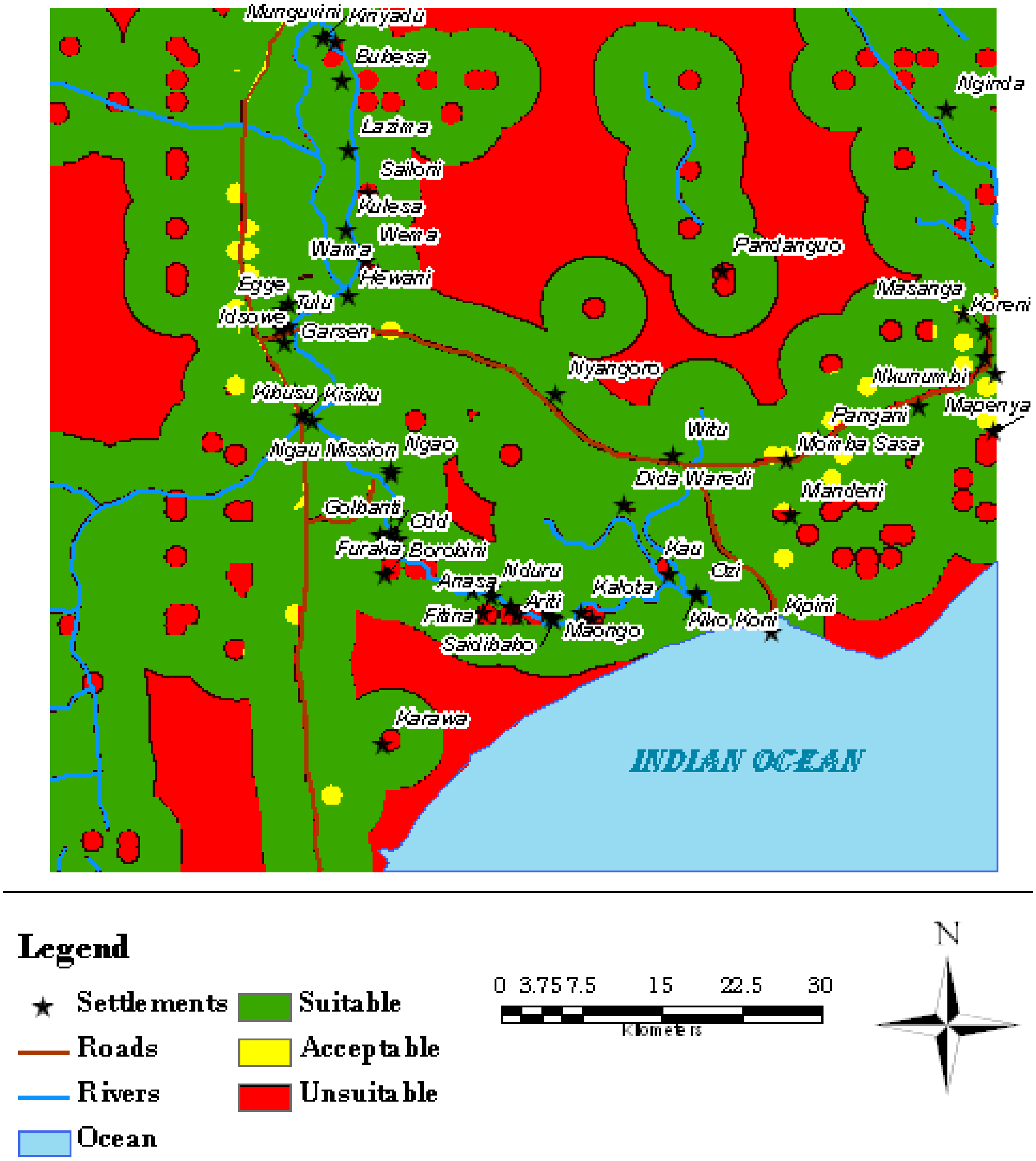

Figure 5. Combined buffers around settlements, roads and rivers courses.

Table 1. Weighting of rasters used in suitability analysis.

Input raster	Age influence (%)
Soils characteristics	85
Gullys	7
Ridges	4
Former river courses	2
Tracks	1
Villages	1
Total	100

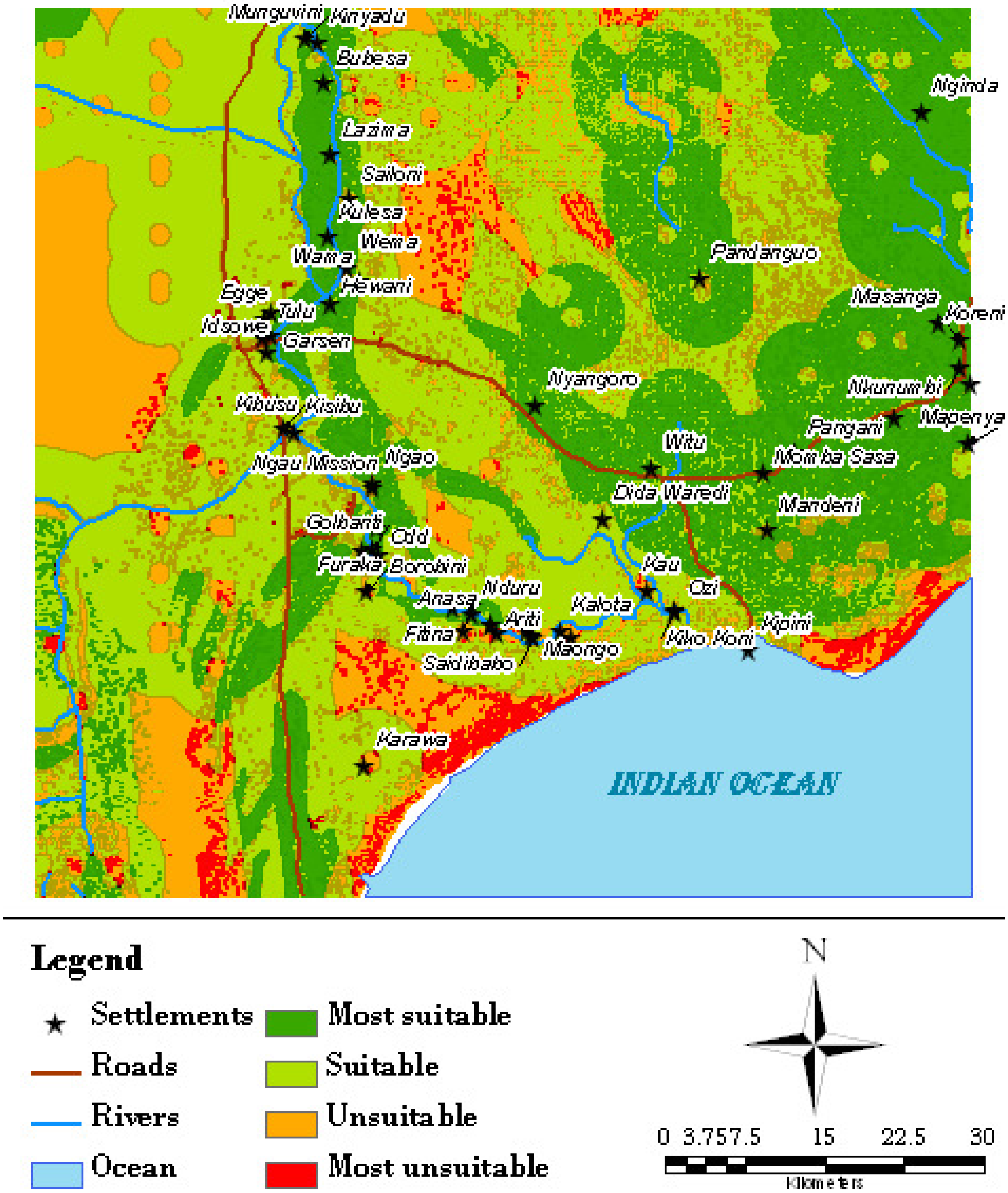

Figure 6. Final rice suitability map.

Table 2. Area comparison for the two scenarios.

Case	Un S.	Marg. S.	Mod S.	M. S.	Total area
Case 1	1139.5 8.9%	1297.4 10.1%	1795.7 14.1%	8564.1 66.9%	12796.7 100%
Case 2	1139.5 8.9%	1339.8 10.5%	4117.5 32.1%	6200.1 48.5%	12796.7 100%
% change	0	0.4	18.0	-18.4	0

Un S.= Unsuitable; Marg. S.= marginally suitable; Mod S.= moderately suitable; M. S.= most suitable.

only the soil characteristics. Gullies and ridges had a comparable high weighting in calculation of the overall suitability.

Conclusion

This research effort sought to establish a prototype spatial model in land evaluation for rice growing using GIS. It has been demonstrated that using GIS it is easy to determine sites that are best suited for growing rice. It has been shown that it is also important to consider other terrain features in addition to soil characteristics in order to come up with a more informed decision on optimal rice growing areas. Two suitability models scenarios have been presented in the two scenarios: (1) case 1 ignoring other terrain characteristics other than soil charactersitics and surface slope and (2) case 2 considering terrain features. Case 1 can be used in the preliminary stages or in the absence of terrain information.

From this study it has been demonstrated that majority of the area reasonably suitable for rice growing, and development efforts should therefore be directed towards realising this potential.

However, while this research highlighted the suitability for rice growing, it is important to have verification of the factors considered and their relative significance in informing the decision on suitability. It is proposed that an optimization of the values adopted be conducted in future to allow an optimal suitability determination for rice growing.

REFERENCES

ESRI (2002). “Land evaluation for an agricultural land reform area using GIS.” Accessed on 14th Jan 2011 from http://www.esri.com/industries/agriculture/research/suitability.html

Food and Agriculture Organisation (FAO) (1978). “Report on the Agro-ecological Zone Project.” Methodology and Results for Africa, World Soil Resource Report, FAO, 1(48).

Jacobs JH, Angerer J, Vitale J, Srinivasan R, Kaitho R (2007). “Mitigating Economic Damage in Kenya’s Upper Tana River Basin: An Application of Arc-View SWAT.” J. Spatial Hydrol., 7(1): 23-46.

Perera LK, Tateishi R (1994). “Do remote sensing and GIS have a practical applicability in developing countries?” Int. J. Remote Sens., 16(1): 18-35.

TARDA (2004). TARDA Strategic Plan 2004 – 2009.