ENVIRONMENTAL SCIENCES

GEOSPATIAL MODELING OF LAND USE MANAGEMENT FOR SUSTAINABLE URBAN DEVELOPMENT IN KARU, NASARAWA STATE, NIGERIA

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Date Manuscript Received: 27/04/2016 Accepted: 30/11/2016 Published: December, 2016

ABSTRACT
Land use management is a major challenge of urban development in Africa. Karu Area of Nasarawa State, a principal satellite town of the Federal Capital Territory, Abuja is the fastest growing city in Africa since the relocation of the Federal Capital from Lagos to Abuja in 1991. The proximity of the area to Abuja has attracted rapid economic and population growth with speed up urban expansion and poor living environment. This study used geospatial technology in Land use management of the area. Multi-Criteria Decision Analysis using Euclidean distance and weighted overlay from spatial analyst tool of ArcGIS, supported by Analytical Hierarchical Process were used to assess the suitability of the area for urban development. The Land Use Act Cap 202 of 1990 and the Nigeria Urban and Regional planning Act of 1990 were adoptedusing buffering operation in ArcGIS to determine encroachment of buildings/structures into approved setback areas of water bodies and road network. The study revealed land acquisition through informal delivery, resulting to haphazard constructions, and encroachment of buildings/structures into the approved setback areas. In addition, the areas are prone to flooding and erosion. It is recommended that, urgent need for the use of geospatial technology for land acquisition and management be adopted for sustainable development of the area.

Keywords: *Land Suitability, Urban Expansion, Geospatial Modeling, Multi-Criteria Decision Analysis*

INTRODUCTION

Land use management as conceived by Mabogunje (1992); Durand-Lasserve (1990) and Kombe (1995) is a process` involving different stakeholders in planning, facilitation and controlling land use for sustainable development. Land use management entails decision making and the implementation of decisions about land. It involves making fundamental policy decisions about the nature and extent of investment. The scope of land use management involves private and public sectors that develop and make use of land; law which sets out rules and procedures in the management system; agencies which make decisions on how land may be used at various levels of government and plans which inform decisions on how land may be used (Nags and Kudrat, 1998).Most African countries have a history of land use management processes dating back to their respective periods of colonial rule. However, Land use management in Nigeria could be said to begin in 1863 when the Nigerian Town and Country Ordinance was enacted by the Colonial Government (Mabogunje, 1992). Formal land use management in Nigeria began in1946 with the enactment of the Town Improvement Ordinance.

The content of land use management can be described in terms of ecological, social and market values which must be brought into balance by land use planners (Sui, 1992). Among the many concerns of land use planners in guiding the spatial arrangement of activities is the optimum utilization of land for the benefit of society (Shuaib, 2005). This involves making choices between available alternatives which involvesthe assessment of the fitness of the land for urban development.

Land use including cultivation, residential, commercial and industrial uses has been proved to alter the structure and functioning of the ecosystem (Sodeinde, 2002).Of recent time these land use areexperiencingspatio-temporal changes due to the rapid growth of population and migration with increases pressure on land.

A number of policies has been articulated and implemented to impinge urban land use in Nigeria; these include the Land use Act of 1978, Urban Development Policy of 1992, Urban and Regional Planning Act and the Housing and Urban Development Policy of 2002. Similarly, land use planning and control measures have been introduced to improve urban land use planning and urban development (Aribigbola, 2008). Despite the existence of these laws and policies, there is a general inefficiency of land policies and inadequate land use management in the study area..This study used geospatial technology and spatial multi criteria decision analysis (MCDA) for land use management of Greater Karu Urban Area of Nasarawa State, Nigeria.

MATERIALS AND METHODS

Greater Karu Urban Area has a central location in the middle belt region of Nigeria. The area stretches between Latitude 8° 461 N and 9° 07I N and Longitude 7° 33IE and 7° 50IE; and covers an approximate land area of 704 SqKm. The area incorporates the settlements of Mararaba, Ado, New Karu, New Nyanya and Masaka in Karu Local Government Area of Nasarawa state. The area is bounded with Abuja, the Federal Capital Territory to the west, Keffi Local Government Area to the South and Jaba Local Government Area of Kaduna State to the North (Figure 1). The terrain of the area is gently undulating with altitude range between 180 to 500m above sea level and dissected by a network of streams and rivers, with Uke and Ado being the major. Mean annual rainfall is between 1000 mm and 1500 mm with vegetation type of the southern Guinea Savannah which consist trees, shrubs, grasses and gallery forest along major streams, valleys and pronounced depression (Illoeje, 1985).

The geology of the area is founded by Precambrian basement complex structure with a combination of different metamorphic, igneous and sedimentary rocks including alluvial deposits found mainly in the stream-beds. The soils derived from this bedrock structure are generally deep and well drained with high fertility rating and variable run-off potential (Yari *et al* 2002, Obaje *et al.,* 2007). GKUAhas an estimated population of 124, 427. Specific ethnic groups in the area include Gbagyi, Koro, Yeskwa, Gwandara,Gade,Mada, Igbo, Tiv, Yoruba among others Nigerian ethnic groups who migrated to the area to take advantage of the economic potentials of the area.

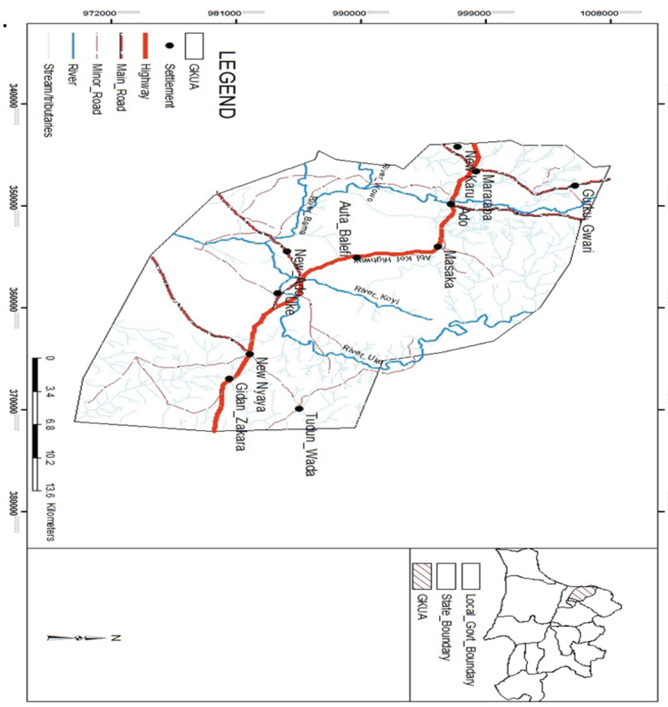


Figure 1: Greater Karu Urban Area

The data and materials used for this study were SPOT-5 image with spatial resolution of 5 meters acquiredfrom National Centre for Remote Sensing, Jos. Also the topographic, soil and geological map of the study area at a scale of 1:50,000 were also acquired from the office of the Surveyor General of the Federation and Geologic Survey of Nigerian Agency Abuja.

The data sets were used to extract information on water bodies, road network and intersections, contour, soils and Geological featuresof the study area using onscreen digitization in ArcGIS 10.2 software. Global positioning system was also used to capture locations (coordinates) of schools, health centers, Public water (Bore holes), and markets. Questionnaires were also administered to stake holders (land holding households, agents, developers and professionals) to establish ways in which people access land in the study area. Data acquired under this source include; the process of land acquisition, the physical features of the study area and the players in the informal land market in the area among others. Stratified random sampling technique was used to sample 229 respondents spread across the study area. Respondent include.

For each criterion, a suitability score was applied using a 10-point scale to determine the qualitative rankings of the suitability on each criterion. The rankings range from 1 (Not suitable) to 10 (Highly suitable). This “positive direction” Voogd (1983) is chosen to keep the scores understandable since the higher the score the more suitable the site is. The suitability classes are given below:-

***Not suitable** (1): This is attributed to sites with characteristics imposing certain constraints which cannot be overcome or technically excluded for development e.g. steep slope areas, areas prone to flooding, etc.*

Moderately Suitable (5): A level for sites with characteristics imposing constraints which can be overcome but by moderate and massive investment.

***Highly Suitable** (10): Areas with characteristics imposing no significant constraints for development. This includes sites with flat topography, good soils forconstruction and lands free from flooding. Lands economically suitability were based on the distance from a specific feature. For instance the closer a lands to a schools, existing residential areas, roads, health care, public water, and existing commercial areas the higher the suitability for residential and commercial use. Though this type of suitability ranges between 1 and 10 however, the distance between value 1 and 10 may differ between features. For a certain sub-objective the suitability value of 5 could be at 1 km from the feature while for another sub-objective the value 5 is at 5 km. This depended on the importance of a feature to be at close range.*

The weighted overlay technique is a GIS-based method of modeling the suitability in any particular situation. This involves setting up of an evaluation scale. For this study, the attributes of each datasets were ranked based on a scale factor of 1-10 using Analytical Hierarchical Process.The influence value of each factor was based on their suitability for urban expansion. If an objective contained sub-objectives, the result was a weighted combination of all the sub-objective maps. However, if the objective did not contain sub-objectives, it was created the same way as a sub-objective. In both cases, though the final result was a map, the creation of the goals was more or less similar as the objectives. The resulting maps of the objectives were combined and weighted which resulted in a final map for that goal.

Sub-objectives were based on one or more layers depending on what they represented. Sometimes a combination of layers was needed to cover a topic. To illustrate a sub-objective from the urban expansion aimed at finding places proximal to medical centers, one data set with hospitals and another data set with medical Centre were combined to cover the topic of health care. Then the Euclidean distance from these health centers was calculated and reclassified in values between 1 and 10, where 10 represent highly suitable areas and 1 low suitable area. All these steps were modeled within the Model Builder with a map as final result.Figure 2 presents the flowchart showing the research design of Land-use model for GKUA. The weighting was done using Analytical Hierarchical Process.

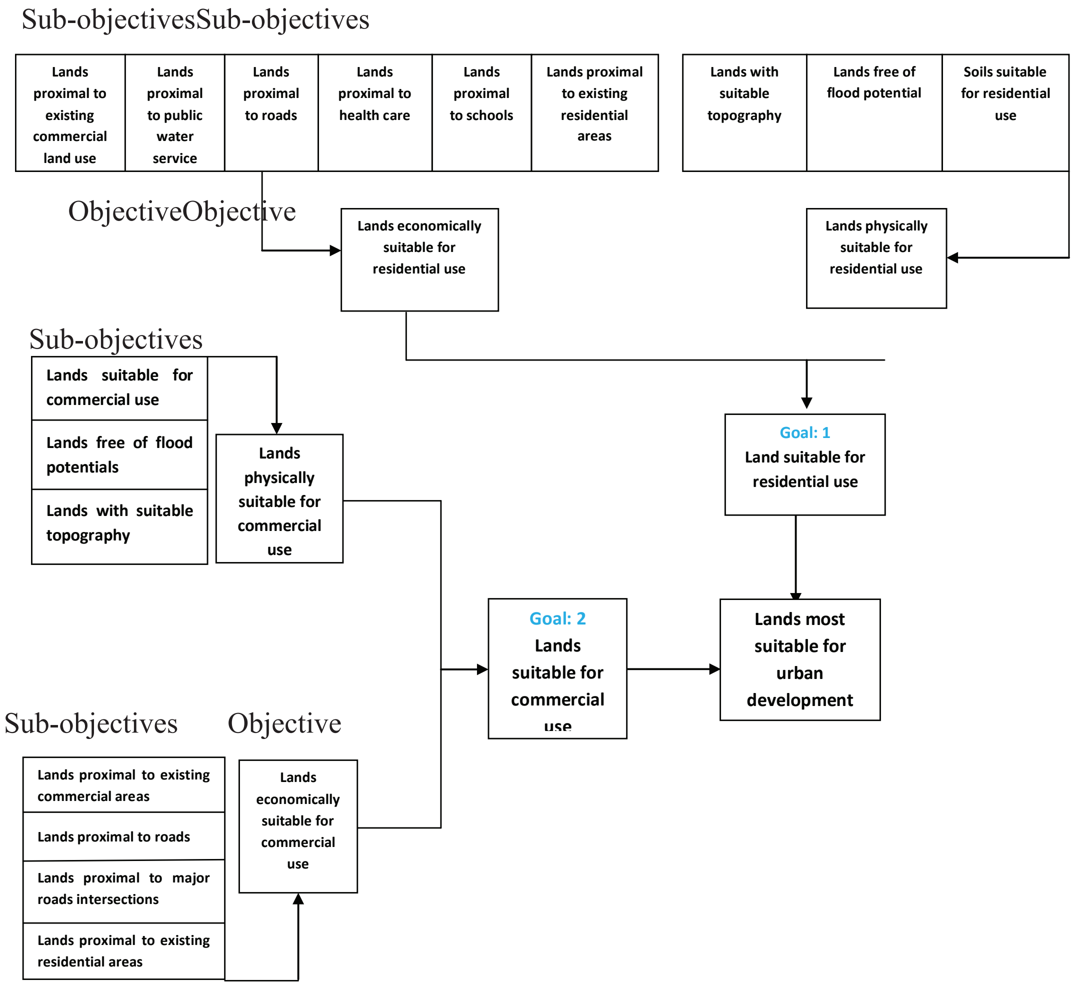


Figure 2: Land-use model of GKUA modified after Carr and Zwick(2007).

RESULTS AND DISCUSSION

From the results presented in Table 1, 74.0% of the respondents accessed their plots of land through the landholding families who constitute the greatest suppliers of land in the informal delivery channels in the study area. The traditional authorities delivered 1%. Land allocated by government agencies for land administration accounted for about 2.9%. This reveals weak influence by the public authorities over access to land in the area.

Table 1: Channels of Plot Acquisition

Channels	Frequency	Percentage
Bought from Landholding families	154	74.0
Allocated by Traditional Authority	2	1.0
Allocated by Government	6	2.9
Gift	11	5.3
Inheritance	15	7.2
Not Applicable	20	9.6
Total	208	100.0

Source: Author's field survey, 2012

Table 2: Size of Plot (m2)

The results presented in table 2 shows that 38.0% of the respondents who own their plot of land within GKUA had less than 900m2 of land. 29.8 had their lands measuring above 900m2, with 21.6% respondents having plots of land measured 900m2 . This shows that 38% out of 88.9% of those who own land within GKUA have their plots measure less than 900m2, which depicts a dominance of high density leading to compact pattern of development which is largely horizontally inclined. This comes with attendant consequences such as; congestion, overdevelopment, overcrowding, overstretch of utilities and infrastructure.

Size	Frequency	Percent	Valid Percent	Cumulative Percent
900 Square metre	45	21.6	21.6	21.6
Above 900 Square meter	62	29.8	29.8	51.4
Less than 900 Square meter	79	38.0	38.0	89.4
Not Applicable	22	10.6	10.6	100.0
Total	208	100.0	100.0	

Source: Author's field survey 2012

Urban Expansion

Urbanexpansion includes everything that is important when it comes to urban development. Carr and Zwick (2007) defined this category to include all land-uses commonly found within the umbrella of urban area. These include residential, commercial, institutional and industrial land uses. Two goals were particularly stressed in the urban expansion: Lands most suitable for residential and commercial use. Each goal was subdivided into two objectives; lands most suitable from both physically and economically point of view. These were then further subdivided in themes that were of relevance for the concerning objectives. In dialogue with Nils Viking (personal communication, 2009) project manager and urban planner, it was decided to create mixed development instead of block zoning. To achieve this, all urban types except industrial land-use are included in each other's preferences and defined as suitable. This means that residential and retail areas are also suitable for office and commercial land- uses.

Lands Suitable For Residential Use

The first goal aimed at finding the most suitable lands for residential uses consist of two objectives and nine sub-objectives based on economic and physical suitability as presented in Figure 2. First, the objective dealing with economic suitability revealed that it is important to live close to facilities like schools and health care for the vast majority of the population. In general, people prefer to live near one another and therefore lands proximal to existing residential areas were included as most suitable. Furthermore, it is convenient to live close to roads. Also, it is cost-effective to have residential areas close to existing public water services. Finally, lands proximal to existing office/commercial and retail land-uses were also identified as suitable as presented in Table 3 and Figure 3.

Table 3: Weighted overlay table of Lands economically suitable for residential use

Parameters	Influence (%)	Scale value
Existing residential land use	50	Ranked between 1-10 based on proximity
Land proximal to schools	10	Ranked between 1-10 based on proximity
Land proximal to health care	10	Ranked between 1-10 based on proximity
Land proximal to roads (buffered)	10	Ranked between 1-10 based on proximity
Land proximal to bore holes	10	Ranked between 1-10 based on proximity
Land proximal to existing commercial land use	10	Ranked between 1-10 based on proximity

Source: Authors GIS analysis, 2012

Apart from sub-objectives dealing with economical suitability, there are also a number of Sub-objectives describing the physical suitability for residential land-use. Three sub-objectives were included to model this type of suitability. First of all, the soil should be suitable to build on. Lixisols is the most suitable for construction use as such ranked the highest-7. Secondly, the land must be free of potential floods in order to be a safe place to live. Finally, the topography must be suitable for residential use; flat topography is more suitable than steep sloppy terrain as presented in Tables 3, 4, 5 and Figures 3 and 4.

Table 4: weighted overlay table of Lands physically suitable for residential use

Parameters	Influence (%)	Scale value
Soils	25	Lixisols -7 Arenosols -2 Leptisols -1
Flood potential	40	5- Very low 4- Low 3- Moderately low 2- High 1- Not suitable (very high)
Slope	35	Low -5 Medium -3 High -2

Source: Authors GIS analysis, 2012

Table5: weighted overlay table of Flood potential areasw

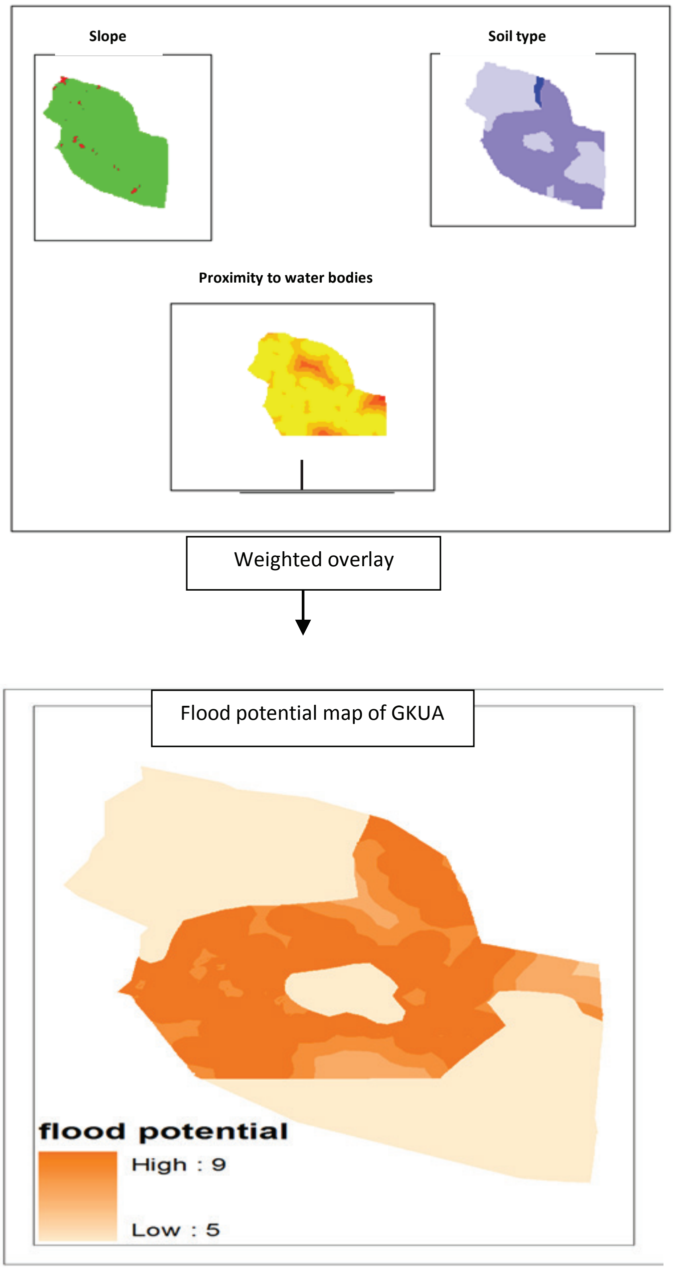
Parameters	Influence (%)	Scale value
Slope	20	Low -5 Medium -3 High -2
Water Bodies	65	Ranked from 1-10 based on proximity to water bodies
Soils	15	Arenosols -7 Leptosols -2 Lixisols -1

Source: Authors GIS analysis, 2012

Table 6: weighted overlay table of Lands suitable for residential use

Parameters	Influence (%)	Scale value
Land physically suitable	70	5 High 3 Medium 2 Low 1 Restricted (Not suitable)
Land economically suitable	30	5 High 3 Medium 2 Low 1 Restricted (Not suitable)

Source: Authors GIS analysis, 2012



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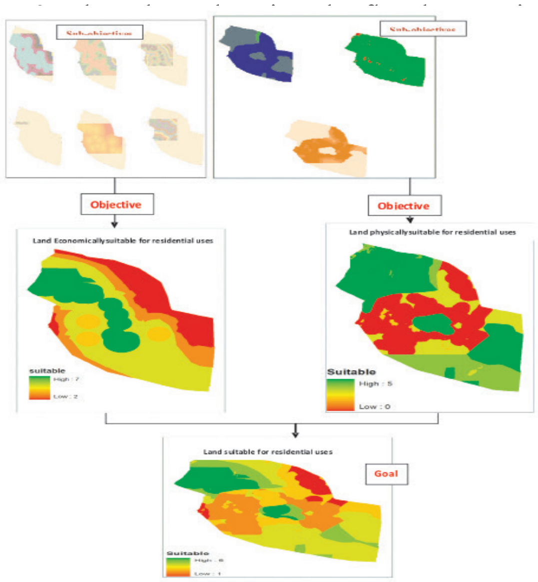

Figure 4: Flowchart showing the creation of objectives and goals for Lands suitable for residential uses. Fictive weights have been added to illustrate the method.

Lands Suitable For Commercial Use

The second goal is aimed at finding lands suitable for commercial use. The sub-objectives describing the physical suitability for commercial land-use were similar to the ones for residential land-use as presented in table 5.

Table 7: weighted overlay table of Land physically suitable for commercial use

Parameters	Influence (%)	Scale value
Soils	20	Lixisols -7 Leptisols -2 Arenosols -1
Flood potentials	50	5- Very low 4- Low 3- Moderately 2- High 1- Restricted (very high)
Topography	30	Low -5 Medium -3 High -2

Source: Authors GIS analysis, 2012

With relation to economic suitability, there were differences in what was important compared with residential land-use. For commercials, it is important to be located along roads to be easily reachable for customers. To amplify this, a sub-objective was included that such lands should be proximal to major roads which are even more attractive for offices to be located. Also lands proximal to major roads intersections are suitable for commercial uses. Furthermore, it is preferable to develop commercial areas/offices proximal to existing residential areas to increase the chance of success. Finally, areas close to existing commercial areas such as markets were identified as preferable concerning cost effectiveness as presented in Table 6 and Figure 5.

Table 8: weighted overlay table of Lands economically suitable for commercial use

Parameters	Influence (%)	Scale value
Land proximity to existing commercial land use	50	Ranked between 1-10 based on proximity
Lands proximity to roads	30	Ranked between 1-10 based on proximity
Land proximal to road intersections	15	Ranked between 1-10 based on proximity
Land proximal to residential	5	Ranked between 1-10 based on proximity

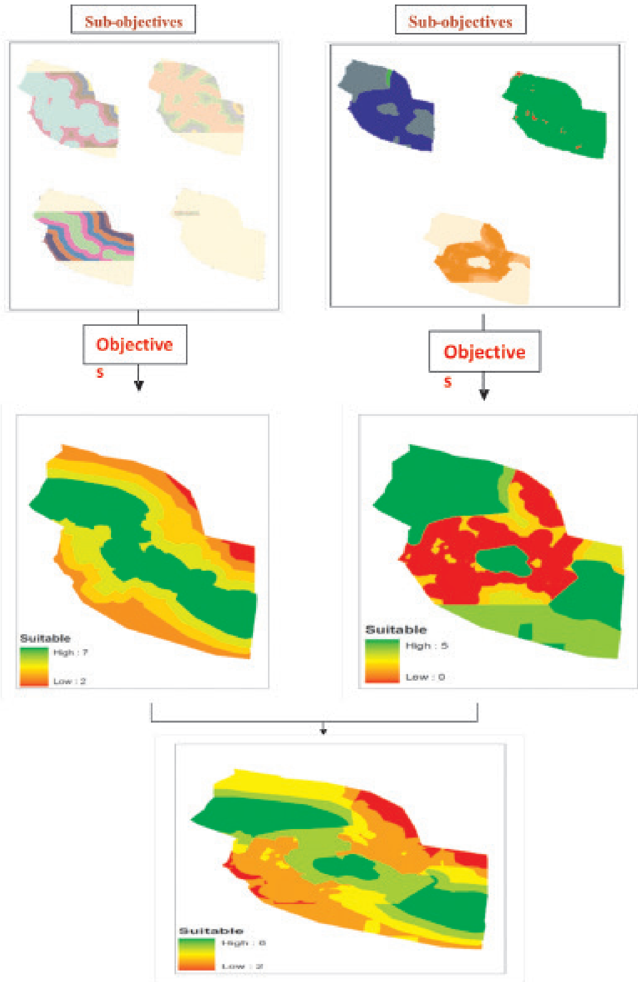

Figure 5: Flowchart showing the creation of objectives and goals of Land suitable for commercial use. Fictive weights have been added to illustrate the method.
Suitability maps for residential and commercial land-use

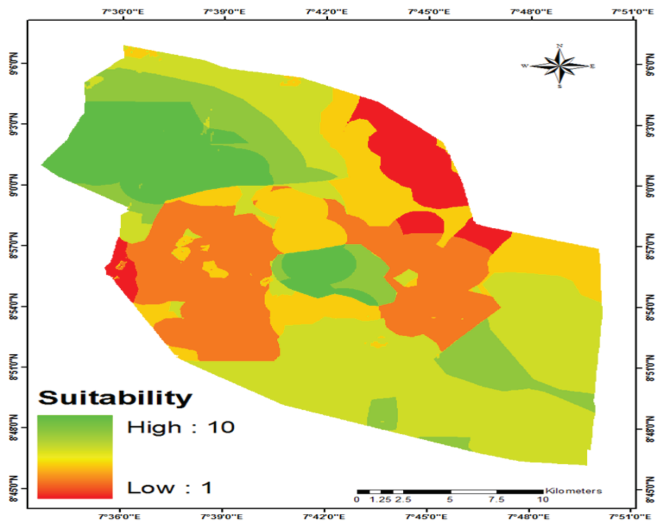

Figure 6: Final Suitability map for residential land-use.

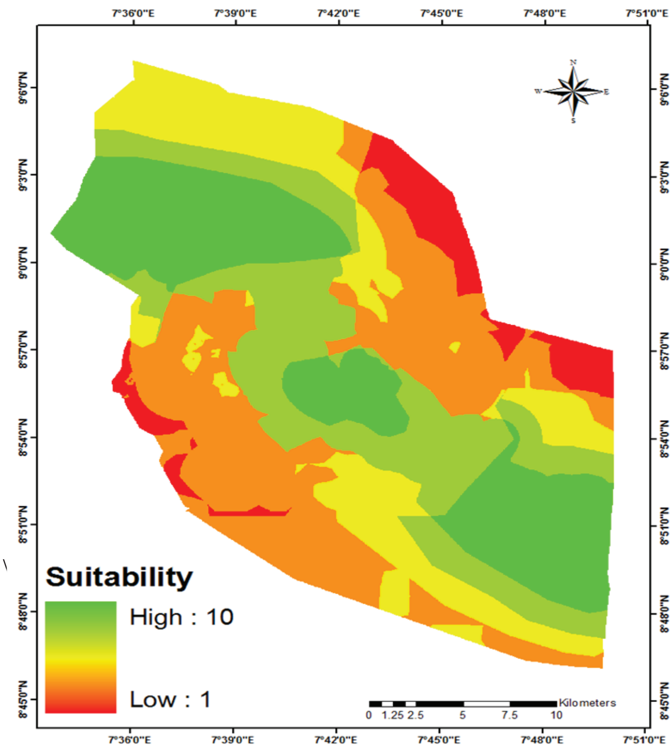

Figure 7: Final Suitability map for commercial land-use.

Limitations of the Model

The GIS model presented in this paper has two limitations related to the methodology and criteria. For the methodology, the weighted summation technique is limited to compensatoryproblem. This means that a cell with a low score on one criterion may gain fromother criteria on which it scores higher. The criteria limitation considers the factors of urban development. Several factors such as proximity to industry, employment, social services, land availability and prices were not included inthe design of the suitability model, yet they are important. This was due to non-availability ofdata on these factors. Furthermore, areas that are suitable for urban development are considered suitable for agricultural uses. This factor was not considered because of two reasons; first, areas suitable for agriculture are in most cases generally suitable for residential uses. Secondly, there is urban agriculture in the area, usually done on spaces between houses, open land and undeveloped plots. It is generally assumed that areas suitable for residential use are also suitable for agriculture thus it does not hinder urban agriculture since residents of the area engage in the activity.

CONCLUSION

Land acquisition through informal delivery with selling of plots of land measured less than 900m2 has immensely contributed in making land available and affordable for low and middle income class within a short period of time. This also possesses great challenges to land use management with attendant consequences of congestion, over development, overcrowding, overstretch of utilities and infrastructure, haphazard development, encroachments and poor living environment. The rapid economic and population growth with speed up haphazard urban expansion call for geospatial management of land use in the Area. The use of geospatial techniques and multi-criteria decision analysis has been proved to be efficient, accurate, quicker and cost effective tools for sustainable future development of the area. The model presented can also be used by planners and authorities to formulate suitable plan for sustainable development of the area.

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