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## Application of GIS in Locating New Sites for Health Facilities

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### **Abstract:**

*Construction of public facilities like school, hospitals and even roads in Kenya has always been advanced by politicians which in most cases end up not being optimized because of poor locations in which they are setup. GIS is a powerful tool that captures, manages, manipulates, analyses and presenting geographical data. Arc Gis 10.2.2 software was employed in this process. This helps in solving geospatial problems like urban planning, shortest economical routes from one point to another, locating best locations for new facilities based on provided factors like in this case. In this setup, we use GIS to locate best location for health facilities by combining, overlaying and manipulating geospatial datasets to attain our goal. The datasets for this being geo-referenced maps of roads, rivers, school, existing health facilities and population dataset. The GIS software tool proved to be a reliable to tool in manipulating these datasets and providing a solution, and presenting in form of maps showing the best locations for new health facilities.*

**Keywords;** GIS (Geographic Information systems) DEM (Digital Elevation Model) datasets, data manipulation and analysis, suitable locations health facilities, former Kaka mega district.

### **1. Introduction**

Public health facilities are government establishments constructed all over the country for purposes of taking care of health needs of its citizen. (Richard, M. Paul, K. Michael, M, and Terry, G. 2005). Health facilities in Kenya are classified in levels from level one to level five. Level one covers areas where medical personnel frequently visit to offer medical services like vaccinations to children, prenatal and postnatal clinical checkups, dental health and general clinical observations. These setups could be schools, churches, or chief's centers. Mobile clinics in vehicle tracks are in this category. The essence of this setup is to bring medical services closer to the people because of shortage of health facilities in these locations. In places with adequate facilities, we do not have such setups. The next class is level two which are Dispensaries. These are the smallest permanent facilities usually manned by a maximum of four medical personnel. They are the first point of contact of patients with health personnel in the rural setup. They do not have medical stores. They usually have simple equipment that can diagnose blood sugar levels, malaria, typhoid and a few common diseases. Most of these are in the rural areas. Level three are the Health centers. These have a maximum of sixteen health personnel and are equipped with medical stores for drugs, clinical facilities and vaccines. Have laboratories that perform more detailed test and analysis. Minor medical operations are performed like caesarian sections. Level four are the Sub County Hospitals. These are replicas of level three only that they have more personnel, larger medical store and a more structured administration system. Cases that need more medical attention are referred here from levels one two and three. Level five is the County referral Hospital. This is the overall in hierarchy. All cases that cannot be handled at the other levels are referred here in accordance to their complexity. The county referral hospital is located at the county headquarter and is the only one in the county. The rest are all scattered in the rural areas. They are the first line of access to medical aid in the rural areas. Accessibility to health facilities is concerned with ability to access the facilities in reasonable time and ease for the required medical services. Ease with which one can access medical facilities in developing countries can be a matter of life and death. It is also a factor that contributes to the economic growth of a region and country at large.

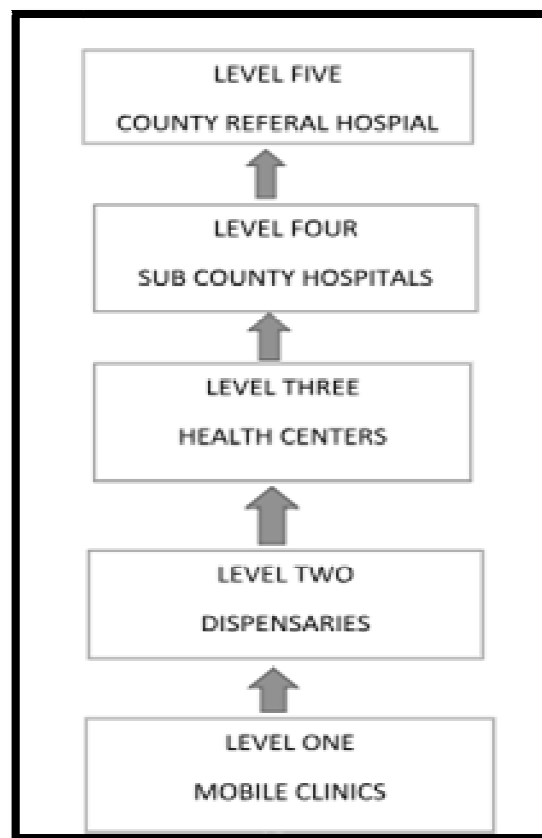


Figure 1: Hierarchy of Health Facilities in Kenya

This data was sourced from the Kakamega county medical officer's office. Abdison, M. Noor. Victor, A. and Peter, W. (2009). The government recognizes that health is prerequisite to social and economic development of its citizen. By so doing it has tried to expand and offer more services in the existing facilities for example by promoting kakamega county hospital to a referral hospital and by encouraging citizens to join the health insurance organization (NHIF) that caters for some hospital expenses. Providing funds through CDF for construction of new facilities. However, challenges are still experienced in accessing the health facilities and quality health care especially in the rural settings.

We cannot talk about distribution of health facilities without mentioning the population and its increase in the last few years. Population increase in an area has a direct impact on the provision of health services. Calculations from the table below show that population in the study area has increased by 54.47% between 1989 and 2009 from the (KNBS, 2009).

	Location	Population 1989	Population 2009	Area_Sq Km
1	Central Kabras	34 571	63 427	142
2	West Kabras	30 329	66 114	109
3	South Kabras	47 464	63 373	176
4	Bunyala	48 113	89 722	175
5	North Butsotso	34 694	73 121	102
6	East Isukha	25 618	41 343	73
7	South Butsotso	31 048	40 604	96
8	Municipality	63 796	93 881	75
9	Central Isukha	47 996	62 913	273
10	West Isukha	42 126	55 219	62
11	North Idakho	43 266	61 724	75
12	South Idakho	39 331	42 945	67

Table 1: Population of Study Area between 1989 and 2009 Census

Source of Data Kenya National Bureau of Statistics Kakamega County Office (KNBS)

### 1.1. Problem Statement

Health facilities are not evenly distributed in Kenya. Research by (Dustin, R. 2010) reveals that in Kenya 16 facilities serve an average of 100 000 people and in western Kenya we have an average of 15.4 hospital beds per 100 000 persons.

Some locations have more facilities than others. Some factors attributing to this disparity are population density and political muscle exercised by some powerful politicians in arbitrary constructing health facilities without considering the outlying factors like population distribution. The population of the area has grown but the number of health facilities has not increased in proportion with population growth. Access to the existing facilities is made worse by distance one has to cover to. Because of increase in population most of the existing facilities are overcrowded.

### 1.2. Justification

The government has made effort to improve health care in the country by passing general polices like offering free child birth and free medical care for children below five years of age but has not addressed this disparity.

It is obvious with increasing population there has to be more health facilities to help cater for the many cases that arise and cannot be handled adequately by the current facilities. Sick people move long distances to access medical care.

With advent of geographic information system GIS, it is possible to locate new sites for health facilities by combining and analyzing different data sets, in this case elevation, population, schools, existing health facilities and roads, as opposite to the wayside pronouncements made by politicians in deciding locations for health facilities.

This study stands to benefit the local population, county Government and medical planning institutes within the county.

#### 1.2.1. General Objective

To identify new sites for health facilities in the former kakamega district (study area) using geographic information system GIS.

#### 1.2.2. Specific Objectives

- To analyze the geographic distribution of existing public health facilities.
- To select the most suitable location for new facilities in the study area

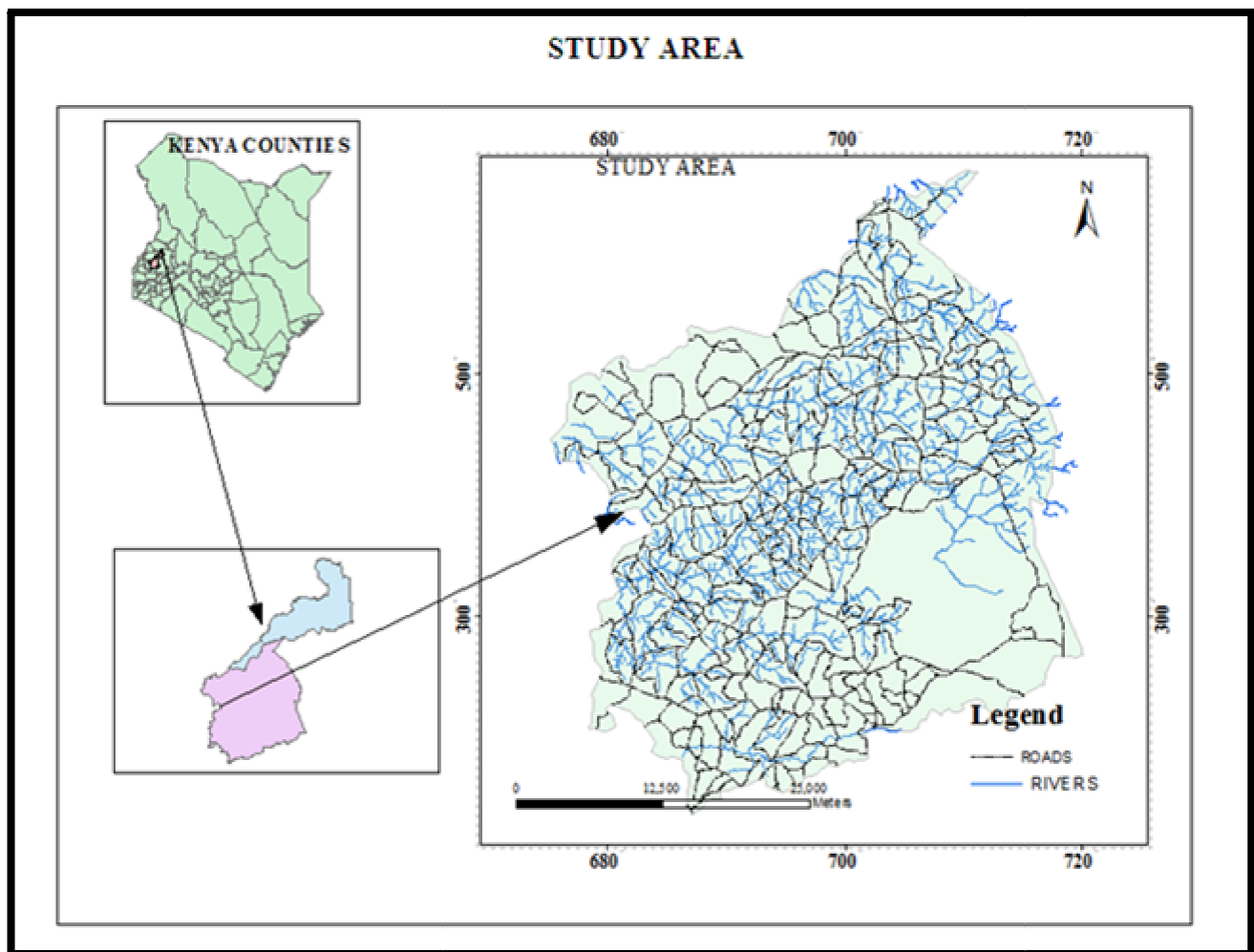


Figure 2: Map 1 Study Area

The study area which was formerly called Kakamega District is made up of, Ikolomani, Shinyalu, Navakholo, Lurambi, and Malava sub counties. The area lays within latitudes 0° 08' 00" and 040° 00' 00" North and 34° 32' 00" and 34° 58' 00" East. It covers an area of approximately 1745 sq km. The area is blessed with one of the remaining natural equatorial forests (kakamega forest) that used to extend up to the Congo forest. It borders Lugari Sub county and Bungoma county to the North. Nandi County to the East, Vihiga county to the South Mumias and Butere sub counties to the West.

The area has an equatorial climate, with long and short rains from February to June and short rains from August to November. The main economic activities in the area are;

- Sugarcane farming which is now the main cash crop in almost all the sub-counties.
- Growing maize and beans is practiced as subsistent farming by most people. Maize is the main stable food for the residents of this area.
- Small scale dairy farming also practiced by most farmers.
- None mechanized small scale gold mining is practiced in Ikolomani and shinyalu sub counties.

## 2. Literature Review

### 2.1. Back Ground

Health facilities are few and not evenly distributed in Kenya. This scenario cuts across the country including the study area. During my research, I encountered situations where sick people cover more than five kilometers to access health care. This study attempts to solve this problem by using GIS (geographic information system) to locate new suitable sites for public health facilities.

#### 2.1.1. Geographic Information System

A geographic information system (GIS) is any system that is capable of capturing, storing, editing, manipulating and displaying spatial geo referenced data. Otto Huisman and Rolf A. de By (2009) in their book (principles of geographic information systems) defines GIS as a computer-based system that provides the following four sets of capabilities;

- Data capture and preparation,
- Data management including storage and maintenance,
- 3, Data manipulation and analysis,
- Data presentation.

A GIS platform comprises of a desktop, geographic database for storing and managing spatial data, software toolkit for assembling and integrating GIS applications with other servers and mobile GIS.

#### 2.1.2. Arc Map

ArcMap is the main application used for mapping editing query and analysis functions in ArcGis. Spatial information is represented by ArcMap in form of layers. Other ArcMap elements are display panels. These are data frame and data layout. The data frame is used to compose maps for display and printing.

#### 2.1.3. Geo Data Base

It is a collection of geographic datasets of various types held in a common file system folder, a Microsoft Access database, or a multiuser relational database. It stores GIS data in a central location for easy access and management (Esri 2011). The geo data base software logic provides the common applications used for accessing and working with geographic data in a variety of files and formats. It has a transaction model for managing GIS data workflows. A geodatabase contains datasets. Datasets represent collection of information with real world interpretation. Types of datasets are tables, feature classes, relationship classes and feature datasets. Feature datasets contain topologies, networks, rasters and cadastrers. Datasets have associated information that help manage integrity, behavior, interpretation domains, default values and metadata.

#### 2.1.4. ArcCatalog

ArcCatalog help organize and manage spatial information such as images, maps, databases, datafiles and geoprocessing toolboxes. It is from these databases in ArcCatalog that spatial data is manipulated from onto the table of contents for processing.

#### 2.1.5. Spatial Analyst Tools

Spatial Analyst tools available are used to perform spatial analysis data. They can provide answers to spatial questions, such as how steep is it at this location, where is the best location for a new facility? Or which is the least costly path from point A to point B? Spatial Analyst extension tools have a wide range of cell-based GIS operations among them are;

#### 2.1.5.1. Derive New Information

Spatial Analyst tools are applied to create useful information from existing data by combining data through union or merge functions to create new data files that have both attributes of the original data files, rasterization and vectorizations functions and many others.

#### 2.1.5.2. Identify Spatial Relationships

Explore relationships between layers through weighted overlay and combinations. Spatial Analyst tools make it possible to model data by use of cell-based modeling.

#### 2.1.5.3. Find Suitable Locations

By combining layers, spatial analyst tools can find areas that are the most suitable for new facilities. They can also locate areas that are prone to floods.

#### 2.1.6. Data Capture and Preparation

Are the processes of inputting data in the GIS. The processes involve the following procedures;

- Scanning- Analogue topographic maps are scanned and entered in the GIS in digital form.
- Digitizing- We have on table digitizing where an analogue map is fixed on a digitizing table and the features digitized manually by tracing the feature with a cursor. The scanned maps can also be manually digitized or semi automatically digitized on the computer screen.
- Key board entry- the attribute data is typed in the computer using the key board.
- Remotely sensed data in form of aerial photographs and satellite images is directly downloaded in the GIS. Accuracy depends on image resolution.
- GPS and total station survey data is directly downloaded in the GIS using the provided software that is supplied with the equipment.
- Existing digital data, usually attribute data from relevant agencies like national bureau of statistics is directly entered in the GIS.

#### 2.1.7. Data Management, Storage and Maintenance

After data is captured and entered in the GIS, it has to be cleaned or edited and generalized. This involves removing unnecessary or excessive details from the data, enhancing some details for clarity and adding some details to single out the prominent entities of interest. The processed data is stored in the GIS database.

#### 2.1.8. Data Manipulation and Analysis

Geographic data in a GIS is stored in feature class layers. This allows combining of different layers by overlaying them. This way comparison can be made between different features allowing for data analysis and decision making.

#### *2.2. Data Presentation*

This is the final step in the processes. The results are presented in different formats depending on the user's preference. They can be presented as maps in soft copy or print, bar charts, statistical format depending on the user's request. They can also be presented on the web for wider viewing.

GIS has many advantages over traditional methods since it has the capabilities of eliminating duplication of data by capturing, storing, manipulating and displaying data in a structured way (Shiraz, 2009). GIS database stores large volumes of georeferenced spatial and non spatial data that can be retrieved for planning, management and decision making in delivery of essential services in the health sector. As a mapping tool, locations of health facilities in relationship to infrastructure and other facilities like school's spatial distribution can be visualized and their apparent relationship revealed. Through overlay analysis and modelling capabilities, the results of new locations are provided by this research.

#### 2.2.1. Applications of GIS in Health

Health officials involved development planning and implementing facilities master plan have to make crucial decisions about locating new site for health facilities in an efficient and accurate manner. Modern technology can now aid planners and administrators in county planning.

With the use of Geographic Information Systems (GIS), decisions that once required weeks and months of planning can be made within a very short time. For example, when determining the location of a new health facilities, administrators would usually perform hours of research to find available and affordable land. This process for collecting the data can take long working hours and would still contain many errors. With GIS, current aerial photos can be analyzed to determine suitable land for a new health facilities. Planners can use GIS to overlay the area's populations to determine people are living close to the proposed site.

Mapping existing facilities together with other information like roads, rivers, population and terrain provides ground reality to plan for new facilities that provides optimum coverage of the population based on facts and not perspective.

### 3. Research Methodology

#### 3.1. Methodology

The main problem in the study area is spatial distribution of health facilities and accessibility to the existing facilities (Mulefu Oduori 2011). The project covers accessibility and mapping of existing health facilities to try to solve this problem. Land is expensive to buy and the available land may not be in the most suitable site for constructing a health facility, public schools have ample land and are well served by roads and other utilities like electricity, that is why this project proposes to have the new health facilities close to schools for ease of serve provision and access, and availability of land.

GIS varies index ratios like distance from existing health facilities, roads, public schools, population density and rivers. The general process involves system design, data collection and analysis of the data which results in maps showing population density, distribution of public health facilities, public schools, roads and rivers. The procedure is as shown in the flow diagram figure below.

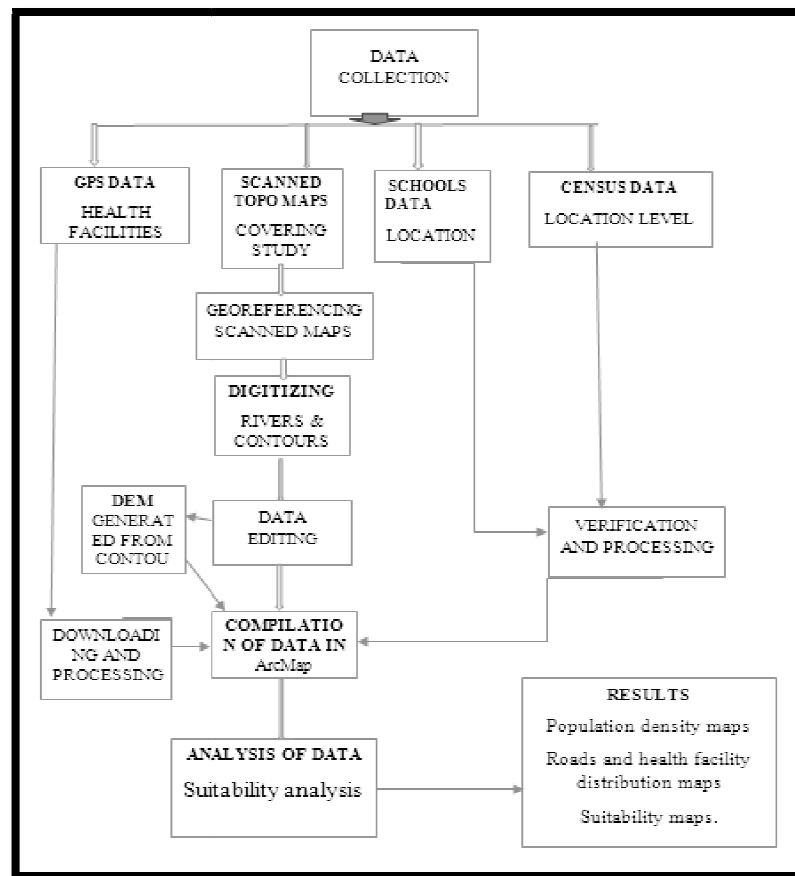


Figure 3: Methodology

#### 3.1.1. Data Sources

Source	Data
Kenya National Roads Authority (KERA)	Roads data
Kenya National Bureau of Statistics (KNBS)	Census data
Survey of Kenya	Topographic maps and boundaries
Ministry of Education	Public schools data locations
Ground Survey (GPS)	Health facilities location

Table 2: Various Sources of Data

#### 3.1.2. Data Collection

Data for this project includes scanned topographic maps, administrative boundaries, digitized contours, roads, rivers, schools locations and and GPS data. The topographic maps were sourced from survey of Kenya. The topographic maps were six in number. They were scanned then georeferenced.

### 3.1.3.GPS Data

The ground survey data to be collected are the locations of existing health facilities. The first step was to get the physical addresses of the health facilities from the county health officer's office. A hand held GPS(etrix) was used to get the geographic coordinates of the facilities at suitable positions on the facilities compound mostly near the administration blocks. The GPS records the values received from the satellites and stores them in its file system. This data was downloaded in mapsource (an etrix GPS downloading software) then imported in excel and finally in GIS where it was stored as a shapefile.

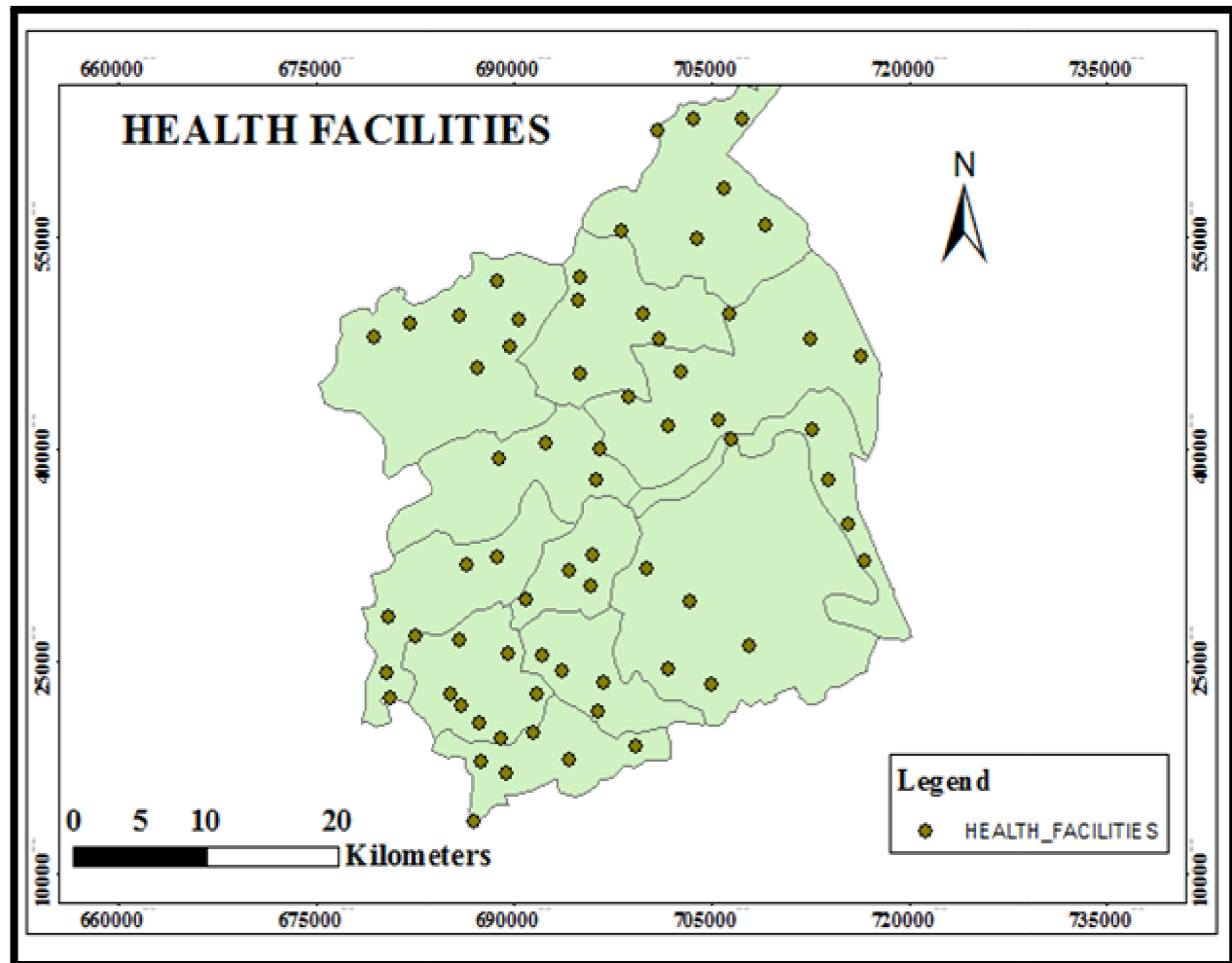


Figure 4: Map 2 Showing Distribution of Health Facilities

### 3.1.4. Roads Data

This was sourced from the (KRA) Kenya National Roads data in soft copy as a shapefile. Since this data was for the whole country, the roads covering the study area were clipped by application of a GIS function known as clip. The function delineates only the area of interest from the rest of the data. Clipping is the process of cutting off a small area of interest from a provided large area. The data was cleaned and corrected for errors. Additional roads were digitized from the scanned topographic maps. In analyzing accessibility areas that fall within the 300m road buffer zone were considered suitable for new health facilities.

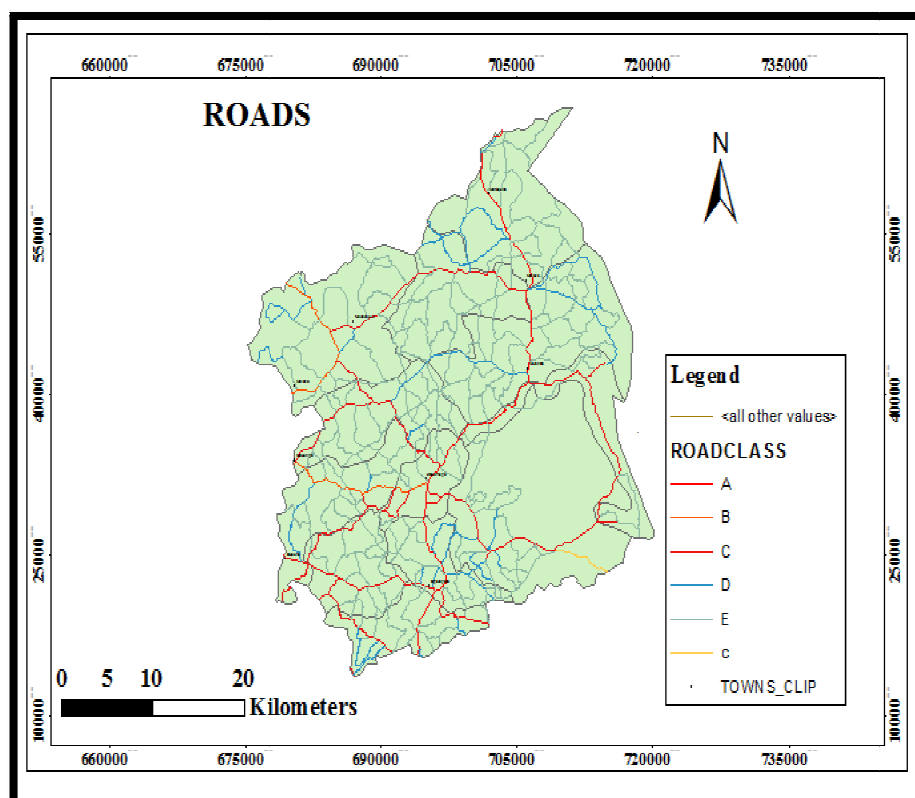


Figure 5: Map 3 Motorable Roads in the Study Area

### 3.1.5. Rivers and Streams Data

The data for rivers was obtained by digitizing the rivers from the scanned georeferenced topographic maps by on screen method. This is more accurate because it is possible to zoom in and digitize finer details. It was noted that some streams are seasonal and others have dried up with time but still appear on the topographic maps. It was necessary to capture them as they still form the watershed of the area and are important to consider when medicating floods. We do not want to have health facilities in locations that may flood during heavy rains.

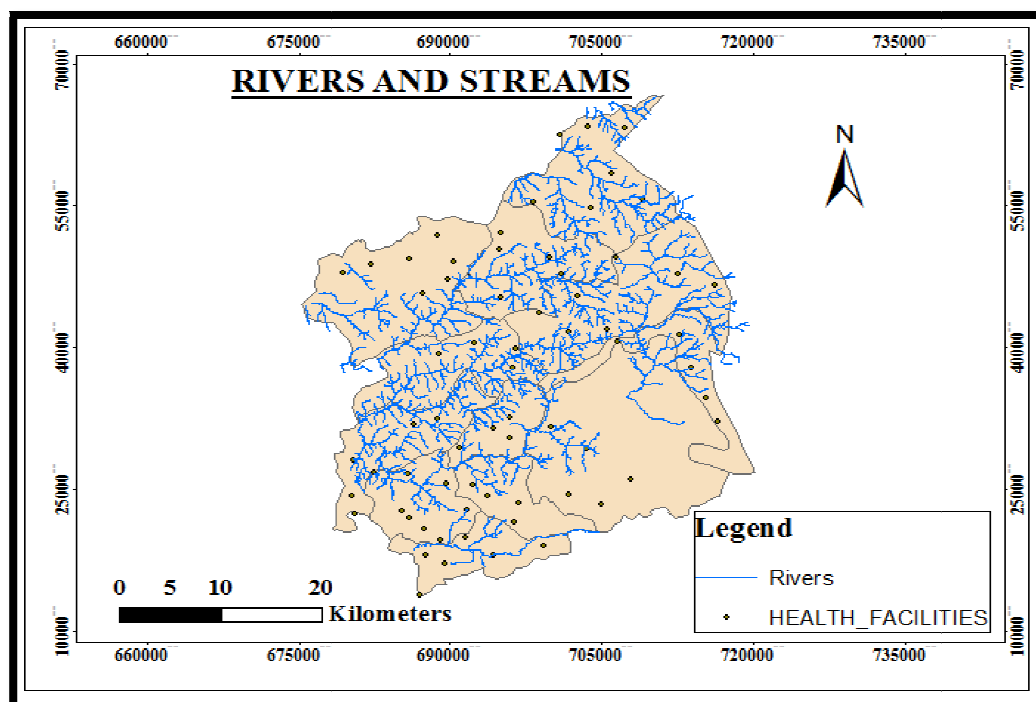


Figure 6: Map 4 Rivers and Streams



### 3.1.6. Public Schools Data

Schools data from county ministry of education office was in excel format with x, y coordinates in soft copy. It was for all schools both private and public. To separate public school from private schools, selection method by attributes was applied which uses SQL to select only all public schools from the mixed school's data.

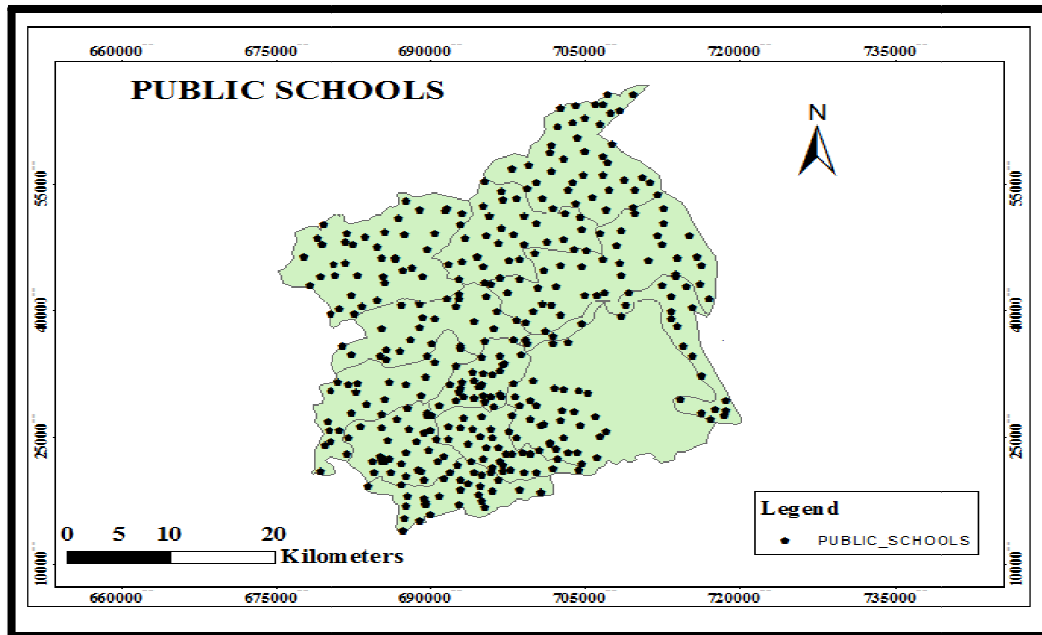


Figure 7: Map 5 Public Schools

### 3.1.7. Contours Data

Contours were obtained by digitizing the contours on the scanned digital topographic maps by on screen digitizing method. Each contour was assigned its correct elevation value as an attribute. The contours were edited for removal of errors that may have occurred during digitizing. The map contour interval of 20m was adopted. This to be used in setting the DEM resolution to the same.

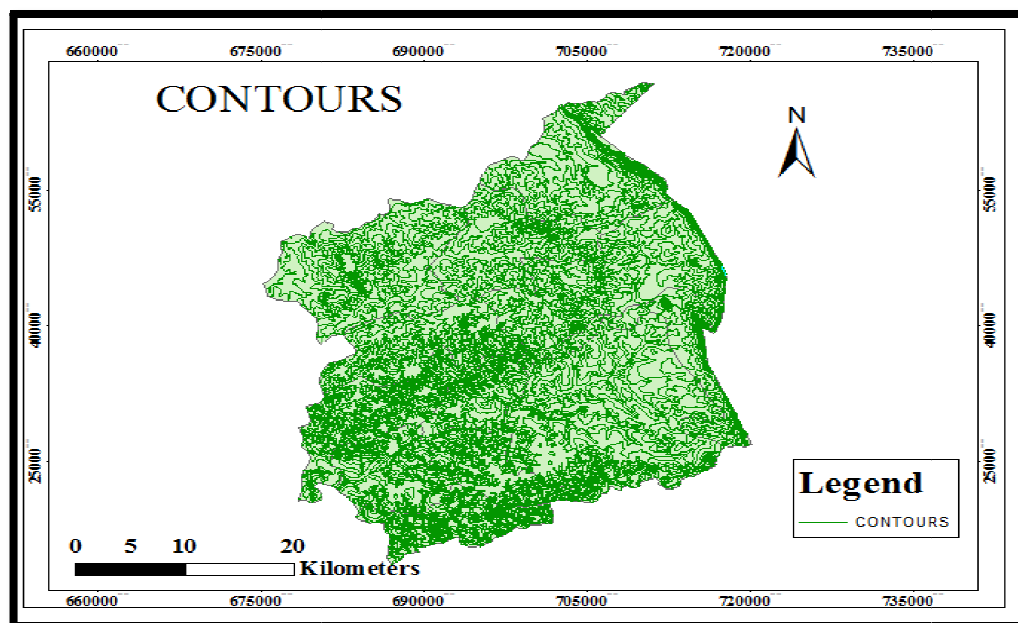


Figure 8: Map 6 Contours

### 3.1.8. Population Data

Population data was obtained from Kenya bureau of statistics county office. It included population of males and females to sub-location level and population density. Population for 1989 and 2009 was obtained for calculation of population

growth which was found to be 54.47%. For this project Locations are the smallest unit of analysis. The study area has 12 locations, namely, Central Kabras, West Kabras, South Kabras, Bunyala, North Butso, South Butso, East Isukha, Central Isukha, West Isukha, Municipality, North Idakho and South Idakho. The location unit is used in preparation of population density map of the study area. Municipality has the highest population density while central Kabras has the lowest.

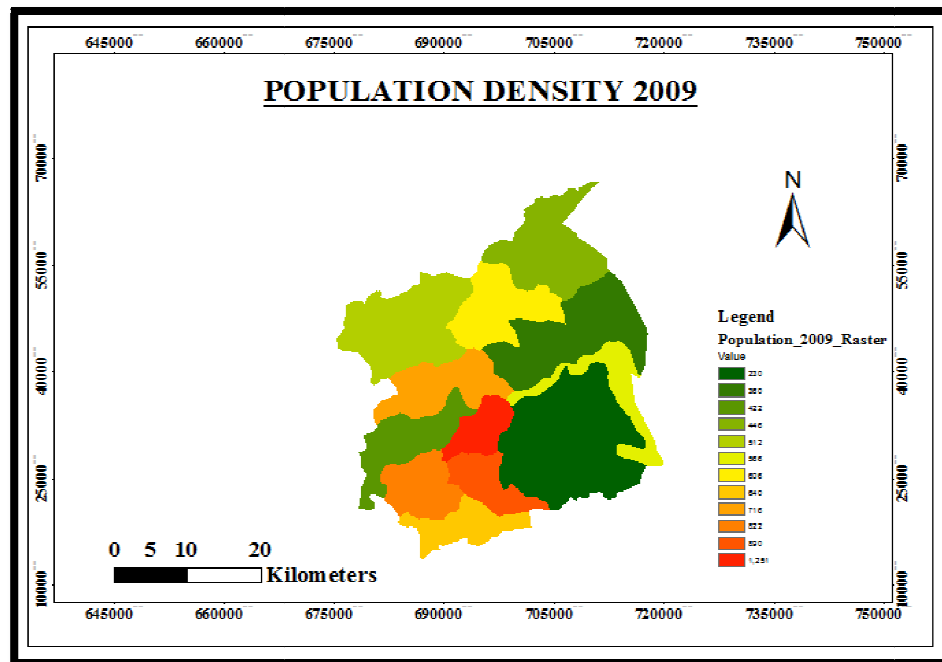


Figure 9: Map 7 Population Density

### 3.2. Data Processing and Results

#### 3.2.1. Digital Elevation Model (DEM)

The DEM was created from contours digitized from scanned topographic maps of the study area by onscreen digitizing technique. The DEM adopted the base map contour interval of 20m as resolution. To generate a DEM, a TIN was first generated from the digitized contours using the 3D Analyst tool in ArcMap. The procedure involved placing the contour dataset in table of contents and selecting “create TIN from contours” in the search window. The 3D Analyst then generated the TIN. TIN to raster was typed in the search window, and TIN used in the input. A DEM was then generated.

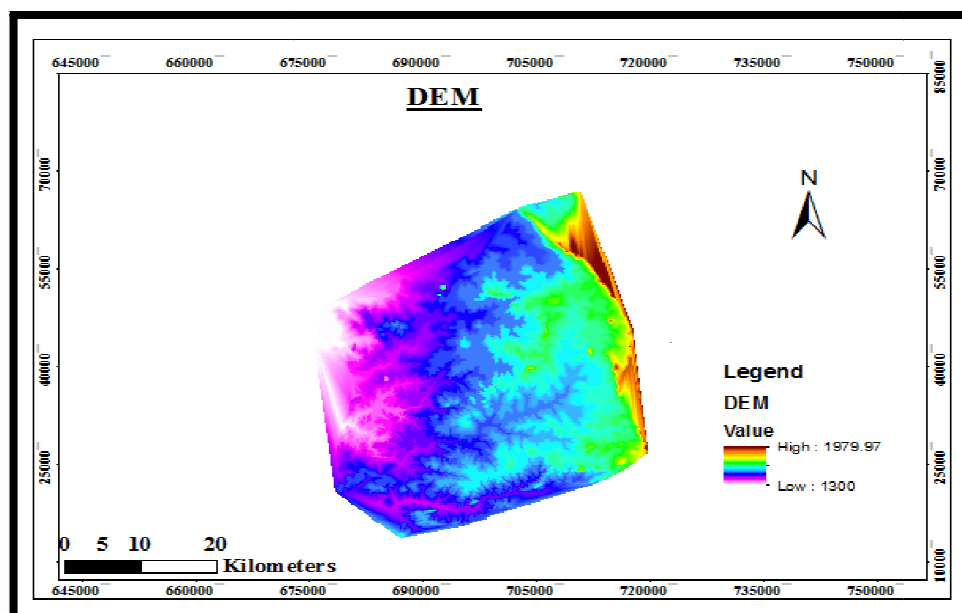


Figure 10: Map 8 DEM

### 3.3. Suitable Locations

To locate suitable locations for new health facilities, we consider the following facts;

- The facilities have to be as close to motorable roads as possible for ease of access. A road buffer of 500m is used to determine locations within this buffer.
- They should be located close to public schools so as to share the existing utilities at the schools like electricity, and publicity. The schools are convenient for holding public health education forums.
- The area population density is important in the distribution of the new health facilities. Locations with more population density are given more weight.
- The facilities are best located on areas with gentle slope, the elevation data set generated from TIN is used in setting the suitable slope acceptable.
- Landuse dataset is considered to identify protected areas like forests and restrict them from being selected.
- They should be located at a distance from rivers, the river buffer of 200m is generated and used overlaid over the selected sites to determine locations 200m from rivers.

The first datasets to be used in this process are public schools, existing health facilities and DEM. These three data sets are loaded on the table of contents then a suitability model Builder is created using spatial analysis tools that will help locate the most suitable locations. To create a suitability model, a toolbox that will hold the model is created in the geodatabase and a new model builder created. Before performing analysis on the data, relevant environment settings are set because the environment settings apply to each process of this model only. The model was renamed as “find locations for health facilities” then the cell size set as same layer as DEM and extend as same layer as DEM.

#### 3.3.1. Deriving Data Sets

Slope was derived from the DEM dataset, distance to schools from the public schools’ dataset and distance to health facilities from the health facilities dataset. From table of contents, the layers DEM, health facilities, and public schools were dragged onto the model, and the Slope tool from the Spatial Analyst Surface toolset onto the model and placed in line with DEM data. Located the Euclidean Distance tool in the Spatial Analyst Tools Distance toolset, drag and place it in line with public schools’ data then repeat the same for health facilities data. Using the connection tool connect DEM, public schools and health facilities to slope and Euclidean distance respectively.

#### 3.3.2. Deriving Slope and Distances (Slope from DEM, Distance to Schools and Distance to Health Facilities)

Since some areas are very steep, the slope of the land was considered to find relatively gentle slopes or flat land suitable for new health facilities. Rename Output raster to REC\_SLOPE and add to display.

To find locations close to public schools, Euclidean (straight-line) distance from public schools was calculated and the Output distance raster on the model renamed “Distance to Schools”.

Locations for new health facilities have to be far from the existing health facilities. To find locations far away from existing health facilities, Euclidean (straight-line) distance from existing health facilities was calculated and the output variable on the model renamed “Distance to Health Facilities”. On running the model, maps of derived slope, derived distance to schools and derived distance to health facilities were generated. The model looks like the figure below.

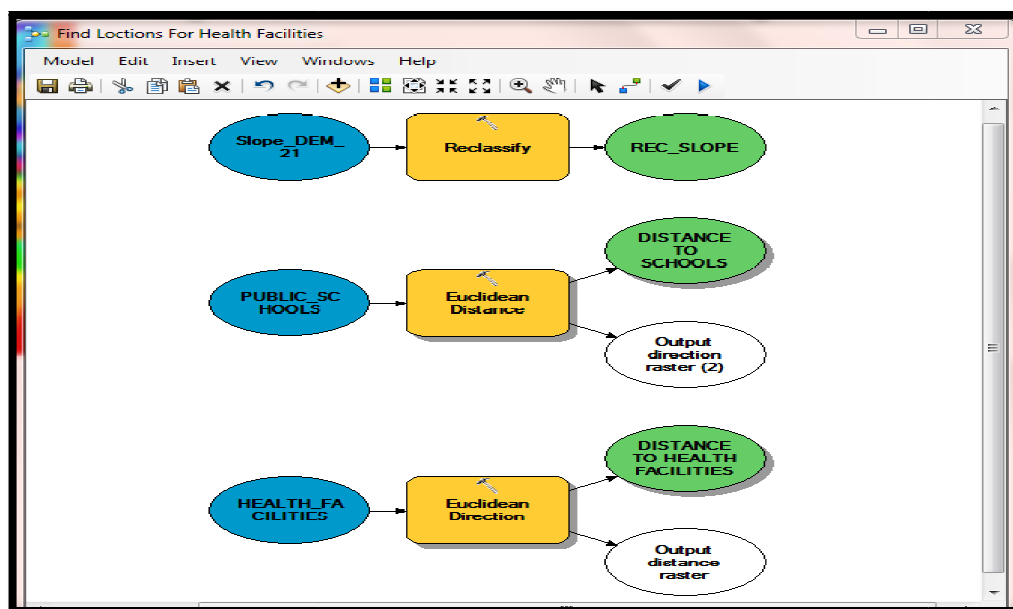


Figure 11: Model 1 The First Step of the Model for Deriving Distances and Slope

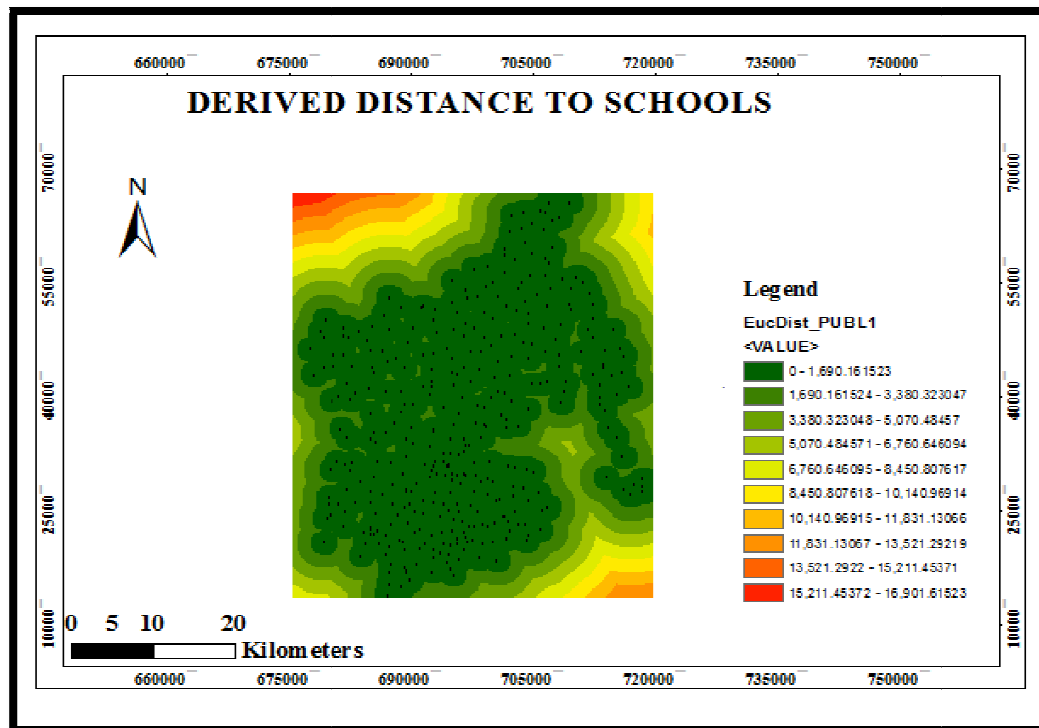


Figure 12: Map 9 Derived Distances to Schools  
The Most Desirable Areas Are Those Close to Schools in Green Color

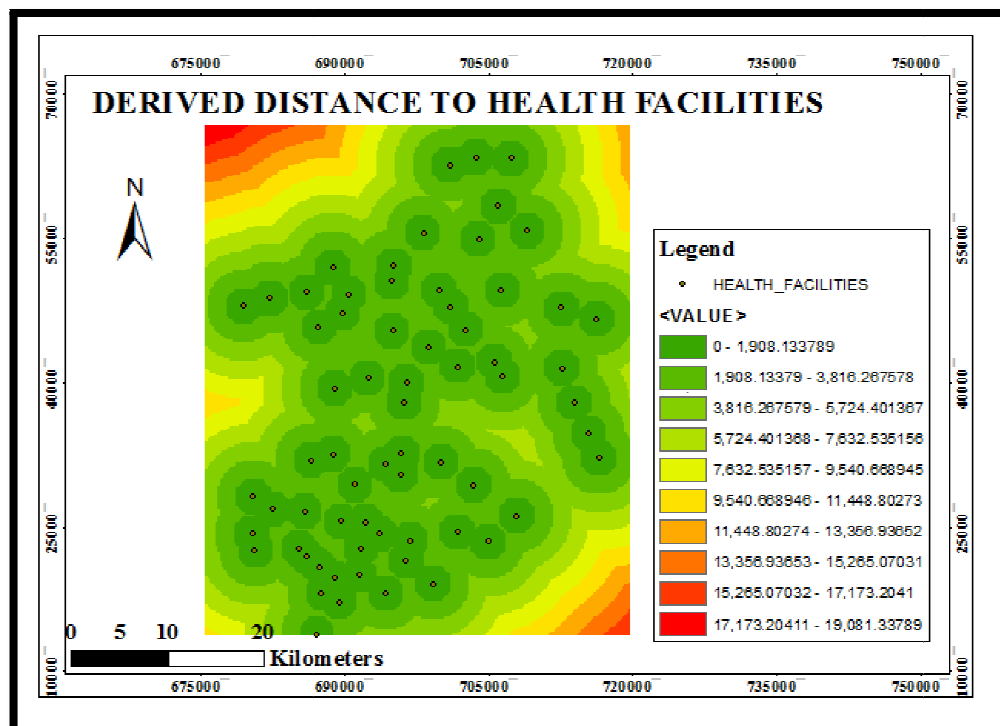


Figure 13: Map 10 Derived Distances to Health Facilities

Derived distance to health facilities map, green areas are distances close to existing health facilities and are not suitable for health facilities.

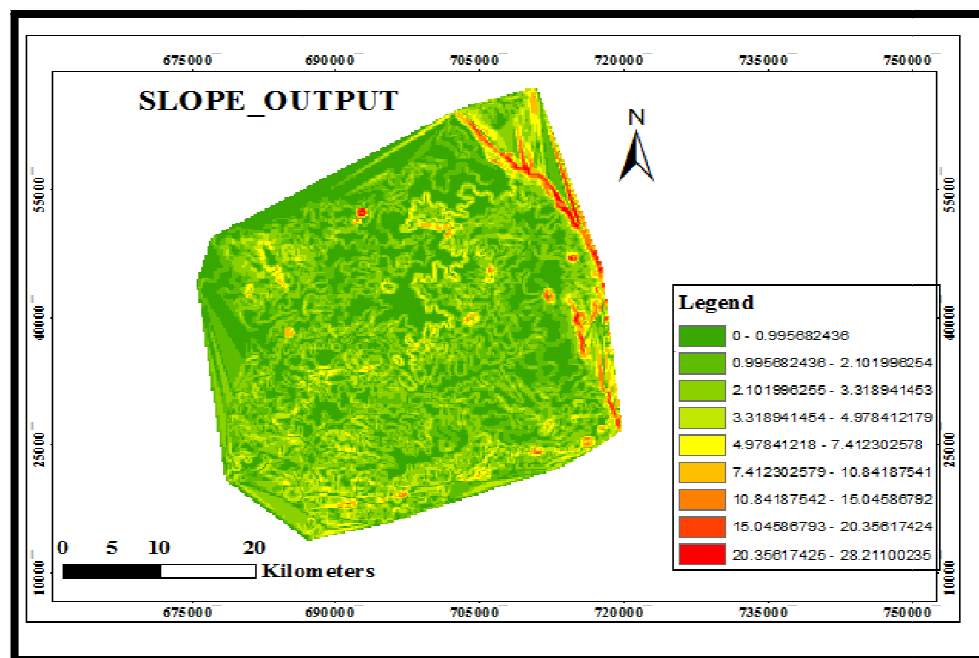


Figure 14: Map 11 Slope Output

Derived map for the slope of the study area. Areas in red are steeper and not suitable sites for health facilities. The areas in green are the most suitable sites with gentle slope.

### 3.3.3. Reclassifying Datasets

Each cell in the study area has a value for each input dataset (slope, land use, distance to schools, distance to health facilities and population, sites). Cell values in the datasets are different. To be able to combine the datasets, they first need to be set to a common measurement scale, such as 1 to 10. It is that common measurement scale that determines how suitable a particular location each cell is good for a new health facility. Higher values indicate more suitable locations. We use the Weighted Overlay tool to weight the dataset values of each dataset and combine them. After reclassifying the schools, health facilities and slope data sets, the resulting generated maps for the data sets were as below.

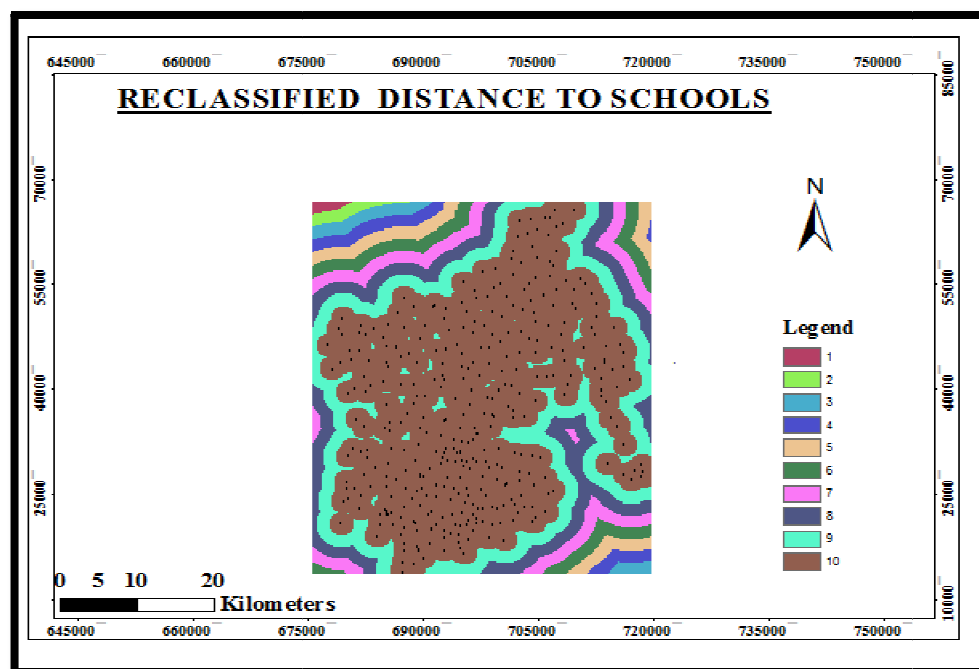


Figure 15 Map 12 Reclassified Distance To Schools

Reclassified distance to schools' map with high values indicating most suitable areas.

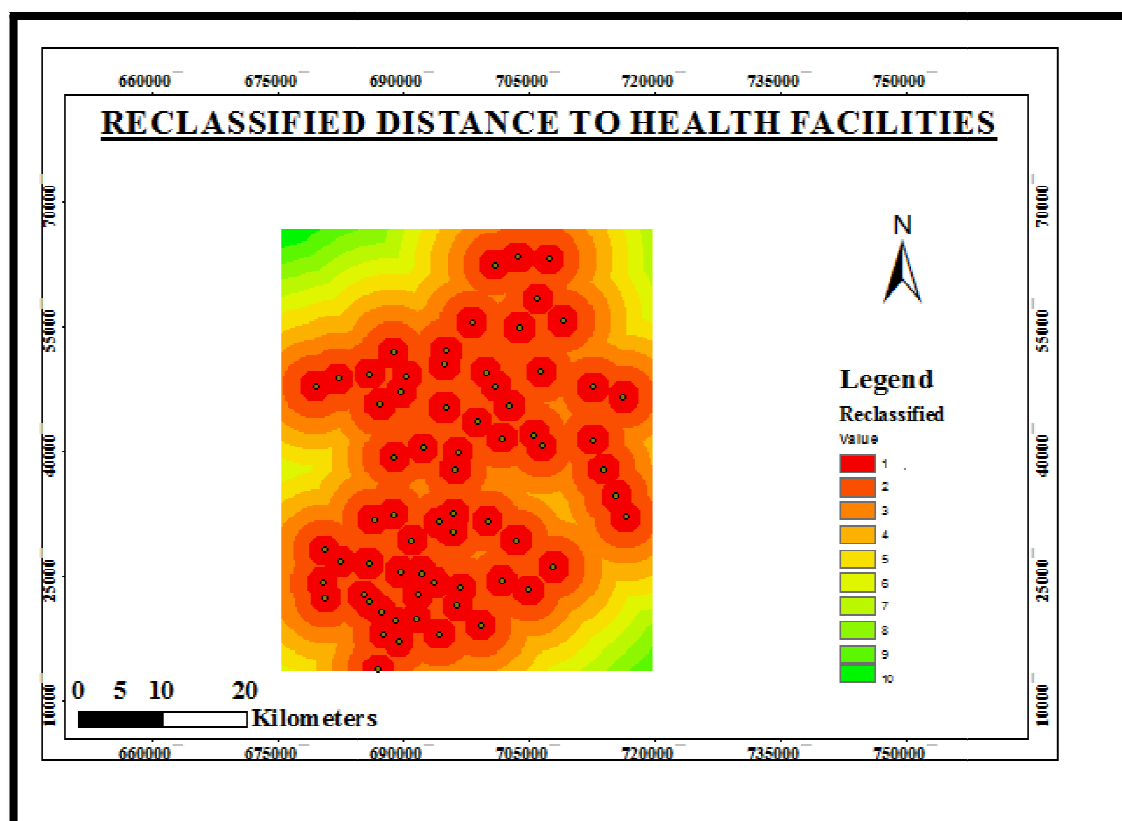


Figure 16: Map 13 Reclassified Distance to Health Facilities Map

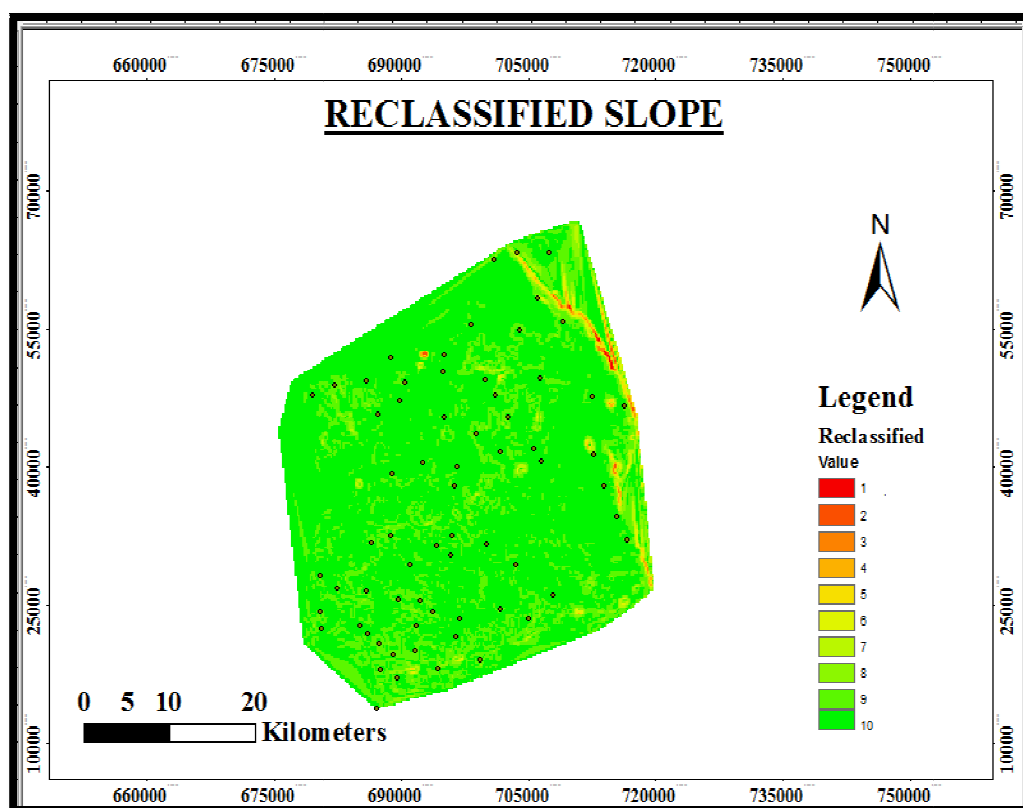


Figure 17: Map 14 Reclassified Slope

Reclassified slope, areas with high values is the most suitable locations with gentle slope.

### 3.3.4. Combining and Weighting Datasets

The model for weighting and combining the datasets looks like the figure below.

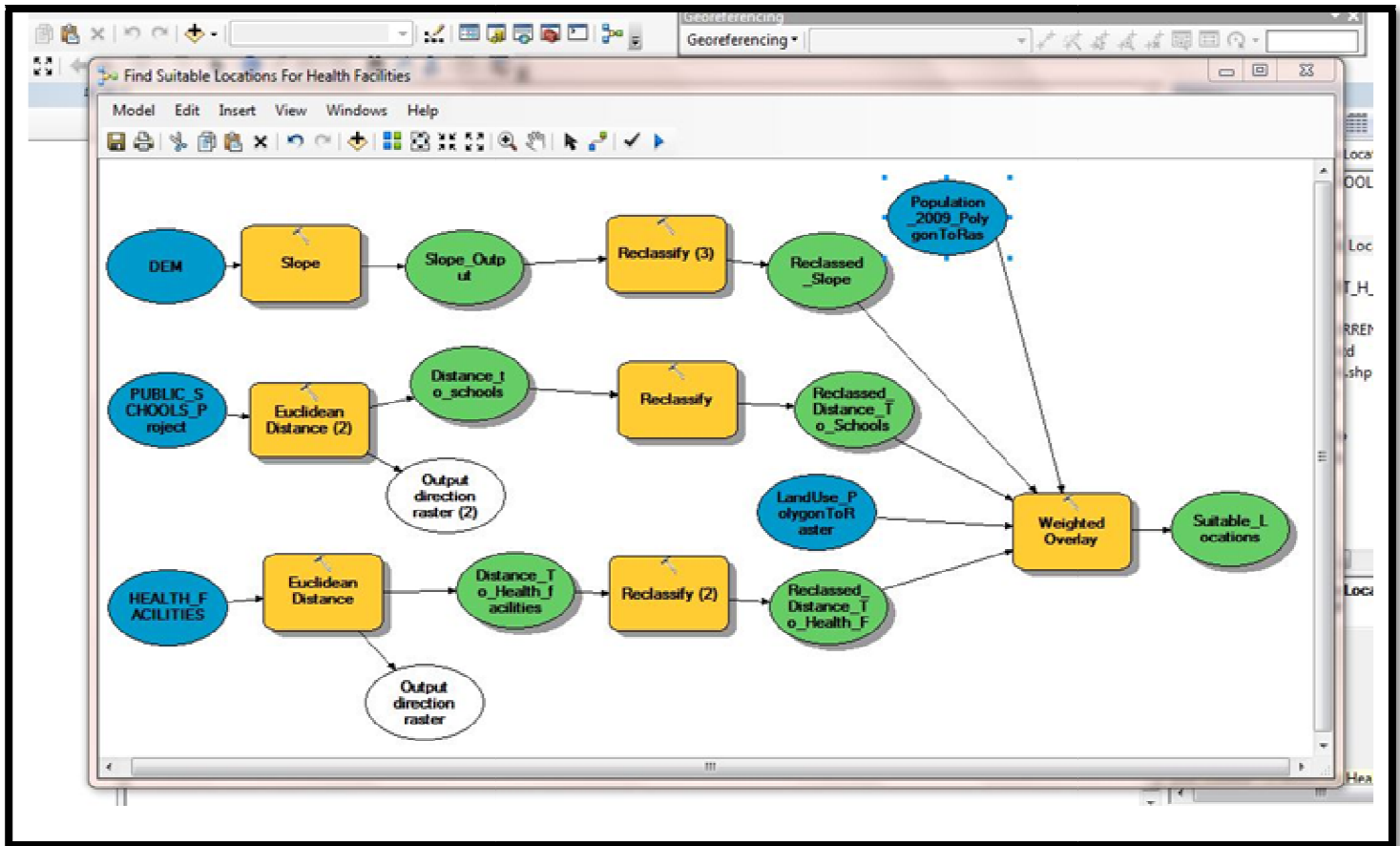


Figure 18: Model 2 Weighting and Combining Model

The weighted overlay tool was dragged onto the model. This is used for weighting the datasets. Population and use datasets are rasterized since we are working with raster datasets. Since a scale of 1 to 10 was used when reclassifying datasets, before adding input raster to the Weighted Overlay tool, the evaluation scale was set from 1 to 10 by 1. The datasets reclassified slope, reclassified distance to schools, reclassified distance to health facilities, rasterized land use and population density were added to the weighted overlay tool. Since high values of 10, 9, and 8 represent maximum slope that is not suitable to build on, the values were given the value restricted in the value table. And since forests are protected areas, the value forest in the land use dataset was restricted. Influence percent for each raster was selected. The overall total of influence for all the raster is 100%. Running the model gave the resultant suitable locations for new health facilities.

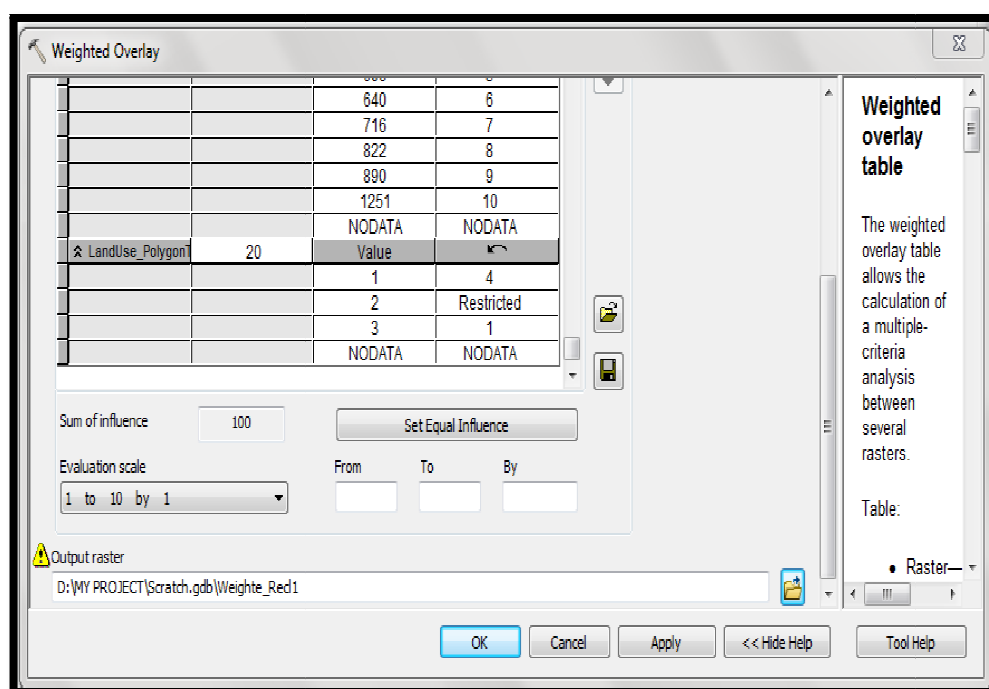


Figure 19: Weighted Overlay

The weighted overlay tool with table for different input values to be applied.

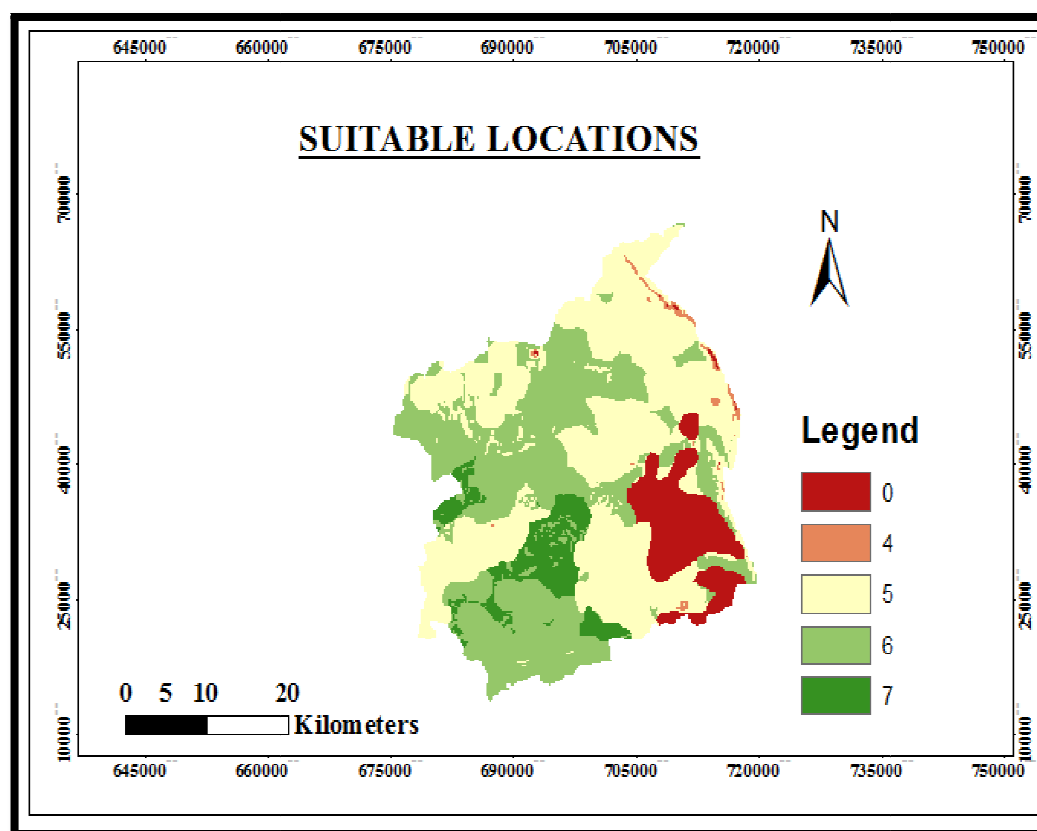


Figure 20: Map 15 Suitable Locations

Suitable locations map, most suitable areas have high values in this case seven is the most suitable. Areas with zero value are the restricted places like forests and those with steep slope. Regions selected as the most suited is based on the set parameters in the model. Altering the parameters definitely will change the position of the locations.



### 3.3.5. Selecting Optimum Sites

Each pixel on the suitable layer has a value that indicates how suitable that location is. Pixels with the value of seven are most suitable, and pixels with the value of zero are not suitable. Optimal site locations for health facilities has values of seven. The con tool with conditional expression that sets the most suitable location to seven is used. The input dataset was suitable locations and on running the model the optimum areas was generated. The output was converted to polygon for compatible processing with vector data of roads and rivers.

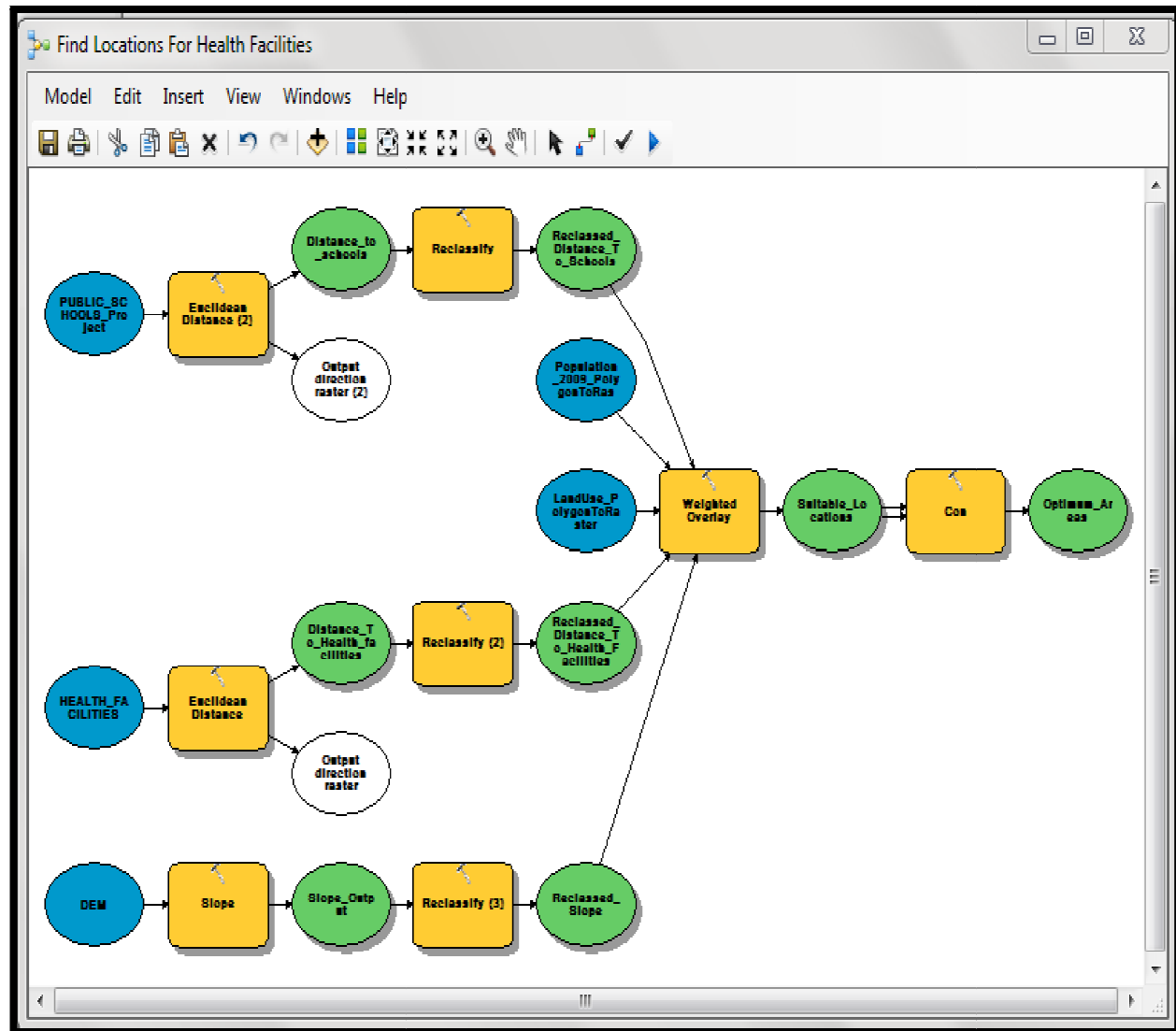


Figure 21: Model 3 the Optimum Site Selection Model

The condition used to set the criteria for selecting optimum locations on the model. In this case the condition was set as (value =7) since 7 represents best or optimum locations.

## 4. Analysis and Results

Analysis was carried out using Arc GIS extensions (spatial and network analysis). Buffering, Overlays and clipping. This assisted in the analyzing areas close to rivers and streams as well as those that are within a given distance from roads for ease of access. Buffering is a spatial analysis operation in GIS that defines a zone or an area surrounding an entity. The define zone may be a road reserve, river riparian, security zone or a study area.

### 4.1. Rivers and Streams Analysis

To analyze areas 200m from rivers, a river buffer of 200m was generated and overlaid on the selected optimum locations. This will help visualize areas suitable areas 200m from rivers and streams when deciding to construct health facilities. This is very necessary since the study area experiences heavy rains in the wet season.

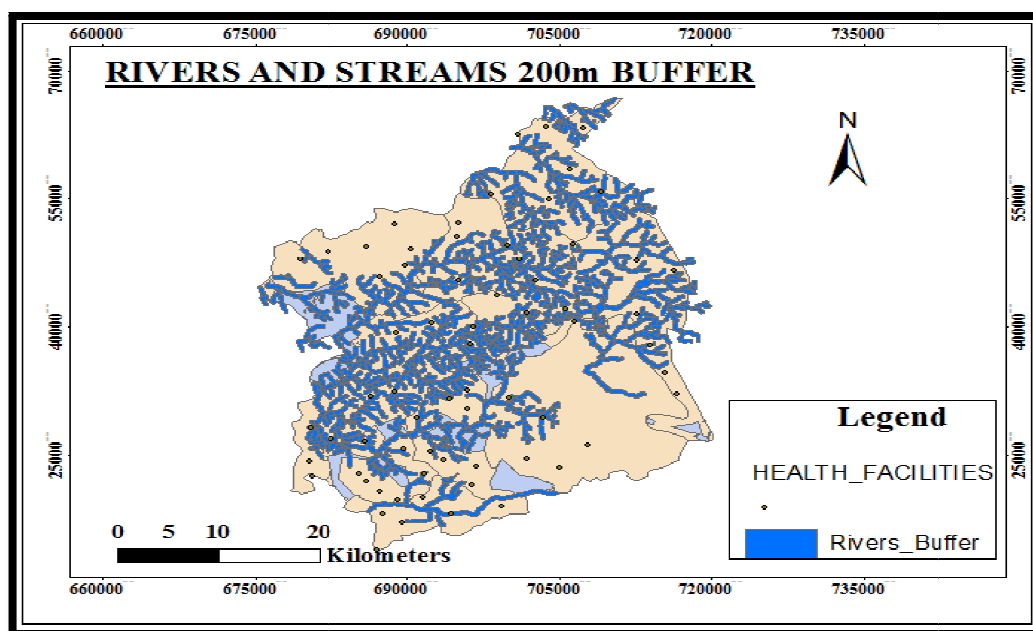


Figure 22: Map 16 Rivers and Streams 200m Buffer

The rivers and streams buffers showing how they interact with the optimum locations

#### 4.2. Accessibility Analysis

From the 500m roads buffer analysis, it is evident that all the existing health facilities are located within 500m from the motorable roads. It will also be ideal to have the new health facilities within the roads buffer of 500m for ease of access. It will also be cheap to open up roads less than 500m to the sites since the sites have been selected from flat areas or those with gentle slope during processing.

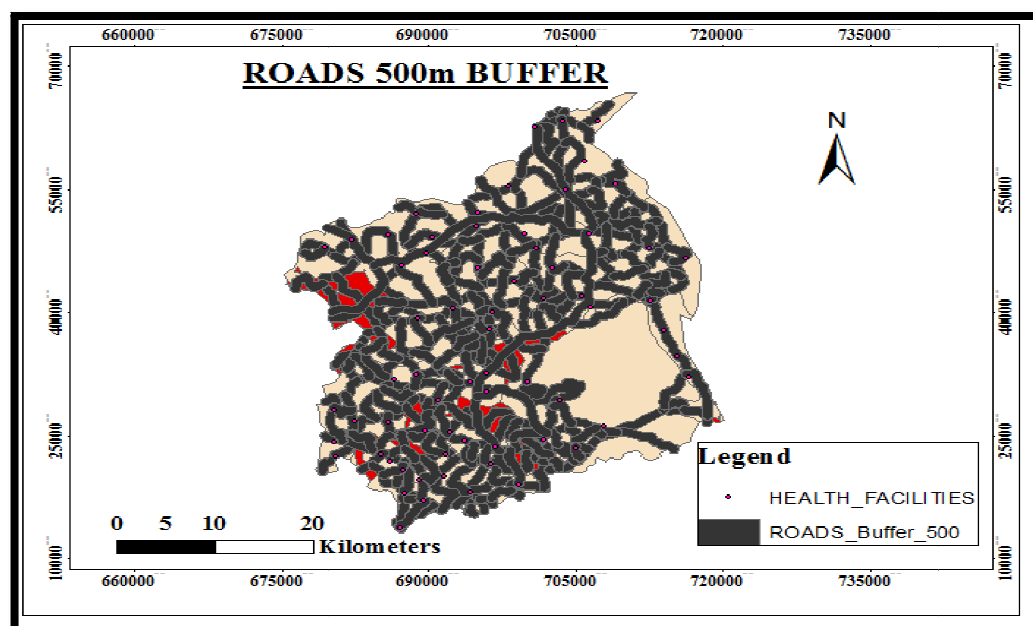


Figure 23: Map 17 Roads 500m Buffer

The map showing 500m buffer road buffer with selected optimum areas and existing health facilities.

#### 4.3. Final Locations

To select the final locations, the 500m roads buffer was used to clip the optimum locations resulting in areas only 500m from the roads being selected. Overlaying the 200m river buffer makes it possible to visualize selected sites that are 200m from river and not more than 500m from the motorable roads.

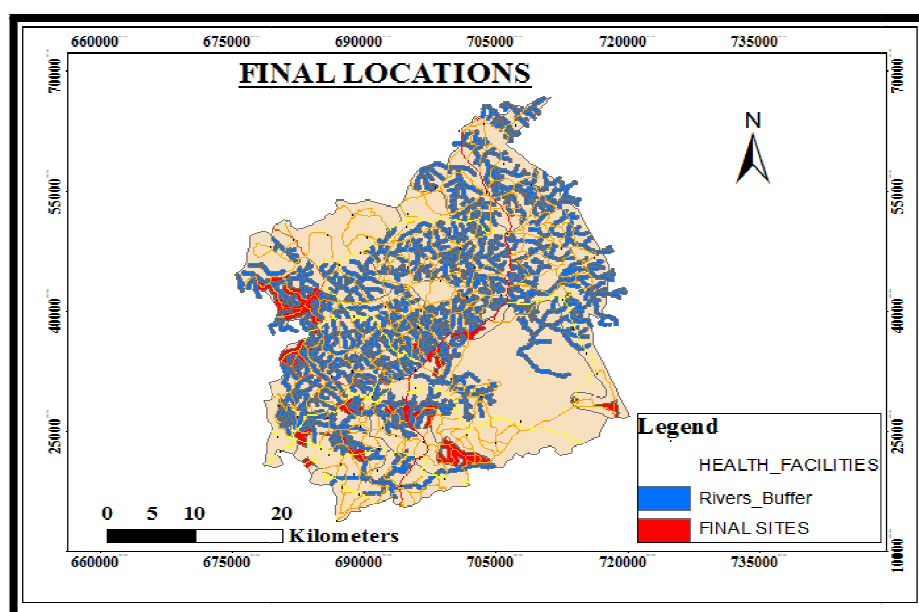


Figure 24: Map 18 the Map Showing the Final Selected Sites in Red

## 5. Conclusions and Recommendations

The project showed the capabilities of GIS in locating suitable locations for new health facilities and analyzing positional related data. By using GIS tools like buffer, it was possible to analyze accessibility to suitable locations and selected distances from rivers. By visual inspection of overlays of optimum locations map, 500m road buffer map and 200m river buffer map, quick decisions can be made on which site is ideal for a health facility.

The results of the optimum locations can be used by the county government to address the problem of congestion in existing health facilities as a priority. Other locations selected as suitable but not optimum can also be considered in accordance with set criteria for example population density may be lower but health facilities may not be evenly distributed. Further study can be undertaken to locate the most suitable site for setting up another level five hospital in the study area and the least cost paths from the furthest health facilities to the hospital.

Further research could be done using the present population and more intense land use data. In this project, population from 2009 census and land use were used. Much has changed since then. None spatial factors like disease prevalence areas maps and distribution of health personnel could be incorporated to analyze their influence on the health sector.

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