# SUITABLE SITE SELECTION OF ALTERNATE HEALTH CENTER USING REMOTE SENSING AND GIS AT JIJIGA, ETHIOPIA

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*Abstract*— **Jijiga is one the largest population and the fastest growing regional town in Ethiopia. The general public's demand for health is rising promptly with the improvement of the living standard. However, the limited and unbalanced medical resources have caused the prominent problems of the society. Along with the technology development and Internet popularization, GIS approaches and related products has been widely used in the people's daily life. The main focus of this paper is to select suitable site for health center in Jijiga city using GIS-based Multi-Criteria Analysis.**

*Keywords*— **AHP (Analytic Hierarchy Process), GIS (Geographic Information System), MCA (Multi Criteria Analysis), ROM (Rank of Matrix), Buffer, Multi-buffer.**

## I. INTRODUCTION

Health centers are one of the most important infrastructural objects. Suitable site selection plays a vital role in the health center construction and management. Health center site selection is related to various aspects of the society. GIS-based multi criteria analysis (MCA) method with factor criteria necessity tests and sensitivity tests in this study transfers all these qualitatively determined criteria into a quantitative analysis, making the results more convincing.

## II. LITERATURE REVIEW

Bache (1994) has given some location criteria which should be satisfied by any Health center. A health center site has to meet a number of location and geotechnical design Criteria and be acceptable to the public. Since acceptability to the public is crucial to the health center siting process, the citizens affected should be informed regarding the site Selection process.

Tchobanoglous ET. al. (1993) elucidate on the factor to be considered in Evaluating the potential site for the long term health center including haul Distance, location restrictions, and available land area and site accessibility.

Alan Murray and Richard Church (1995) have addressed several issues raised by Ramu and Kennedy (1994). This paper addresses a basic assumption which suggests that such a facility can be located along any road linkage of a transportation network. The other major issue addressed in this paper is health site selection heuristic. An alternative solution approach is presented that identifies a solution.

Basak Sener (2006) has used two different MCDA methods (Simple Additive Weighting and Analytical Hierarchy process). Candidate sites for a health center area in the Vicinity of Ankara are determined by using the integration of Geographic Information System and Multi-Criteria Decision Analysis (MCDA). For this purpose, 16 input maps Layer were used. Comparison of the maps produced by these two different methods showed that both methods yield conformable results. Field checks also confirmed that the candidate sites agreed well with the selected criteria.

Javaheri and Khoshnam (2006) have used Weighted Linear Combination and Geographical Information Technology to evaluate the suitability of the vicinity of Girofts city in Kerman province of Iran for health center. Considering relative priority of the Criteria in comparison with others, a specific weight was designed to each criterion According to their total influence on the whole process of decision making. The results from the application of the presented methodology were zones for health center with varying Zonal land suitability. Finally, the zones were ranked in descending order to indicate the priority of different options.

Myungin (2007) presented a method for determining an optimal site from the two perspectives of physical factors. First, the spatial distribution for physical factors Will estimated using various costs for health center.

Narayanaswamy and William Kennedy (1994) have considered the costs associated with any location and the minimum cost location technique based on map distance. The algorithm developed for the network location models is a simple heuristic that will help in reducing the number of location to consider. This heuristic technique can also be number of location to consider. This heuristic technique can also applied to other facilities location problem for quick and feasible solution.

Sadek (2006) has illustrated the use of a Geographic Information System (GIS) to analyze the spatial relationships between various geologic, hydrologic, and geographic characteristics as they relate to the investigation of identifying suitable Health center sites. The siting scheme developed within the study consisted of elimination of unsuitable sites and identification of potentially good sites. The author has developed a coherent set of criteria for siting health center, and established a robust methodology for analyzing the necessary data in a relatively quick and reliable manner.

Salman and Gholamalifard (2006) have implemented a type of Multi-criteria Evaluation (MCE) method called Weighted Linear Combination (WLC) in a GIS environment to evaluate the suitability of the study region for health center. The WLC procedure is characterized by full tradeoff among all factors, average risk and offers much flexibility than the Boolean approaches in the decision making process. The relative importance weights of factors were estimated using the Analytical Hierarchy Process (AHP).

## III. OBJECTIVE OF THE STUDY

### *A. General Objective*

To select suitable site for health center using GIS based multi criteria analysis process in Jigjig town by considering various factor criteria, Analytical Hierarchy Process (AHP) and Rank Order Method (ROM) are used here for weight setting.

### *B. Specific Objective*

- Prepare land use and land cover of the study area from satellite image.
- Generate factor maps for each criteria
- Create factor maps, and assign weights for factor maps in AHP method and ROM.
- Building an MCA model to generate the final result map.
- Develop the suitable site map for new health center.

## IV. STUDY AREA

Jigjiga is a city in the Somali Region of Ethiopia. It became the capital of the Somali Regional State in 1995 after it was moved from Godey . Located in the Fafan zone with 60 km (37 mi) west of the border with Somalia, the city has an elevation of 1,609 meters above sea level. It is spreader over a land area of about 9218 Ha (structure plan, 2012). The municipality astronomically lies 9°16'30" to 9°24'30"N latitude and 42°44'0" to 42°51' 0" E longitude (Figure 1).

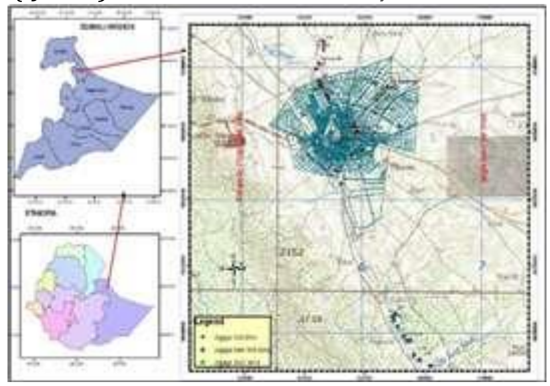

Fig 1 Study Area Map of Jijiga

### *A. Population and Socio-economic characteristics*

Important activities of a given society are governed by socio-economic and demographic characteristics. Hence, having good insight about socio-economic and demographic character is highly relevant for the study. It is useful for formulating various development plans and evaluating purpose.

### *B. Temperature*

The monthly maximum and minimum temperature data is accessed from Jijiga meteorological station. With this analysis the mean temperature of the project site ranges from 17.0$^0$C at December to 21.7$^0$C at May and June (Table I).

TABLE I
MONTHLY MAXIMUM, MINIMUM AND MEAN TEMPERATURE OF PROJECT AREA

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max ($^0$C)** | 27.2 | 29.1 | 29.4 | 28.5 | 28.4 | 27.5 | 26.4 | 26.4 | 27.1 | 28.0 | 27.4 | 26.8 |
| **Min ($^0$C)** | 7.2 | 8.3 | 11.4 | 13.7 | 15.1 | 16.0 | 15.8 | 15.7 | 15.1 | 10.6 | 8.1 | 7.2 |
| **Mean ($^0$C)** | 17.2 | 18.7 | 20.4 | 21.1 | 21.7 | 21.7 | 21.1 | 21.0 | 21.1 | 19.3 | 17.7 | 17.0 |

### *C. Rainfall*

The project area is characterized with bi-modal rainfall regimes with two peak months in April and August. It receives a total of 646 mm annual rainfall.

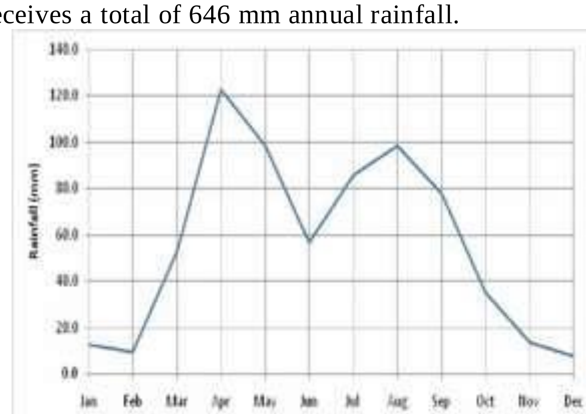


Fig 2 Seasonal Rainfall distribution of the study Area

*D. Nature of geology*

The eastern and south eastern areas of the country including the Somali Region are in general overlain by Mesozoic limestone and sandstone deposits over the crystalline bedrock of granite and gneiss. The other important geological structure is the bedding of the sedimentary rock and formation of karsts on the limestone formation.

## V. METHODOLOGY AND ANALYSIS

The methodologies and analyses for the site selection used in this study are: AHP, ROM, GIS-based MCA, necessity tests and sensitivity tests. Necessity tests check the necessity of factor criteria. Sensitivity tests assess the sensitivity of the result to the weights' change of factor criteria. The variables and weights are described below.

*A. Data source*

- Primary data
- Point of location of existing health centers

*B. Secondary data*

- Structure master plan of Jijiga city
- DEM to prepare slope data (contour map)
- Population data
- Satellite image(USGS Earth Explore Landsat 8 and Google Earth) to prepare Land use land cover map
- Administrative map
- Road network map

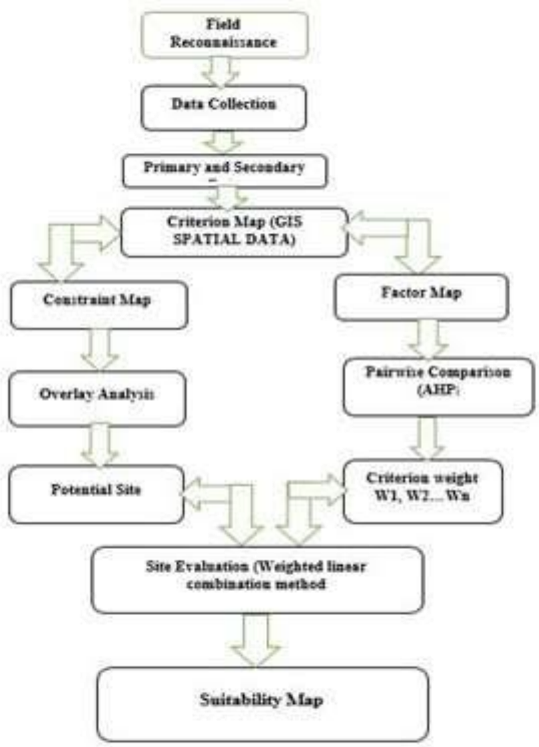


Fig 3 Methodology design

*C. Materials and Software used*

1) *Hand Held GPS:* Used for primary data collection for point data collection of existing health centers and gas station.
2) *Software:* The software employed here are Arc Map 10.1, USGS Earth Explorer Landsat 8 and Google earth. Almost all the maps derived from the raw data were in Shape file vector format. However, raster data are needed to execute the MCA model, Shape file format files are thus converted to raster format. Arc Map 10.1 is applied throughout the whole process.

*D. Data Used*

*1) The different data layers that have been used are*

- Roads Map
- Land use Map
- Geology Map
- Population Density Map
-

*2) Buffering*

Buffering is a spatial analysis tools and also called proximity analysis. It is used to generate areas within a given distance using a specified criterion for health center site selection.

*3) Location Criteria*

Before the spatial analysis is performed to identify suitable Health center sites, objective, criteria and factors are set and evaluated for their suitability of the study area. Thus, related legislation, restriction, rules, experience and local expertise are considered. The location criteria for Health center are as follows.

1. The further away from the existing hospital Greater than or equal 100 m of a Road.
2. The further away from the existing hospital Greater than or equal 300 m from river.
3. The further away from the existing hospital Greater than or equal 100m Public Park.
4. The further away from the existing hospital Greater than or equal 100 m from a notified habitant area.
5. The further away from the existing hospital Greater than or equal 300 m of reservoir.
6. The further away from the existing hospital Greater than or equal 300 m of bore hole.
7. The further away from the existing hospital Greater than or equal 500 m of Gas station.
8. The further away from the existing hospital Greater than or equal 500 m of Agriculture.
9. The further away from the existing hospital Greater than or equal 500 m of Exiting health center.

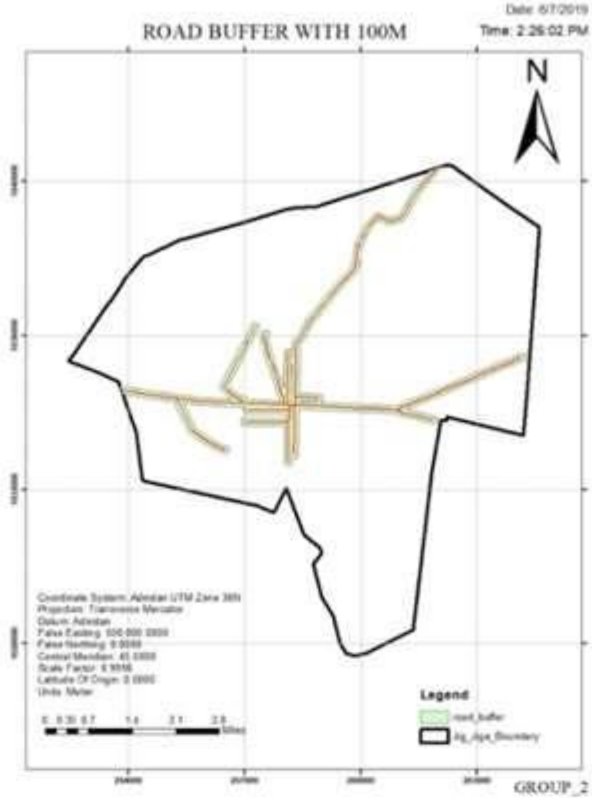


Fig 4 Road buffer map with 100 m

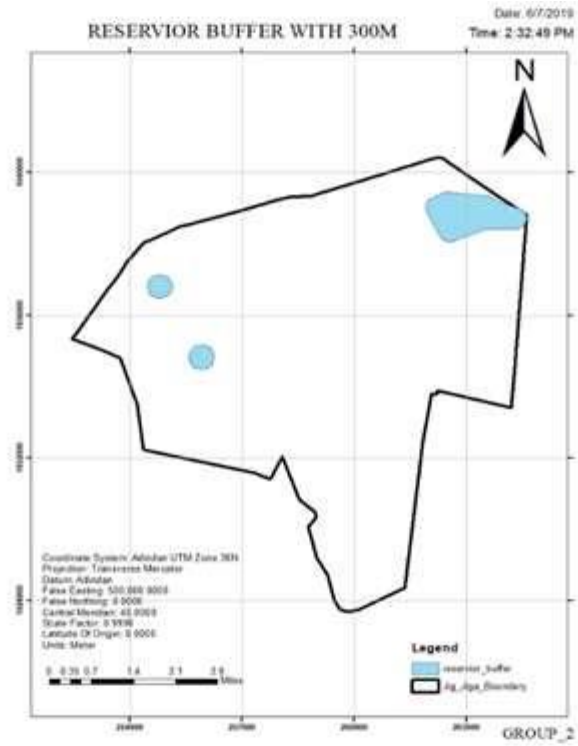


Fig 6 Reservoir buffer map with 300m

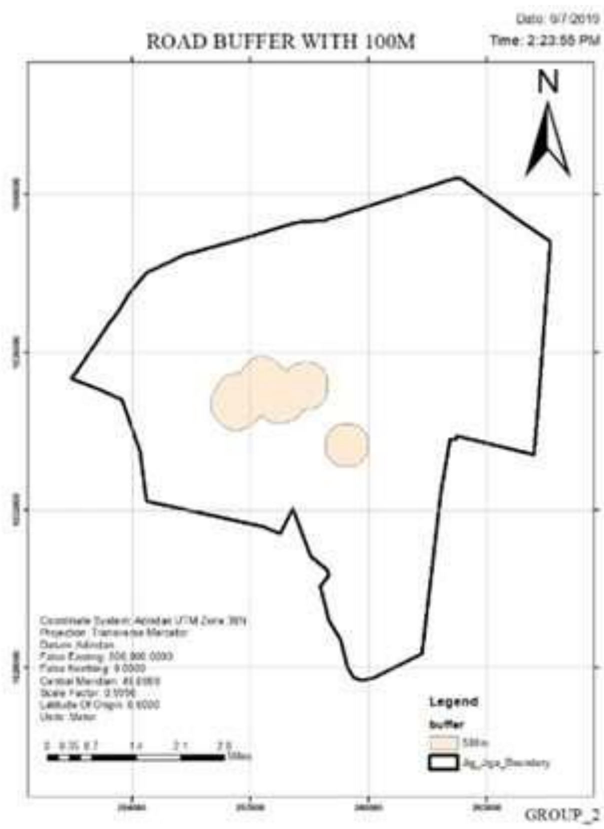


Fig 5 Existing health center buffer map with 500 m

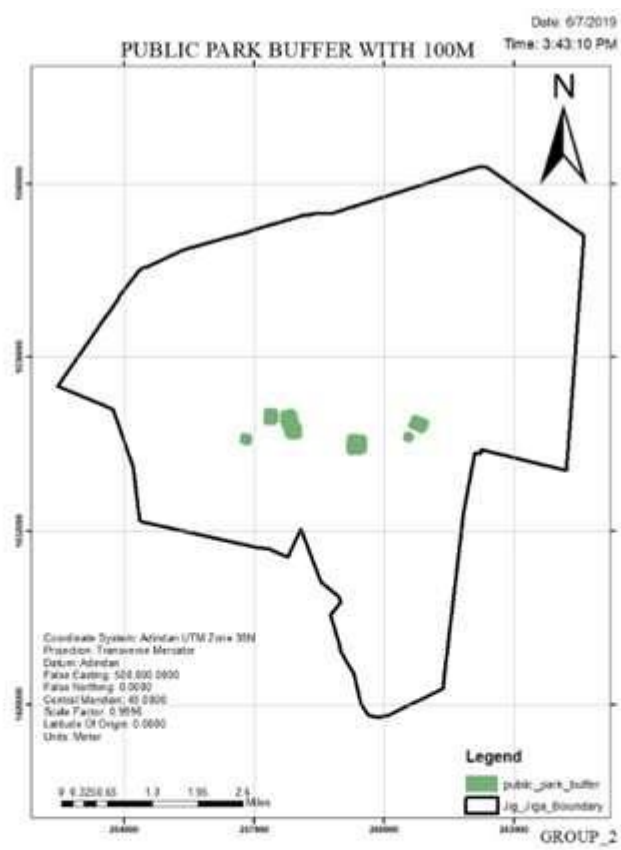


Fig 7 Public park buffer map with 100m

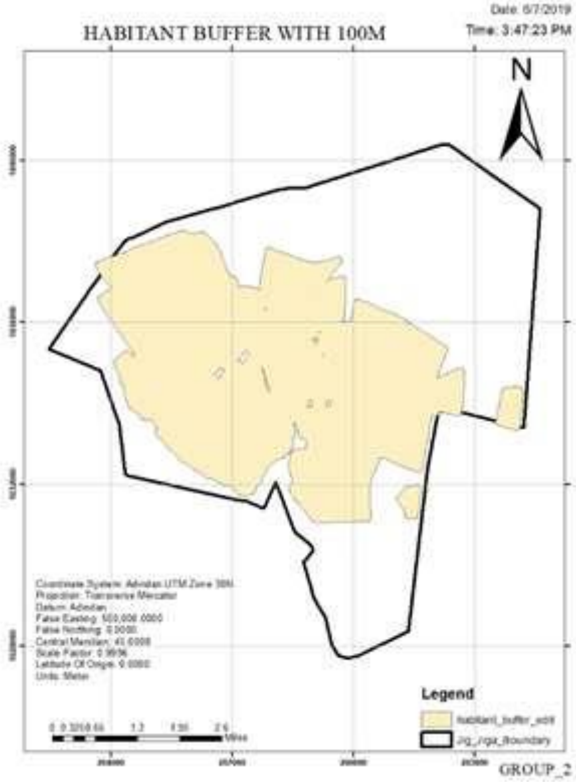


Fig 8 Habitant buffer map with 100m

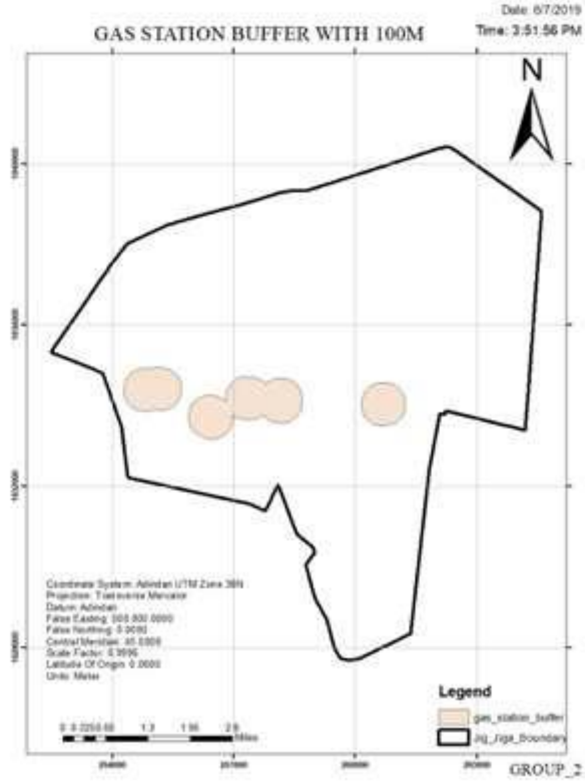


Fig 10 Gas station buffer map with 500m

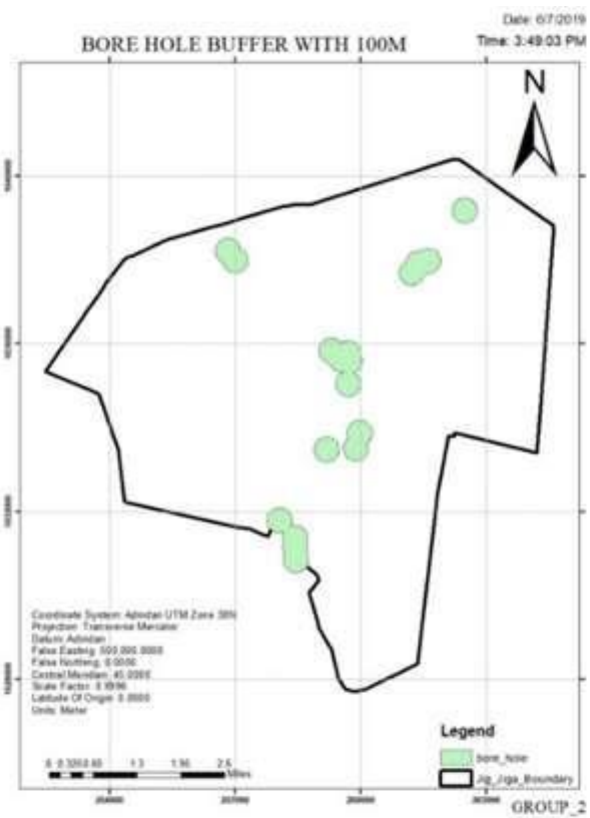


Fig 9 Bore hole buffer map with 300m

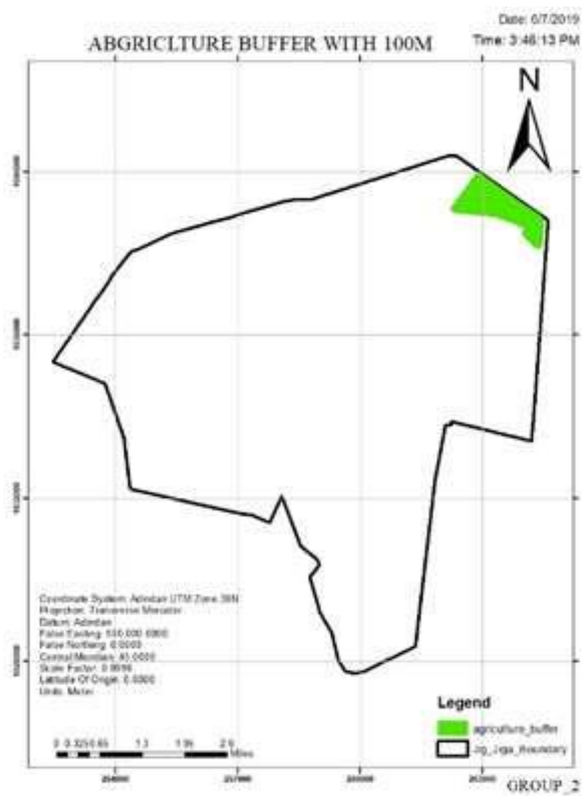


Fig 3 Agriculture buffer map with 300m

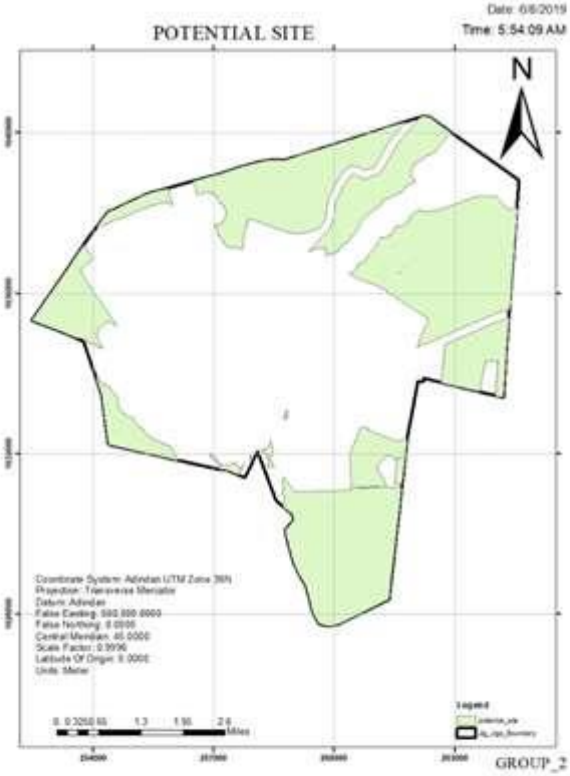


Fig 12 Potential site map

### E. Data preprocessing

The data of the geo-referenced factor map with the main layers needed are in shape file format. Considering the GIS methods used in this study, the data need to be converted to raster format before multiplying them to get the results.

### F. Identification and Reclassifications of criteria

Criteria are variables that justify or explain the environmental impact on making decision to select the most suitable site for project. They are chosen depending on the characteristics of the alternatives. It is necessary to have enough information about the chosen criteria so as to allow for comparison among the alternatives.

### G. Existing health center

New health center constructions should take this criterion seriously. Service area of a health center represents its potential demand. A balanced distribution of service centers provides community with a higher level of social equity. Being more away from other medical centers can be a positive factor for an alternative site. Keeping the distance from other existing health centers as well as anticipating impact from each other, is not only relevance to rational resource allocation, but also does matter to the fair competition in the market economy. There is an oral agreement that normally the distance is 500 meters. Unsuitable 1000m slightly suitable, 2000m moderate suitable and 3000m high suitable said by Ji-Shun (2011), the deputy chief of the Medical Affairs Section in Haidian Health Bureau. Hence, in this study, the new health center is also wished to keep a distance of 500 m from the existing health center, the further away the better.

TABLE II
DISTANCE FROM HEALTH CENTER SUITABILITY VALUE AND WEIGHT

| S.No | Distance from Existing Health center | Suitability Value | Weight factor |
|---|---|---|---|
| 1 | 500m | 1 | 0.05 |
| 2 | 1000m | 2 | |
| 3 | 2000m | 3 | |
| 4 | 3000m | 4 | |

1 – Unsuitable;
2 – Slightly Suitable;
3 – Moderately Suitable;
4 – Highly Suitable

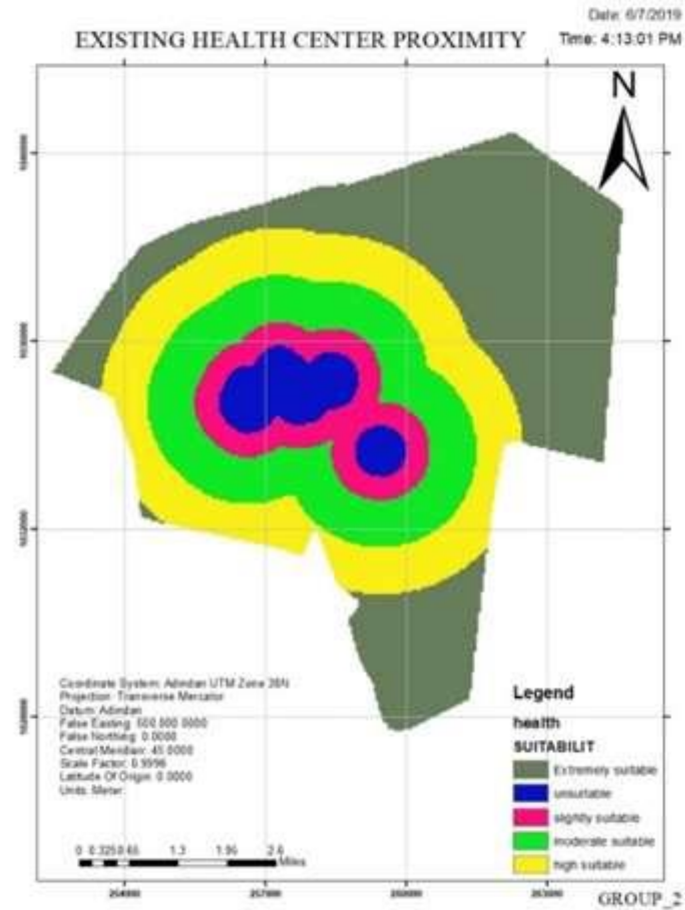


Fig 13 Reclassification Of Existing Health Center

### H. Road

Roads should be designed and constructed to provide for the safe, convenient, effective and efficient movement of people and goods.

TABLE III
DISTANCE FROM ROADS SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Roads | Suitability Value | Weight factor |
|---|---|---|---|
| 1 | 100 | 1 | 0.07 |
| 2 | 500 | 2 | |
| 3 | 1000 | 3 | |
| 4 | 2000 | 4 | |

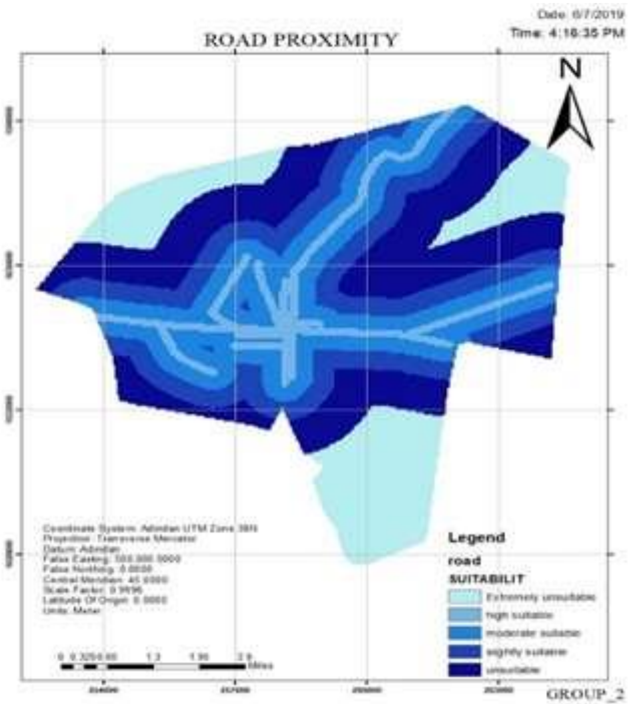


Fig 14 Reclassification Of Road

*I. Land use land cover*

Land use is the major criteria which play a greater role in selecting suitable site for health centers. It can be residential area, forest, commercial, agricultural, industrial &so on. Therefore, having information about the land use helps us to identify areas which are suitable or not suitable for health centers.

TABLE IV
POTENTIAL SITES LITHO LOGY UNIT SUITABILITY VALUE AND WEIGHT

| SI No | Lithology unit | Suitability Value | Weight |
|---|---|---|---|
| 1 | Late Cretaceoues-Paleocene Sandstone | 1 | 0.01 |
| 2 | Triassic-Middel Jurassic Sandstone | 2 | |
| 3 | Alluvial And Lacustrine Deposite:Sand,Silt Clay | 3 | |

1-High suitable
2-Moderatly suitable
3-Slightly suitable

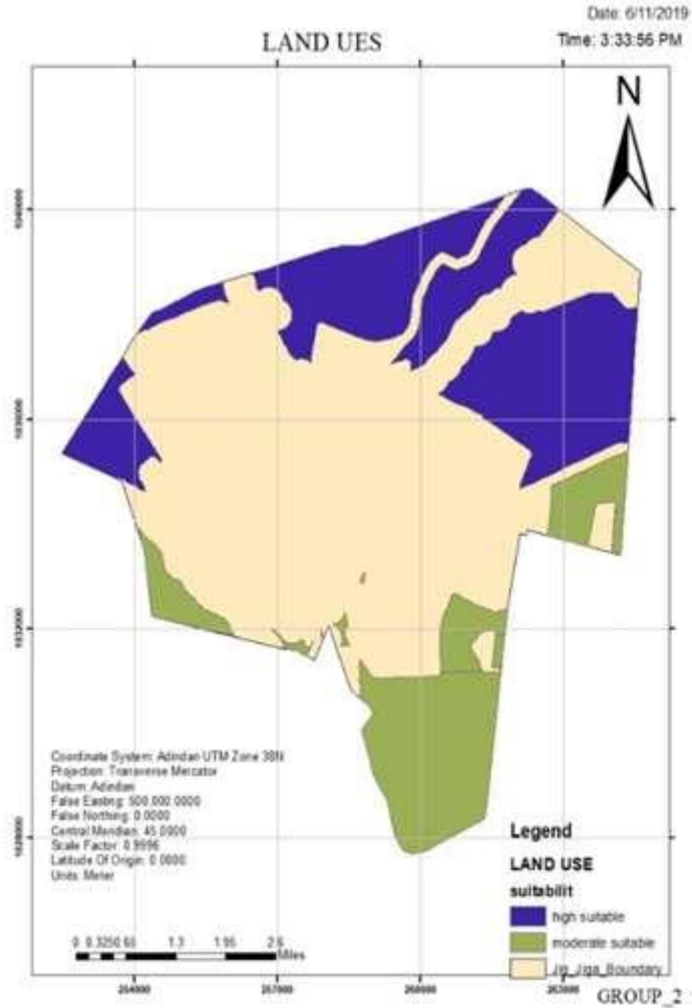


Fig 15 Reclassification Of Land Use

*J. Habitant*

In a way that means the resident population, so the nearer from the residential area, the better. 100m suitable 500m moderate suitable 1000m slightly suitable and 2000m unsuitable.

TABLE V
DISTANCE FROM HABITANT SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Habitant | Suitability Value | Weight |
|---|---|---|---|
| 1 | 100m | 1 | 0.11 |
| 2 | 500m | 2 | |
| 3 | 1000m | 3 | |
| 4 | 2000m | 4 | |

1 - Highly Suitable
2 - Moderately Suitable;
3 -Slightly Suitable;
4-Unsuitable;

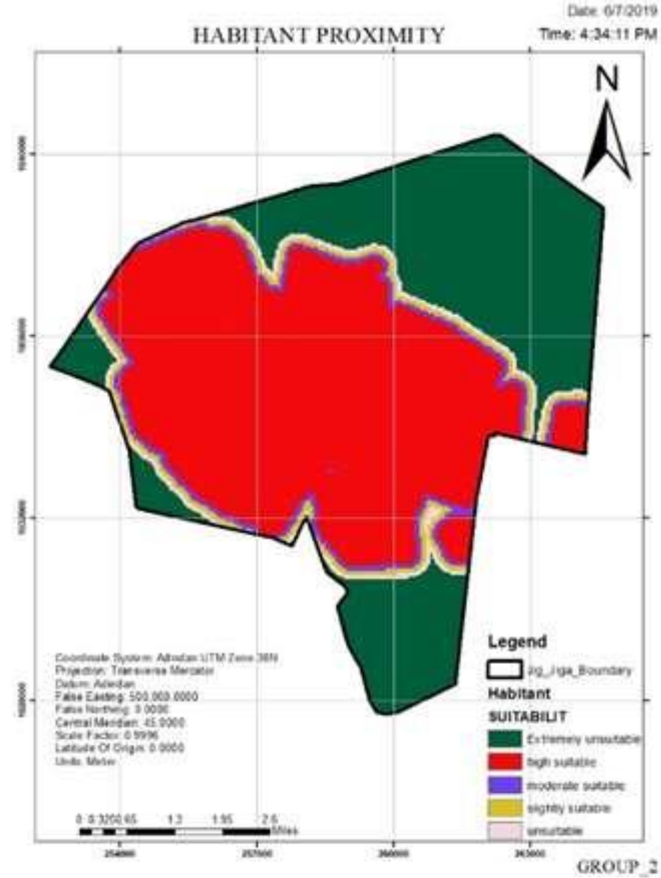


Figure 46 Reclassification Of Habitat

## K. Agriculture

In the generated factor maps; the higher values represent areas farther from the feature. Therefore 500m unsuitable, 1000m slightly suitable, 2000m moderate suitable and 3000m high suitable So for agriculture and the produced factor maps satisfy the conditions of the study, i.e. the farther, the better.

TABLE VI
DISTANCE FROM AGRICULTURE SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Agriculture | Suitability Value | Weight |
|---|---|---|---|
| 1 | 500m | 1 | 0.13 |
| 2 | 1000m | 2 | |
| 3 | 2000m | 3 | |
| 4 | 3000m | 4 | |

1 – Unsuitable;
2 – Slightly Suitable;
3 – Moderately Suitable;
4 – Highly Suitable

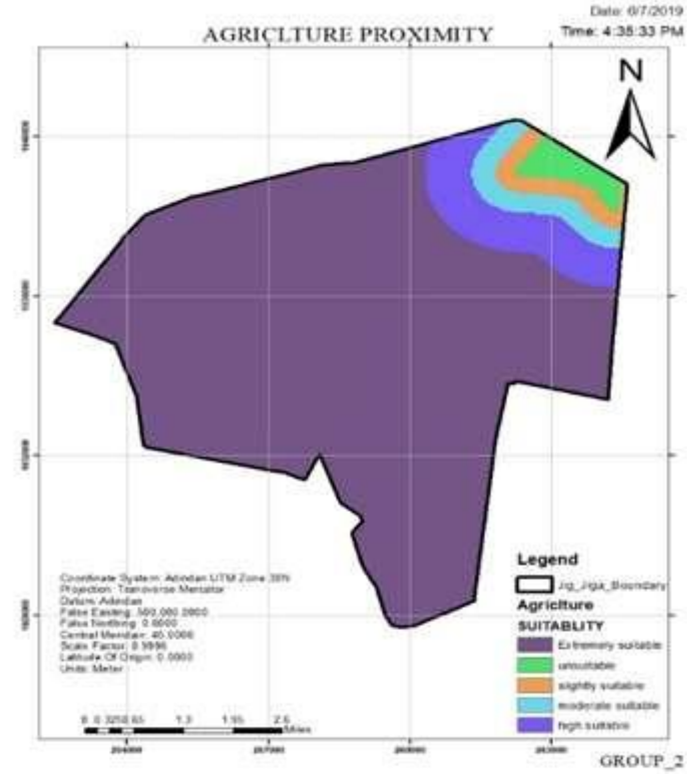


Fig 17 Reclassification Of Agriculture

## L. Gas station

Health center cannot be built around a gas station, in case the gas station is pollution and hazardous problem by construction or gas station discharged by the health center in the future.

TABLE VII
DISTANCE FROM GAS STATION SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Gas station | Suitability Value | Weight |
|---|---|---|---|
| 1 | 500m | 1 | 0.31 |
| 2 | 1000m | 2 | |
| 3 | 2000m | 3 | |
| 4 | 3000m | 4 | |

1 – Unsuitable;
2 – Slightly Suitable;
3 – Moderately Suitable;
4 – Highly Suitable

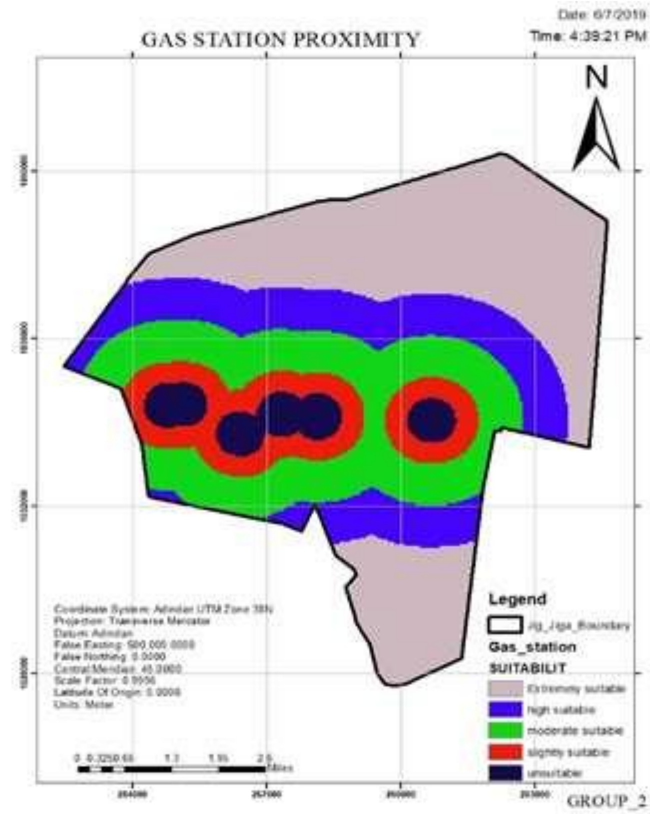


Fig 58 Reclassification of Gas station

*M. River*

In case the new health center drains sewage to river, 300m unsuitable, 500m slightly suitable, 1000m moderate suitable and 2000m high suitable distance along the river should be used. Outside the buffer zone, the further away, the better.

TABLE VIII
DISTANCE FROM RIVER SUITABILITY VALUE AND WEIGHT

| SI No | Distance From River | Suitability Value | Weight |
|---|---|---|---|
| 1 | 300m | 1 | 0.02 |
| 2 | 500m | 2 | |
| 3 | 1000m | 3 | |
| 4 | 2000m | 4 | |

1 – Unsuitable;
2 – Slightly Suitable;
3 – Moderately Suitable;
4 – Highly Suitable

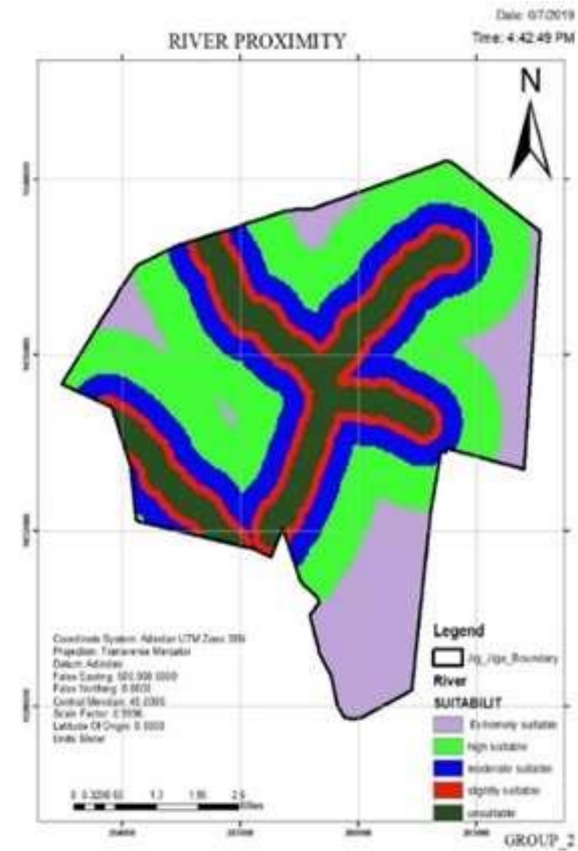


Fig 69 Reclassification of river

*N. Public park*

New health center is rarely built near the public parks; it is better to protect those areas which are grown much green from the pollution of health center. Therefore 100m high suitable,500m moderate suitable,1000m slightly suitable and 2000m unsuitable.

TABLE IX
DISTANCE FROM PUBLIC PARKS SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Public park | Suitability Value | Weight |
|---|---|---|---|
| 1 | 100m | 1 | 0.22 |
| 2 | 500m | 2 | |
| 3 | 1000m | 3 | |
| 4 | 2000m | 4 | |

1 - Highly Suitable
2 - Moderately Suitable;
3 -Slightly Suitable;
4-Unsuitable;

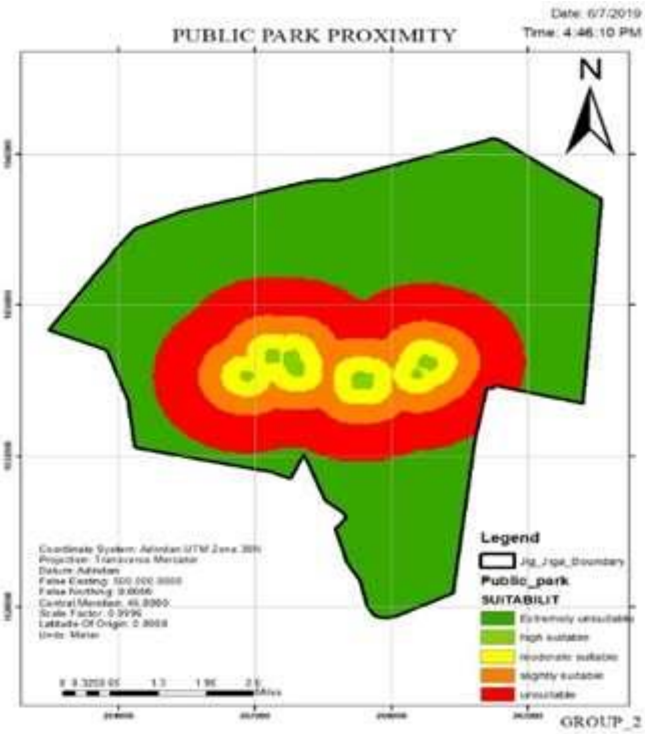


Fig 20 Reclassification of Public Park

*O. Reservoir*

A health center cannot be built around a reservoir; in case the reservoir is polluted by construction or drainage discharged by the health center in the future. Therefore 300m unsuitable,500m slightly suitable, 1000m moderate suitable and 2000m high suitable.

TABLE X
DISTANCE FROM RESERVOIR SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Reservoir | Suitability Value | Weight |
|---|---|---|---|
| 1 | 300m | 1 | 0.04 |
| 2 | 500m | 2 | |
| 3 | 1000m | 3 | |
| 4 | 2000m | 4 | |

1-Unsuitable
2-slightly suitable
3- Moderately suitable
4- High suitable

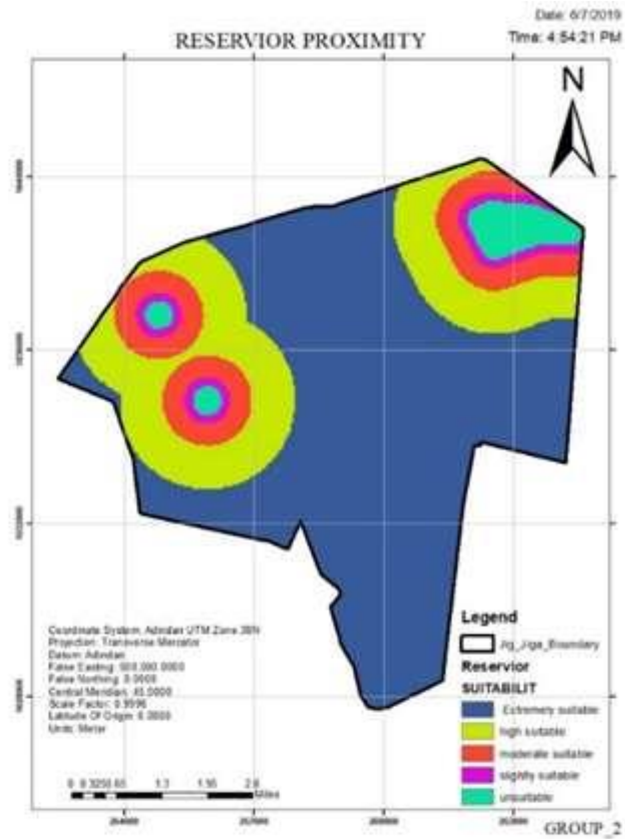


Fig 21 Reclassification of reservoir

*P. Population density*

Population density is associated with potential demand and performance effectiveness of a health center. The higher the score is for an alternative. The weights obtained from AHP or ROM calculations are applied in GIS to the criteria form Kebele boundary map to generate a screening map.

TABLE XI
POPULATION DENSITY SUITABILITY VALUE AND WEIGHT

| SI No | Population Density | Suitability Value | Weight |
|---|---|---|---|
| 1 | 0.07255-0.9 | 1 | 0.04 |
| 2 | 1.127-4.8 | 2 | |
| 3 | 5.5-123 | 3 | |

1-Unsuitable
2-Moderate Suitable
3- High Suitable

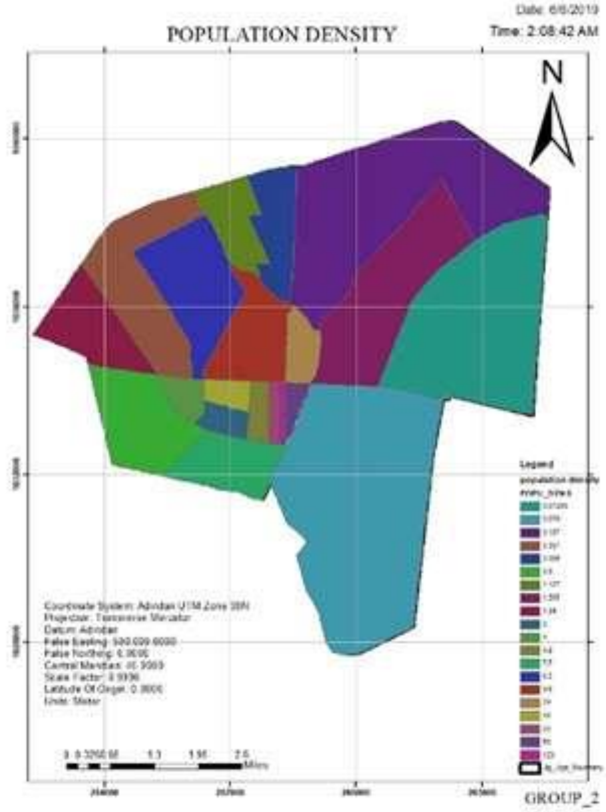


Fig 72 Population Density

## *Q. Slope*

Among topographic factors that affect the land use planning slope is considered for the analysis. From the master plan policies, it is known that the sites on or near cliff is not suitable for constructing health centers. Areas with the slope exceeding 15% are usually not suitable for health center construction (Chapin and Kaiser 1978).

TABLE XII
SLOPE SUITABILITY VALUE AND WEIGHT

| SI No | Slope Reclassification | Suitability Value | Weight |
|---|---|---|---|
| 1 | 0 - 2.579563395 | 1 | 0.03 |
| 2 | 2.579563396 - 5.841952395 | 2 | |
| 3 | 5.841952396 - 19.34672546 | 3 | |

1-Moderate Suitable
2-High Suitable
3-Very High Suitable

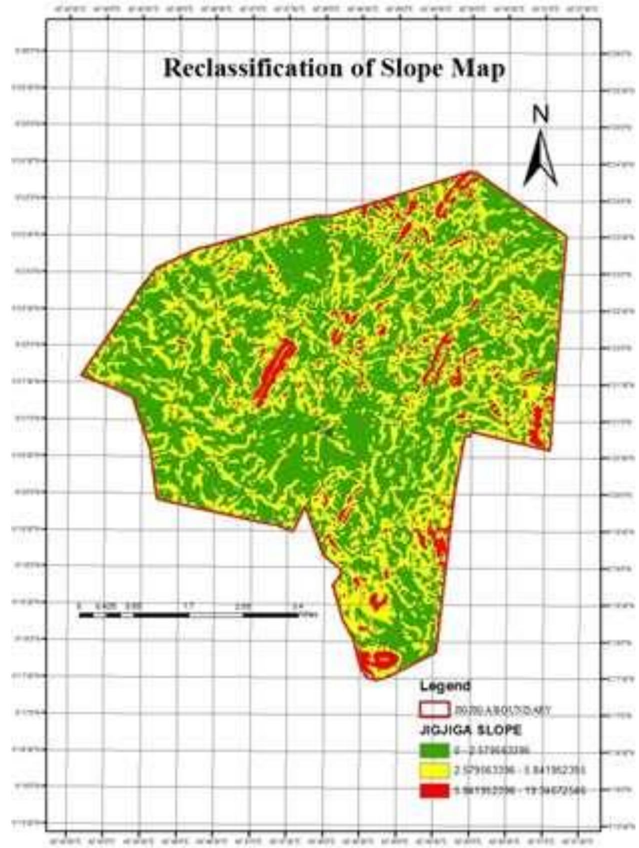


Fig 23 Reclassification of Slope

## *R. Aspect*

Aspect is the direction of slope faces eastern, western, northern and southern exposure where identified to be more suitable sites.

TABLE XIII
ASPECT SUITABILITY VALUE AND WEIGHT

| SI No | Aspect Reclassification | Suitability Value | Weight |
|---|---|---|---|
| 1 | -1 - 118.9861247 | 1 | 0.06 |
| 2 | 118.9861248 - 238.9722493 | 2 | |
| 3 | 238.9722494 - 358.958374 | 3 | |

1-Moderate Suitable
2-High Suitable
3-Very High Suitable

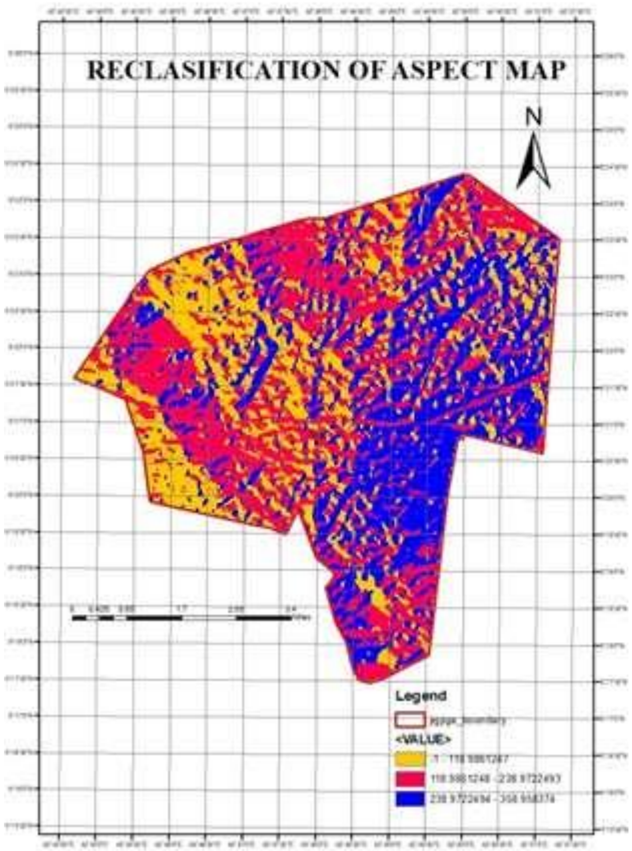


Figure 84 Reclassification of Aspect

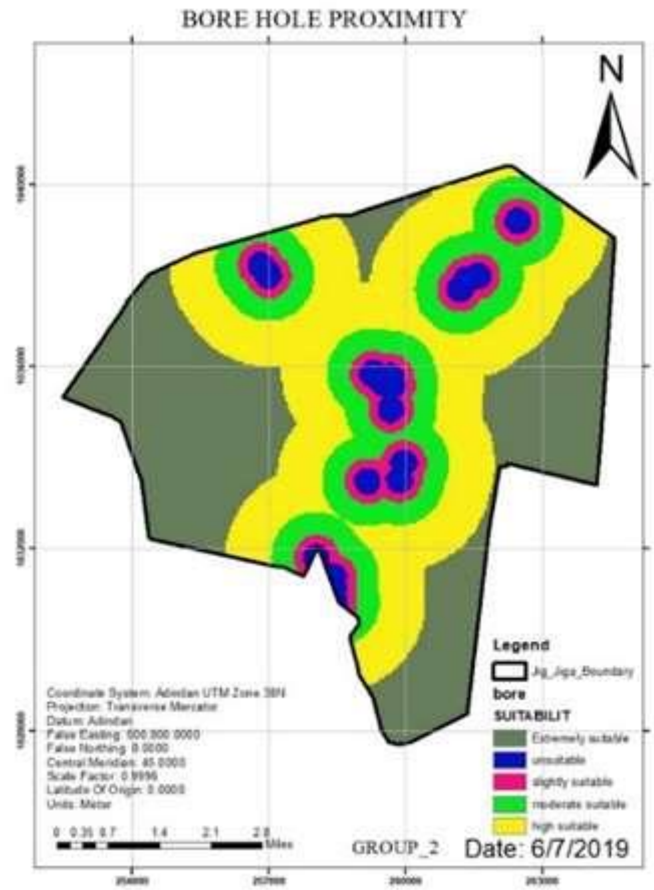


Figure 25 Reclassification Of Bore Hole

### S. *Existing bore hole*

A health center cannot be built around a bore hole; in case the bore hole is polluted by construction or drainage discharged by the health center in the future. Therefore 300m unsuitable,500m slightly suitable, 1000m moderate suitable and 2000m high suitable.

TABLE XIV
BOREHOLE SUITABILITY VALUE AND WEIGHT

| SI No | Distance From Bore Hole | Suitability Value | Weight |
|---|---|---|---|
| 1 | 300m | 1 | 0.04 |
| 2 | 500m | 2 | |
| 3 | 1000m | 3 | |
| 4 | 2000m | 4 | |

1-Unsuitable
2-slightly suitable
3-moderately suitable
4-high suitable

### T. *Analysis*

The analysis is based on three fundamental principles namely breaking down the problem, pair wise comparison of the various alternatives, synthesis of the preferences.

### U. *Weight setting in Analytical Hierarchy process (AHP)*

The weights calculated for each factor using AHP are applied in the influence column of WOA. In mean of normalized values method which gives an approximation of lambda max method, the sum of elements in each column in pair wise comparison matrix is calculated.

### V. *Pair wise Comparison Matrix*

Pair wise comparison matrix for each thematic layer, the weight, value, and consistency index and consistency ratio are shown in table XV.

TABLE XV
FACTOR WEIGHT OF GEO-ENVIRONMENTAL FACTOR

| | Geology | Land use | River | Bore hole | Reservoir | Slope | Aspect |
|---|---|---|---|---|---|---|---|
| **Geology** | 1 | 5 | 3 | 3 | 3 | 3 | 1 |
| **Land use** | 0.2 | 1 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 |
| **River** | 0.333 | 3 | 1 | 0.2 | 0.2 | 0.333 | 0.333 |
| **Bore hole** | 0.333 | 3 | 5 | 1 | 1 | 3 | 0.333 |
| **Reservoir** | 0.333 | 3 | 5 | 1 | 1 | 3 | 0.333 |
| **Slope** | 0.333 | 3 | 3 | 0.333 | 0.333 | 1 | 0.333 |
| **Aspect** | 1 | 3 | 3 | 3 | 3 | 3 | 1 |
| **Total** | 3.732 | 21 | 20.33 | 8.866 | 8.866 | 13.67 | 3.665 |

| | Geology | Land Use | River | Bore Hole | Reservoir | Aspect | Slope | Cumulative | Normalization | Weight factor |
|---|---|---|---|---|---|---|---|---|---|---|
| **Geology** | 0.268 | 0.238 | 0.148 | 0.338 | 0.338 | 0.22 | 0.273 | 1.82 | 26.00 | 0.26 |
| **Land use** | 0.054 | 0.048 | 0.016 | 0.038 | 0.038 | 0.024 | 0.091 | 0.309 | 4.4 | 0.04 |
| **River** | 0.089 | 0.143 | 0.049 | 0.023 | 0.023 | 0.024 | 0.091 | 0.442 | 6.3 | 0.06 |
| **Bore hole** | 0.089 | 0.143 | 0.246 | 0.113 | 0.113 | 0.22 | 0.091 | 1.05 | 14.5 | 0.14 |
| **Reservoir** | 0.089 | 0.143 | 0.246 | 0.113 | 0.113 | 0.22 | 0.091 | 1.05 | 14.5 | 0.14 |
| **Aspect** | 0.268 | 0.143 | 0.148 | 0.338 | 0.338 | 0.220 | 0.273 | 1.39 | 19.9 | 0.20 |
| **Slope** | 0.089 | 0.143 | 0.148 | 0.038 | 0.113 | 0.073 | 0.091 | 0.695 | 9.9 | 0.10 |
| **Total** | 1.00 | 1.002 | 1 | 1 | 1 | 1 | 1 | 6.004 | 100 | 1 |

| | |
|---|---|
| **Λ** | 7.6 |
| **N** | 7 |
| **CI** | 0.1 |
| **RI** | 1.32 |

CR = 0.076 < 0.1
(Accepted)

TABLE XVI
FACTOR WEIGHT OF SOCIO- POLITICAL FACTOR

| | Road | Population | Existing health center | Existing gas station | Agriculture |
|---|---|---|---|---|---|
| **Road** | 1 | 1 | 3 | 3 | 0.333 |
| **Population** | 1 | 1 | 1 | 1 | 0.333 |
| **Existing health center** | 0.333 | 1 | 1 | 3 | 0.333 |
| **Existing gas station** | 0.333 | 1 | 0.333 | 1 | 0.333 |
| **Agriculture** | 3 | 3 | 3 | 3 | 1 |
| **Total** | 5.666 | 7 | 8.333 | 12 | 2.332 |

| | Road | Population | Existing health center | Existing gas station | Agriculture | Cumulative | Normalization | Factor weight |
|---|---|---|---|---|---|---|---|---|
| **Road** | 0.176 | 0.143 | 0.36 | 0.364 | 0.25 | 1.072 | 21.4 | 0.214 |
| **Population** | 0.176 | 0.143 | 0.12 | 0.091 | 0.083 | 0.665 | 13.3 | 0.133 |
| **Existing health center** | 0.059 | 0.143 | 0.12 | 0.091 | 0.25 | 0.715 | 14.3 | 0.143 |
| **Existing gas station** | 0.059 | 0.143 | 0.04 | 0.091 | 0.083 | 0.468 | 9.4 | 0.094 |
| **Agriculture** | 0.529 | 0.429 | 0.36 | 0.25 | 0.429 | 1.997 | 39.9 | 0.399 |
| **Total** | 0.999 | 1.001 | 1.00 | 0.916 | 1.001 | 4.917 | 100 | 1 |

| | |
|---|---|
| **Λ** | 5.394 |
| **N** | 5 |
| **CI** | 0.099 |
| **RI** | 1.12 |

CR=0.088<0.1

(Accepted)

TABLE XVII
FACTOR WEIGHT OF SOCIO- ECONOMIC FACTOR

| | Habitat | Public park |
|---|---|---|
| **Habitat** | 1 | 0.5 |
| **Public park** | 2 | 1 |
| **Total** | 3 | 1.5 |

| | Habitat | Public park | Cumulative | Normalization | Factor weight |
|---|---|---|---|---|---|
| **Habitat** | 0.333 | 0.333 | 0.666 | 33.3 | 0.333 |
| **Public park** | 0.667 | 0.667 | 1.334 | 66.7 | 0.667 |
| **Total** | 1 | 1 | 2 | 100 | 1 |

| | |
|---|---|
| **Λ** | **2** |
| **N** | **2** |
| **CI** | **0.00** |
| **RI** | **0.00** |

**CR=0.00<0.1**

**(Accepted)**

TABLE XVIII
THE SUM OF WEIGHT FACTOR

| Selection criteria | Factor Weight |
|---|---|
| Road | 0.07 |
| Population | 0.04 |
| Existing Health Center | 0.05 |
| Gas station | 0.31 |
| Agriculture | 0.13 |
| Habitant | 0.11 |
| Public park | 0.22 |
| Geology | 0.09 |
| Land use | 0.01 |
| River | 0.02 |
| Existing Bore hole | 0.04 |
| Reservoir | 0.04 |
| Slope | 0.03 |
| Aspect | 0.06 |

*W. Process of Calculate the Consistency Ratio (CR)*

CR = Consistency index (CI)/Random Consistency Index (RI)

Where, CI = Consistency index which provides a measure of departure from consistency and has the formula in equation (1) described before.

CI= (λ - n)/ (n-1)

Where, ***n*** is the number of factors, λ is the Principal Eigen Value which the summation of products between each element of the priority vector and column totals.

### A. *Weight setting in rank order method (ROM)*

This is the simplest method for evaluating the importance of weights which includes that every criterion under consideration is ranked in the order of decision maker's preferences. Due to its simplicity, the method is very attractive. However, the larger the number of criteria used, the less appropriate is the method. The ROM method is calculated with the formula mentioned below

$$W(I) = \frac{2(n-i+1)}{n(n+1)}$$

Where I = Rank position of criterion,
n = Number of criteria

TABLE XIX
RANK ORDER METHOD

| RANK | Multi criteria | Weight factor |
|---|---|---|
| 1 | Gas station | 0.31 |
| 2 | Public park | 0.22 |
| 3 | Agriculture | 0.13 |
| 4 | Habitant | 0.11 |
| 5 | Geology | 0.09 |
| 6 | Road | 0.07 |
| 7 | Aspect | 0.06 |
| 8 | Existing Health center | 0.05 |
| 9 | Population | 0.04 |
| 10 | Reservoir | 0.04 |
| 11 | Bore hole | 0.04 |
| 12 | Slope | 0.03 |
| 13 | Land use | 0.03 |
| 14 | Aspect | 0.03 |

### X. *Raster calculator*

The raster calculator is used to perform various operations on the raster datasets. The raster calculator provides you a powerful tool for performing multiple tasks. Input can be raster datasets or raster layers, coverage's, shape files, tables, constants, and numbers. The raster calculator enables you to perform many different types of queries on your data. Cells that meet the criteria are selected in the output raster.

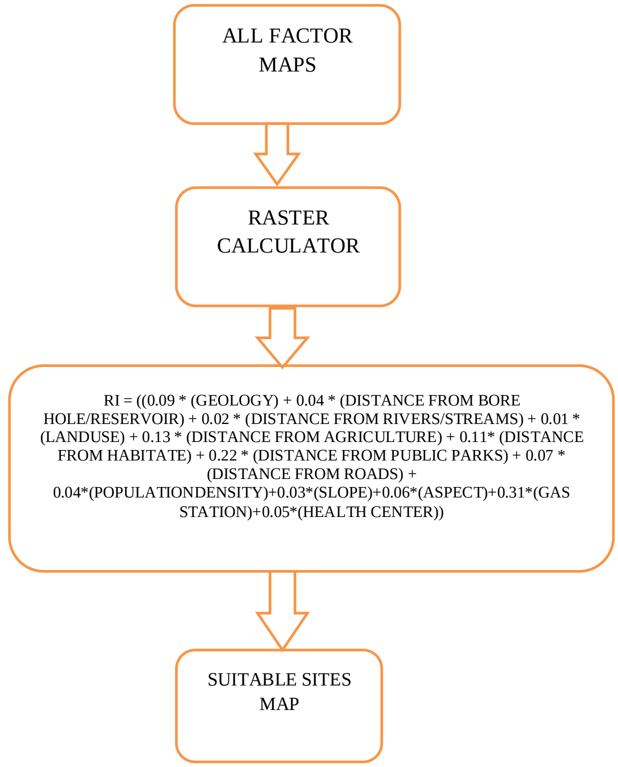


Fig 26 Methodology AHP Weighting (Final Suitability Map)

## VI. RESULTS AND DISCUSSIONS

The purpose of the site selection is finding the optimum site resulting from a series of pre-determined criteria. Typically, the process includes two phases: the screaming and evaluation. After the GIS-based MCA models, usually there are several results with maximum value depending on the same selection standards, so they are screamed out as the candidate sites from massive geographical areas. Then a deep evaluation with extra standards on these alternatives should be carried out to get the optimum site.

### A. *Site selection results*

The purpose of the site selection is finding the optimum site resulting from a series of pre-determined criteria. Typically, the process includes two phases: the screaming and evaluation. After the GIS based MCA models, usually there are several results with maximum value depending on the same selection standards, so they are screamed out as the candidate sites from massive geographical areas. Then a deep evaluation with extra standards on these alternatives should be carried out to get the optimum site. The ranking value is give as follows

1) *Unsuitable areas:* The areas displayed as unsuitable in the suitability map are obtained a result of those areas was considered which restricted area for health center development.
2) *Slightly suitable areas:* The areas displayed as slightly suitable in the suitability map are obtained a result of those areas was considered which slightly restricted area for health center development

3) *Moderately suitable areas:* The areas displayed as moderate suitable in the suitability map are obtained a result of those areas was considered which moderately restricted area for health center development
4) *High Suitable areas:* The areas displayed as high suitable in the suitability map are obtained a result of those areas was considered which comfortable area for health center development
5) *Extremely suitable:* The areas displayed as unsuitable in the suitability map are obtained a result of those were considered which high comfortable area for health center development.

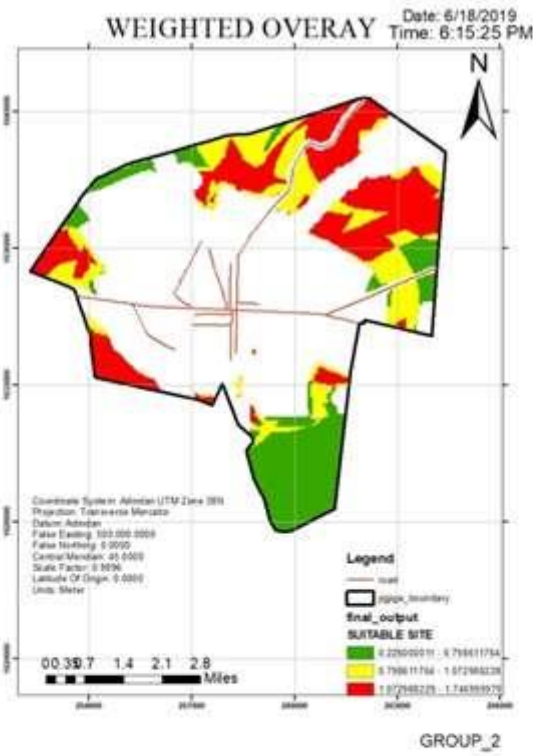


Figure 97 Suitable Areas map for Health Center at Jijiga

## B. Discussions

Comparatively speaking, GIS-based MCA provides a more technological, convenient and precise way for health site selection. Two different MCDA methods, Simple Additive Weighting (SAW) method or rank order method (ROM) and the Analytical Hierarchy Process (AHP), are used to locate the candidate health center site selection. The method includes ranking of every class in a map under consideration in the order of decision maker's preferences. However, this method can be criticized for the lack of the theoretical foundation. In this study, the interaction between layers was tried to be kept at minimum. For example, geology has a direct control on topography, but they are used as different layers because geology and topography layers have different impacts on the site selection process. The Analytical Hierarchy Process decomposes the complex decision problem into simpler decision problems which provides easiness during decision making.

# VII. Conclusions and Recommendation

## A. Conclusions

This project shows how to use GIS- based Multi - Criteria Analysis (MCA) to select the optimal site for a Public health center, and it also shows how effective the method is. From the whole process, we can see that GIS- based MCA is a scientific, convenient and precise way for site selection, although there are still some limitations in this project and need to be improved in the future. The project can be concluded briefly in 4 steps.

- Study the background and read some literatures related to the topic.
- Acquire the data from open sources, preprocess the data.
- Create constraint maps and factor maps, and assign weights for factor maps in AHP method and ROM and finally
- Building an MCA model to generate the final result map.

## B. Recommendation

In the future study, the determination of criteria and weight can use some suggestions from local GIS experts. And as the weight calculation, in this study, the AHP and ROM formula method are used to do a comparison. If these aspects can be improved in the future, the optimal site selection study will be huge improved. With the development of the GIS and remote sensing technologies, more precise data and higher resolution image can be found for this kind of study.

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