GIS Based Suitable Site Selection and Road-map Preparation for Equitable Distribution of Secondary Schools of Amhara Region, Ethiopia

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Abstract
The main objective of this study is to select suitable sites for high school construction and prepare 10 years Road-map plan for the equitable distribution of secondary schools in Amhara Region, Ethiopia. The school site selection analysis is done by Multi-Criteria Analysis Method (MCAM) using Arc GIS software and GIS models. Three models: Restriction Model, Suitability Model and Integrated Suitable Sites Model were developed. First, Restriction Model was developed to identify areas excluded from suitability site analysis. Constraints or restrictions considered in this study includes: the area covered by roads, 150-meter noise level buffer along roads, 5-kilometer radius area around existing high schools, ecologically sensitive areas (parks and conservation areas), lakes and dams, and gorges of major rivers. Having Restriction Model results, Suitability Model was developed to identify suitable areas for high school construction. The major criteria used were: number of students in each school and their spatial distribution, slope, access to road, power access, drinking water access and telecommunication access. Finally, the integrated suitable sites model was developed to combine the restricted areas and suitable areas. The combination gives the final suitable sites for construction of new high schools. The finding of high school suitability sites of Amhara Region indicated that 235,903.67ha (2.1%), 2,551,599.57ha (22.3%), 7,518,477.63ha (65.8), 1,127,206.72ha (9.9%) of the areas of the Region were least suitable, marginally suitable, moderately suitable and highly suitable respectively. Finally, prioritization was done by clustering the primary schools according to the number of students, nearness to each other and considering geographical barriers. In general, about 902 school sites were selected and prioritized for the construction of new high schools in the coming 10 years. In connection, a 10-year road-map plan was prepared so as to achieve a reasonable high school coverage in Amhara region.
Keywords: Geographic Information System (GIS); Multi-criteria Evaluation Technique; Restriction Model; Suitability Model.

1. Introduction

Ethiopia is striving to join the middle-income country in the year 2025. To achieve this goal, our country planned Growth and Transformation Plan (GTP) in different sectors. Education is one of the main sectors among others to realize this vision. During GTP II, Ethiopia has continued to show remarkable progress in basic service delivery as in education and health, in a way that promotes equitable access to services. Investing in human development is a key for long term growth and transformation. This rapid expansion of basic services has helped Ethiopia in achieving the millennium development goals (MDGs) as related to gender parity in primary education, reducing child mortality, fighting HIV/AIDS, malaria and access to primary education.

According to the study of Ajala and Kerebih (2008) on the distribution of the schools in Amhara region, there is a wide gap between the numbers of schools available for different levels of education. Currently, secondary school coverage of Amhara Region is estimated about 36.01%. This participation should be increased into 74.14% in the year 2020. The rest 25.86% of coverage expected to be achieved up to 2025. Therefore, to increase secondary school participation, working on equitable distribution of secondary schools is vital. One of the means to ensure quality education and equitable distribution is applying systematic planning and scientific methods of school site selection. Schools construct in a strategic area play an important role in improving students' performance and excellence.

In Ethiopia, using GIS for education sector has started recently. Some of the applied areas in recent years are: (a) developing thematic maps (Gross Enrolment Ratio (GER) map, Gender proportion of Secondary Students and teachers map), (b) facilitating micro-planning (school infrastructure and elevation map, school enrolment and gender ratio map, school catchment area map) and (c) other further possible uses(IIEP, 2001).

Today, with the development of geographic information system (GIS) and sophisticated computer technology, a site selection and land suitability become an uncomplicated assignment for planners (Bukhari et al, 2010). Even though in Ethiopia GIS for education has been applied for developing thematic maps and facilitating micro-planning, the application of GIS for suitable site selection for new school construction and road map preparation is not yet started. Therefore, this study is the first in its kind at the regional as well as national level.

Planners and decision makers need to consider many factors such as size, access/traffic, utilities, shape,

security/safety, costs, locations, noise levels, topography/drainage and soil conditions/plant life (Alaska Department of Education, 1997; Public Schools of North Carolina, 1998; Bukhari et al, 2010).Till now in Amhara Region, the selection of school site has been normally carried out by organized committees from different sectors at the woreda level. This method has some weaknesses such as: (a) absence of considering scientific social, economic and environmental factors that determine the suitable site selection of secondary schools; (b) lack of transparency in the site selection process that leads to conflict among communities and political leaders, and (c) time consuming.

As a result of these problems, Amhara Region Bureau of Education decided to use a more advanced and scientific way of site selection methods. Using Geographic Information System (GIS) techniques and the embedded models of the software with the application of multi-criteria decision methods is a vital step forward to use better way of site selection and achieve equitability. Therefore, the following suitability factors were proposed by the Bureau to be considered during suitable site selection processes: student population density, distance from existing high schools, minimum area of high school compound, road accessibility, and accessibility to utilities (electricity, water supply and telecom), noise levels, topography, environmentally sensitive areas, and drainage/rivers. Factors proposed by the Bureau of Education were used a milestone for the study team.

Therefore, to develop a roadmap of secondary schools in Amhara Region for the improvement of equitable education access and sustainable socio-economic development, spatial multi-criteria analysis (SMCA) approach in geographic information system will play a vital role. Several studies have focused on school sites issue. However, there are still lacks of research for school site selection modeling (Bukhari et al, 2010). GIS is a decision support system and not a decision-making system (Saleh, et al, 2013). Therefore, it is required to integrate some weighting or decision techniques such as Multi-Criteria Decision Methods (MCDM) with GIS to increase their analysis capability in site suitability process. Thus, this study is intended to improve the quality of the school site selection methods, increase the equitable distribution of schools and provide solution by integrating the multi-criteria decision analysis and geographic information system (GIS) into the decision-making process.

The overall objective of this study is to select suitable sites and develop a road-map of high schools in Amhara Region for the improvement of equitable education access and sustainable socio-economic development. The specific objectives of the study are:(a)inventory of existing elementary and secondary schools in the region and identifying the gap,(b)suitable site selection to decide the number of new schools that shall be constructed within GTP-II period and prioritize the newly identified suitable sites of secondary schools in Amhara Region, and(c) produce maps that indicate the existing secondary school distributions as well as the proposed suitable sites for the future school building; and, show the integration between secondary schools and elementary schools, and between secondary schools and kebeles.

2. Methods

2.1 Study Area Description

Amhara National Regional State is located in the north-western and north-central part of Ethiopia. The State shares common borders with the state of Tigray in the north, Afar in the east, Oromia in the south, Benishangul-Gumuz in the south west, and the Republic of Sudan in the west. The Regional State of Amhara consists of 10 administrative zones and one special districts hereafter referred as woreda encompassing Wag Hemera, North Wollo, North Gondar, South Gondar, South Wollo, North Shewa, Oromia, East Gojjam, West Gojjam, Awi and Argoba special woreda (see Figure 1), 168 woredas, and 40 town administratives. The capital city of the State of Amhara region is Bahir Dar (BoFED, 2012).

The region's topography includes plains, gorges, plateaus, hills and mountains and its altitude ranges from a low of 498 meters to a high of 4,620 meters found at the peak of Ras Dashen. The Ras Dashen Mountain, which is found in North Gondar administrative zone, is Ethiopia's highest mountain. The State of Amhara is divided mainly by three river basins, namely the Abay, Tekeze and Awash drainage basins. It is one of historically rich and worth visiting regions of Ethiopia. It has a wide variety of both natural and manmade attractions. The Rock-Hewn churches of Lalibela and the palaces in Gondar are the world known heritages of the country found in Amhara Region

Figure 1. Location Map of Amhara Region

2.2 Methods

The methodology used to carry out this GIS Based suitable site selection and road map preparation for equitable distribution of secondary schools includes: desk review, field survey and data collection, criteria selection and standard setting, clustering, modeling suitable sites, field verification and produce final road map. The work flow and detailed methodologies followed to carry out this study are depicted and explained briefly in the sections below:
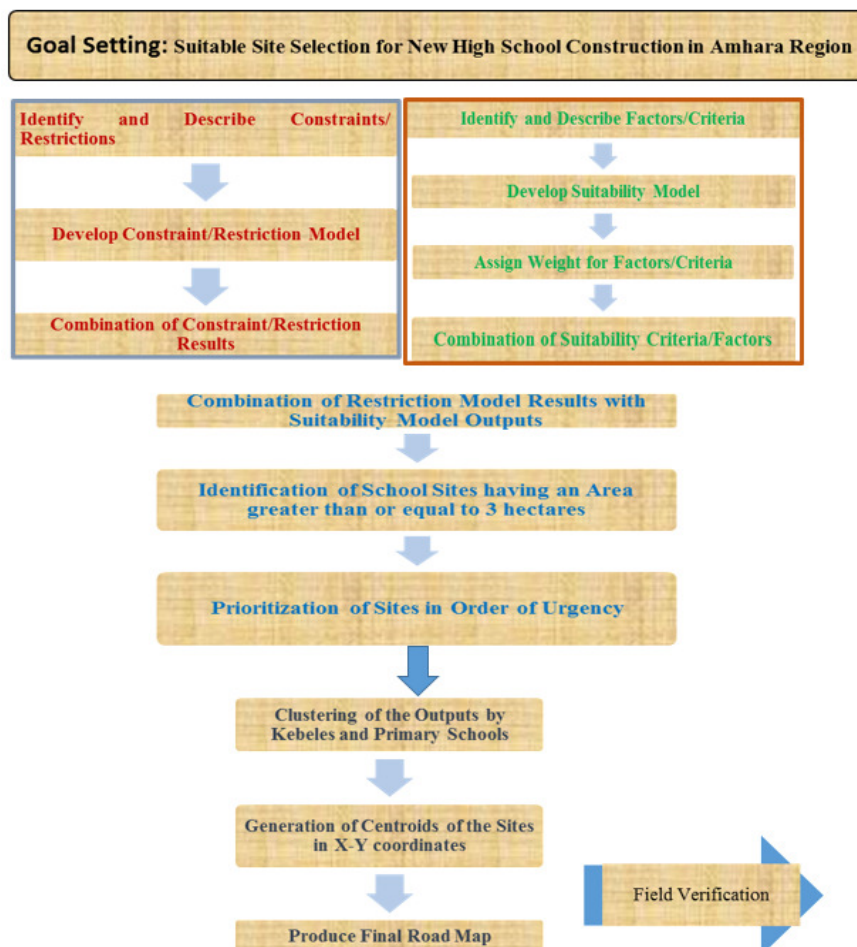

Figure 2.Work Flow of the Study and Model Design

2.2.1 Desk Review

Relevant documents on previous studies as well as important guidelines relevant to attain high school accessibility were reviewed. Studies on school distribution of Amhara Region, standards developed by Regional Education Bureau, and literatures related to GIS-based mapping of suitability area for school building, Ethiopian Growth Transformation Plan-II, and five-year education strategic plan were reviewed. In addition, significant secondary and primary data are collected.

Secondary data such as: (a)Amhara National Regional State (ANRS) protected area Geodatabase were obtained from Environment, Forest and Wildlife Protection and Development Authority (EFWPDA), (b) power access (list of energized kebeles) were obtained from Ethiopian Electric Power of Bahir Dar Branch office, (c) water access (Hand-Dug and Deep Wells) were obtained from ANRS Bureau of Water Resource Development and (d) telecommunication accesses were obtained from Ethiopian Telecommunication of Bahir Dar branch office. And, e) schools' location data were obtained from education bureau studied by the cooperation of UNICEF.

The collected secondary data was analyzed and the gaps of each data were identified. Maximum effort was exerted to fill the gaps of the data at the office by making some technical correction. The school data collected from Bureau of Education in excel format is analyzed in detail and converted into GIS shape files. Corrections are made in projection; location coordinates and gaps are outlined in different aspects. Then, the missed information is planned and articulated in the checklists to collect from field survey.

2.2.2 Field Survey and Data Collection

Three main objectives were met during the field survey: primary data collection, secondary data collection and conducting consultation with different stakeholders. These activities helped to analyze existing school's distribution, establish baseline data on environmental condition and socio-economic characteristics of the study area. It also enabled to identify the gaps and develop methods or criteria to propose the future high school construction sites.

Secondary data were collected from sectorial offices for this study. Having the gaps of the data, checklists were prepared before the field work. The format was aiming at collecting information with the purpose of filling the identified gaps and helping to locate of existing school infrastructures. The field data collection format includes information of name of school, grade level, ownership, name of kebele, X-Y coordinates, and data collector name and signature.

During the field survey, first we held short consultation meeting with zonal education offices before travelling to each woreda. In addition to informing the zonal offices about the objectives of the consultancy assignment, secondary data was also collected where available; such as, number of students with grade at woreda level. The consultation meeting was also held with each woreda educational offices and detail data collection methods are outlined.

The primary data collection from field includes information of existing schools up to 2016, high schools under construction, upgraded primary schools, identified sites for future construction of high schools by zones and woredas, coordinates of each woreda capitals and identification of schools in towns and surrounding woredas. The data collection also included the gathering of number of students from each school in grade level in each woreda.

2.2.3 Criteria Selection and Standard Setting

Criteria selection plays a crucial role to identify suitable sites for school construction and management. An appropriate criteria selection helps optimizing the school resources allocation, the urban and rural education service development coordination, facilitate education accessibility, travel time reduction, satisfy and promote the education quality. 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.

A constraint is a criterion that determines which areas should be excluded from or included in the suitability analysis. Constraints are binding criteria so no compensation is allowed. Areas in an input map (added as a constraint) that do not satisfy a constraint condition, will obtain a composite index value of zero, no matter how well these areas perform in any other criterion (factor). Whereas, factors allow for compensation. A factor is a criterion that contributes to a certain degree to the suitability. Poor performance in one criterion can be compensated by good performance in another criterion. A factor can be a benefit (the higher the value, the better), or a cost (the higher the value, the worse). All the criteria and constraints have been input as GIS file in the personal geodatabase.

After the field survey and data collection, multi-disciplinary discussion meetings were held at the office and the study team members identify constraints and factors considering the baseline issues of the client. Constraints/restrictions considered in this study includes: road width, noise level, 5km radius buffer of existing high schools, protected areas including 200-meter buffer, Lakes and dams including 100-meter buffer, major rivers in Amhara region including 50-meter buffer, and the proposed new high school construction site should have an area of at least 3 hectares while factors/criteria considered in this study includes: number of students, slope, road access, telecommunication access, power access, and water access.

Standardization is the process of implementing and developing technical standards based on the consensus of

different parties that include users, interest groups and governments. Standardization can help to maximize compatibility, repeatability or quality of data. It also facilitates commoditization of formerly custom processes. In most cases, the standards set in the 'Terms of Reference' were used. Amhara Region Education Bureau has proposed different analysis standards acquired from their long years of site selection experiences. Some other standards are a result of studies in site selection of schools anywhere in the world. On the other hand, all inputs used are transformed to common analysis scale using software.

Weights assigned to criteria are an important step as final results of the decision largely depend on such weights. Assigning weights to criteria in a multi-criteria analysis approach is the most difficult task. The main purpose of a weighting method is to attach ordinal values to different criteria to indicate their relative importance in a multi-criteria decision-making method. These values are then used in subsequent evaluation of the alternatives in the decision.

Table 1.Weights of the Criteria

No	Criteria	% influence	Ratio
1	Number of students	70	0.70
2	Slope	13	0.13
3	Road access	10	0.10
4	Power access	3	0.03
5	Water access	2	0.02
6	Telecommunication access	2	0.02
	Total	*100*	*1.0*

2.2.4Clustering

One of the ultimate objectives of this study was clustering of primary schools and kebeles for the selection of new high schools. The clustering was expected to be based on the number of primary schools to one high school and kebeles to a single high school ratio. The initial standard from the Bureau says that one high school expected to contain 5 to 7 primary schools and a high school need to have 1 to 5 ratios with kebeles.

These two-clustering ratios have been used together with a combined analysis. This is because that the number of primary schools which supply students for a high school are determined, the kebeles where the schools found are also identified and clustered at the same time. The grouping was done using tools of ArcGIS software overlaying hill shaded digital elevation model (DEM) on schools point map to visualize which schools in which kebeles can be clustered with minimum distance and better terrain condition with each other.

2.2.5Modeling Suitable Site Selection

In this assignment, 'Model Builder' in ArcGIS/Spatial Analyst was used for school suitability model, which is well known as flow chart approach (Malczewski, 2004). In the flow chart approach a school suitability model was constructed from individual processes of input data, basic GIS operations, and derived data which are then linked together. The model includes restriction model, suitability model, integrated suitable sites selection model and prioritization model.

The GIS packages and tools were used to facilitate different stages of evaluating suitable sites for high school construction in Amhara Region particularly in mapping of each constraints and factors, combination of different constraints, combination of different factors, combination of each constraints outputs (overall suitability evaluation), identification of school sites having an area greater or equal to 3 hectares, stratification of sites in order of urgency, clustering of primary schools, generation of centroids of the sites in XY Coordinates, produce final road maps and presentation of GIS outputs for decision makers (see figure 2).

Figure 3.Model Diagram of Restriction Model
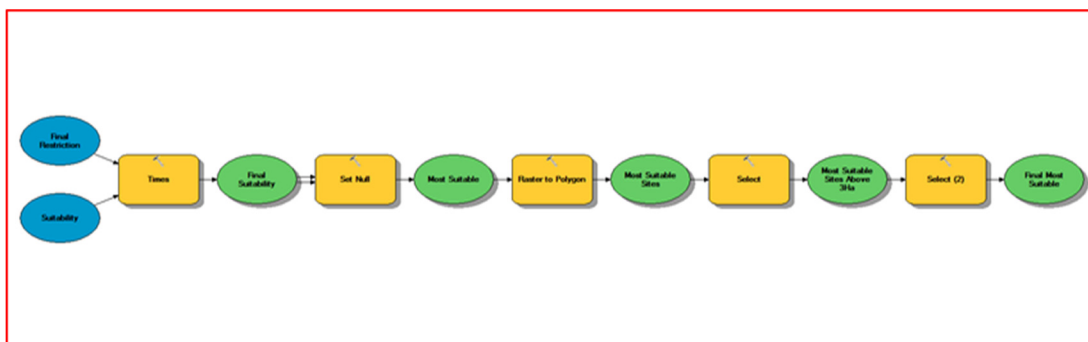

Figure 4.Model Diagram of the Suitability Analysis

Figure 5. Model Diagram of the Final Suitable Sites

2.3 Materials
The software employed to evaluate suitable sites for high school construction, being spatial plan, was ArcGIS 10.3 Software. GIS package and tools used in this consultancy assignment were: (a) spatial analyst tools (surface, raster calculator, extraction, interpolation, map algebra, overlay); (b) analysis tools: extract (clip), proximity (create thiessen polygon); (c) conversion tools (to KML, to raster, to shape file); (d) Arc hydro tools (watershed

processing); and (e) data management tools (generalization, projections and transformations, raster). Hardware's such as Laptop computer, Digital Camera, Garmin GPS series 72H were used in this study.

3. Results and Discussion

3.1 Restriction Model Results

The restriction model evaluates those areas which are not permitted for the construction of high schools. It uses those factors which enable to identify areas which are not suitable for high school construction. Six constraint factors are used for this model.

3.1.1 Road Width

The sites of the school need to be some distance far from roads. The GIS shape files of roads used here are simple lines and needs buffer distance to cover the width of the road. About 40-meter width, 20 meter in both side of the line, was used as a maximum and common width for all roads. This means the whole area cover by a 40-meter width of roads is prohibited for school's construction (figure 6a).

3.1.2 Noise Level

Noise, as defined as unwanted sound, is a common complaint in public institutions and residence areas. Noise is measured in decibels on the A scale of a sound meter (dBA) where higher frequencies are weighted more heavily. Sound intensities greater than 50 dBA are believed to distract office workers and students (Sanders and McCormick, 1993).

Activities such as industrial, development projects and traffic generate excessive noise. Noise pollution has an impact on health and reduces productivity. School is categorized under Noise Sensitive Area. The noise level for Amhara Region is not available. Therefore, the location of roads that generate excessive noise was considered.

Noisy offices and classrooms may increase a worker's and student's feelings of negative mood. In addition, studies have shown that certain levels of noise can harm a person's ability to concentrate on a particular task, thereby leading to a stress response (Hedge, 1982). Increased stress leads to the release of certain chemicals, such as epinephrine and norepinephrine, which are found in both blood and urine (Maxwell, 2005). Prolonged exposure to stress has serious health effects. A study in the New England by McEwen (1998) found that stress could cause insulin resistance, heart disease, memory loss, immune system dysfunction and decreased bone mass density.

Vehicle is one of such with distractive sounds which cause noise. The acceptable noise level for school classroom is 35 dBA. To protect the sound noise above this limit, a range of distance between 150 and 300 meter is commonly used. Therefore, the minimum 150-meter distance from roads was used for this analysis in order to use the maximum transport access to schools. Hence, a 150-meter noise buffer has developed starting from the sides of roads. That means, about 150-meter width area on both side of the road is protected from the selection of high school construction sites (figure 6b).

3.1.3 Existing High Schools

There is a total of 534 secondary schools in the region including under constructions. Among these, 362 are high schools, 46 are preparatory and the rest 126 are high school & preparatory together. Only high schools or high schools & preparatory are used for restriction analysis. Since preparatory are not the concern of the analysis, about 46 schools are out of the analysis.

Hence, based on the standards, 5-kilometer radius area of existing high schools should not be considered as site of new high school construction. Therefore, the area found within 5-kilometer radius of existing high schools is completely protected from analysis; which are called in this case "restricted areas" (figure 6c).

3.1.4 Ecologically Sensitive Areas

Ecologically sensitive areas refer to areas located within the primary impact zones, which are classified as "Ecologically Sensitive". These areas include Natural Habitat, or area legally protected, officially proposed for protection, or unprotected but of known high value for conservation and/or provision of ecosystem services (Janker et al., 2011). This impact indicator was included because the international finance corporation (IFC) and World Bank policy does not support projects that would lead to the significant loss or degradation of such areas.

Maps of protected areas in Amhara Region such as existing and proposed national park, and community based conservation areas were obtained from Amhara Region Environment, Forest and Wildlife Protection and Development Authority. Therefore, Ecologically Sensitive areas were considered as constraint areas that represent the lands which are not allowed for any kinds of school construction. These parks and conservations areas are not only considered but also there is a need to leave some distance from the boundary to build schools. Therefore, these areas are buffered about 200 meters all round. Hence, the total area indicated in table 2 and the area covered by 200-meter buffer around each protected area are restricted or not suitable for high school construction (figure 6d).

Table 2. Protected Areas in Amhara Region

No	Parks/ Conservations	Location/zone	Area in hectares
1	Alatish National Park	North Gondar	263,542.45
2	Bagusa National Park	Awi	55,301.04
3	Borena-Sayint National Park	South Wollo	15,224.60
4	Semien Mountain National Park	North Gondar	41,133.82
5	Menz-Guassa Community Conservation Area	North Shewa	7,728.35
6	Abune Yosef and Aboye Gara CCA	North Wollo	8,058.85
7	Mahebere Selassie Community Conservation Area	North Gondar	19,070.48
8	Guna Proposed Community Conservation Area	South Gondar	4,614.84
9	Godebe Proposed National Park	North Gondar	18,691.03
	Total		*433,365.46*

3.1.5 Lakes and Dams

Water bodies in Amhara region particularly natural lakes and artificial reservoirs/dams including 100meter buffer around those water bodies were also considered as restricted areas. Therefore, major lakes and dams in the region are identified and restricted (table 3). Again, to keep suitable distance from these water bodies, there is 100-meter buffer from the boundary (figure 6e).

Table 3. Major Lakes and Dams in Amhara Region

No	Lakes/dams	Relative location	Area in hectares
1	Lake Tana	Western Amhara	306,083.32
2	Lake Haik	Eastern Amhara	2,275.90
3	Lake Ardibo	Eastern Amhara	1,550.86
4	Lake Zengena	Western Amhara	125.66
5	Geray Weir	South-western Amhara	4.92
6	Koga Dam	Western Amhara	341.33
7	Tekeze Dam	North-eastern Amhara	10,197.11
	Total		*320,578.22*

3.1.6 Major Rivers/Flood Hazard Prone Areas

Schools should be located far from streams to ensure schools are safe from flood hazard which stem from their closeness to river. Indian State Board of Education School Facility (2002) clearly states no school can be built within 500 feet (152.4 meter) of a stream. Spatial multi-criteria decision analysis for safe school site selection of Malaysia by Bukhari et al. (2010), states that the acceptable distance from the school site to the nearest stream was at least 300m. For this study, the acceptable distance from the school site to the nearest stream needs to be at least 50m. Such small distance is taken to keep suitable gentle slopes near rivers. Large and wide gorges of rivers are not suitable for the construction of schools. Therefore, to protect these unsuitable sites, a 50-meter buffer was developed along major rivers (figure 6f).
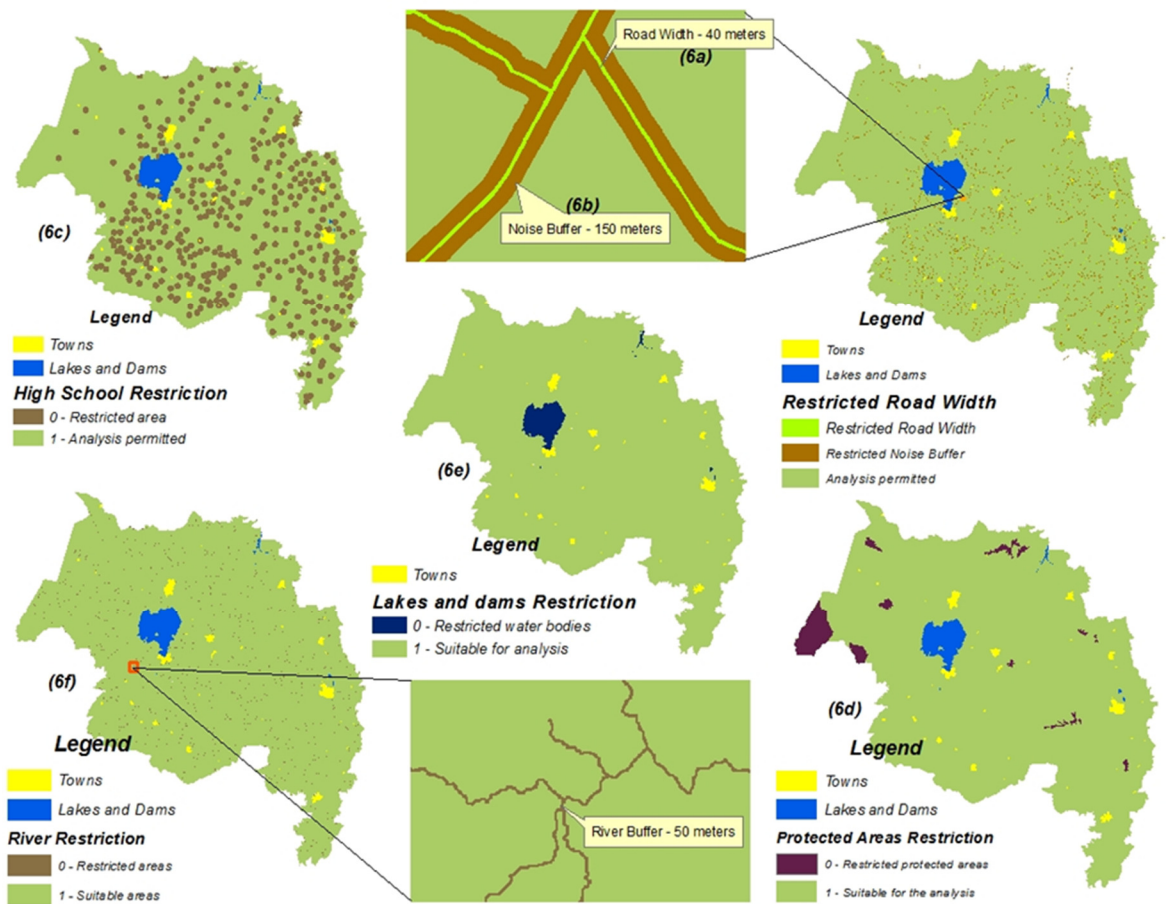
Figure 6.Maps of Restrictions Developed for School Suitability Mapping

3.1.2 Combination of the Restriction Criteria

The final results of each restriction criteria analysis were combined together to produce the final restriction area. The combination of the criteria using "Raster Calculator" tool in ArcGIS software enabled to have final restriction output (figure 7).
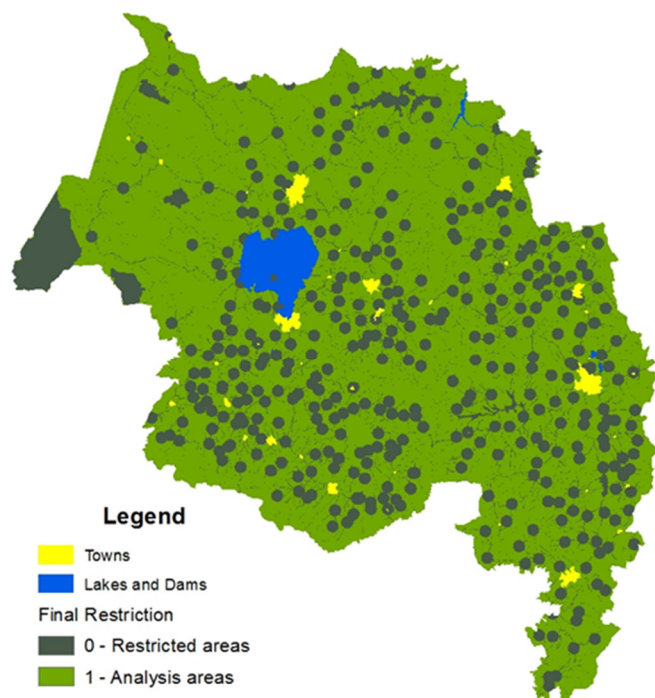

Figure 7. Final Restriction Areas for Rural Analysis

3.2 Suitability Model Results

A suitability model is a model that weights locations relative to each other based on given criteria. Suitability models are important in finding a favorable location for a new facility, road, commercial business centers, institutions like schools or habitat for a species of bird. Overlay analysis is a common method for creating a suitability model which involves using GIS techniques. With the advancement of computer mapping software, suitability modeling has become much easier and faster to implement, and today it is used for varying tasks.

3.2.1 Analysis of Suitability Factors/Criteria

3.2.1.1 Number of Students

The most important input of the suitability analysis is number of students in each school. High schools will expand and built considering number of students as a major criterion. The significance of other factors is too small as compared to the number of students. The number of students will be a dominant and the most influencing factor throughout this site analysis (figure 8a).

3.2.1.2 Slope

Landscape of the area is one of the most significant factors of the site analysis. The school compound needs to be suitable and comfortable for student's movement, playing grounds and even for the construction of the buildings. On the other side, it is also important for the appraisal of environmental issues like landslide, flash and sheet erosion, and flooding. Therefore, irrespective of other influences, suitability of the sites for construction of high schools increases as slope decreases. Gentle slopes are the most suitable areas for school construction. The slope of Amhara region was divided in to four groups for the analysis including gentle, sloping, steep and very steep slopes (table 4). As indicated in figure 13, the eastern and north eastern part of the region are dominated by steep and very steep slopes with the exception of some isolated pockets (figure 8b).

Table 4.Slope range and the percentage of area in each category

No	Slope range (%)	Code	Total area (ha)	%
1	0-20	4	8,549,771.18	54.71%
2	20-40	3	3,728,352.99	23.86%
3	40-80	2	2,953,008.32	18.90%
4	80-500	1	395,562.80	2.53%
	Total		*15,626,695.29*	*100.00%*

3.2.1.3 Road Access

Even though the roads are restricted for about 40-meter road width and 150-meter noise level buffer distance, the sites, which will be selected as suitable, need to be easily accessible. Therefore, accessibility is a significant criterion of analysis in the evaluation. After the distance of each specific area from existing road is calculated, it is grouped in to four categories starting from most accessible to the farthest area from major roads. The grouping is a result of noise level reference and the minimum distance that the students travel to schools. Nearly 60% of the rural area in the region found within 5 kilometers from roads and 90% within 15 kilometers. Therefore, accessibility is not a major problem in the region with some exceptions (figure 8c).

3.2.1.4 Power Access

Power is mandatory for all high schools specifically for laboratory services. Power access data was collected from Rural Electrification project office in the north-western branch office of EEA. A total of 1,300 electrified rural kebeles list was collected and integrated with their spatial references. In addition, considering that all major towns and rural kebeles along main roads and major power transmission lines have the chance to be electrified, the total number of kebeles energized in the region reaches about 1,610 (figure 8d).

3.2.1.5 Water Access

The construction of high schools should be restricted some distance from rivers, lakes and dams. This is done to avoid river gorges, water pollution and flood hazards related to water bodies. However, access to potable water and for other day-to-day school services is vital. Hence, some weight was given to the accessibility of sites to hand-dug and deep wells. A total of 11,761-point data of water institutions were used for this analysis. Four categories established in order to assess access to water taking in to consideration the guideline of the Bureau (figure 8e).

3.2.1.6 Telecommunication Access

The objective of using this criterion is for the plasma learning media in secondary schools. Currently, schools use VSAT receivers. However, there is a possibility of using wireless devices for plasma learning transmission. Now, all parts of the region have a wireless access, according to the information given by Ethiopian Telecommunication Corporation North-western branch office. Therefore, every parts of the region has got equal value relation to telecommunication (figure 8f).
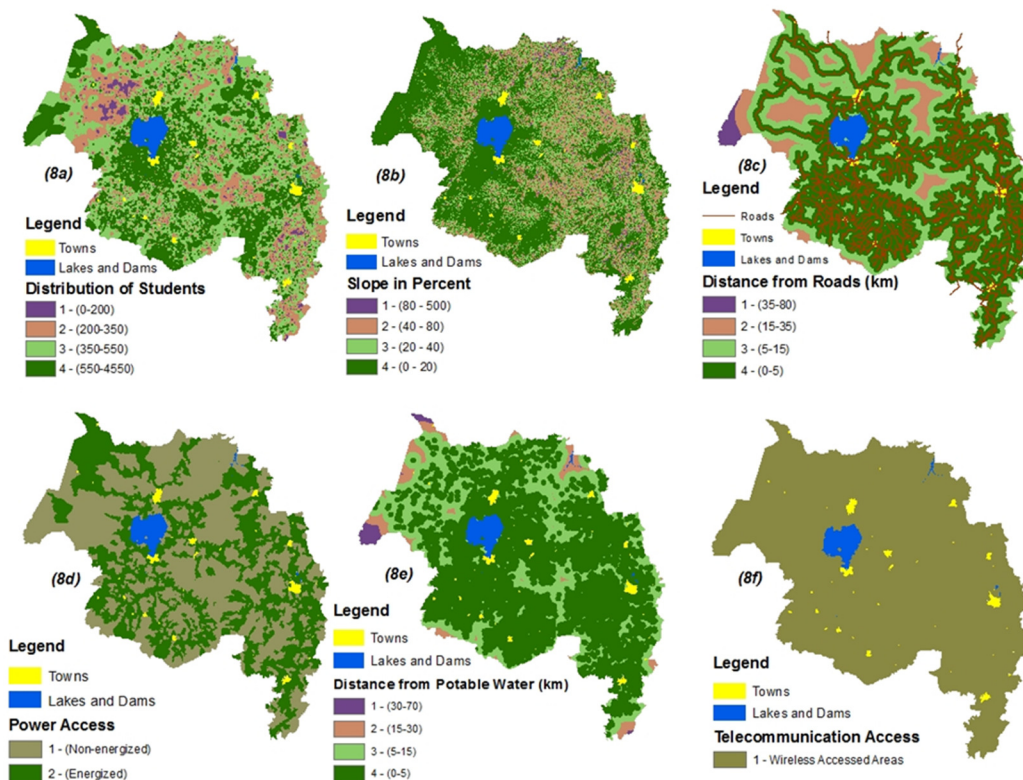
Figure 8.Maps of Factors Developed for High School Suitability Mapping

3.2.2 Combination of the Criteria and Assigning Weights

All the suitability analysis criteria are combined together using a weighted overlay method. The combination gives a vast area of suitable area for construction of high schools. This result indicates only the suitable lands without considering restricted sites. However, the combination of this suitability map with the restriction areas will give the final suitable sites.
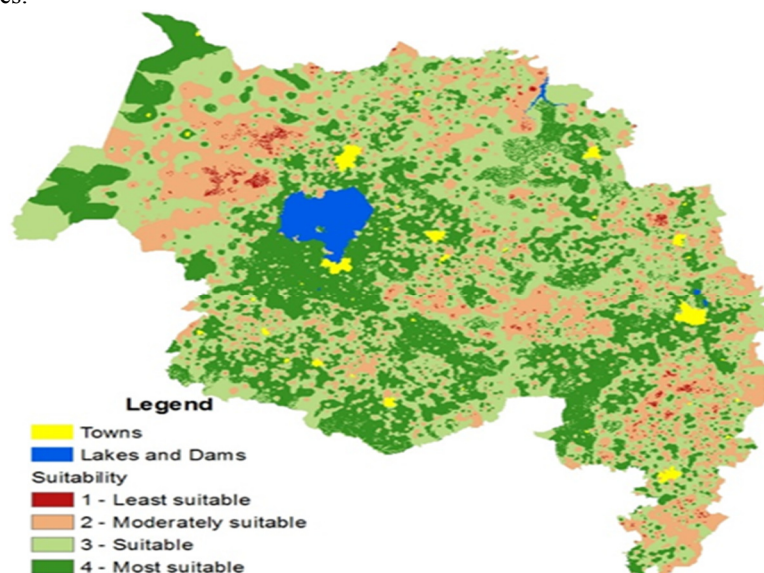

Figure 9.Suitable Sites in the Rural Areas without Considering Restricted Sites

3.3 Integrated Suitability Sites Model Results

The comprehensive suitable sites were generated by combining the restricted areas and the suitability analysis results. The suitable sites are results of the combination of restriction model output with the model results of suitability. The restriction model result indicates those areas which prohibited from suitable site selection analysis. On the other hand, the suitability model result shows the level of suitability of the areas for high school construction. The combination model produces a stratified level of suitable areas from most suitable to least suitable sites, having

restricted or completely non-suitable lands. As indicated in table 13, about 11,433,187.59 hectares of the region has classified and stratified with levels of suitability and the rest parts of the region is non-suitable or restricted from suitability analysis.
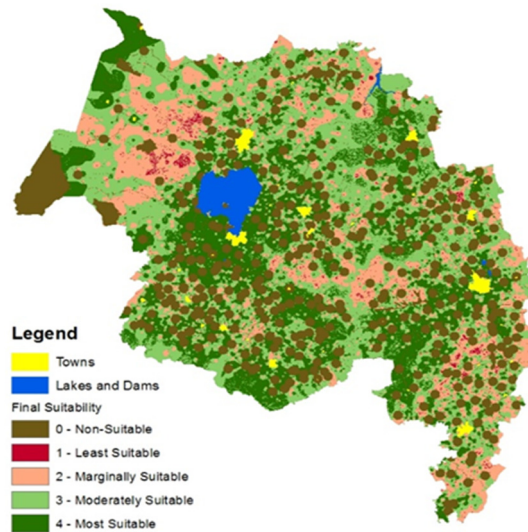

Figure 10.Suitability Levels for High Schools

Table 5. Levels of Suitable Sites after Combination

No	Code	Suitability level	Area (ha)	%
1	0	Non-suitable	4,396,348.68	27.77
2	1	Least suitable	235,903.67	1.49
3	2	Marginally suitable	2,551,599.57	16.12
4	3	Moderately suitable	7,518,477.63	47.50
5	4	Highly suitable	1,127,206.72	7.12
	Total		*15,829,536.27*	*100*

As indicated the result, 7.12% of the region is the highly (most) suitable sites and are the best preferable sites of high school construction. These sites are those which most satisfy the standards of the criteria used in the suitability model. Therefore, high schools are preferred to be constructed on these sites.

However, it doesn't mean that those parts of the region which lack the highly suitable sites will have no area of high school construction. Rather, the selection of sites goes through the levels of suitability if the prior suitable site is not found. This means, the selection even can be "Least suitable" sites if the area has a need of high school due to high number of primary school students. Still, the main determinant factor is the number of students.
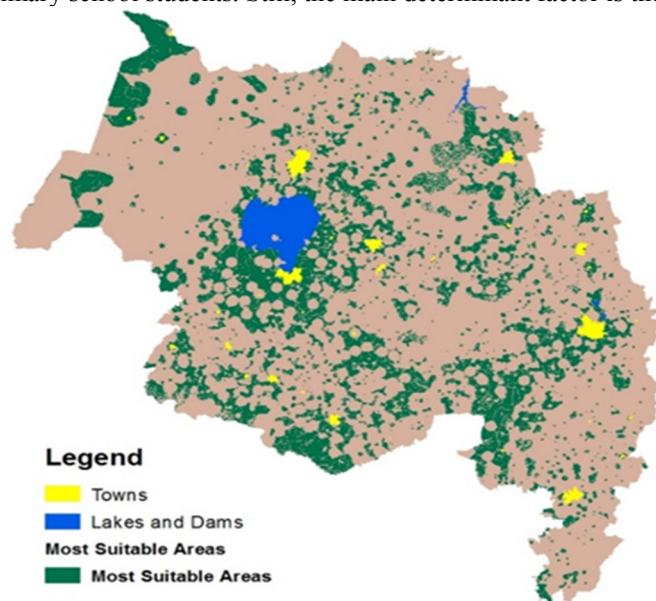

Figure 11. Highly Suitable Sites

4. Concluding Remarks

It is possible to conclude that GIS tools are very significant to facilitate a systematic and comprehensive suitable site selection processes in a more effective and scientific way by combining and spatially assessing multiple constraints and factors. In this project work, the application of GIS for suitable site selection for high schools adds a new dimension to the existing school site selection modeling using GIS. This project work also indicates that GIS can serve as a support tools in suitable site selection processes for construction of new high schools in mapping of each constraints and factors, combination of different constraints, combination of different factors, combination of overall constraints output with overall factors(overall suitability evaluation), identification of school sites having an area greater or equal to 3 hectares, stratification of sites in order of urgency, clustering of out puts, generation of centroids of the sites in X-Y Coordinates, produce final road maps and presentation of GIS outputs for decision makers.

For this study, different constraints and factors were considered for suitable site selection of new high school construction in Amhara Region. Road width, noise level, 5km radius of existing high schools, protected areas including 200 meter buffer, Lakes and Dams including 100 meter buffer, major Rivers in Amhara Region including 50 meter buffer; and minimum area size of the proposed new high school construction sites (at least 3 hectares) were considered as constraints; while, number of students, slope, road access, power access and water access were considered as factors or criteria. Then a MCA model was built to analyze all constraint maps and factor maps by giving them different weights, and to get the final high school construction suitability map. Generally, the most important limiting factor for suitable site selection for construction of new high schools in Amhara Region is number of students. Power access and water access were the least important limiting factors. However, Telecommunication access is common limiting factor for suitable site selection for new high school construction in region.

The overall evaluation results revealed that there is a need to build many secondary schools that can accommodate fast growing number of students who will graduate from primary schools. The analysis result also indicated the availability of vast area of suitable sites which satisfied many of the criteria used in the evaluation. Therefore, the remaining major tasks will be fund raising and effective implementation of the assigned plans.

In light of the results of GIS application to support the development of road-map of secondary schools in Amhara Region for the improvement of equitable education access and sustainable socio-economic development, the following key recommendations are forwarded:

1. Integration and Implementation of the study results: The proposed new high school construction sites expected to be implemented with maximum effort of the Bureau as well as the regional government. Each annual plan expected to cover in the same year. Hence, it requires immediate action plan and implementation. For precise project location and detail implementation, the use of GIS and modelling tools is vital. While locating the precise project location of the proposed high school sites, necessary care should be taken in order not included areas of road infrastructures, road (highway and main road) buffering of 150meter to reduce impacts of noise, 5km radius of existing high schools, protected areas including 200metter buffer, lakes and dams including 100 meter buffer. gorges of major rivers including 50meter buffer.

2. Micro-development planning: To make socially acceptable, economically feasible and environmentally sound suitable site selection decisions, educational planners and implementers of the Bureau as well as the region should use and integrate the GIS assessment result of this project with the future detail level of school micro-development planning. The implementation of the analysis result and school mapping should be in woreda level. Hence, the local mapping and implementation needs to be supported by GIS techniques.

3. Future Educational Geodatabase and Guideline Development: One of the major problem both regional and local level is lack of effective and accurate Geodatabase. For instance, during the study of this suitable site selection project, the main shortcoming was lack of adequate educational Geodatabase and guidelines from both Bureau of Education and Woreda offices. This is also a major problem of other sectors. Therefore, adequate educational Geodatabase and guidelines must be produced with cooperation of Bureau of Education and other consultants.

4. GIS and related skill training for woreda experts: In addition, the woreda experts need to be equipped with the necessary skill and knowledge of how to collect and handle spatial data about schools and students. Therefore, the Bureau must plan to train experts in woreda level in GIS and related tools and skills.

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