

Applying ArcGIS ModelBuilder to Determination the Suitable Sites for Establishing Basic Schools (Case Study: Eastern Unit - Port Sudan City)

Sahar I. M. Abd Elrahman, Badria Ali, Ibrahim M. Ataalmanan

Surveying Engineering Dept., Sudan University of Science and Technology, Khartoum, Sudan

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ABSTRACT- Geographic Information Systems (GIS) play an effective role in societal development, including supporting and developing the educational process with essential capabilities characterized by effectiveness, speed, and ease, which help support decision-making. The educational sector in the Eastern Unit - Port Sudan City suffers from randomness and poverty of equitable spatial distribution, therefore, this study was carried out to determine the appropriate sites for establishing new basic schools according to the recommended criteria, consequently, a model was created using model-builder tools and the spatial analyst tools were taken advantage in GIS. The criteria used in the study were obtained from the General Administration of Planning - Ministry of Urban Planning - State of Khartoum - Sudan and a satellite image of the study area was acquired and stratified into several layers that meet the objective and a lot of work was done in the ArcGIS 10.3 program until the best sites were found, and the final best site for a new basic school was determined from them. This shows the effectiveness of the program used in accurately determining the best sites according to international and local standards, which are difficult to access without the help of ArcGIS ModelBuilder, and thus benefit from it in serving the community by equitable distribution of basic schools and the possibility of all students to enroll in them.

Keywords: Sudan, Elementary Schools, Best Site, Spatial Analyst Tools.

المستخلص- تلعب نظم المعلومات الجغرافية الدور الفعال في التنمية المجتمعية، بما في ذلك دعم العملية التعليمية وتطويرها بقدرات جوهرية تتميز بالفعالية والسرعة والسهولة، مما يساعد على دعم اتخاذ القرار. يعاني القطاع التعليمي في الوحدة الشرقية - مدينة بورتسودان من العشوائية وفق التوزيع المكاني العادل [10]، لذلك أجريت هذه الدراسة لتحديد المواقع الملائمة لإنشاء مدارس أساس جديدة وفق المعايير الموصى بها، لتحقيق ذلك تم إنشاء نموذج باستخدام أدوات بناء النماذج وتمت الاستفادة من أدوات التحليل المكاني في نظم المعلومات الجغرافية. تم الحصول على المعايير المستخدمة في الدراسة من الإدارة العامة للتخطيط - وزارة التخطيط العمراني - ولاية الخرطوم - السودان وتم الحصول على صورة الأقمار الصناعية لمنطقة الدراسة وقسمت إلى عدة طبقات تفي بغرض الدراسة وتم الكثير من العمل داخل برنامج ArcGIS 10.3 حتى تم الحصول على أفضل المواقع ومن بينها تم تحديد أفضل موقع نهائي لإنشاء مدرسة أساس جديدة. يوضح هذا فاعلية برنامج ArcGIS في التحديد الدقيق لأفضل المواقع وفقاً للمعايير الدولية والمحلية والتي من الصعب الوصول إليها دون الإستعانة ببناء النموذج في البرنامج، وبالتالي الاستفادة منه في خدمة المجتمع من خلال التوزيع العادل للمدارس الأساسية وإمكانية التحاق جميع الطلاب بها.

INTRODUCTION

The school site is an important part of the educational process, because schools that are well-located, planned according to a systematic plan, safe, and run efficiently contribute to society's progress [1]. Site selection is a tough problem to solve because it involves technological, political, social, environmental, and economic criteria that are difficult to meet with a single technique that may be incompatible with others. Schools must be located in secure areas; these secure areas must also be optimal and cost-effective for the public in terms of accountability. The location of these schools is

frequently done without the use of scientific methodologies, which might result in the sprouting of schools in inconvenient areas [2].

Choosing a proper location is a crucial decision because poor site selection can be costly and difficult to rectify. The goal of selecting a suitable location is to discover the best location that meets the stated criteria [3]. The selection of school locations is a difficult task that necessitates the consideration of numerous factors. Such difficult difficulties can be solved with geographic information systems. GIS is used to display maps

connected with an attribute as spatial data that is spatially related to the Earth's surface ^[4].

Site selection and land appropriateness have become a simple task for planners because of the advent of geographic information systems and advanced computer technologies ^[5]. GIS has been successfully used in the land management domain to deal with geospatial data for screening and evaluation, allowing for optimal site selection ^[6].

The geographical information system offers a wide range of applications in urban planning and educational decision-making. Where, there has been a tendency of assisting decision-makers in general, and education ministries in particular. One of these uses is the use of GIS software to choose new school sites or, in some cases, to expand existing schools ^[7].

Spatial analyst in ArcGIS delivers a variety of advanced spatial analysis modeling. It could extract a variety of geographic data, including topography analysis, spatial relations, appropriate sites, and the total cost of accessibility. The model is represented by a flux diagram in the modelbuilder's graphical user interface, which allows users to build, visualize, edit, and execute geoprocessing workflows, as well as use, share and apply them to other areas ^[8]. Many studies depend on spatial analysis in geographic information systems, where the spatial analyst tools present in the ArcGIS program are very important due to their high potential for effective assistance to reach the best results, as it is difficult to reach these results without making use of the capabilities available in geographic information systems.

In light of the maximum utilization of spatial analyst tools, this paper was made to determine the appropriate sites for the establishment of new basic schools in the Eastern Unit - Port Sudan city, depending on the relevant criteria ^[9], which were obtained from the General Administration of Planning - Ministry of Urban Planning - State of Khartoum – Sudan. And considered reliable criteria because it was obtained from the relevant accredited authorities, as these criteria stipulate that the sites of the schools are in a flat area and avoid areas of a sloping nature, as close as possible to student buildings, far enough from established old basic schools, are close to roads so that students can easily reach their schools. As far away as possible from sources of pollutants, far from fuel stations,

and from a suitable distance from the valleys to keep students safe, all these criteria were taken into consideration along with taking into account of the nature of land use.

All relevant data to the study were obtained, and all previous criteria were dropped on them in the ArcGIS 10.3 program, where the suitable sites were obtained according to the entered criteria, among them, the best site was chosen.

METHODOLOGY

The Eastern Unit in Port Sudan city (see Figure 1) was chosen as a study area to determine the best sites for establishing new basic schools, as the distribution of basic schools in this area is characterized by random ^[10], and at the same time, it has empty areas that are not served by schools and have unplanned random areas. To achieve the objective of the study, the ArcGIS 10.3 program was used because of its many benefits, where the passage through several phases was done in it, as shown in Figure 2. A satellite image of the study area was obtained from the Google Earth Pro program in Universal Transverse Mercator in 2022 by about 60 cm to 15 m resolution. Accordingly, the area was divided into several vector layers to meet the requirements of the study, and a digital elevation model was also obtained from which the slope layer is derived later.

In the ArcGIS 10.3 program, the coordinate projection was set, all layers were created inside it, and the model was also built by creating a toolbox within the new file geodatabase that contains the study layers and from it, the model was built and opened. All the necessary operations were performed in it to determine the suitable sites for establishing basic schools, where the relevant tools were called inside the model one by one and worked on, and then the results were shown in ArcMap display.

Based on the criteria followed, inside the model raster layers were derived for all the established layers and a reclassified was done for them, weighted, and combined, and thus the suitable sites were obtained for the establishing the new basic schools, and from them were obtained the optimal sites, where the pixels with a high value indicate the optimal sites, and by deleting the single cells the best sites were obtained, and finally the best site was obtained based on the area criterion.

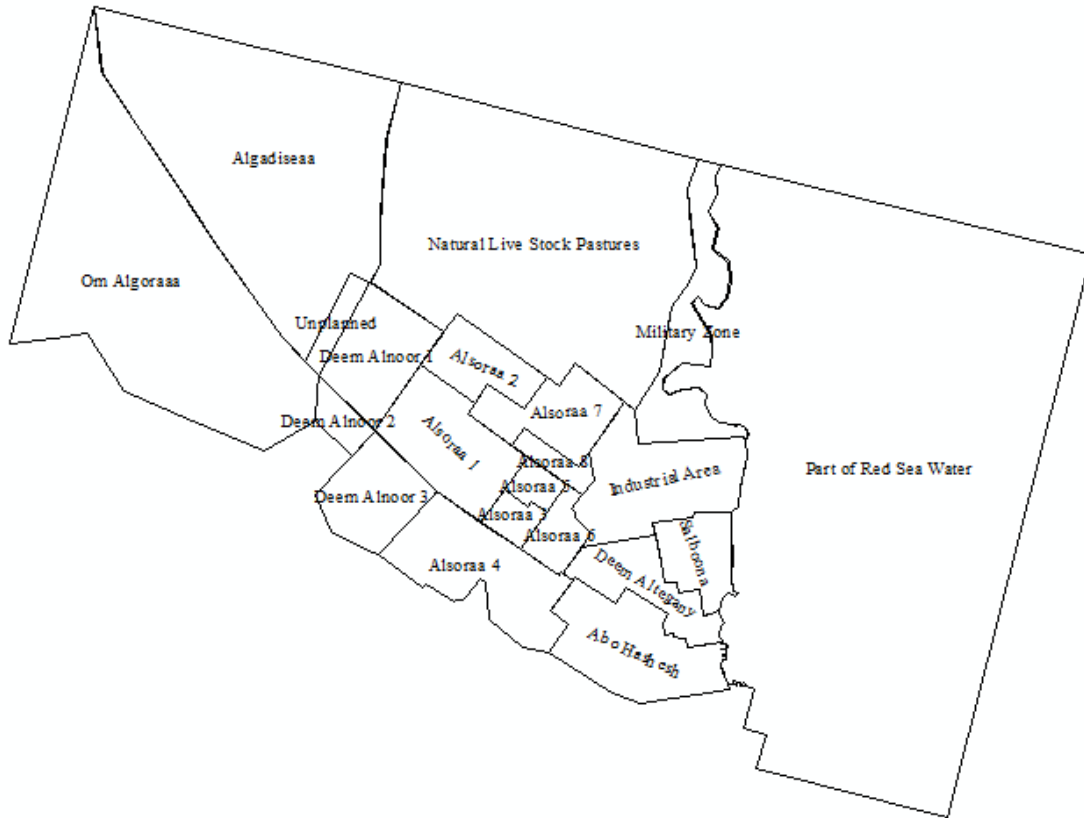


Figure 1: Map of Study Area, (Created by the Author on a scale 1:80,000, 2022)

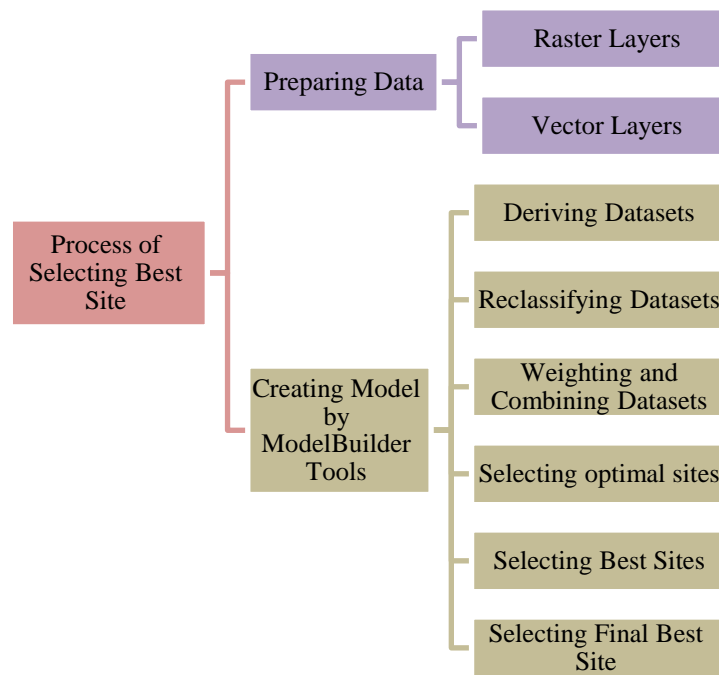


Figure 2: Phases of Study

RESULTS, ANALYSIS, AND DISCUSSION

In the ArcGIS 10.3 program in coordinate projection WGS 1984 – UTM Zone 36N, the satellite image (see Figure 3) and the digital elevation model (see Figure 4) of the study area were called, and then was created the vector layers (see Figure 5) represented in the basic schools and fuel stations (as points), roads and valleys (as polylines) and buildings, pollutants and land use (as polygons).



Figure 3: Satellite Image of Study Area

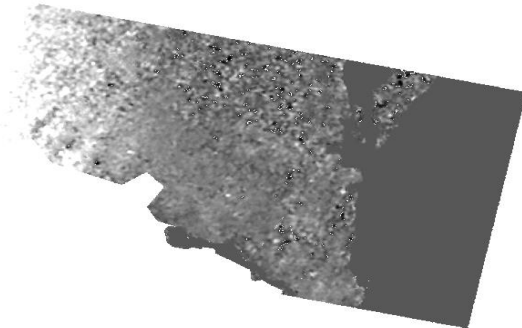


Figure 4: Digital Elevation Model of Study Area



Figure 5: Vector Layers

A table was attached with the population census of the neighborhoods of the area under study to be used and studied when reaching the current results of the analysis (see Table I).

TABLE I: NEIGHBORHOODS POPULATION CENSUS ^[10]

Name	Population	Population Under 18 Years
Abo hashes	8104	6203
Deem altegary	2049	1588
Salboona	7575	5798
Alsoraa 1	6697	5126
Alsoraa 2	2586	1979
Alsoraa 3	2201	1685
Alsoraa 4	5584	4274
Alsoraa 5	3004	2299
Alsoraa 6	3466	2653
Alsoraa 7	14015	10727
Alsoraa 8	6778	5187
Deam alnoor 1	11982	9171
Deam alnoor 2	18341	14037
Deam alnoor 3	3923	3003
Om algoraa	26597	20358
Algadiseaa	43834	33551
Random	0	0

A model was created to perform the spatial analysis tasks by model builder tools, and in it, the working environment was set. Within the model, all operations were performed until the final best site for establishing a new basic school was obtained:

Firstly: the datasets were derived based on the previously mentioned criteria as follows:

- The slope raster layer was derived from the digital elevation model (elevation) layer using the slope tool from the surface toolset located in the spatial analyst tools toolbox (see Figure 6).

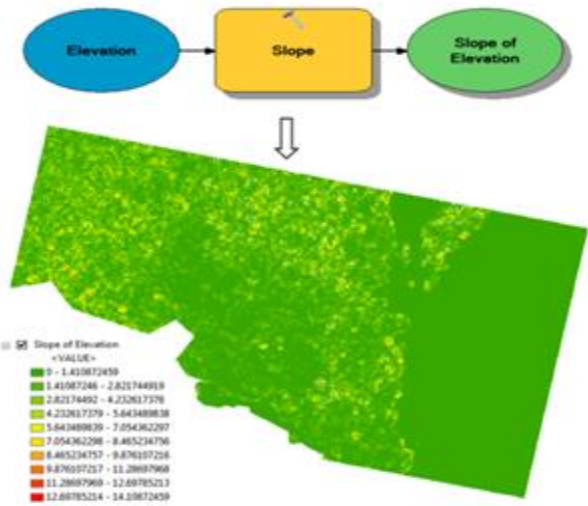


Figure 6: Derived Slope of Elevation Layer

- The distance was derived from buildings by the Euclidean distance tool located in the distance

toolset in the spatial analyst tools toolbox, the result is a raster layer (see Figure 7).

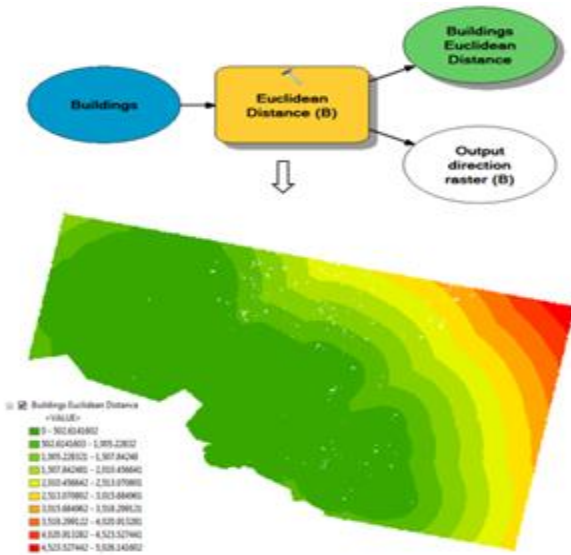


Figure 7: Derived Buildings Euclidean Distance Layer

- The distance was derived from basic schools using the Euclidean distance tool, where the output is a raster layer.
- The distance was derived from roads by the Euclidean distance tool, the result is a raster layer.
- The distance was derived from pollutants by the Euclidean distance tool, where the result is a raster layer.
- The distance was derived from fuel stations using the Euclidean distance tool, the output is a raster layer.
- The distance was derived from valleys by the Euclidean distance tool, the result is a raster layer.

In all previously produced raster layers, the hue is from green and yellow to red color (changed from the properties to clarify), as shown in Figures 6 and 7, where the preference, according to the criteria followed, returns to the classes with the green color, followed by the yellow color and the red color respectively.

Secondly: the produced datasets were previously reclassified by the objective of the analysis process and the criteria used within 10 weighing ranks so that the value 10 was given to the most appropriate areas and the value 1 to the worst-appropriate areas, and the gradient between them respectively, this

was done by the reclassify tool from the toolset of reclass located in the spatial analyst tools toolbox, as follows:

- The slope of the elevation layer was reclassified, where the sites of the basic schools to be established must be located in a relatively flat area, the value of 10 was given for the areas that have the lowest angle of inclination, and the value of 1 for the steep areas, where the result is a new raster layer (see Figure 8).

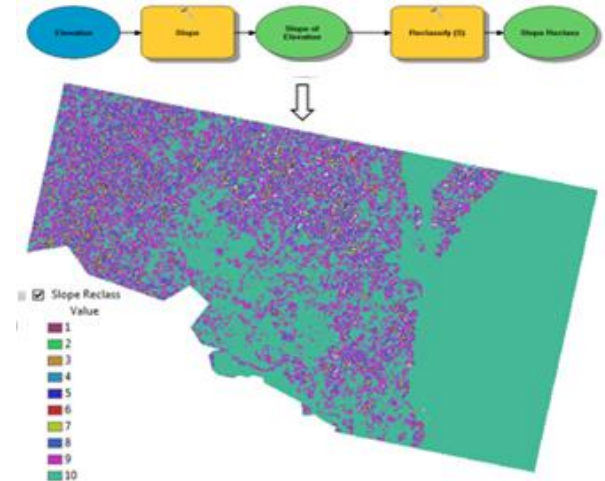


Figure 8: Produced Slope Reclass Layer

- The building's Euclidean distance layer was reclassified, where the preference is for areas close to buildings and was assigned the value 10 for them and the worst is remote areas and was assigned the value 1 (see Figure 9).

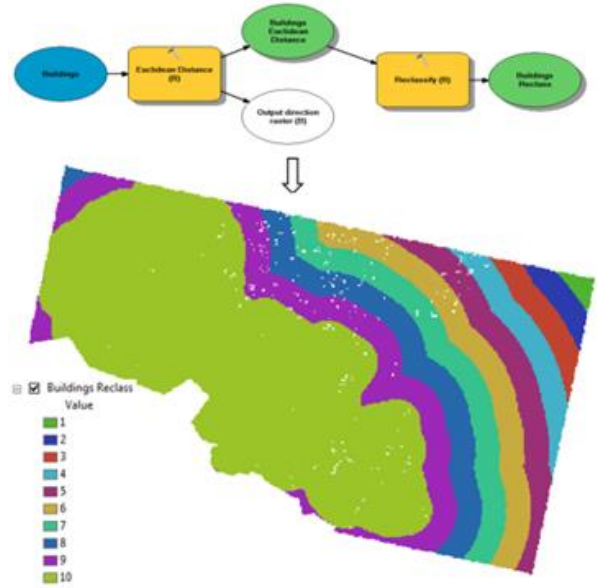


Figure 9: Produced Buildings Reclass Layer

- The basic school's Euclidean distance layer was reclassified, where value 10 is the best and was given for areas far from the current basic schools, and value 1 is the worst and was given for close areas to schools.
- The roads' Euclidean distance layer was reclassified, the sites to be determined must be close to the roads by a sufficient distance to facilitate students' access to their schools, the value of 10 was given to the areas near the roads, and the value 1 to distant areas thereof, where the result is a raster layer.
- The pollutants Euclidean distance layer was reclassified, and the risks caused by pollutants must be avoided, therefore, the sites to be selected must be far from the sources of pollution, where the value of 10 was given for remote areas of the pollutants and the value 1 for nearby areas.
- The fuel stations Euclidean distance layer was reclassified, the preference for remote areas from fuel stations and was given the value 10 for them and the worst for the nearby areas and was given the value 1, the result is a new raster layer.
- The valleys Euclidean distance layer was reclassified, to avoid the dangers of valleys the basic schools to be established must be far from them, the value 10 was assigned to the distant areas of the valleys and the value 1 to the areas near them.

In previously obtained layers, the value 10 indicates the most suitable areas for establishing new basic schools on them, and the gradient respectively, until we reach the value 1, and indicates the worst suitable areas.

Thirdly: previously produced datasets and land-use layer were weighted and combined to choose the

suitable sites using the weighted overlay tool located in the overlay toolset from the spatial analyst tools toolbox. To weight the land use layer, firstly it was transformed into a raster layer, this was done by the feature to raster tool in the two-raster toolset from the conversion tools toolbox. Each type of land use was given a specific scale value from 10 according to the nature and importance of each type, where the value 10 was assigned for the areas of highest impact in the analysis and the value 1 was assigned to areas of least impact in the analysis, the gradient between them respectively, and the restricted value was excluded from the analysis (see Table II).

Each of the produced layers in the second stage, in addition to the land-use layer, was given a certain weight (see Table III) according to the exploratory studies, area nature, previous studies, author experience, and importance of each criterion in determining the suitable sites. Figure 10 shows the produced raster layer from the above operations.

In Figure 10, the highest value indicates the most suitable sites for the establishment of new basic schools in them, this means that sites with a value of 8 are the most appropriate and respectively until we reach a value of 4 which is the worst and the sites with a value zero is the restricted.

TABLE II: VALUES OF LAND USE

Type of Land Use	Scale Value/Author	Scale Value/Palestine ^[11]
Empty	10	10
Residential	6	8
Military	3	5
Industrial	2	5
Random	1	2
Pastures	Restricted	Restricted
Cemeteries	Restricted	Restricted
Water	Restricted	Restricted

TABLE III: WEIGHTS OF CRITERIA

No	Criterion	Weight/Author		Weight/Palestine ^[11]	
		As a Fraction	As a Percentage	As a Fraction	As a Percentage
1	Area Slope	0.10	10%	0.03	03%
2	Proximity to student Buildings	0.20	20%	0.18	18%
3	Dimension from existing basic schools	0.18	18%	0.25	25%
4	Proximity to the roads	0.13	13%	0.15	15%
5	Dimension from the pollutants	0.11	11%	0.07	07%
6	Dimension from the fuel stations	0.08	08%	0.07	07%
7	Dimension from the valleys	0.07	07%	0.07	07%
8	Land Use	0.13	13%	0.18	18%
	Total	1	100%	1	100%

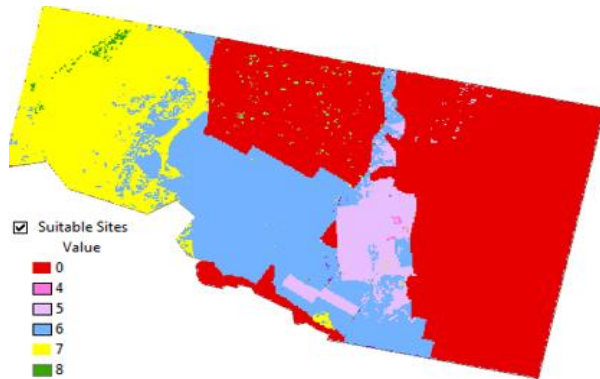


Figure 10: Suitable Sites Layer

Fourthly: The optimal sites were chosen from the suitable sites layer using the con tool in the conditional toolset in the spatial analyst tools toolbox (see Figure 11), where the pixels with a value of 8 refer to the optimal sites to establish new basic schools and those with values less than 8 changed to no data.

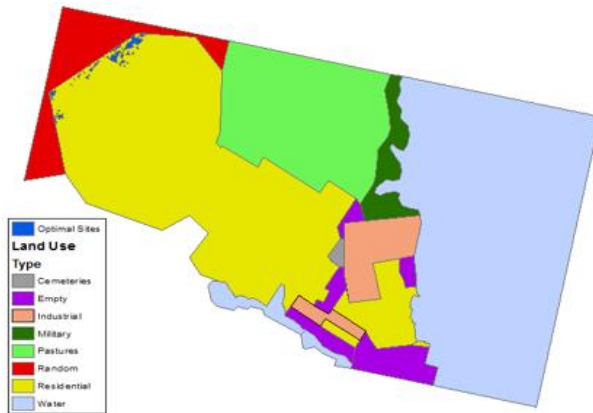


Figure 11: Optimal Sites (in Lapis Lazuli Color)

Fifthly: The best sites were chosen from among optimal sites (see Figure 12).

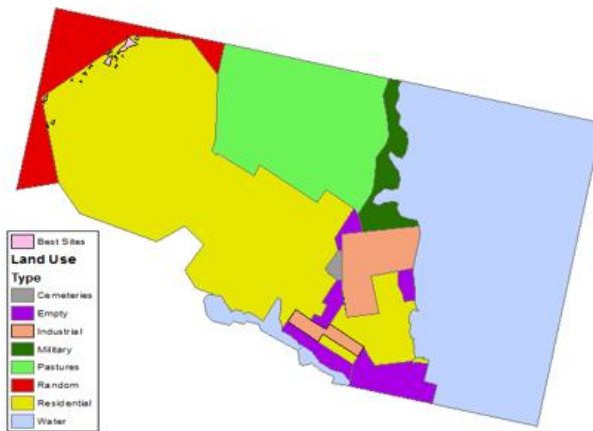


Figure 12: Best Sites (in Violet Color)

There are several single cells and they are very small for school sites, they were removed by the majority filter tool from the generalization toolset located in the spatial analyst tools toolbox.

Sixthly: The final best site was chosen, firstly, the best sites raster layer was converted into a shape file type from the raster to polygon tool in the raster toolset located in the conversion tools toolbox, after that the best sites shapefile layer was converted into feature class type using the feature class to feature class tool from the two-geodatabase toolset in the conversion tools toolbox.

The area criterion was applied to the best sites feature class layer, where, from the select layer by attribute tool in the layers and table views toolset in the data management tools toolbox, the area equal to or greater than 19,350 square meters were selected and one site was found to meet the criterion (see Figure 13), and thus it is the final best site for the establishment of a new basic school.

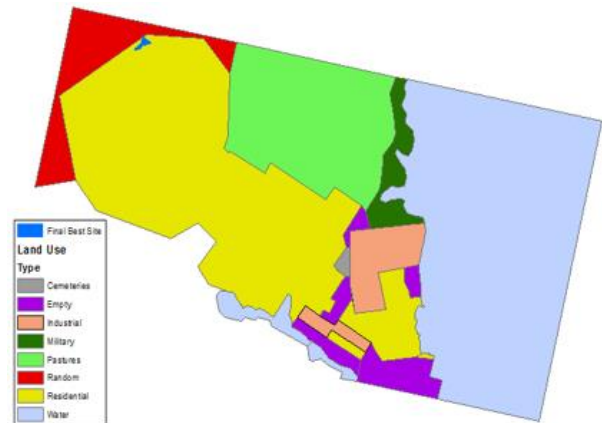


Figure 13: Final Best Site (in Cretan Blue Color)

Thus, was taken the maximum benefit from the capabilities of geographic information systems, as the previous methods used to obtain these sites were random and unstudied. Bearing in mind that the application of such criteria is somewhat costly, this does not negate the many benefits arising from it. And also takes into account that the program helps support decision-making only, as the beneficiary must take the appropriate decision himself based on the reality and nature of the region.

CONCLUSION

All layers related to the study were obtained and created, all the criteria were applied to them, and all produced layers were reclassified and weighted, and combined. Thus, the layer that clarifies the

suitable sites for the establishment of new basic schools on it is acquired. Suitable sites were chosen the optimal sites were. From it were obtained the best sites. From which the final best site for establishing a new basic school is obtained based on the criterion of the school area.

REFERENCES

- [1] Baser, Volkan, (2020) "Effectiveness of School Site Decisions on Land Use Policy in the Planning Process" *International Journal of Geo-Information*, Vol. 9, No. 662, PP. 1-16.
- [2] Hussaini, Alhaji, Amerudin, Shahabuddin, Tang, Kelvin Kang Wee and Musa, Sulaiman Ibrahim, (2018) "Integration of GIS and Multicriteria Evaluation for International School Site Selection" *The 39th Asian Conference on Remote Sensing*, PP. 39-48.
- [3] Namaziana, Zahra and Roghanian, Emad "A decision problem for bank branch site selection: A GIS Mapping perspective with Maximal Covering Location Problem: A case study of Isfahan" *Iran, K. N. Toosi University of Technology*, PP. 1-34.
- [4] Lagrab, Waleed and Aknin, Noura, (2017) "A suitability analysis of elementary schools-based geographic information system (GIS) a case study of Mukalla districts in Yemen" *Journal of Theoretical and Applied Information Technology*, Vol. 95, No. 4, PP. 731-742.
- [5] Ayele, Leykun Getaneh, Wondim, Yirga Kebede and Abebe, Abiyu Demessie, (2018) "GIS-Based Suitable Site Selection and Road-map Preparation for Equitable Distribution of Secondary Schools of Amhara Region, Ethiopia" *Journal of Environment and Earth Science*, Vol. 8, No. 1, PP. 100-113.
- [6] Zhou, Lina, and Jie Wu, (2012) "GIS-Based Multi-Criteria Analysis for Hospital Site Selection in Haidian District of Beijing" *China*, P. 1-50.
- [7] Nayroukh, Soundos, and Thawaba, Salem, (2016) "The Integration of GIS Into School Mapping A Case of Ramallah City" *Birzeit University, Palestine*, P. 1-29.
- [8] Schaller, Joerg, and Mattos, Cristina, (2010) "ArcGIS ModelBuilder Applications for Landscape Development Planning in the Region of Munich" *Bavaria*, PP. 42-52.
- [9] General Administration of Planning, (2016) "A Guide to Standards and Planning and Construction Terminology for Services (in Arabic)" *Ministry of Urban Planning - State of Khartoum, Sudan*, P. 1-39.
- [10] Mohieldeen, Sahar Ismael, Mohamed, Wafa Abdelrahman and M.Ibrahim, Ibrahim, (2021) "Spatial Planning and Evaluation of Schools Distribution in the Eastern Unit - Port Sudan Locality - Red Sea State using GIS" *American Journal of Engineering Research*, Vol. 10, No. 05, PP. 240-256.
- [11] Asker, Ahmad, (2015) "Spatial Analysis of Governmental Schools in Gaza City using Geographical Information Systems (in Arabic)" *Islamic University, Gaza, Palestine*, P. 1-139.
- [12] Breetzke, Gregory, Eksteen, Sanet, Pretorius, Erika, (2011) "Based GIS: A Practical Answer to the Implementation of GIS Education into Resource-Poor Schools in South Africa" *Journal of Geography*, Vol. 110, PP. 1–10.
- [13] Pandey, Dharendra, Shukla, Anil Kumar, Shukla, Abhinav, (2013) "GIS: Scope and Benefits" *International Conference on Advances in Engineering and Technology*, PP. 60-65.
- [14] Suh, Jangwon, Kim, Sung-Min, Yi, Huiuk, Choi, Yosoon, (2017) "An Overview of GIS-Based Modeling and Assessment of Mining Induced Hazards: Soil, Water, and Forest" *International Journal of Environmental Research and Public Health*, PP. 1-18.
- [15] Mohieldeen, Sahar Ismael, (2021) "A Geographical Database for the College of Technology in Sudan University of Science and Technology using (GIS)" *SUST Journal of Engineering and Computer Sciences*, Vol. 22, No. 1, PP. 56-67.
- [16] Abd Elrahman, Sahar I. M., (2021) "Capabilities of Geographic Information Systems in Creating Databases" *LAB LAMBERT Academic Publishing*, P. 1-121.