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Application of GIS and AHP Technologies to Support of Selecting a Suitable Site for Wastewater Sewage Plant in Al Kufa City

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ABSTRACT

Sewage water treatment before disposing of it in surface water is one of the most important steps in reducing pollution in these waters, which requires a high-capacity treatment plant for this purpose. Al Kufa city is one of the important cities in Iraq. The city faced a rapid growth of population. This situation creates big environmental complications and hazards. One of the biggest pollution issues in the city is the lack of modern and efficient Waste Water Treatment Plant (WWTP). The aim of this study is to find a suitable site for wastewater plant in Al Kufa city using remote sensing (RS) and Geographical Information System (GIS) modern technologies. There are eight parameters considered in the analysis consists of residential area, sewage areas, roads, a slope of the ground, surface water (river), green areas, historical, and land use. In addition to that, the analytic hierarchy process (AHP) was used to apply the weights for each criterion and sub-criterion, to get the best result and find the ideal site. At the first place, about thirty-eight sites have been identified as suitable sites for wastewater plant throughout the study area which represented through a red region color in a satellite image with its' coordinate table. The best location will be chosen according to the required land area on which the project is to be built from thirty-eight locations. However, a complementary field study is critical to manifest the obtained results T with specialized engineers to find the most effective site for WWTP between these sites.

1. Introduction

The sewage treatment problem is one of the primary issues in many urban communities worldwide and it deteriorated as of late in various districts. In Najaf _ Iraq, Shatt Al Kufa (Kufa River) is the major supply of water needed for drinking, irrigation, industry, and other applications. This river shows decreasing quantity and quality of water because of the rapid growth of industrial, agricultural and municipal activities [Khassaf, 2017]. This matter makes this river more susceptible to pollution easily. Therefore sewage water should dilute from its pollution before throwing it in this river, it through an efficient treatment plant. Al-Barrakiya station in Kufa is working on treating heavy water in all the joints of Najaf governorate, which generated very large pressure on that station, which is almost beyond its absorptive capacity figure (1), which necessitates to search for another treatment plant to relieve this pressure. Taking advantage of modern GIS and remote sensing techniques GIS/RS, this study proposes a technique for selecting an optimal site for sewage treatment plant depending on eight criteria. In the recent time, the RS/GIS data and geospatial analysis

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fundamentals have been applied to many water and wastewater engineering facilities, particularly in their planning, design, and monitoring before construction and maintenance after construction. The RS/GIS applications give a simple way of integrating and analyzing this environmental data for efficient and successful implementation of an environmental project [Usman, 2013]. Use of GIS programming as a decision-making tool permits for arranging of alternatives which meet the required multiple criteria fully. Analytic Hierarchy Process (AHP) is a one of Multi-Criteria Decision Making (MCDM) has been applied (for the criteria evaluations) to build an evaluation model and has criterion weights [Al Maliki, 2017]. In this paper, we merge the AHP with GIS approaches to support ideal site choice. Numerous environmental studies have shown widespread GIS /RS applications for solving this problem such as [Zaho, 2015] which shows how can choosing an ideal site for a sewage treatment plant in Guangyuan of China in a scientific way by using GIS technic. Another study was [Zaho, 2009] which proved Based on GIS technology, using eco-suitability evaluation method integrating economic, social and ecological factors to optimize the locations of the sewage treatment plants. And [Abdulla and El Khidir, 2017] imploded study which clear how can build a decision-making model for selecting the ideal site for a WWTP utilizing the remote sensing and GIS data and analysis coupled with the multi Criteria Analysis (MCA) for six criteria in Omdurman city Sudan.

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Figure 1. A sewage treatment plant in Al Kufa city [6]

2. Study Area

In this search (Al Kufa city) is the Study area, as the biggest city in the Najaf Governorate it is a city in Iraq, it lies about 170 kilometers south of Baghdad, and 10 kilometers northeast of Najaf. It is located on the banks of the Euphrates River. The estimated population in 2016 was (31.129.225), Geographical coordinates, it located in degrees minutes seconds (WGS84) Latitude(32◦02'05"), Longitude (44◦ 24' 12"). The total area is 438.317 km2, approximately. [www.http//alkufa,2018] figure (2, 3). The main hydrological features are the perennial Al Kufa river represents the main source of agriculture and drinking water.

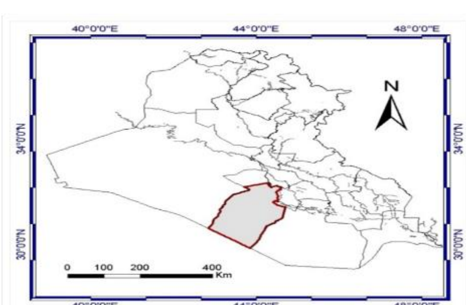


Figure 2. Located off the study area [5]

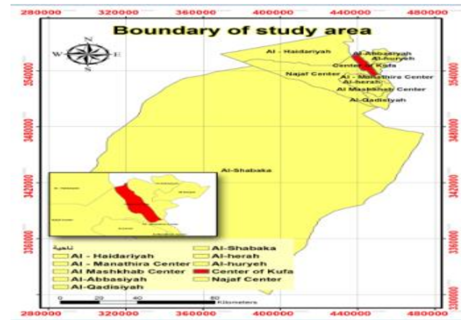


Figure 3. A boundary of the study area [5]

3. Materials and Methods

Different information sources have been used during this study, they can be classified into two main sorts as raster and vector information sources, the following data are employed in this study. Original Data, the obtained map data represent different aspects, of the residential area, sewage, roads, slope of the ground, surface water, green areas, historical, and land use maps. The methodology adopted in this study is principally supported using the geospatial analysis and Multi-Criteria Analysis (MCA) among the framework of GIS [Abdalla,207]. Depends on the importance of location in the arrange. Finally, the result was introduced by the MCA model.

Various factors have been thought of so as to find appropriate areas for wastewater treatment plant The factors described criteria and parameters of the selection of the optimum site. A number of 3 teams of criteria, including the environmental, geological and economic criteria and a total of eight parameters (as above), for selecting an acceptable place for construction of WWTP.

4. Criteria for Site Selection

Wastewater plant siting needs to consider many factors, and site selection refers to the process of selecting a suitable location for the facilities. The criteria according to the most world sources can be inserted as below:-

- Distance from residential areas.
- Proximity to main and regional roads.
- Proximity to agricultural land (green areas).
- Proximity to drainage network (sewage system).
- Distance from historical areas.
- Distance from the river.
- The location should be in a few slope areas.
- Some conditions for the station's location for land use.

5. GIS Criteria Description and Analysis

The procedure of Multi-Criteria Analysis "MCA" for site choice of Waste Water Treatment Plant (WWTP) involves AN integration and analysis of varied information. This kind of research was performed among the geospatial analysis of GIS framework besides the Analytical Hierarchy Processes (AHP).

6. Results and Discussions

Based on their importance, the main criteria are ones that have a right away influence on the chosen website. They consist of eight elements: the residential area, sewage system, roads, slope of the ground, surface water (Al Kufa River), green areas, historical, and land use. Each criterion was divided into two classes: appropriate and inappropriate. The results are shown in four stages as insert below :-

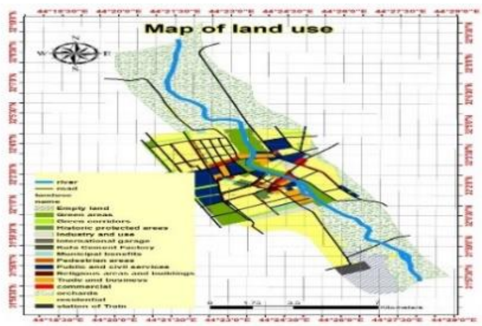


Figure 4. Land use map of the study area [4]

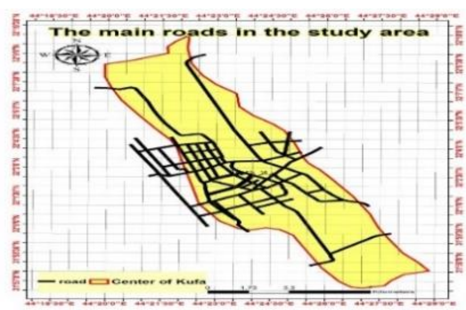


Figure 5. Main roads map of the study area [made by Researchers based on 4]

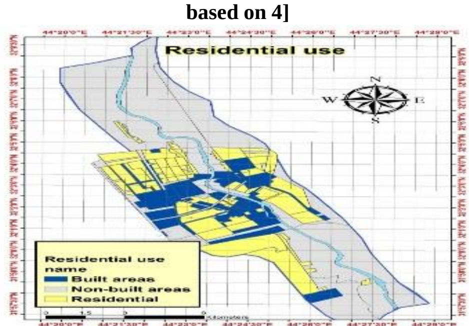


Figure 6. Residential map of the study area [made by researchers based on 4]

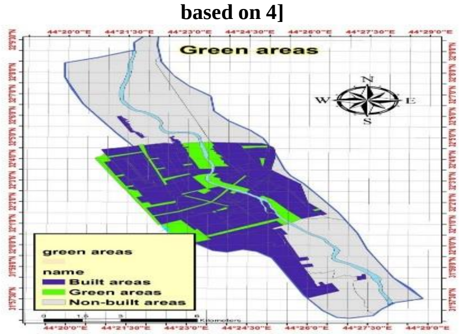


Figure 7. Green areas map of the study area[3]

6.1. First Stage (Input Data)

It contains the original maps related to the search as shown in figures (4-11).

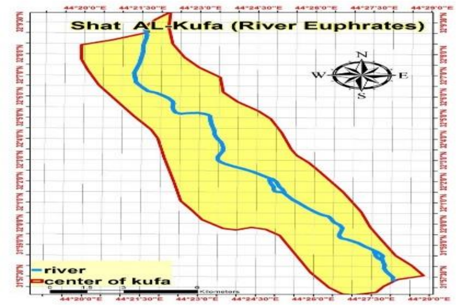


Figure 8. Kufa river map of the study area [made by researchers based on 7].

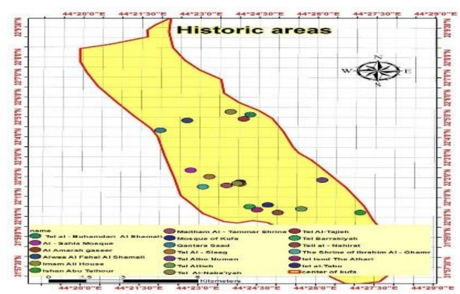


Figure 9. Historic map of the study area [7]

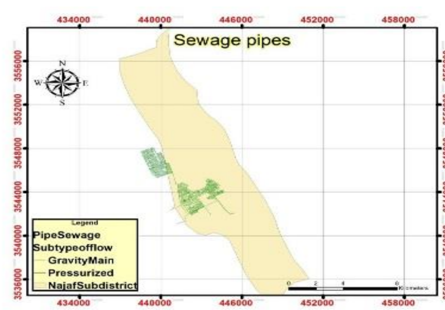


Figure 10. Sewage map of the study area[3]

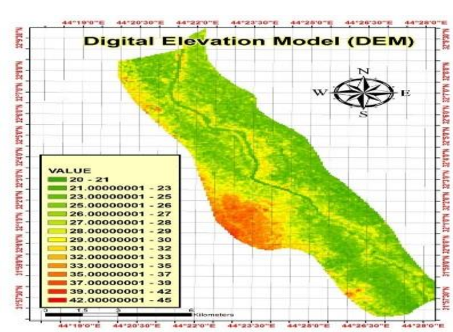


Figure 11. Slope of the ground map of the study area[7]

6.2. Second Stage (Derive Dataset)

It means to convert all features to raster for all layers as shown in figures (12-19). [all maps in this section made by researchers through GIS program].

Figure 12. Land use raster

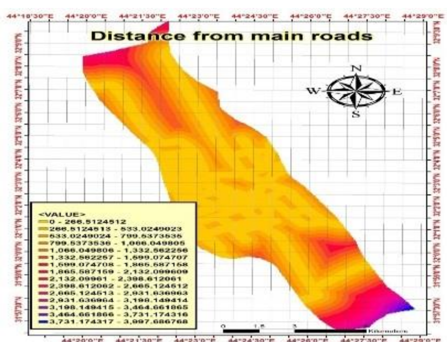


Figure 13. Main roads raster

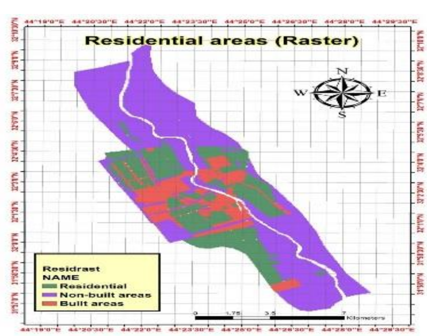


Figure 14. Residential areas raster

Figure 15. Green areas raster

6.3. Third Stage (Reclassify Datasets)

Reclassification of layers be within a common scale of 1-15, the higher values in the measure must be most appropriate. [all maps in this section made by researchers through GIS program].

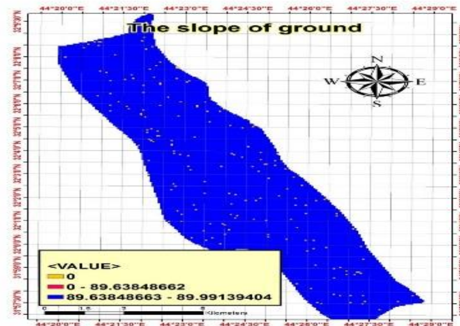


Figure 16. Slope areas raster

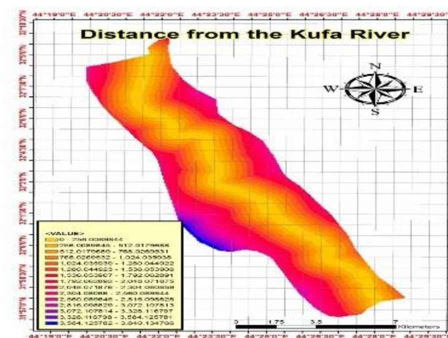


Figure 17. Kufa river raster

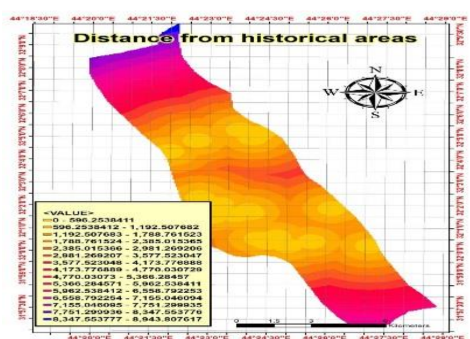


Figure 18. Historical areas raster

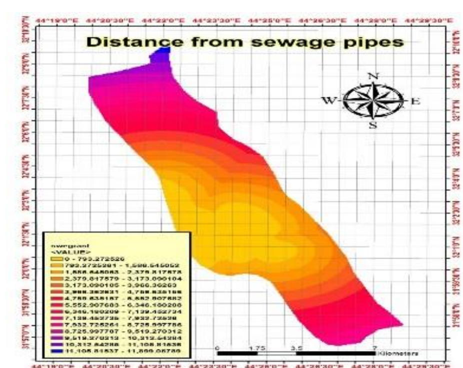


Figure 19. Sewage pipes raster

6.3.1. Reclassification Distance From Land

The land is used for various functions like agricultural, industrial, and residential. as these areas are the most vulnerable lands, they were marked as the unsuitable class. Whereas the industrial and commercial lands thought-about as less vulnerable land. Other area units as such as blank lands are considered appropriate as no activities on them. The land use map of the study area shows the varied sorts of land use Figure (20).

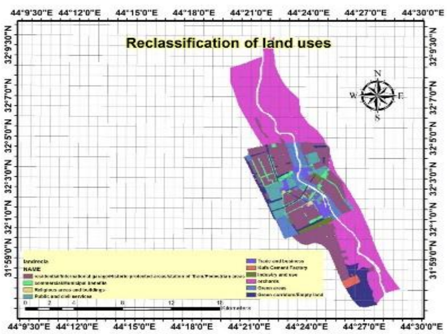


Figure 20. Land use reclassify map

6.3.2. Reclassification Distance From Main Roads

The location of the station should preferably be close to the main roads, so the areas near will take the highest scale of 15, which is the most appropriate, while the remote areas are the least appropriate number1 as shown in figure (21)

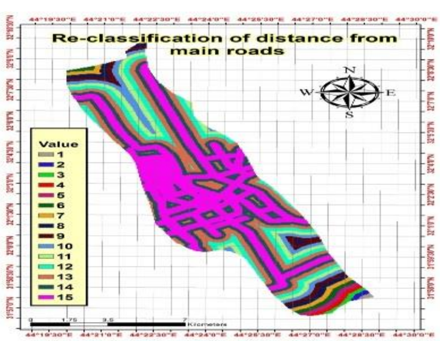


Figure 21. Main roads reclassify map

6.3.3. Reclassification Distance From the Residential

Due to inappropriate environmental conditions and creating unpleasant odors, wastewater treatment plant should be placed far from residential areas. Therefore, number 15 is given to the region that farthest to the residential, which are appropriate and the number 1 for the closest which are defined as, not appropriate as shown in figure (22)

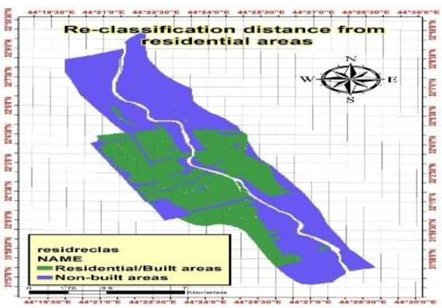


Figure 22. Residential reclassify map

6.3.4. Reclassification Distance From the Green Areas

Distance from the vegetation like a forest is necessary to safeguard the worth of the lands. The station should preferably be far from the green areas Therefore, number 15 is given to the region that farthest to the green areas, which are appropriate and the number 1 for the closest as shown in figure (23).

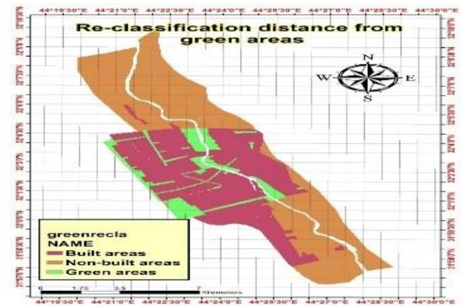


Figure 23. Green areas reclassify map

6.3.5. Reclassification Distance from the Surface Water Areas

Distance from the surface water is necessary to safeguard the water and fish from pollution because of the domestic use of the water in the city as drinking and farming water from the surface water. The Al Kufa River represent the making source of this surface water, The location of the station should preferably be away from the river so the areas farthest from the river will take the highest scale of 15, which is the most suitable while the nearby areas are the number 1 which is the least suitable as shown in figure (24)

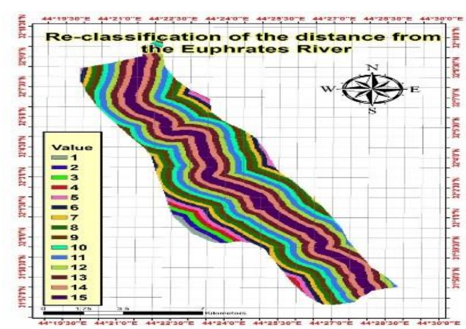


Figure 24. River reclassify map

6.3.6. Reclassification Distance from the Historical Areas

The station should preferably be far from the historical regions Therefore, number 15 is given to the region that farthest to the historical regions, which are appropriate and the number 1 for the closest which are defined as, not appropriate as shown in figure (25)

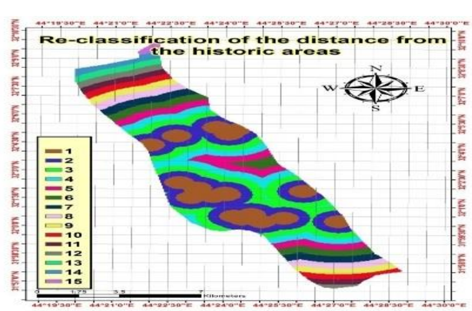


Figure 25. Historic roads reclassify map

6.3.7. Reclassification Distance from the Sewage Areas

The station should preferably be close to the sewage net, Therefore, number 15 is given to the region that closest to the sewage, which are appropriate and the number 1 for the farthest which are defined as, not appropriate as shown in figure (26).

6.3.8. Reclassification Distance from the Slope of the Ground

In site choice studies, the slope is a necessary element both environmentally and economically the station should preferably be on a low slope. Therefore, slope layer will be reclassified and the number 15 is given to the slopes with the lowest angles, which are appropriate and the number 1 for the lowest slopes which are, not appropriate as shown in figure (27).

6.3.9. Fourth Stage (Weight and Combine)

At this stage, the layers will be weighed according to the effect ratios of each layer in the project, and then the balanced classes will be summed with each other. The output of this process is the map of the fit (Map of relevance) as shown in figure (28). [Map made by researchers through GIS program and table 1].

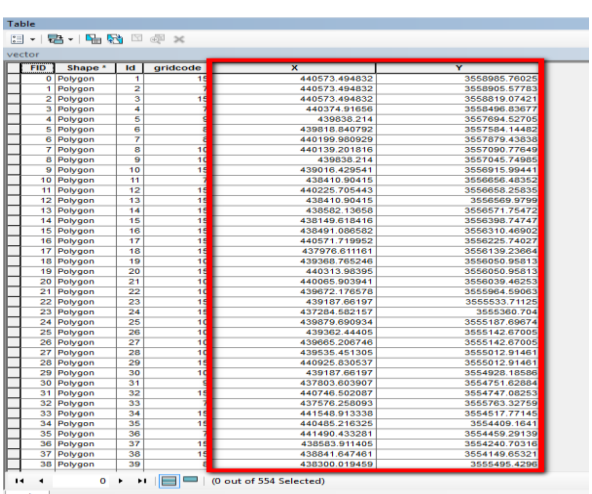
6.3.10. Fifth Stage (Project Drop on the Ground)

The boundaries of the appropriate areas with values 15 or close are converted to coordinates(Red Areas) by reclassifying the relevance map, and then transfer it to vector as shown in figure (29,30) and table (2) [maps and table made by researchers through GIS program].

Table 1. Weight and combine [researchers based on criteria influence].

Ratio%	Layers	No.
1	Sewage	23
2	Residential Areas	17
3	Euphrates River	15
4	Main Roads	11
5	Historic Regions	10
6	Green Regions	9
7	Land Uses	8
8	Slopes	7
	Sum	100

Table 2. Coordinate of relevance region as found in arc map(10.5)



Table

vector

FID	Shape *	Id	gridcode	X	Y
0	Polygon	1	15	440573.494832	3558985.76025
1	Polygon	2	7	440573.494832	3558905.57783
2	Polygon	3	15	440573.494832	3558819.07421
3	Polygon	4	7	440374.91656	3558496.83677
4	Polygon	5	9	439838.214	3557694.52705
5	Polygon	6	8	439818.840792	3557584.14482
6	Polygon	7	8	440199.980929	3557879.43838
7	Polygon	8	10	440139.201816	3557090.77649
8	Polygon	9	10	439838.214	3557045.74985
9	Polygon	10	15	439016.429541	3556915.99441
10	Polygon	11	7	438410.90415	3556656.48352
11	Polygon	12	15	440225.705443	3556658.25835
12	Polygon	13	15	438410.90415	3556569.9799
13	Polygon	14	15	438582.13658	3556571.75472
14	Polygon	15	15	438149.618416	3556398.74747
15	Polygon	16	15	438491.086582	3556310.46902
16	Polygon	17	15	440571.719952	3556225.74027
17	Polygon	18	15	437976.611161	3556139.23664
18	Polygon	19	10	439368.765246	3556050.95813
19	Polygon	20	15	440313.98395	3556050.95813
20	Polygon	21	10	440065.903941	3556039.46253
21	Polygon	22	10	439672.176578	3555964.59063
22	Polygon	23	15	439187.66197	3555533.71125
23	Polygon	24	15	437284.582157	3555360.704
24	Polygon	25	10	439879.690934	3555187.69674
25	Polygon	26	10	439362.44405	3555142.67005
26	Polygon	27	10	439665.206746	3555142.67005
27	Polygon	28	10	439535.451305	3555012.91461
28	Polygon	29	15	440925.830537	3555012.91461
29	Polygon	30	10	439187.66197	3554928.18586
30	Polygon	31	9	437803.603907	3554751.62884
31	Polygon	32	15	440746.502087	3554747.08253
32	Polygon	33	7	437576.258093	3555763.32759
33	Polygon	34	15	441548.913338	3554517.77145
34	Polygon	35	15	440485.216325	3554409.1641
35	Polygon	36	7	441490.433281	3554459.29139
36	Polygon	37	15	438583.911405	3554240.70316
37	Polygon	38	15	438841.647461	3554149.65321
38	Polygon	39	8	438300.019459	3555495.4296

(0 out of 554 Selected)

vector

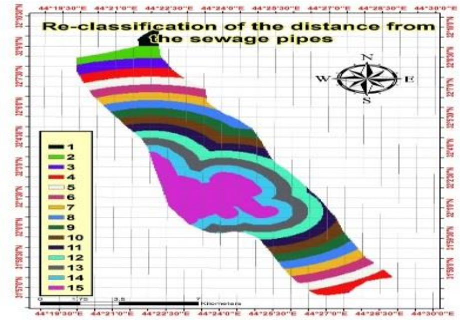


Figure 26. Sewage pipes reclassify map

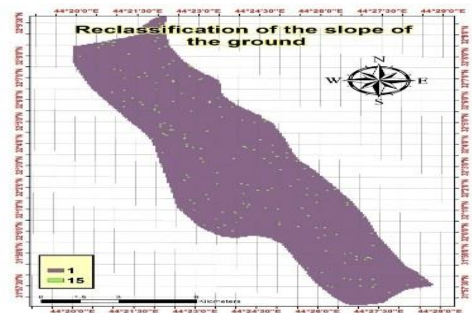


Figure 27. Slope of the ground reclassify map

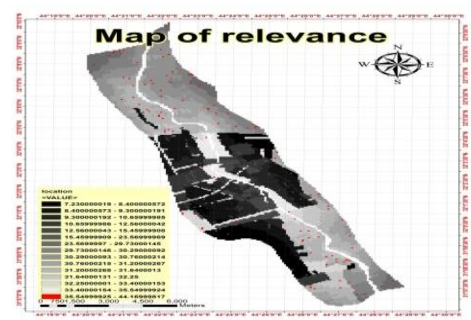


Figure 28. Relevance map

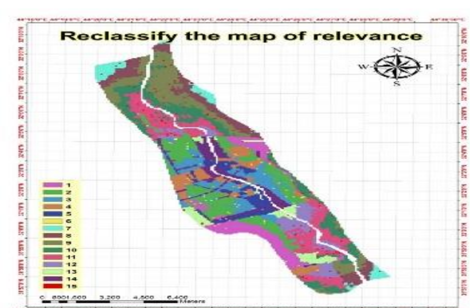


Figure 29. Relevance map reclassify

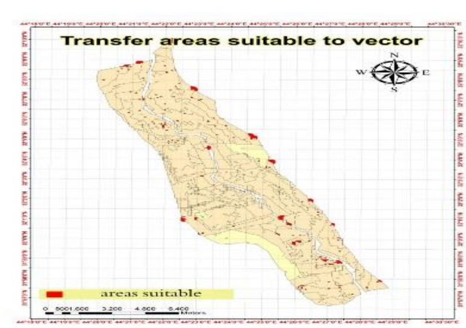


Figure 30. Relevance raster to vector map

7. Conclusions

ArcGIS geoprocessing is an important component of ArcGIS and includes many processes that can be used to extract information from presented data. The study mentioned the importance of modern technologies for using it to solve environmental problems the Waste Water Treatment Plant (WWTP) within the progress of environmental protection. The methodology adopted within the study combined the techniques of the remote sensing and GIS to create the study easier and to urge valuable info regarding the study space. Moreover, It offers additional correct results compared to standard ways. Hence, GIS has verified to be a robust tool in managing special and non-spatial information in suitableness analysis.

Integration of GIS and AHP provides best call tool in choosing acceptable WWTP in the acceptable website. Eight criteria were selected, that is residential, sewage, roads, the slope of the ground, surface water, green areas, historical, and land use. A paired comparison matrix was ready for criteria. The weights were applied in linear summation equation to get a unified weight map containing due weights of all input variable. Finally, all weighted maps were reclassified to urge the most effective potential website location of WWTP.

The results disclosed that many of separated sites (as shown above with red color) will function sites for the WWTP. These sites wide are distributed within the north, south and west Al Kufa localities. The best location will be chosen according to the required land area on which the project is to be built from thirty-eight locations However, a complementary field study is critical to manifest the obtained results. during this respect, it's extremely recommendations to conduct any field survey of the chosen areas with the presence of specialized engineers to find the most effective location for WWTP between these sites and with every zone. Moreover, such studies require the use of high- special resolution remotely perceived information and GIS Geodatabase layers to get a lot of elaborated and good results. The adopted methodology is often applied to get optimum sites choice in similar analysis covering studies.

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