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Research Article

Application of GIS Based Multi-criteria Analysis in Site Selection of Water Reservoirs (Case Study: Batu Pahat, Malaysia)

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Abstract: Malaysia is well endowed with abundance of natural water resources, which has significantly contributed to the socio-economic development of the country. However, the situation has somewhat changed over the last decade. The aim of this study is to apply GIS in identifying the most suitable location for water reservoir for area of Batu Pahat, Johor in Malaysia. The main criteria selected for this study are pipe line, elevation, rive, Land use, road network, water supply network and slope. Methodology is designed in such a way to achieve the objectives of this study as to identify the important criteria for locating water reservoir, to model the location of reservoir using Analytical Hierarchy Process (AHP) and Weighted Overlay (WO) methods. Based on the criteria chosen, the data are processed and analyzed the existing 52 reservoir locations and their capacities. Based on the projected number of population for the year 2050, as a result, 5 new reservoir locations have been identified to fulfill the future demands of water for the study area. Thus, it can be concluded that the weights derived from AHP integrated in Arc GIS can be a useful tool in GIS analysis for the determination of suitable locations for water reservoir in the study area.

Keywords: AHP, GIS, Malaysia, sitting, water reservoir

INTRODUCTION

The rising tendency in urbanization and population has increased the water demand. This rising tendency in urbanization and population has raised the demand for new water reservoirs to meet the growing need of water (Shiklomanov, 1993). To ensure a reliable and safe supply for future generations, more and more reservoirs will be required. The selection of suitable site for water reservoir is extremely difficult in recent years as the proper selection of suitable site considers many factors such as hydrological, geological and socio-economic parameters (Bartram and Ballance, 1996; Rahman, 2007).

A shocking statistics revealed that 70% of Malaysians utilize greater amount of water than it is necessary. At 226 L/person/day, Malaysians take undue advantage of the abundant rainfall and water. However, this alarming trend can result in a dangerous water crisis. The year 2013's wave of water shortages and water cuts have negative impacts on common citizens of Malaysia. Generally, irritations will develop among hundreds of thousands of people whenever their access to water is truncated (Ruslan, 2014).

Presently, Malaysians consume a grated quantity of water than their neighbouring countries. A survey conducted in 2011 revealed that an average Thai consumes 90 L of water/day, while Singaporeans consume 154 L/day with a focus to reducing it to 147 L/day by the year 2020. There is a reason for Malaysians to be awakening and understand that excessive use of water may result in water scarcity (Ruslan, 2014).

It is necessary to identify and quantify these factors for selecting a suitable area for water reservoir in a particular area. A Geographic Information System (GIS) can be used effectively for this purpose to combine different themes objectively and analyze those systematically for identifying suitable places (Shahid *et al*., 2000).

In the past many studies has been carried out for the selection of suitable sites by using GIS for example, site for subsurface dams (Chenini *et al*., 2010; Jamali *et al*., 2013; Krishnamurthy *et al*., 2000; Rahman *et al*., 2012), landfill site (Chang *et al*., 2008; Şener *et al*., 2006, 2010; Shahabi *et al*., 2014; Sumathi *et al*., 2008; Wang *et al*., 2009), hospital site selection (Kaiser *et al*., 2003; Kar and Hodgson, 2008; Soltani and Marandi, 2011; Vahidnia *et al*., 2009), geothermal site selection (Noorollahi, 2005; Noorollahi *et al*., 2007, 2008) and

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others. Also, some researches has been carried out for water resources planning and management and hydrologic modeling by using GIS modeling (Coskun *et al*., 2008; DeVantier and Feldman, 1993; Leipnik *et al*., 1993; McKinney and Cai, 2002).

In GIS modelling, weights are assigned to obtain the relative importance of one criterion over the other. Several numbers of weighting methods are available, which are mainly classified as subjective and objective methods. In subjective weighting methods, the weights are derived according to the knowledge and preferential judgment of decision makers. In this study two popular method i.e., AHP (Saaty, 1988) and weighted sum model will be used for deriving weights (Marler and Arora, 2010).

The main difference between previous studies and the present study is there has been no comprehensive study to date involving the application and assessment of GIS based multi-criteria analysis in the Malaysia for identify the suitable sites in water reservoir. The purpose of this paper is to assess and compare the results of site selection of water reservoir sites using two GIS based multi-criteria methods including AHP and weighted sum model in the Batu Pahat, Johor in Malaysia.

Study area: Batu Pahat is a town under Johor state of Malaysia. Geographically it is located between Longitudes 102°56′ and 102.933’E and Latitudes 1°51′N and 1.850°N. The town share borders with Pontian, Muar, Kluang to the southeast, west and east respectively and in the north Ledang and Segamat (Fig. 1). The area of Batu Pahat is 1,999 km^2 with a population of 406,000 and is the second populous district in Johor state. The population density is 203 person by km^2 (DOS, 2010). The urbanization rate is related to population growth. It is projected that urbanization will be 95% in 2050. The long term mean monthly rainfall at Batu Pahat station is 2057 mm and mean potential evaporation rate is 1324 mm. The water demand was 174.22 Million L/day (M/L/d) and it is projected to be 270.77 M/L/d in 2050 (DID, 2010).

This district is divided into (14) sub districts known as MUKIM. Depending of the Average Annual Population Growth Rate, initial population and (time) the period of years do expect by using formula population growth {P = Po ert} when (P) final Population, (Poe) initial Population, (r) Rate of Growth and (t) time (years passed) (Johnson and Lichter, 2008).

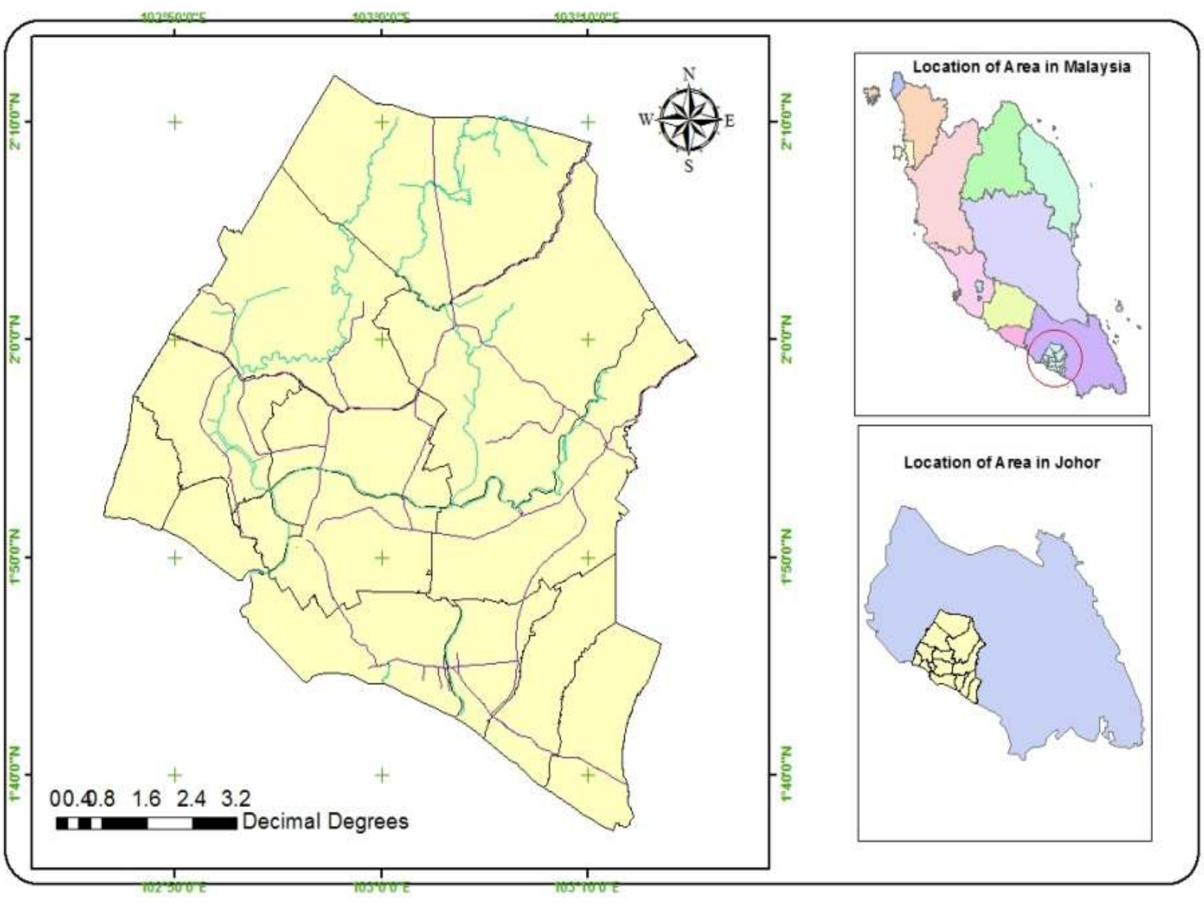

Fig. 1: Location map of the study area in the state and country

MATERIALS AND METHODS

In the present study most of the data used came from various sources using different types of coordinate systems and having different quality. Most of the time is spent on the data adjustments and transformation. Similarly, not all data are available for comprehensive analysis which is probably effects the result obtained in this study. Reservoir site investigations are often carried out by a team of specialists. However, it is impractical for such a team to survey all potential areas. Thus, for the reservoir site selection in the Batu Pahat district with help of Arc GIS and AutoCAD, the input datasets are in shapefile (shp) format. Therefore, the first step is converting the layers into Geo-database then making a new toolbox and environment setting.

In this study, datasets or criteria are derived as the followings:

- Distance from road network by road layer and near the road is suitable. (Euclidean distance)
- Distance from pipeline by the pipe layers and near the pipe is suitable
- Distance from land use by the land use layers and near the Residential is suitable
- Distance from river by the river layers and near the River is suitable

The slope layer is high slope is suitable.

The DEM (Elevation) layers are high elevation is suitable.

In order to find a new site for a reservoir in Batu Pahat region in Johor Malaysia, it should come up with a ranked suitability map as it shows a relative range of values specifying the suitability of each location on the map. This research solves the problem by the method of AHP but before starting with the first method the collected data (primary data and secondary data) should be processed and be ready for analysis.

Questionnaire was another tool that used this research for provided to collect the data. These questionnaires will be designed by "google. docs" and will be sent to people. The questionnaires will focus on comparative between the six criteria. Basically, the question will be based on the likert scale nine measurements of agreement and significance. This scale of measure is illustrated in 1-Equal Importance, 3-Moderate importance, 5-Strong importance, 7-Very strong importance, 9-Extreme importance (2, 4, 6, 8 values in-between) (David and Saaty, 2007).

For the creation of map distance, special analysis toll in ArcGIS. Which analysis tools have many types; Path Distance Back Link, Path Distance Allocation, Path Distance, Euclidean Distance, Euclidean Allocation, Cost Path, Cost Distance, Cost Back Link, Cost Allocation and Corridor. The Euclidean Distance was chosen as tools to explain the inter-connection of individual cell and its source or a set of sources using straight-line distance (Cerchiai *et al*., 2001).

The distances for each (River, Road network and Pipeline) are identified. These types of distance could be extremely useful for site selection of Reservoir. By using Arc Tool Box\Spatial Analysis Tools\ Distance\Euclidean Distance and input shape file. In this study, Natural Breaks classes are used depending on natural groupings present in the classifications of the layers. Class breaks are recognized that best distinguish related values and that increases the differences between classes.

Analytical Hierarchy Process (AHP) method: The multi criteria MCE technique integrated with AHP that relate Boolean logic and used the overlay the results in one final digital map (Gorsevski *et al*., 2012). Seven criteria namely, Road, Soil, River, Geology, Land use and slop were examined to establish spatial decision support system. The AHP that utilize a four down method to resolve a multi criteria decision making problem is proposed to be used. The decision problem was splited into a hierarchy (tree) of associated decision components. The input data was then obtained by pair wise comparisons of decision components (Saaty, 1988).

The "Eigen value" approach was utilized to obtain the relative weights of decision components. Then it was summed to obtain at a set of rankings for the decision alternatives. The pair wise assessment model was used to obtain the relative weights of the reservoir in the study (Cerchiai *et al*., 2001). All the factors (layers) should be standardized to common scale, as the fuzzy maps of all the layers form the last step are available, so the cell value of each raster has a scale of (0.0 to 1.0).

There are seven layers that those restrictions and our criteria have been implemented on them (Şener *et al*., 2010). Allocate a relative weight to individual criterion, depending on its significance in the node to which it assigned. The summation of all the criteria of a shared direct parent criterion in the equivalent hierarchical grade must be equal to 100% or 1. A universal priority is calculated that measures the relative significance of a criterion in the complete decision model. After initializing the problem, the following step is to obtain the relative weights of individual attributes of comparison. The AHP utilizes a pair-wise comparison method. It works with the highest-level attribute classifications. The next step is to compare the relative importance of each criterion as shown in Table 1.

For making pair-wise comparison matrix, there are six criteria:

$$N = 7 \rightarrow N\,(N-1)\,/2 = 21$$

As in table nigh number of comparisons follows the illustrated in Table 2.

So for weighting the criteria used the following judgment (comparison) and we have 30 Number of comparisons. Scale: 1-Equal Importance, 3-Moderate

Table 1: Point intensity of relative importance scale (Do and Kim, 2012)

Intensity of relative importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to objective
3	Moderate importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored, and its dominance is demonstrated in practice
9	Extreme importance	Evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When a compromise is needed
Reciprocals of the above nonzero numbers	Reciprocal for inverse comparison	

Table 2: Number of comparison (Do and Kim, 2012)

Number of things	1	2	3	4	5	6	7	n
Number of comparisons	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

importance, 5-Strong importance, 7-Very strong importance, 9- Extreme importance (2, 4, 6, 8 values in-between) and depending the result of these Questionnaires before done.

Weighted Overlay (WO) method: Weighted overlay technique utilizes the most implemented method for overlay analysis to resolve multi-criteria problems like site suitability and selection models (Store and Kangas, 2001). In a weighted overlay analysis, individual overlay analysis general stage is obeyed. As with all overlay analysis, in weighted overlay analysis, the problem is defined, broken into sub models and models and identified as the input layer (Ross, 1998).

However, the input essential strata are coded in contrasting number methods with separate ranges, to add them in a single analysis, individual cell for specific criterion are regrouped into a general preferential scale like 1 to 10, with 10 being the highest positive. An allocated grade on the general scale mean that the phenomenon's preference for the criterion. The preference values are on a relative scale. That means, a preference of 5 is half as favor as a preference of 5.

Weighted overlay tool lets you accomplish numerous stages in the common overlay analysis process using a single technique. The system combines the following stages:

- Reclassification of values in the input raster's to a general assessment scale of eligibility or preference, risk, or some uniform comparable scale.
- Multiplication of the cell values of individual input raster by the roasters' weight of significance.
- Addition of the resulting cell values combined to obtain the output raster.

Final step is using weighted overlay function in spatial analysis tool and create optimal site area and after that with condition function we select the area with high priority and after that filth consideration one limitation like distance from exciting reservoirs then can select the best site for reservoir. Also can use majority filter and finally convert to vector the best site. Figure 2 shows the using obtained weight in weighted overlay to get optimal site selection.

RESULTS AND DISCUSSION

Firstly, the population of Batu Pahat was expected for 50 years and it was found that Batu Pahat has 51 existing water reservoirs. Also, several maps were created to find the optimum site selection of the reservoir. Additionally, this study used Natural Breaks classes in the data and the criteria were reclassified as to make the result more accurate. Moreover, weights of criteria were used in Weighted Overlay tool (using Arc GIS 10.1) based on the feedback of the questionnaire. As a result, the optimal site was selected and the maps produced have been clarified by adding some layers and changing the colors for better presentation.

A system of water supply system collects, transmits, treats, stores and distributes water from its origin to the end users like irrigation facilities, industries, commercial establishments, public agencies and homes. This study focused on water demand for residential area of Batu Pahat, Johor in West Malaysia. The Batu Pahat has 51 existing water Reservoirs which the capacity of all reservoirs have 208,687 Million L (M/L) for example, as shown in Table 3.

Analysis of main criteria selected for this study: Researcher was used Natural Breaks classes are based on natural groupings inherent in the data. Class breaks are identified that best group similar values and that maximize the differences between classes. These criteria were reclassified to making the result more accurate. The euclidean distance output raster contains the measured distance from every cell to the nearest source.

The distances are measured as the crow flies (euclidean distance) in the projection units of the raster, such as feet or meters and are computed from cell center to cell center. This tool can be used when creating a suitability map, when data representing the distance from a certain object is needed. The distances

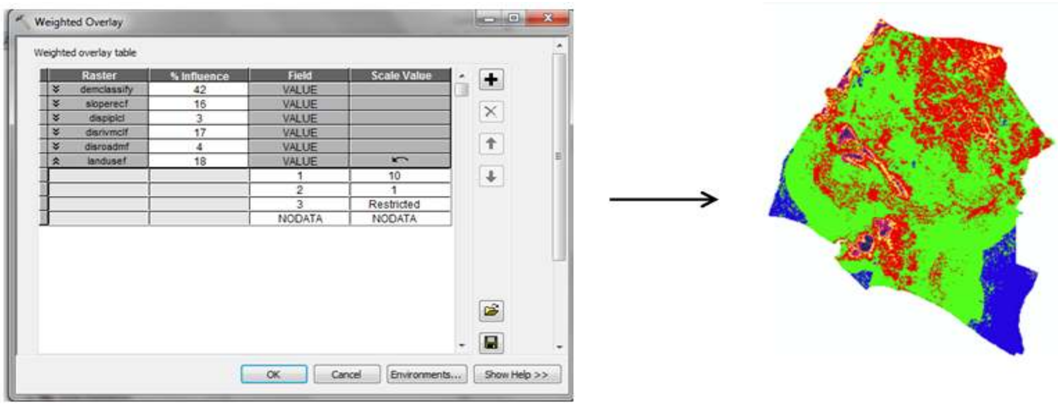

Fig. 2: Weight overlay for site selection (optimal site)

Table 3: Existing water reservoir in Batu Pahat (SAJ holdings Sdn Bhd)

No.	No. id	Nama tangki	Kapasiti (ML)
1	3001	Soga east A	11.365
2	3002	Soga east B	11.365
3	3003	Soga west C	11.365
4	3004	Soga west 2	11.365
5	3005	Bukit gariba	2.270
6	3006	Bukit belah 2	2.273
7	3007	Yong peng 1	4.546
8	3008	Rengit 2A	0.636
9	3009	Semerah	1.137
10	3010	Parit sulong	4.646
11	3011	Banaag jaya A	1.368
12	3012	Bukit banang 2	1.591
13	3013	Bukit banang 1	4.548
14	3014	Banang jaya	1.380
15	3015	Bukit batu	2.728
16	3016	Bukit belah 1	11.365
17	3017	Bukit tempayan	1.000
18	3018	Felda air hitam	0.273
19	3019	Ind. wawasan	2.728
20	3020	Industri sri gading	19.209
21	3021	Jln. johor air hitam	2.273
22	3022	Jalan maslid air hitam	0.919
23	3023	Kangar baru	1.137
24	3024	Parit raja 4	2.728
25	3025	Rengit 1	9.200
26	3026	Rengit 2B	1.133
27	3027	Senggarang	0.636
28	3028	Soga west 1	1.818
29	3029	Soga west 3	11.365
30	3030	Sri medan baru (2005)	2.273
31	3031	Taman kota	1.591
32	3032	Taman soga 2	1.818
33	3033	Taman soga 1	0.730
34	3034	Combine service strage	11.370
35	3035	Banang height 2	1.581
36	3036	Taman megah	1.250
37	3037	Tmn.bukit perdana	13.636
38	3038	Parit sulong 1	0.270
39	3039	Banang height 1	0.680
40	3040	Banang jaya B (fasa 2)	1.730
41	3041	Banang jaya (fasa 2)	1.360
42	3042	Sg. Ayam	4.546
43	3043	Parit kadir 1	4.546
44	3044	Parit kadir 2	1.600
45	3045	Bandarputera indah	5.900
46	3046	Parit yaani	1.360
47	3047	Evergreen height 1	1.581
48	3048	Evergreen height 2	5.685
49	3049	Yong peng 2	2.270
50	3050	Batu putih	2.270
51	3051	Parit raja 4A	2.273
		Total	208.687

Table 4: Comparative between criteria

Participant rating	Factors influencing poor	Scale 1	2	3	4	5	6	7	8	9	Scale	Remark
1	River better than pipeline	0	0	1	1	5	3	0	0	0	5.0	Strong important
2	Counter line better than pipeline	0	0	1	0	4	4	0	0	0	5.4	Strong important
3	Slope better than pipeline	0	0	0	2	3	3	0	1	0	5.2	Strong important
4	Land use better than pipeline	0	1	0	1	3	3	2	0	0	5.3	Strong important
5	Road network better than pipeline	0	0	1	3	3	3	0	0	0	4.8	Strong important
6	Counter line better than river	0	0	2	0	4	2	1	1	0	5.3	Strong important
7	Slope better than river	0	0	2	5	2	0	1	0	0	4.3	Strong important
8	River better than land use	0	0	3	3	2	2	0	0	0	4.3	Strong important
9	River better than road network	0	1	1	3	3	2	0	0	0	4.4	Strong important
10	Counter line better than slope	0	0	1	3	4	1	0	0	1	5.0	Strong important
11	Counter line better than land use	0	0	2	2	2	2	1	1	0	5.1	Strong important
12	Counter line better than road network	0	0	0	1	3	4	1	1	0	5.8	Strong important
13	Land use better than slope	0	0	1	3	5	1	0	0	0	4.6	Strong important
14	Slope better than road network	0	0	3	2	4	2	1	0	0	5.1	Strong important
15	Land use better than road network	1	0	0	1	4	3	0	1	0	5.1	Strong important

Table 5: The result of weight of criteria

ID	Category	Priority (%)	Ratio
1	Elevation	42	0.42
2	Land use	18	0.18
3	River	17	0.17
4	Slope	16	0.16
5	Road network	4	0.04
6	Pipe line	3	0.03

for each (River, Road network and Pipeline) are identified. These types of distance could be extremely useful for site selection of Reservoir.

Digital Elevation Model (DEM): Definitions of priority in reclassify function for high elevation and low elevation.

Slopes: Were classified due to its importance of selection of reservoir. In other words, slope area is economic and easy to supply water. The slope was classified for 10 classes from low to high priorities.

Rivers: Were reclassified in distance (near to far) from the other Rivers. Ten classes were created from low to high priorities.

Roads: Were reclassified in distance (near to far) from the other Roads. Ten classes were created from low to high priorities.

Pipelines: Were reclassified in distance (near to far) from the other Pipelines. Ten classes were created from low to high priorities.

Land use: Was extracted from SPOT 5 and land use map for Johor in 2010. It has three categories (Residential, Forest and others). In this study the residential area is the best place for site selection.

Selecting an optimum water reservoir site using AHP: The feedback of the questionnaire was based on the respondents. The respondents were asked to compare each criterion with others (with Likert Scale ranging from 1 to 9 in ascending order where:

1 : Equal importance
3 : Moderate importance
5 : Strongly importance
7 : Demonstrated importance
9 : Extreme importance
2, 4, 6, 8 : Intermediate value between two adjacent judgments

Questionnaire was designed online and the data were collected. The data has been analysed to get mean for each question. All these processes have been done to achieve scale for each comparative, as shown in Table 4.

Furthermore, the weights of criteria were written based on the feedback of questionnaires, as listed below:

Elevation is 5 times more important than River
Pipeline is 5 times more important than Elevation
Slope is 4 times more important than River
River is 4 times more important than Road Network
River 4 times more important than Land use
River is 5 times more important than Pipeline
Elevation is 5 times more important than Slope
Elevation is 6 times more important than Road Network
Elevation is 5 times more important than Land use
Elevation is 5 times more important than Pipeline
Slope is 5 times more important than Road Network
Land Use is 5 times more important than Slope
Slope is 5 times more important than Road Network
Land Use is 5 times more important than Road Network
Road Network is 5 times more important than Pipeline
Land Use is 5 times more important than Pipeline

Based on the matrix, the ratio of each factor has been ranked and shown in Table 5.

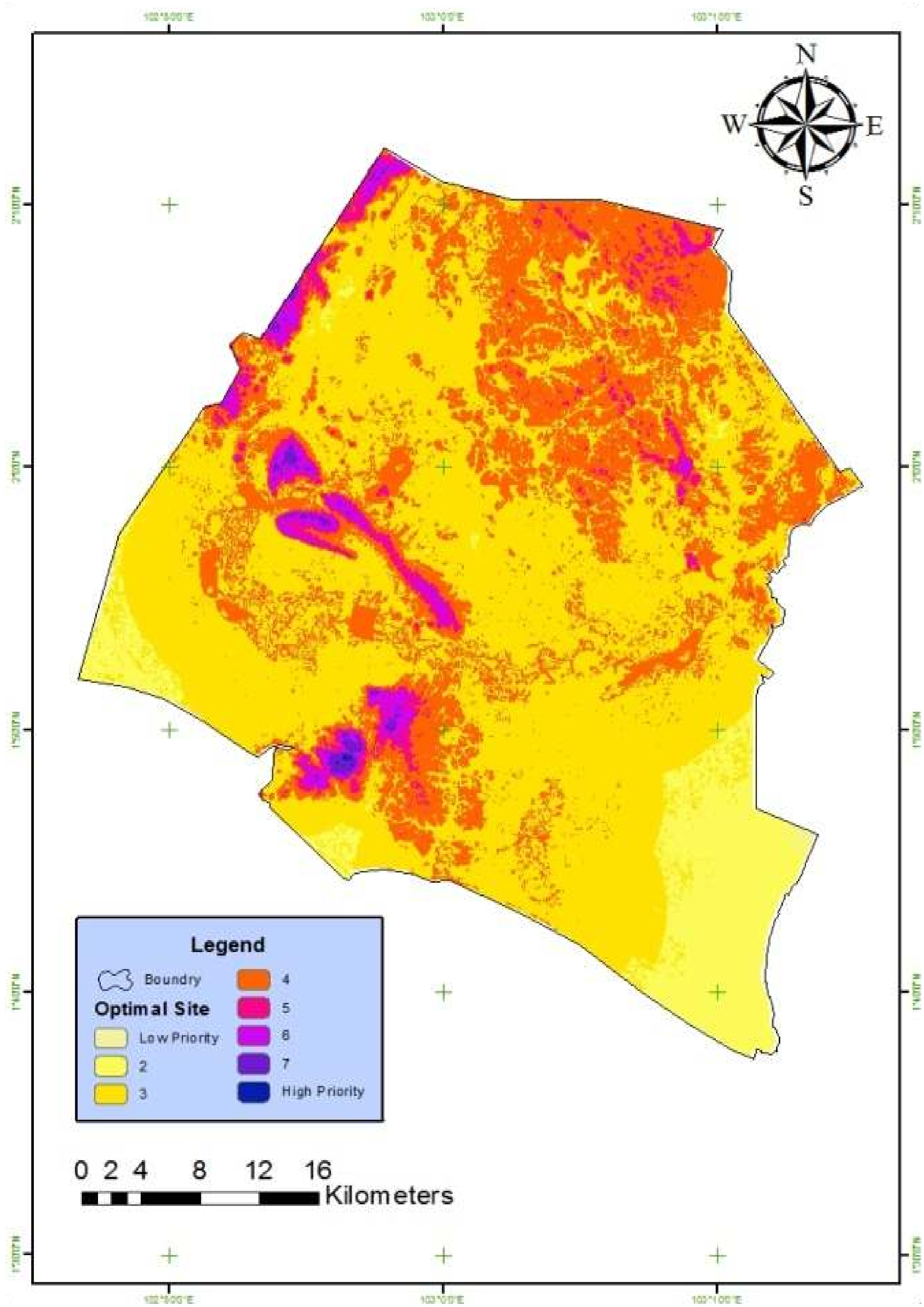

Fig. 3: The optimal site selection reservoir

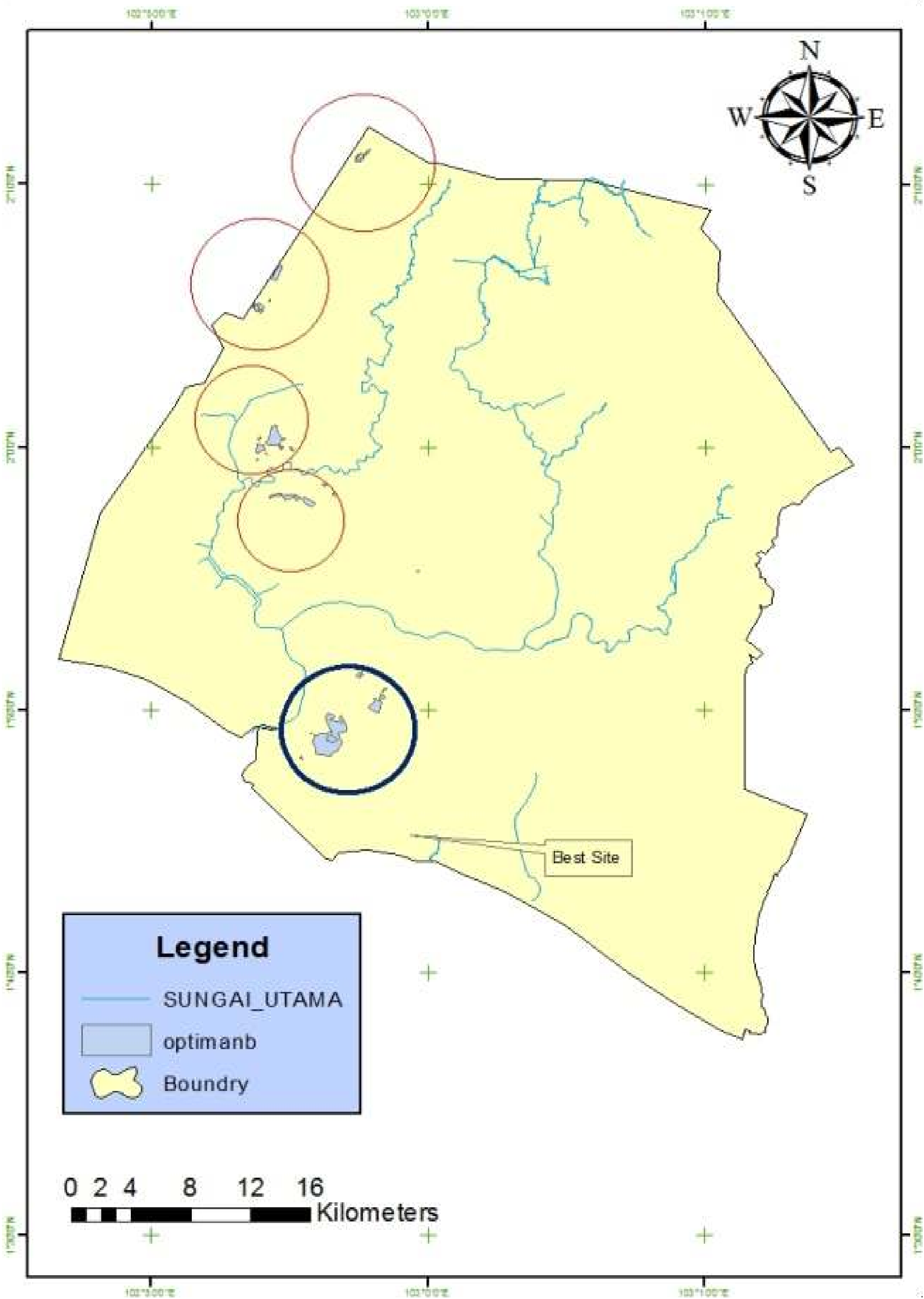

Fig. 4: Optimum sites for new reservoirs

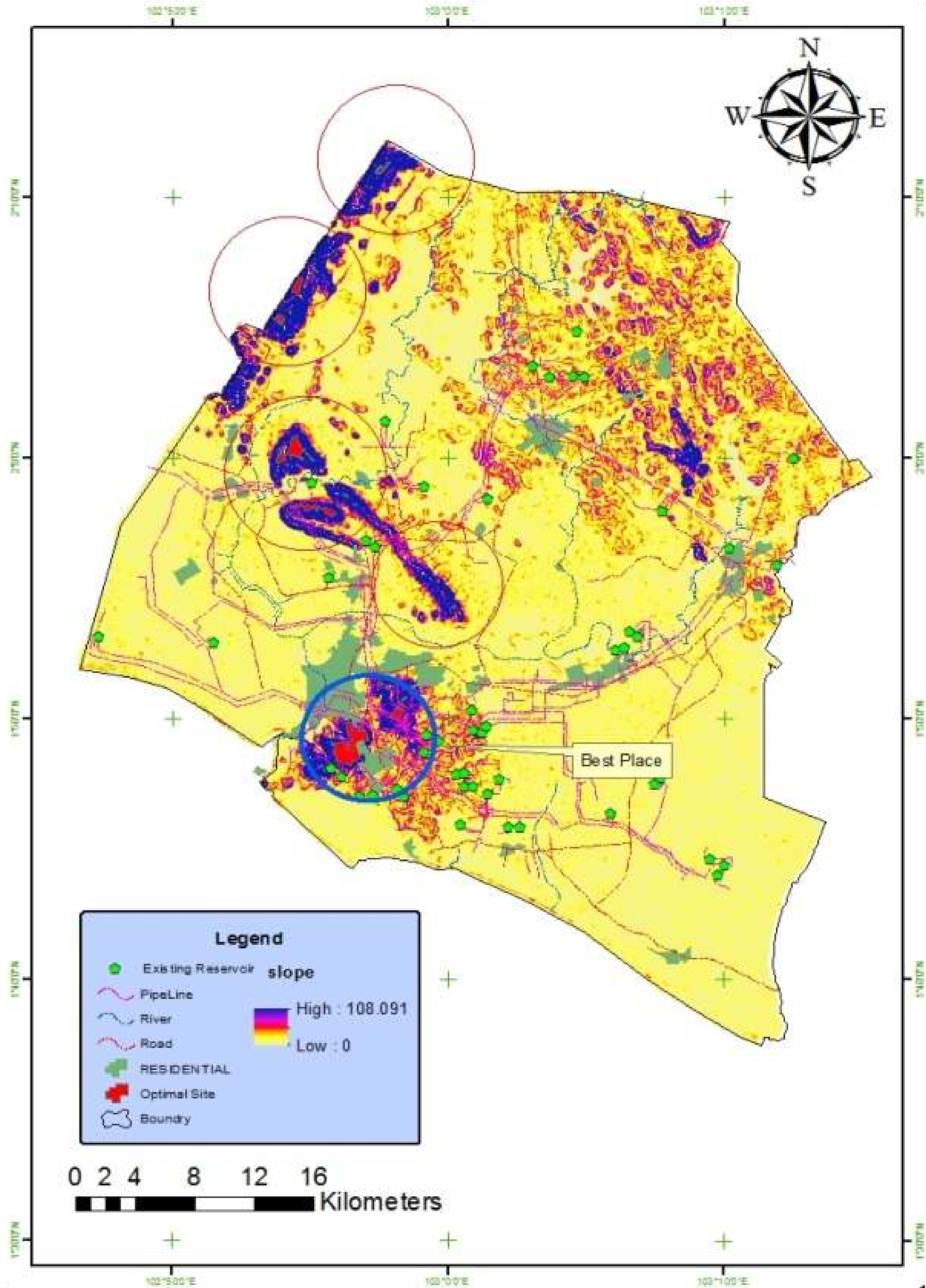

Fig. 5: Selection of suitable site for reservoir

Selecting an optimum water reservoir site using WO: Weighted overlay technique utilizes the most frequent method of overlay analysis to resolve multi-criteria problems like site suitability and selection models. The weights of criteria were inputted in ArcGIS 10.1 to get the optimal site (Fig. 3). The map was classified to eight parts from low priority to high priority by legend. The optimal site for reservoir is the blue one. In other words, the high priority is the best place to be selected for reservoir.

Moreover, the file was imported to the condition (Spatial Analyst) to indicate the highest priority of the selected areas for the optimal site for reservoir, Fig. 4.

After word, after getting optimal site, the maps have been clarified by adding some layers and changing the colors to get best site selection and help readers to have clearer picture the blue circle is the best site selection for reservoir because most of the criteria located in those area (Fig. 5).

CONCLUSION

Based on the results obtained in this study, five areas were selected as the optimal site for reservoir location. Among these sites, one site has been chosen as the best place for reservoir due to many criteria being applied for this particular area. In brief, the best area for reservoir is the site which it achieved after data being analyzed using AHP as a decision making tool. It can be concluded that the weights derived from AHP integrated in ArcGIS can be a useful tool for demarcating suitable places for water reservoir in any area. Furthermore, future water demand is one of the key issues in water supply planning. It is projected that the water demand will be 206 M/L/day by 2020. Therefore; the capacity of existing intakes or structures are unable to fulfill the requirement for future use. Thus, there is a need to construct new water reservoirs to fulfill the future water demand of the study area.

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