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Research Paper

Nuclear power plant locating by WLC & GIS (case study: Iran, hormozgan province)

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Abstract

Nuclear Power, in this current world, is one of the principle sources of energy world-wide. Electricity demand has to be met and nuclear power has the capacity needed for heat production in order to run the large turbines that generate electricity. Though this kind of power generation produces maximum power, it is a non-renewable source of energy and its effect on the environment is not predictable. Actual impact on the environment is very less, if the locating is carefully done. Also, nuclear power plant locating is an important action in environmental protection. Difference criteria should be paid attention in site selection, so using of special methods are necessary to assimilate the criteria. In this research, GIS software and Analytical Hierarchy Process were used. Weighted Linear Combination (WLC) is a relatively new MCDA which has presented more flexible and reliable results for site selection. In this paper, first of all, maps were built in considering to environmental factors, in next step, each layer, was graded. Low grade showed non-coordination or less coordination and high grade showed more coordination. Assimilate of graded map in WLC process, separates area into unsuitable, relative unsuitable, moderately suitable and suitable parts. Suitable parts can have high priority in decision making and also moderately suitable parts can have high priority for development projects in future. This paper reviews the application of WLC method in a GIS environment to select the optimum sites for nuclear power plants using case study in Hormozgan Province.

Keywords: *GIS; Nuclear Power Plant; Site Selection; WLC Method; Hormozgan Province.*

1. Introduction

Energy is essential for development. Nearly every aspect of development from reducing poverty and raising living standards to improving health care and industrial and agricultural productivity requires reliable access to modern energy sources. In this context, it is important to consider the global energy imbalance: today, 1.6 billion people are without access to electricity, and 2.4 billion rely on traditional biomass for cooking and heating because they have no access to modern fuels. Current forecasts suggest the world will see an increase in global energy consumption of over 50% by 2030, with 70% of this growth in demand expected to come from developing countries. Nuclear energy can play a role in providing increased access to affordable energy in many parts of the world [3]. Ran produced 240 billion kWh gross in 2011, giving per capita consumption of about 3200 kWh/yr. Its 2011 electricity production comprised 160 TWh from gas, 67 TWh from oil, both of which it has in abundance, 12 TWh from hydro which is less reliably available, and the first contribution from nuclear power. Demand is growing about 4% per year, and Iran trades electricity with Afghanistan, Armenia, Azerbaijan, Iraq, Pakistan, Syria, Turkmenistan and Turkey. Net export is about 7 TWh/yr. In mid-2013 generating capacity was 68 GWe. Th country plans to boost generating capacity to 122 GWe by 2022, with substantial export potential [13]. An important stage in the development of a nuclear power project is the selection of a suitable site to establish the site-related design inputs for Nuclear Power Plant (NPP). The selection of suitable site is the result of a process in which the costs are minimized. It is also to ensure adequate protection of site personnel, the public and the environment from the impacts of the construction and operation of NPP [4].

The main objective of the model developed in this case study is to identify the most feasible site that would comply with the IAEA standard requirements, as well as some additional factors set by the authors to differentiate between various sites. These factors are then combined using Weighted Overlay Techniques using the Analytical Hierarchy Process.

2. Materials and methods

2.1. Materials

Case Study Area

The study area is the Hormozgan Province which is located in the South of Iran. The area is 70,697.3 km2 in size and includes 23 cities and 2,046 villages. The Hormozgan Province hosts a total of 1,578,183 inhabitants [8]. The elevation increases from -55 to 3228 meters above sea level. Figure 1 shows the location of the study area in within the Hormozgan province and within Iran, respectively.

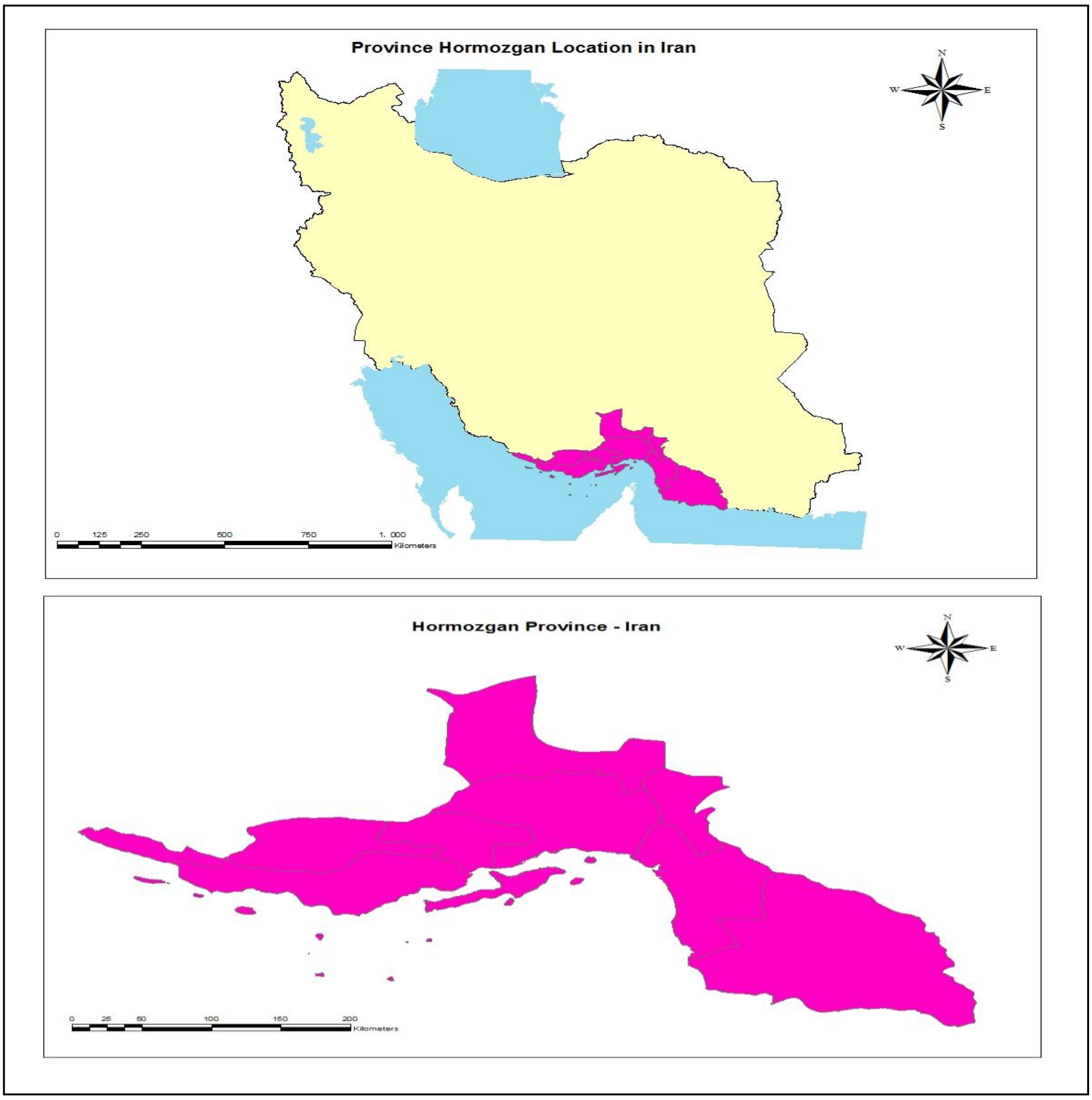

Fig. 1: Location of Case Study Area- Hormozgan Province Iran

2.2. Methods

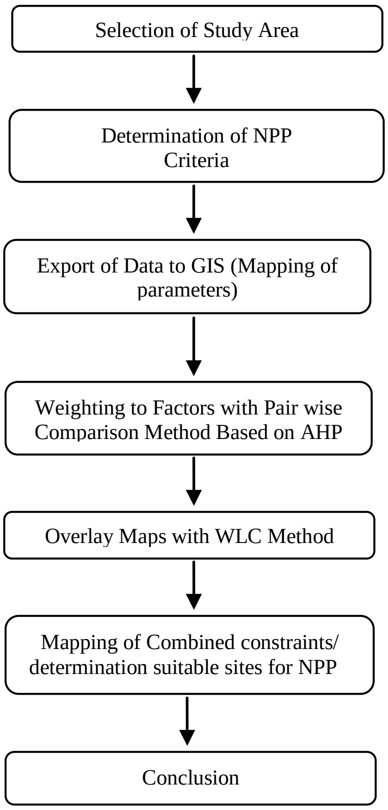

Fig. 2: Stages of Implementation of NPP Site Selection in Study Area

2.2.1. Weighted linear combination method (WLC)

The weighted linear combination (WLC) is one of the most widely used GIS-based decision rules [2, 3, 5, 10, 12]. The weighted linear combination method (WLC) is the most common technique for analyzing multi-scale evaluations. This technique also is called a ‘‘scoring method’’. This method is based on the content of the weight average. The analyzer or decision-maker is based on the ‘‘relative importance’’ weighted directly to the scales. By multiplying the relative weight by the feature value, a final measure can be obtained for each option (such as picture element in spatial analysis). After specifying the final value for each option, alternatives, which have higher values, will be the best option for the desired purpose [9]. Determining the proportion for a specific operation or evaluating the potential of a particular occurrence is considered to be a desired purpose. In this method, decision-making principles calculated the value of each Ai options using Eq. (1):

$$A\text{i} = \sum_{j=1}^{n} \text{Wj} \times \text{Xij}$$

In this equation, Wj is the j criterion weight; Xij is a value، which accepted i place in relation to j criterion. In other words, this value can indicate the appropriate degree of the i location in relation to j criterion; n is the total number of criteria and Ai is a value, which will attach to the i location. In this method, the total weight should be equal to 1; otherwise, in last stage Ai should be divided by the total of all weights, thus the Ai output will be between 0 and 1. Higher or lower amounts of output can be due to an appropriate or inappropriate option, weight normalizing can be omitted. In the end, the ideal option will be the one that has higher amount of Ai [9].

2.2.2. Weighted overlays

Weighted overlay techniques use a continuum of values that range from good to bad for each criterion represented by shades of colors on each grid. The generic form of the weighted overlay technique uses Equation 1 to extract the value of each cell in the resulting grid.

$$\text{Suitability} = \sum_{i=1}^{n} W_i V_i * \prod c_j \quad \text{Equation 1}$$

Where Suitability = combine suitability score for certain cell;
V_i = criterion score for factor i; and

W_i = weight of factor i
Π = Product
Cj = Criterion score of constraint j
The analyst can apply preferential weights to different criteria in order to emphasis the importance of certain criteria versus other criteria. The weights are then multiplied by the values each cell scores in each criterion. The sum of scores for each cell determines if the cell has scored above or below certain threshold that determines whether or not it belongs to the suitable areas. There are many technical points to be discussed in this model configuration; 1- determining the weights of criteria, 2- comparing different criteria, 3- overlay function [1].

2.2.3. AHP

The analytic hierarchy process (AHP) was presented by Saaty. It is based on three principles: refraction, comparative judgment, and the synthesis of priorities. The principle of refraction is needed to place decision-making problems into hierarchical forms. Each element in the resulting hierarchical structures is placed in special levels by considering their origin in higher levels. The synthesis principle represented the priorities for each site using a determined proportion scale for the different levels in a hierarchy and creates a compound set of priorities for elements at the lower levels of a hierarchy (i.e., options).
The defining principle consists of following stages [11]:

1) Produce a binary comparative matrix:
a) This method creates a basic scale with values from 1 to 9 to determine the extent of the relative priorities of two criteria (Table 1).

Table 1: AHP Pair Wise Comparison Scale for 9 Importance

Definition	Extent of importance
Equal importance	1
Equal to average importance	2
Average importance	3
Average to strong importance	4
Strong importance	5
Strong to very strong importance	6
Very strong importance	7
Very strong or super strong importance	8
Super strong importance	9

2) Measuring criterion weight: this stage includes the following steps: (a) Sum of the values for each column in the binary comparative matrix. Divide each matrix component by the total of its column. The resulting matrix is called a ‘‘Normalized binary comparative matrix’’.
b) Measure the mean of components in each row of the normalized binary comparative matrix.
3) Estimating agreement ratio.
4) This stage includes the following steps:
a) Determine the total weighted vector by multiplying the weight of the first scale in the first column of the main binary comparative matrix, then multiply the second scale in the second column, the third scale in the third column of the main matrix and finally, find the sum of these values.
b) Determine the agreement vector by dividing the weight vector by the scale weights which were previously specified.

3. Results

Data Gathering
The authors conducted a thorough search of available data for the case study area. Their efforts resulted in the construction of a Geo Database covering the area, and including most of the required data as per the IAEA site evaluation requirements. Table 2 shows the criteria gathered for the sake of implementing the models.

Table 2: Criteria Gathered For the Case Study

Type	Criteria
Constraints	Existing Agriculture
	Existing Urban
Factors	Geology
	Land Evaluation
	Accessibility - Roads
	Distance to Landslide

	Distance to Agriculture
	Distance to Aquifers
	Distance to Sea Water
	Distance to Shorline
	Distance to Fault
	Distance to Environmetal protected area

4. Weighted overlay operation on maps

Figure 7 illustrates all of the criteria used in the model. This unification is intended to be able to measure effect of each criterion in the same way.

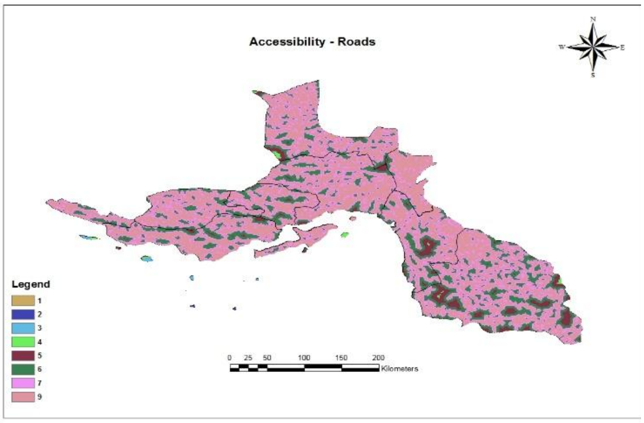

Fig. 2: Accessibility Roads

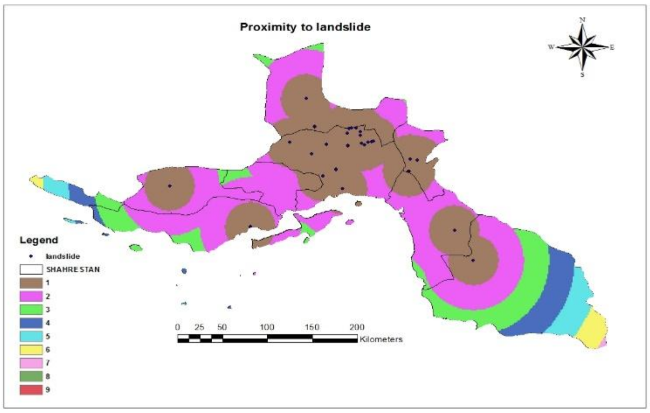

Fig. 3: Proximity to Landslide

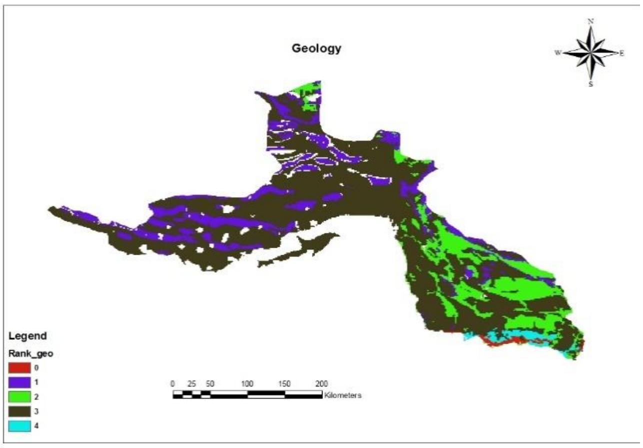

Fig. 4: Geology

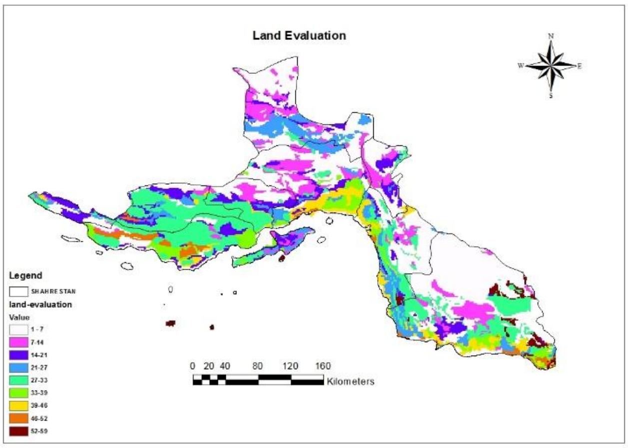

Fig. 5: Land evaluation

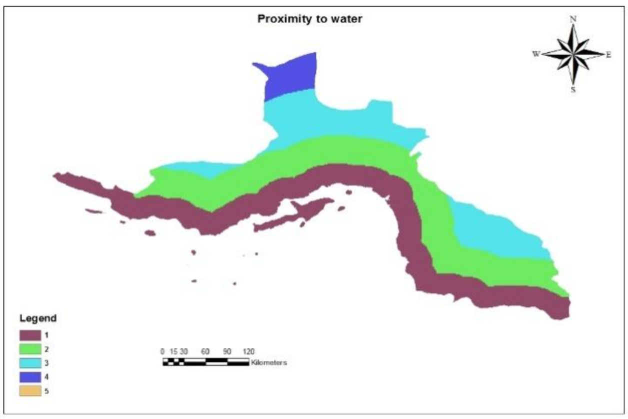

Fig. 6: Proximity to Sea water

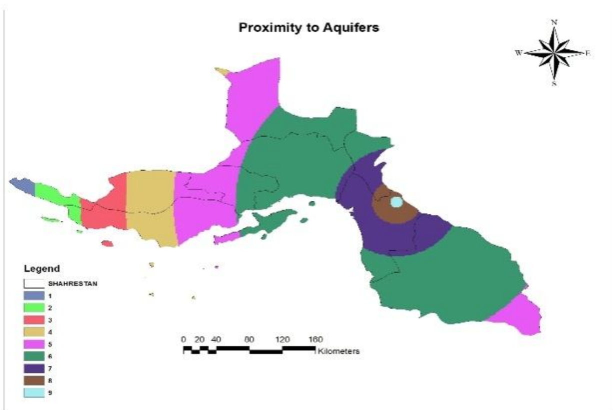

Fig. 7: Proximity to Aquifers

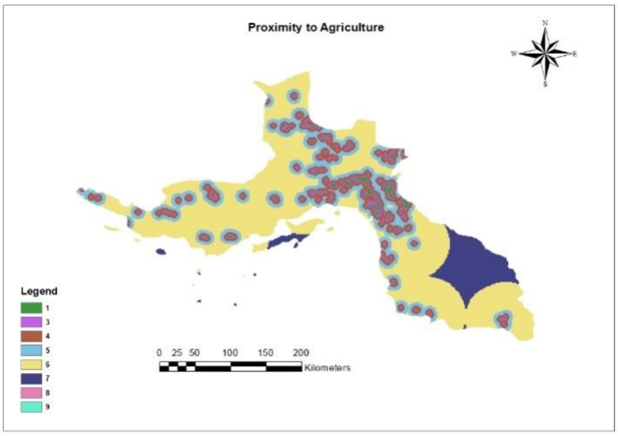

Fig. 8: Proximity to Agriculture

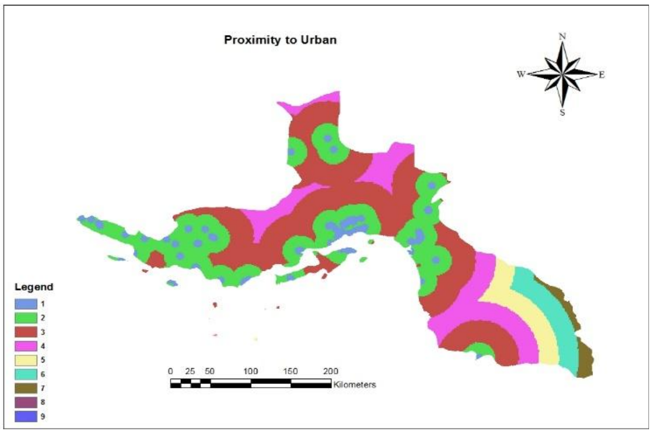

Fig. 9: Proximity to Urban

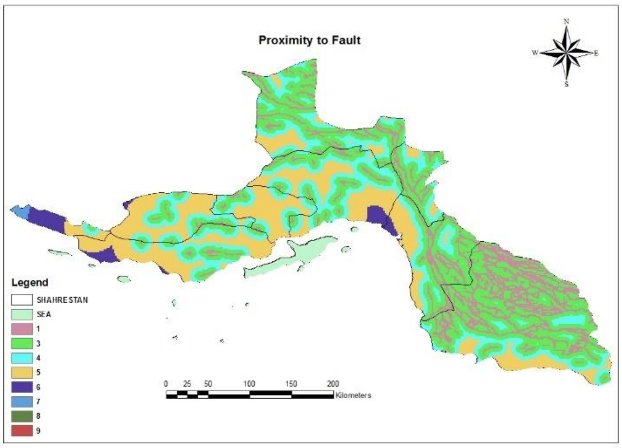

Fig. 10: Proximity to Fault

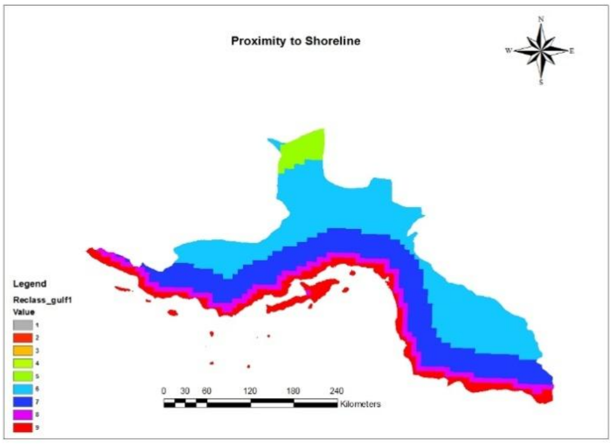

Fig. 11: Proximity to Shoreline

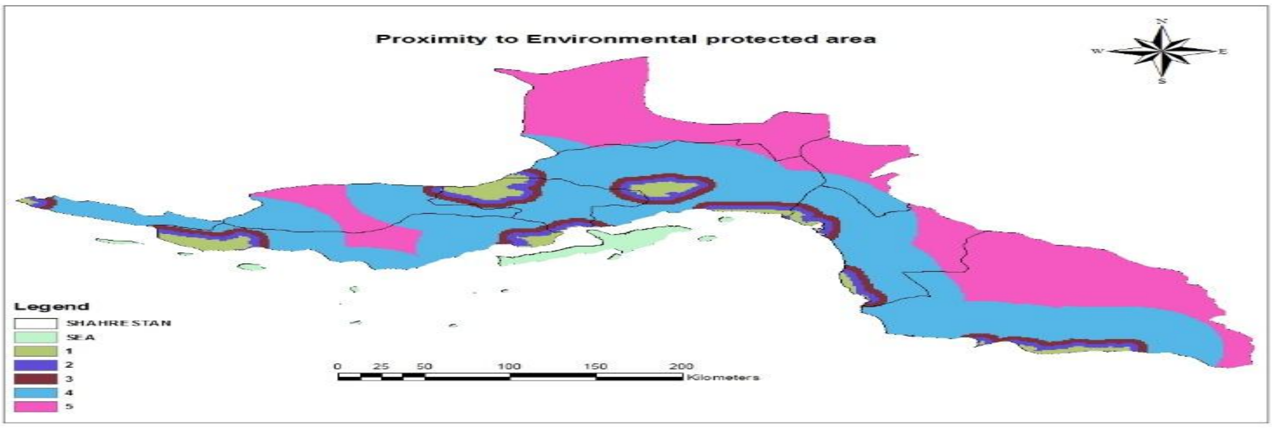

Fig. 12: Proximity to Environmental protected area

As mentioned, the factor weights obtained using AHP process were then ported, In the Weighted Overlay tool in ArcMap Toolbox as shown in Figure 13.

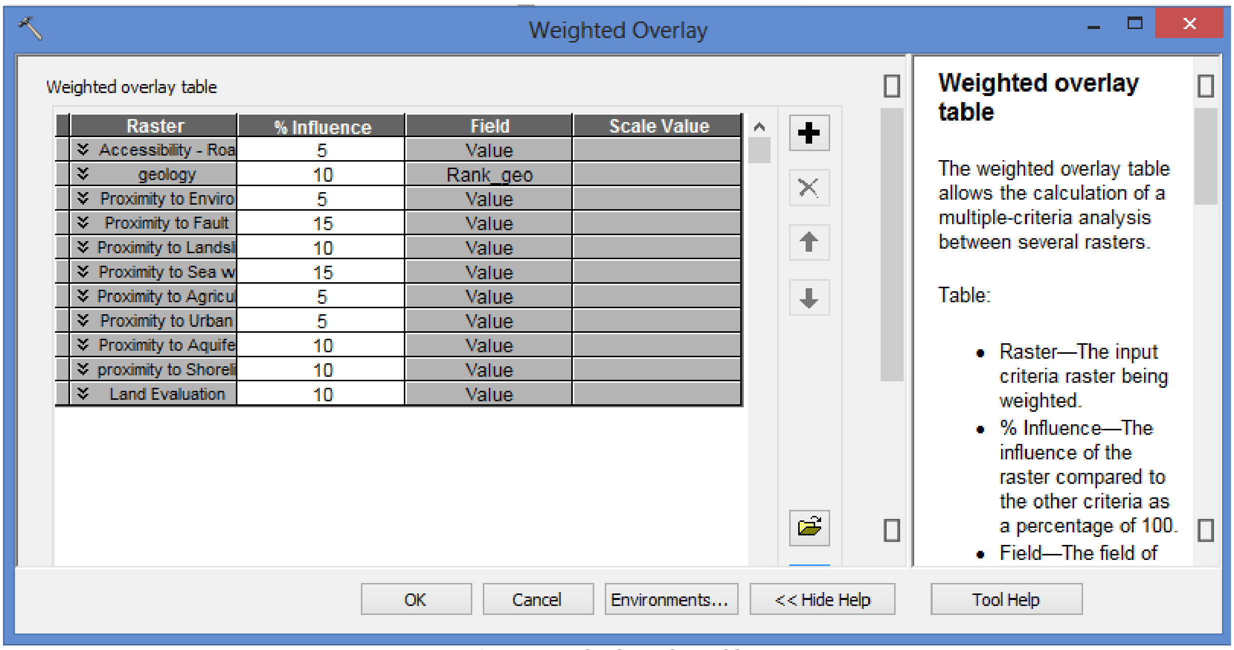

Fig. 13: Weighted Overlay Table

In the present study, 11 criteria were considered in arriving at the suitable site for NPP siting in Hormozgan province. Finally, this map extracted.

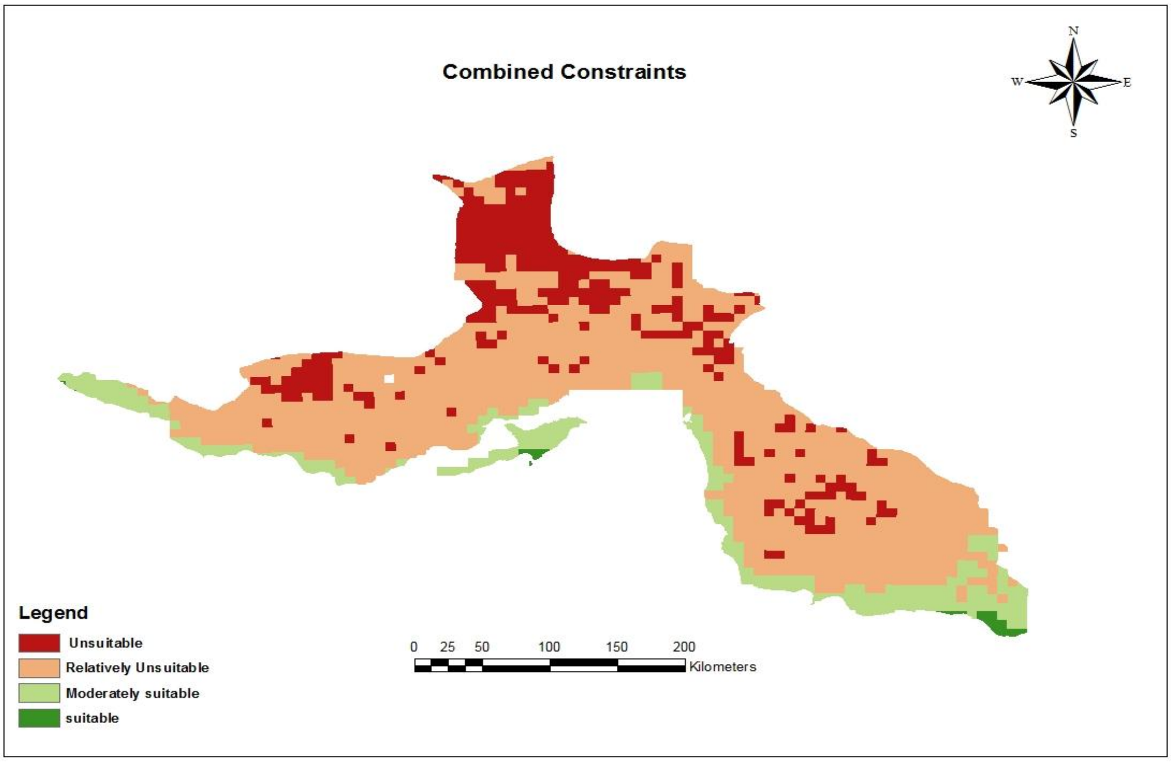

Fig. 14: Selected Sites by the Model for Siting NPP Using OWA Method

5. Conclusions

Iran country is needed to about 7000 MW of electricity per year. If Hormozgan nuclear power plant Commissioning, it will supply 1000 Mw of electricity and other power plants to meet these requirements is essential. Approximately 190 million barrels of oil is consumed for generating electricity. If supply of electricity through nuclear energy will save 5$ billion annually. This paper discussed the need for Nuclear Power Plants, and in line with the Iran directive, examined the techniques and methods used in siting such a plant. The Weighted Linear Combination (WLC) method has a lot of flexibility especially when coupled with tools borrowed from decision sciences such the Analytical Hierarchy Process, which helped in determining the weights of the criteria. The main hindrance to the accuracy of such mode in real life would be the quality of data. The authors spent extensive time collecting the data, it is hoped that this would not be the case in a real life situation. More research is needed to identify the most suitable way of locating nuclear power in the region, as this is the most important environmental problem to be tackled. Finally fuzzy logic and WLC method and comparing their outcomes are recommended for further research to locate a nuclear power plant.

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