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Integrated Analytical Hierarchy Process (AHP) and GIS for Land Use Suitability Analysis

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Abstract: Analysis of land-use suitability requires consideration of variety of criteria. Application of GIS alone could not overcome the issue of inconsistency in expert opinion when trying to judge and assign relative importance to each of many criteria considered in a suitability analysis. To address this issue, the Analytical Hierarchy Process method is used in combination with the GIS tool. The paper presents how the integrated tool has handled effectively a land use suitability analysis for towns around the Anzali lagoon. At first the influential factors were identified. Then the relationships between various factors were obtained by the expertise. Then with modulation and overlay the layers in ArcGIS 9.3, due to influencing factors and the evaluated weight in AHP, the suitable map for structural developing was prepared.

Key words: Suitability · Structural development · AHP · GIS

INTRODUCTION

Increasing population growth, lack of enough service centers and disorder of service distribution and suitable locations are some of major problems of today cities [1].

Land-use suitability is the ability of a given type of land to support a defined use. The process of land suitability Analysis involved evaluation and grouping of specific areas of land in terms of their suitability for a defined use. The principles of sustainable development make land-use suitability analysis become increasingly complex due to consideration of different requirements/criteria. It includes consideration not only inherent capacity of a land unit to support a specific land use for a long period of time without deterioration, but also the socio-economic and environmental costs [2].

One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis [3-6]. Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity. Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity [4, 5].

GIS is a system for creating, managing and analyzing graphic and attribute data and it can be used as a decision support system (DSS) by managers, planner and decisions maker. One of the most useful applications of GIS for planning and management is the land use suitability mapping and analysis [1].

Analysis of land-use suitability requires consideration of variety of criteria. While GIS has been a powerful tool to handle spatial data in land-use analysis, application of this tool alone could not overcome the issue of inconsistency in expert opinion when trying to judge and assign relative importance to each of many criteria considered in a suitability analysis. To address this issue, the Analytical Hierarchy Process method is used in combination with the GIS tool [2].

The integration of MCDM techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis [7, 8, 9, 10]. GIS-based MCDA can be thought of as a process that combines and transforms spatial data (input) into a resultant decision (output) [7].

Suitability analysis in a GIS context is a geographic or GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of GIS suitability analysis is that each aspect of the landscape has intrinsic characteristics that are in some degree either suitable or unsuitable for the activities being

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planned [11]. The results are often displayed on a map that is used to highlight areas from high to low suitability. A GIS suitability model typically answers the question, "Where is the best location?" [12].

This paper presents results obtained through integrating GIS and AHP in analyzing land-use suitability.

MATERIALS AND METHODS

Study Area: The study area is located in the South of Caspian Sea and has about 4168 kilometers in extent. It is included counties of Rasht, Anzali, Somesara, Masal, Shaft and Fooman. Location of longitude is between 48 degrees 45 minutes and 49 degrees 37 minutes and latitude is between 36 degrees 53 minutes and 37 degrees 34 minutes. The highest point on the mountain is 3105 meters height above sea level and the lowest point is - 25 m height.

Criteria Evaluation: According to studies conducted in Iran, especially by [13, 14, 15] the most important criteria used to determine the suitability of land for different uses in Iran, were recognized. The slope, elevation, cover, precipitation, fault, rock and soil of the area was chosen as the effective factors.

Classification and Standardization the Criteria: At this stage all the criteria of ecological models of Iran [14] were classified and according to experts and studies, per wised evaluation among factors and land use numerical value was assigned.

Weighting Criteria: There are different evaluation criteria to determine the suitability of the land; however, the importance of these criteria is different for different land uses. Therefore it is necessary to determine the importance of each of these criteria in the suitability of land for special use than at this stage to determine the weighting of the criteria analytical hierarchy process was used. AHP is a multi-criteria decision method that uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgment of the user [16]. The AHP procedure involves six essential steps [17]:

- Define the unstructured problem
- Developing the AHP hierarchy
- Pairwise comparison
- Estimate the relative weights
- Check the consistency
- Obtain the overall rating

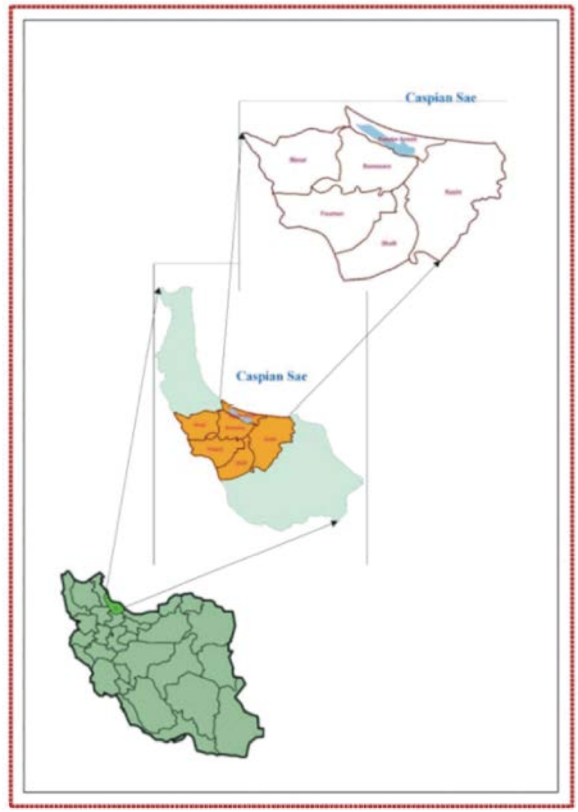

Fig. 1: Study area location

Obtain the Overall Rating: In last step the relative weights of decision elements are aggregated to obtain an overall rating for the alternatives as follows:

$$W_i^s = \sum_{j=1}^{j=m} w_{ij}^s w_j^a, \quad i=1,\dots, n \tag{1}$$

W_i^s = Total weight of site i,
W_{ij}^s = Weight of alternative (site) i associated to attribute (map layer) j,
W_j^a = Weight of attribute j,
m = Number of attribute,
n = Number of site

Mapping the Standardized Measure of Weight: The standard map of the study area according to assigned weight ratio and classification was produced in ArcGIS 9.3.

To prepare these maps topographical maps 1:25000 of Iran surveyor's company and image of the DEM was used to make slope map, aspect and elevation classes.

Integrating the Final Composition, Determining Land Use and Prioritize According to Regional Conditions: At this stage, the final composition and zoning was done

Table 1: Scales for pair wise comparison [16]

Variables	Preferences expressed in linguistic variables
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent scale values

Table 2: Matrix weighting of criteria

	Slope	Elevation	Cover	Precipitation	Fault	Rock	Soil
Slope	1.00	3.00	3.00	3.00	2.00	3.00	5.00
Elevation	0.33	1.00	0.33	1.00	0.50	2.00	3.00
Cover	0.33	3.00	1.00	3.00	3.00	5.00	2.00
Precipitation	0.33	1.00	0.33	1.00	0.33	3.00	2.00
Fault	0.50	2.00	0.33	3.00	1.00	1.00	2.00
Rock	0.33	0.50	0.20	0.33	1.00	1.00	0.50
Soil	0.20	0.33	0.50	0.50	0.50	2.00	1.00
Sum	3.02	10.83	5.69	11.83	8.33	17	15.5

Table 3: Calculation of the coefficient matrix of priorities in each column

	Slope	Elevation	Cover	Precipitation	Fault	Rock	Soil	Sum
Slope	0.33	0.28	0.53	0.25	0.24	0.18	0.32	2.13
Elevation	0.11	0.09	0.06	0.08	.006	0.12	0.19	0.66
Cover	0.11	0.28	0.18	0.25	0.36	0.29	0.13	1.60
Precipitation	0.11	0.09	0.06	0.08	0.04	0.18	0.13	0.69
Fault	0.17	0.18	0.06	0.25	0.12	0.06	0.13	0.97
Rock	0.11	0.05	0.04	0.03	0.12	0.06	0.03	0.44
Soil	0.07	0.03	0.09	0.04	0.06	0.12	0.06	0.47

Table 4: Weight ratio of factors

The factor	Weight
Slope	0.3099
Elevation	0.0998
Cover	0.2303
Precipitation	0.0959
Fault	0.1369
Rock	0.0602
Soil	0.067

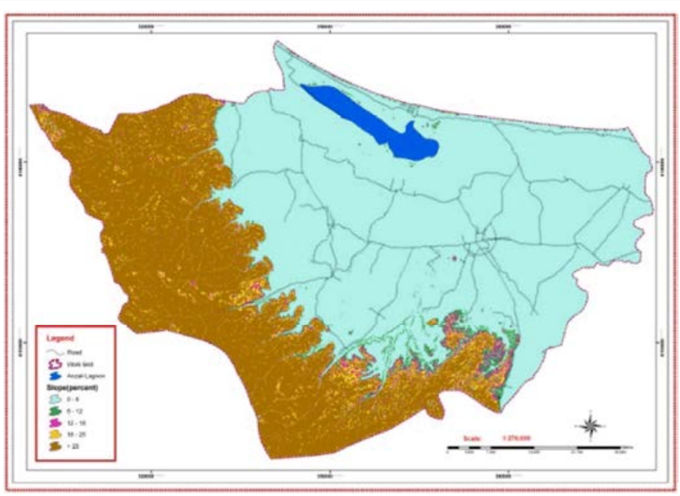

Fig. 2: Slope classes map

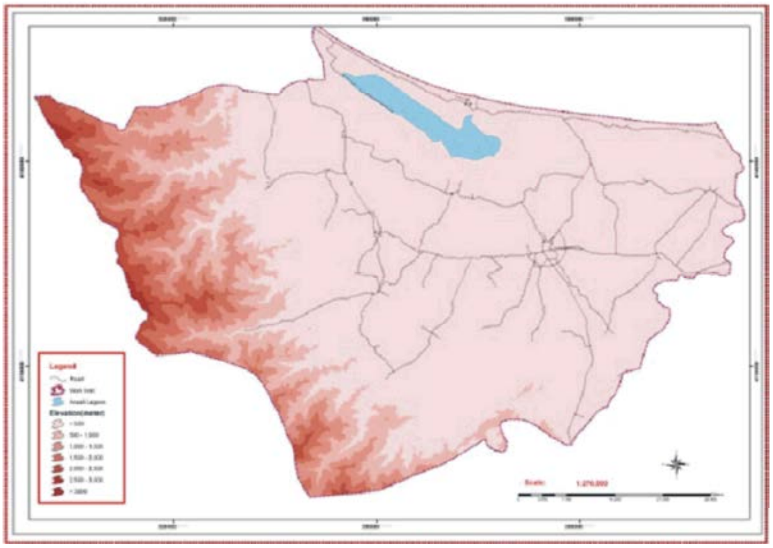

Fig. 3: Elevation classes map

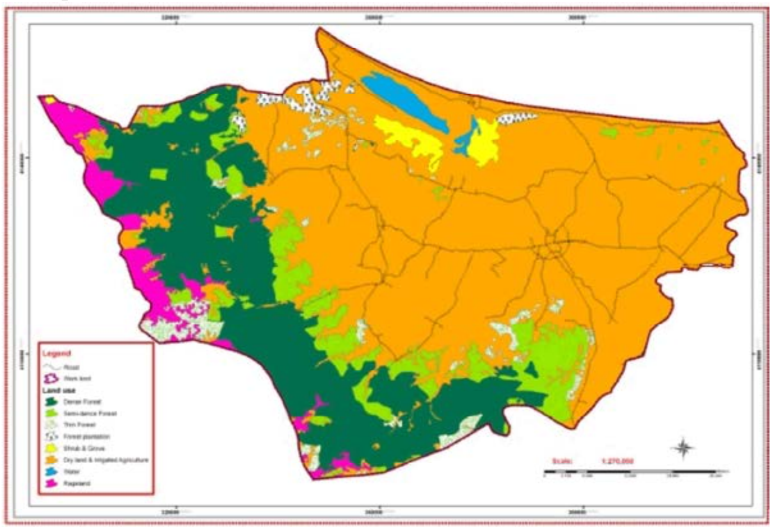

Fig. 4: Cover classes map

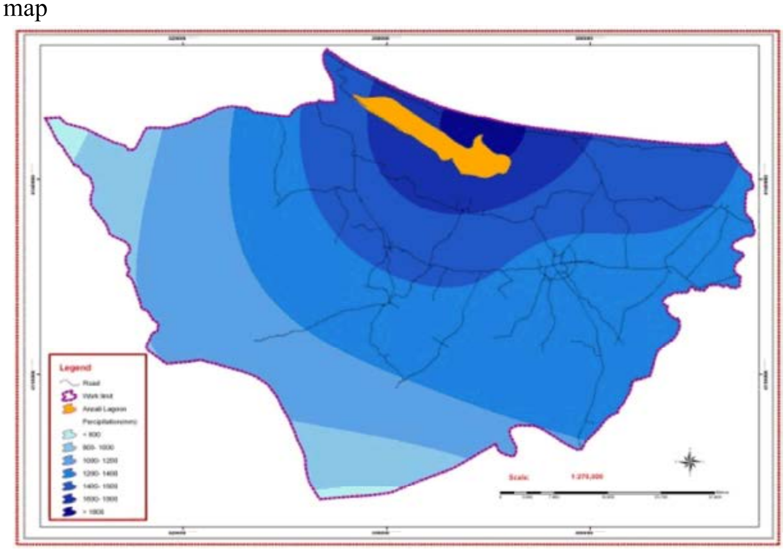

Fig. 5: Precipitation classes map

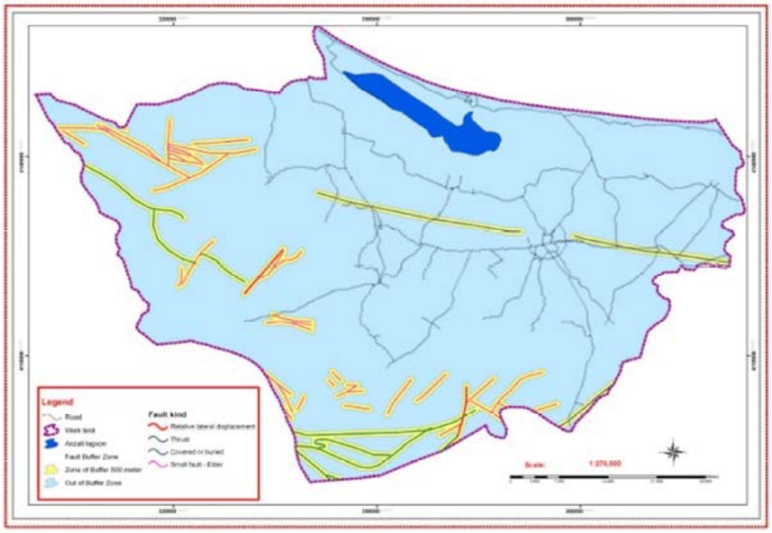

Fig. 6: Fault classes map

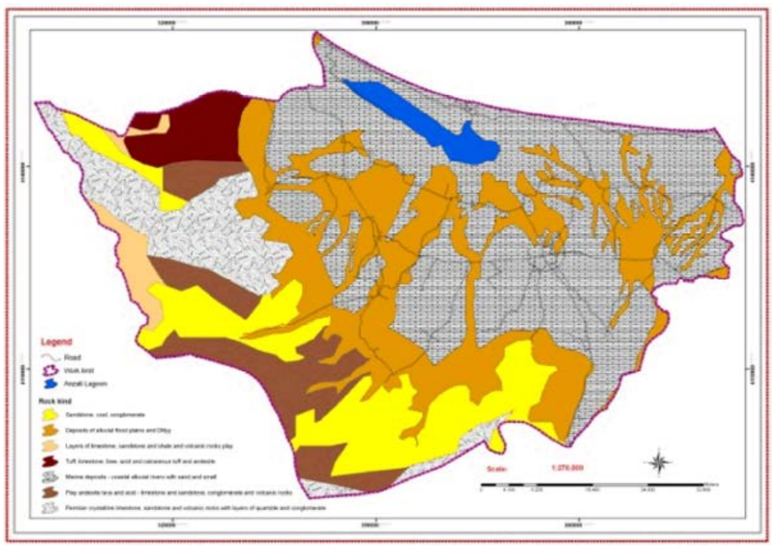

Fig. 7: Rock classes map

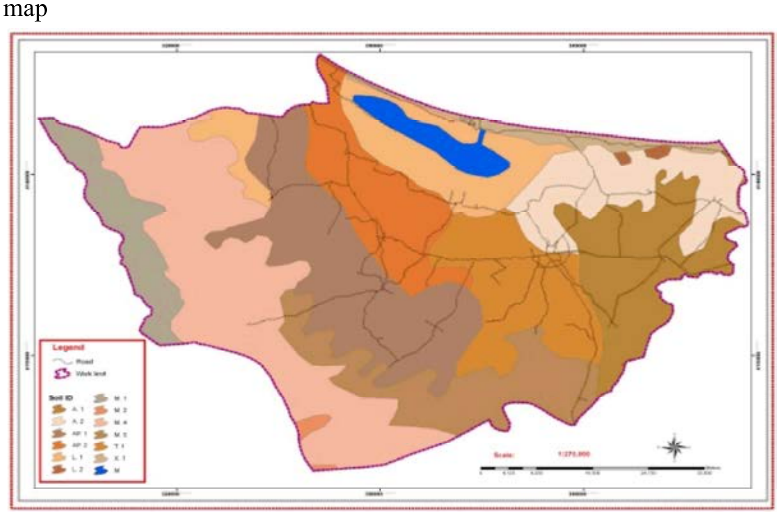

Fig. 8: Soil classes map

according to final composition and determination of land use. One of the most important aspects of the model results is comparison and matching with the existing condition and status of tourist attractions that already exist in the region. In addition to determine the priority among land use, a major criterion is the current situation and land use of the region [18].

Check the Consistency: In this step the consistency property of matrices is checked to ensure that the judgments of decision makers are consistent. For this end some preparameter is needed. Consistency Index (CI) is calculated as:

$$CI = \frac{\lambda \ \max \ - \ n}{n-1} \tag{2}$$

The consistency index of a randomly generated reciprocal matrix shall be called to the random index (RI), with reciprocals forced. An average RI for the matrices of order 1-15 was generated by using a sample size of 100 [19]. The table of random indexes of the matrices of order 1–15 can be seen in [18]. The last ratio that has to be calculated is CR (Consistency Ratio). Generally, if CR is less than 0.1, the judgments are consistent, so the derived weights can be used. The formulation of CR is:

$$CR = \frac{CI}{RI} \tag{3}$$

CONCLUSION

In this paper the application of multicriteria decision making in spatial problems and GIS application is discussed and in resumption AHP as a most applicable tool in this context was introduced. This study brings up a systematic approach and analytical means for planning of structural development.

In according to the goal, 7 Parameters used to evaluate the potential for structural development. With professional ideas that obtained from checklists and by according to the goal that is protecting the natural ecosystems, the weight of each parameter has determined. Pairwise comparisons between the influential factors in AHP has shown the superiority of the slop with 0.3099. Also the lowest weight of parameters allocated to the rock and soil.

After estimating the relative weights of each parameter, land use suitability map for structural development have prepared (Fig. 9). Then this map overlapped with the protected area and the lagoon maps. The result of overlapping was the reclassified Land use suitability map (Fig. 10). At the end compliance rate (CR) has calculated 0.084 which indicated the correctness of the model.

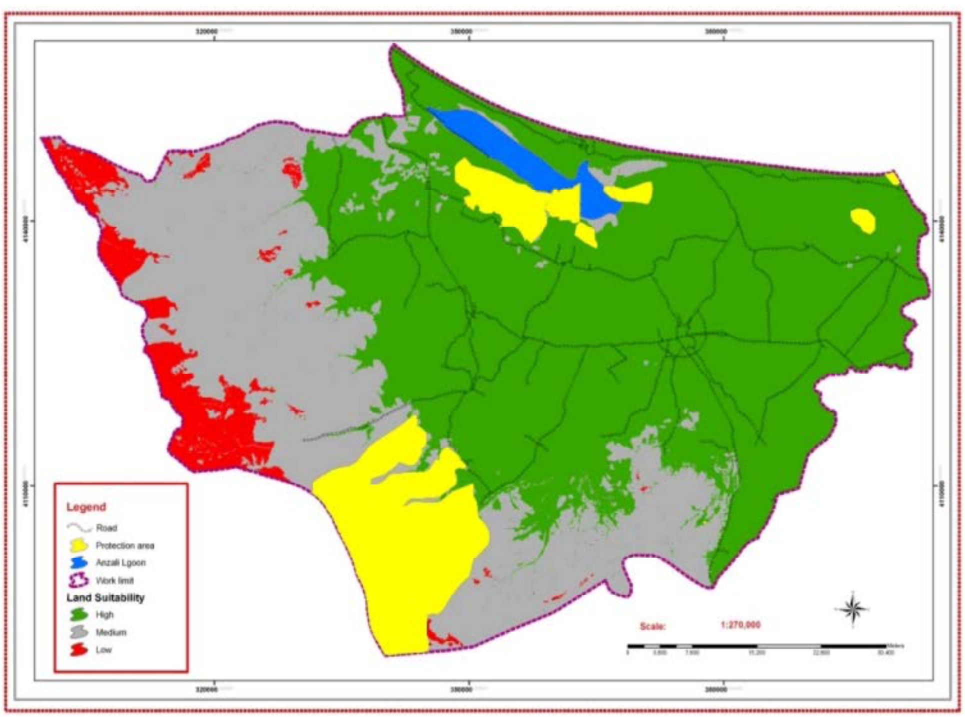

Fig. 9: Land use suitability map for structural development

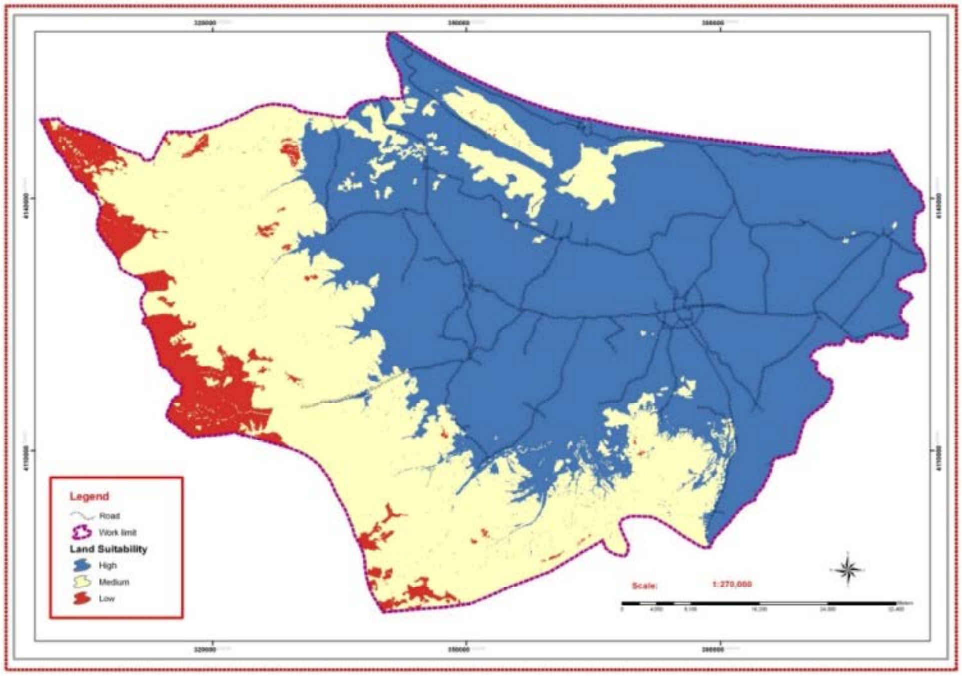

Fig. 10: Reclassified Land use suitability map for structural development

Table 5: Results of evaluation and zoning of Land use suitability for structural development

Area (%)	Area (Km^2)	Land use suitability
62	2,268,519	High
30	1,094,176	Mid
8	304,688	Low

Table 5 shows the areas and the percents of each class. In according to this table, 62 percents of land area equivalent to 2,268,519 Km^2 is suitable zone for structural development which contains plain area.

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