Assessing the Quality of the Environment in Duhok Province, Kurdistan Region of Iraq

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Abstract
Discovering the quality of the environment is essential because it directly affects health status and plays a significant role in the quality of life and public health. This research aimed to evaluate the environmental quality affecting by human-made sources in Duhok province using GIS. Based on the human-made sources affecting the quality of the environment, including population density, solid waste generation, and industrial density, the state of the environment was evaluated in the study area. The overall result indicated that about 85% of the study area has moderate to high-quality state, while low and very low contributed to 13% and 1%, respectively. The integrated analysis of the environmental quality in Duhok province would increase the protection of the ecological environment and help the regional sustainable development and improvement of the built environment.

Keywords: Environmental quality, environmental indicators, GIS, Duhok

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I. INTRODUCTION
Environmental quality is a measure of the state of the environment affected by various conditions [1],[2]. Environmental quality refers to both the natural and built environment. It means not just the features of the natural environment such as water resources, climate conditions, natural disasters, and biodiversity but also human-made factors like population, traffic, and industry affect the quality of the environment [3],[4]. Discovering the quality of the environment is essential because it directly affects public health status and plays a significant role in the quality of life [4], [5]. Assessment of ecological and environmental quality have seen great attention in the last years. However, due to the complexity of the systemic, most of the previous studies emphasized on some particular parameters [1], [5], [6]. GIS has widely been used for environmental assessment. In a study by [6], GIS was applied to residential simulation construction and land use modeling for the Netherlands. [1] combined GIS and remote sensing (RS) to evaluate the ecological state by multiple factors. [7] used GIS-based multi-criteria evaluation for assessing the potential of the human state and air quality in Isfahan Province in Iran. [8],[9] analyzed the risk of landslide using GIS in the Xiaojiang watershed. The main aim of this research was to evaluate the environmental quality affecting by both natural and human-made criteria in Duhok province using GIS and multi-factor analysis approach. More specifically, based on human factors including population density, rate of solid waste generation, and industrial unit density, a state of the human environment was provided and quantified in the GIS environment. Also, the natural environmental quality-analyzed based on the land/ and land cover and average rainfall, and the state of the environmental quality was quantified. In the following case study, Methods, results, discussion, and conclusion are described.

II. CASE STUDY
The case study in this research is Duhok Province, located in the north of the Kurdistan Region of Iraq, as in Fig. 1. is shown. The population of the Duhok province is approximately 1.3 million. The province consists of seven districts, including Duhok, Semel, Zakho, Amedy, Sheikhan, Akre, and Bardarsh. The main economy of the region depends on the selling of crude petroleum and natural gas production and the industries related to it. Agricultural products and tourism are also prominent in the region.
According to the Köppen-Geiger, climate classification system, Duhok has a borderline semi-arid (BSh) and Mediterranean climate (Csa) with extremely hot, dry summers and cold, wet winters. Precipitation falls in the cooler months, being heaviest in late winter and early spring.

III. METHOD

A. Criteria (Factors) definition

In this research, we first reviewed similar studies in order to find the factors that affect the state of the environment. Then, based on the accessibility to the required data, population density, solid waste generation, and density of the industry (numbers of industry) were considered as affecting factors. The overall flowchart of the methodology as in Fig. 2.

B. Population density

Population density (people per km²) is a critical factor that pressures on the environment. It is a measurement of the number of people in an area. In his study, for the evaluation of the population density on environmental quality, first, the information of the population for each subdistrict was attained. Fig. 3. This information was converted to a GIS database. Then the areas of the subdistricts were calculated in ArcGIS software. By dividing population numbers by the area, the population density for each subdistrict and the whole province was calculated. The calculated population density then classified into four classes in which from class 1 to class 4, the density increase, meaning that the quality of the environment decrease.

Fig 2: Flowchart of the methodology
C. Industry

Industries are major sources of environmental pollution. The areas with a high density of industrial units and industrial zones face a higher level of environmental pollution. The number and locations of the industrial units of the Duhok province were attained from Duhok Environment Department as in Fig. 4. The locations were converted to ArcGIS software, and the number of industries in each subdistrict was calculated. Then, the number of industries was classified into four classes, where class 1 to class 4 that class 1 has the lowest density, and class 4 has the highest density. From class 1 to 4, the potential of environmental pollution increase, and the quality decrease.

D. Solid Waste

Solid waste can create significant health problems and a very unpleasant living environment in case the safe and appropriate management plan is not applied. Unfortunately, the solid waste in Duhok province is not treated or deposited efficiently as other parts of the Kurdistan region and Iraq. For calculating the solid waste in the province and subdistricts, the average rate of waste generation per person/day was attained from Duhok Municipality. As in Table I, the rate ranges from about 0.7 to 1.4 kg per person per day. Then, the rate of solid waste generation multiplied in the population number, and the solid waste generated in each county was calculated. The calculated waste classified into four classes in which from class 1 to class 4, the volume of waste increase, meaning that the quality of the environment decrease as in Table I.

### Table 1. Rate of Solid Waste Generation in Duhok Province [12]

| District | Rate of waste generation (person per kg per day) |
|----------|--------------------------------------------------|
| Akre     | 0.89                                             |
| Amedy    | 1.02                                             |
| Bardarash| 0.8                                              |
| Duhok    | 1                                                |
| Semel    | 0.94                                             |
| Shekhan  | 1.33                                             |
| Zakho    | 1.27                                             |

E. Criteria aggregation

Human-made factors are population density, solid waste generation, and industry locations. As mentioned, these three factors were calculated for whole province maps and as small units for each county as well. The maps for factors were created in ArcGIS and aggregated to find the quality of the human environment human. Since the population has a direct relationship with the traffic and fuel consumption, the population density factor was assigned as in Table II. The map of the human environment representing four levels, representing high quality (better), middle, low quality (bad), and very quality (worse), respectively.

### Table 2: Weight of the Criteria

| Human Factor          | Weight (importance) |
|-----------------------|---------------------|
| Population density    | 0.5                 |
| Industry              | 0.25                |
| Solid waste generation| 0.25                |

IV. Results

The quality of the human-made environment was attained by analyzing population density, industrial density, and solid waste generation. The maps of the factors were created and aggregated for showing the final map. Fig. 5. the quality of the human-made environment in the province and as a small unit for subdistricts. The map was classified into four groups, including high (good), middle, low (bad), and very low (worse) quality. As in Table III and Fig. 5, the percent of the classes are shown. Overall, about 85% of the study area has moderate to high, while low and very low contribute to 13% and 1%, respectively.
V. DISCUSSION AND CONCLUSION

Based on the analysis, the Duhok subdistrict has a worse situation since it is the densely-populated city in the province. Also, about half of the industries are located in this subdistrict. Other main cities such as Zakho, Shekhan, and Semel, located in the center subdistricts, have low quality meaning that the pressure on the environment is somehow high. In general, northern and eastern parts have better quality than those regions located in the west and southwest. The overall results showed that most of the province has good environmental quality. However, the center of the province and other big cities contributed to the low level of quality. It also can be concluded that this province has a good situation in the aspect of the natural state. In contrast, human-made elements represented the reverse state. Unfortunately, while the industry has not been developed as in other countries, the rate of solid waste is high in the province. Also, the solid waste has not been treated efficiently or deposed safely. This makes this urgent situation that solid waste should be managed in the best way. This research clearly showed the capability of GIS for spatial analysis and the efficiency of this technique compared to traditional methods. Using a province as a case study can potentially reveal the current state of regional environmental quality and could efficiently resolve the problems of regional problems. This research is a step towards future work on determining an environmental quality evaluation. It also is a framework to add new criteria such as natural risks and hazards, soil erosion, and also environmental pollution to characterize the accurate and precise situations of environmental quality.

### Table III. Percentage and Area of Quality Class

| Class (quality) | Area (percent) | Area (hectare) |
|-----------------|---------------|----------------|
| High            | 28            | 3127           |
| middle          | 58            | 6355           |
| low             | 13            | 1415           |
| Very low        | 1             | 116            |
| sum             | 100           | 11013          |

Fig. 5: Human-made quality of the environment in Duhok province
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