Prediction the Locations of Future Earthquakes in Eastern Part of Iraq Using GIS Techniques

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Abstract. An earthquake is a natural phenomenon and natural catastrophe. It can cause massive damage and losses of life. Future prediction of natural catastrophes such as earthquakes can minimize their risks and save people lives and properties. GIS can be very essential for predicting and estimating a future earthquake. Thus, this study is dedicated to predict the locations of future earthquakes in the eastern part of Iraq using GIS techniques. The study involves establishing a GIS database (DB) of the previous earthquake in the period (1985 - 2015), identifying the parameters that a map layers of all parameters (factors) which are responsible on occurring earthquakes, and using GIS techniques to identify and predict the locations of the future earthquakes.

This research is accomplished through a number of essential stages. The are data gathering, data processing and data analyzing. The gathered data among the period of the study (from 1985 to 2015) was classified into three stages ((1985-1995), (1996-2005), and (2006 to 2015) to distinguish a fine details of past earthquakes easily and precisely. The results show that GIS is a powerful tool that can provide an accurate prediction of upcoming natural phenomena such as earthquakes. This can evaluate earthquake hazards and raise the awareness of the government to save people's lives, properties and infrastructures against the possible future earthquakes and the accuracy assessment processes reveals that about 80% of coming quakes happened where they expected (very close to the prediction seismic line).

1. Introduction
Earthquake is a natural phenomenon and natural catastrophe. It occurs at different parts of the world. It happens due to the deformation of the external hard portions of the tectonic plate or it occurs due to volcanic eruptions. Ground shake happens mostly in belts matching with the boundaries of tectonic plates [1].

The earthquake can cause massive damage and losses of life. Future prediction of natural catastrophes such as earthquakes can minimize their risks and save people's lives. In fact, it is impossible to predict a specific time of earthquake occurrence [2]. However, the spatial locations of the seismic activity can be forecasted and most earthquakes have happened in the predicted locations [3]. Identifying the location of the future earthquake can helps to prepare for early evacuation. Thus, forecasting and assessing the spatial locations of the earthquakes are considered a significant task of many seismologists, experts and specialized institutions [4].

Usually, an earthquake occurrence is controlled by different natural environmental parameters. The location and time of previous earthquakes in a certain region are equally significant in forecasting a future earth activity. Therefore, the probability of occurrence of an earthquake at regions that have a high amount of historical seismic activity can be very high [2]. In addition, the majority of the tectonic
earthquakes have happened in expectable locations along with active fault zones [5]. Consequently, three main parameters can assist researchers in predicating the locations of upcoming quakes; these are time periods, magnitudes and locations of the previous earthquakes [1,2,6,7]. These parameters are considered in the methodology of this study.

2. Literature review

Many previous studies have been devoted to predict and analyze future natural catastrophes or earthquakes. Yosihiko O., 2013 proposed different complex statistical approaches for predicting future earthquakes. Many experiences performed in the study showed that the developed statistical procedures were vital and efficient to forecast the upcoming quakes. However, Haridas M., 2015 mentioned that traditional methods used for forecasting earthquakes are mainly ineffective. The author stated utilizing and analyzing satellite information and imageries can estimate the main earthquakes from (1 to 30 days) before they happen. There is a lot of software can be used to process, display, analyze and enhance satellite imageries for mapping such as ERDAS Imagine, ER Mapper and GIS software. Thus, geographic information system (GIS) software has adopted by a number of researches as a modern technique to analyze satellite imageries and predict upcoming natural disasters. For instance, Carrara et al., 1999 used GIS technique to forecast and observe the landslide hazard. The researchers concluded that GIS is a useful tool in analyzing the effects of the upcoming natural catastrophes. It can be also employed for predicting the regions of the natural disasters however; they stated that GIS needs experts' users to work on it and the data collection process for a big GIS project remains expensive. In addition, Marzieh Z., 2012 used GIS for evaluating the hazard of earthquakes and produced thematic maps to support a risk management of San Francisco. The results of the study showed that GIS was very essential for predicting and estimating the possible damages of a future earthquake.

Based on the above a brief overview, this study is dedicated to predict the locations of future earthquakes in the eastern part of Iraq using GIS techniques. GIS can aid in evaluating risks and support earthquake management by creating thematic maps. The results of modeled earthquake scenarios are utilized to understand the magnitude of losses and to help mitigate the effects of future earthquakes.

Thus, in this study GIS techniques were employed to produce a map displaying where upcoming earthquakes are likely to happen in the eastern part of Iraq. The study involves establishing a GIS database (DB) of the previous earthquake in the period (1985 - 2015), identifying the parameters that a map layers of all parameters (factors) which are responsible on occurring earthquakes and using GIS techniques to identify and predict the locations of the future earthquakes.

3. Study Area

The study area covers the eastern part of Iraq especially the regions experiencing or have a high amount of historical seismic activity and the areas where earthquakes have occurred in the past. This area suffers from a high number of tectonic earthquakes. These earth movements occur at plane margins because of compression, tension or shearing forces. Thus, the study area covers the regions between latitude 31°N to 34°N and longitude 45°E to 42°E as shown in Fig 1. It lies in the Mesopotamian zone at northeastern borders between Iraq and Iran. The study area witnesses active seismic activity because it lies on active faults such as Badra-Amarah fault, Euphrates fault, and Makhul-Hemrin fault. It straddles the seam between Arabian and the Eurasian tectonic plates. The history of this region is plagued with earthquakes.
4. Prediction of Earthquakes

It might be impossible to expect the exact of the earthquake. However, seismologists can predict future quakes by looking at the location of previous earthquakes. In the current time, many methods are employed for earthquakes production. These methods are physical measurements, statistical probability, observations of animal behavior and geochemical observations. A statistical method is an appropriate method for forecasting because it gives precise results and it can be modeled easily. Thus, this method is adopted in this study. The statistical method relies on gathering sufficient historical information about where and when previous quakes strike. The forecasting that depends on a statistical analysis of historical information is recommended for intermediate or long periods of time.

In this study, Geographical Information Systems (GIS) is utilized for future earthquakes prediction by applying a statistical method. GIS can offer a powerful tool to analyze input parameters (historical and geological information) that are significant in predicting the spatial location of a future earthquake. Working on GIS is efficient because it saves time and reduces the cost.

GIS techniques in this study were used to predict the spatial location of future earthquakes in Iraq. To get accurate results, GIS software needs to be fed by precise information (data base (DB)) about the parameters which are significant and helpful in predicting future earthquakes. Although, these parameters are so many, they can be reduced to three main parameters. These parameters are time periods, magnitudes and locations of the previous earthquakes. Generally, the regions of the future earthquake and the areas of seismic risk are always will be in or near to previous quake sites. Nevertheless, the assumption of to the exact positions where the expected earthquakes happened is difficult to be identified [2].
5. Research Methodology

As mentioned in the above, GIS techniques were applied to predict the locations of future earthquakes in the eastern part of Iraq. ArcGis software (ver. 10.1) was used in this study for achieving GIS jobs. This research is accomplished through a number of essential stages. These are data gathering, data processing and data analyzing.

1. **Data gathering**: different types of data were gathered from different sources in order to build a precise database (DB). The main sources of the DB in this study are Iraqi metrological organization and seismology and data collected from previous literature [1,7,10]. These data include the attribute, raster and vector data. The attribute data involves many tables containing paleoseismological data (e.g. data about active faults in the study area) and information about various types of Earthquakes data, involving historical data such as time periods, magnitudes and locations of the previous earthquakes between 1985 -2015.

In addition, raster and vector data involves: a) A calibrated QuickBird satellite imageries (resolution 60 cm) of the study area; b) Geological maps of the area of the study; c) Maps of previous earthquakes at the study area; d) Seismicity maps of the study area for the period (1985-2015); and e) Iraqi tectonic maps.

2. **Data Processing**: ArcGIS software (ver. 10.2) was used for processing and analyzing the collected database. The gathered data among the period of the study (from 1985 to 2015) was classified into three stages ((1985-1995), (1996-2005), and (2006 to 2015), where each stage covers the data of ten years. The location and the magnitude of the previous earthquakes the three stages represented as points in three separate layers using ArcGIS software. The size and the color of each point were used by ArcGIS to identify the magnitude of the earthquakes. Categorizing the earthquake amount by different sizes and color points can be more informative and give a clear picture on the map, as when and where the value of the earthquake is higher as compared to other values.

In addition, an Iraqi tectonic map of the study area was produced in a separate layer. A map represented in Fig 1 was considered a base map used to produce the tectonic layer. This layer contains line futures representing the length and the directions of the active faults in the study area.

3. **Data Analyzing**: ArcGIS is utilized to analyze the input database to produce a map of prediction future earthquakes. The map of future earthquakes was produced is based fully on the location of previous earthquakes and the active faults in the study area. There are weights given to the highest magnitude quakes and those that happened closed to the faults. ArcGIS has been considered a powerful tool in data analyzing. In order to predict the locations of future earthquakes, a number of functions in ArcGIS software were optimized based on produced four layers (e.g. Buffer and spatial analyzing functions). These functions can anticipate a predicted seismic line where future earthquakes may occur and display the obtained results on the produced map. The analysis procedure includes establishing a buffer area around the past earthquakes and supposing that predicted earthquakes will tend to happen within them. Thus, applying spatial and buffering analyzing functions in GIS can integrate spatial information and seismic information together to offer a new technical provision to the future earthquakes forecasting and analyzing.

6. Results Analysis and Discussion

As mentioned in the above, the data of the past earthquakes among the period of the study (from 1985 to 2015) was classified into three different periods ((1985-1995), (1996-2005), and (2006 to 2015) in order to get a precise results and process fine details. ArcGIS software was used to map the seismic line and the past earthquakes of each period in three separate layers as shown in Figs (2-4). In fact, the quakes that have magnitude below 3 Richter were neglected in this study. The figures show that the seismic line and the majority of the quakes falling on (Badra-Amarah) fault. This active fault has a major influence on the earthquakes in this region.
Figs (2 and 3) demonstrate that the number of earthquakes was steadily coming up over time. Fig (1) shows the number of quakes hitting the study area during the first period (1985-1995) was 200 quakes, while in the second period (1996-2005), the increase to 500 quakes as shown in Fig (3). However, the number of earthquakes increased significantly to exceed 4000 shakes as displayed in Fig (4).

Figure 2. A map of past earthquakes during the periods (1985-1995); (a) normal size of the map, (b) The map has been doubled to show seismic line.

7. Description of the Predicting Process
The prediction method of this study mainly depends on the prediction hypothesis of future earthquakes which is addressed by reference [2]. The hypothesis states that distances separating past quakes can be extrapolated to a modified distance; thus, the future earthquake is almost to happen within the same distance [2]. The advantages of this prediction method are: 1) it predictions a pre-fixed ratio of future earthquakes; and 2) the produced maps are precise and efficient over time. The prediction process in this method can be explained the following steps:

- Classifying the previous earthquakes among the periods (1985 -2015) into three sub-periods ((1985-1995), (1996-2005), and (2006 to 2015) and eliminating the small magnitude of past earthquakes (blow 3 Richter).
- Uploading the whole database (attribute, raster and vector data) to ArcGIS and considering only the quakes that happen in the study area region.
- Evaluating which period (among the three sub-periods) involved a bigger number of quakes and giving it a higher weight compared to other.
- Using the ArcGIS to analyze the data based on the prediction method.
- Using the ArcGIS to produce a new prediction map (as shown in Fig (5)) that illustrates the seismic line which represents the spatial location where the future earthquake may occur.
- Assessing the results by checking the location of the coming earthquakes that occur in the study area after 2015 (e.g. from 2015 to 2018). If 80% of the coming quakes occur where they expected (near to the prediction seismic line), the developed prediction model will be acceptable and satisfactory.
Figure 3. A map of past earthquakes during the periods (1996-2005); (a) normal size of the map, (b) The map has been doubled to show seismic line.

Figure 4. A map of past earthquakes during the periods (2006-2015); (a) normal size of the map, (b) The map has been doubled to show seismic line.
8. Conclusion
In this study, GIS techniques were employed to produce a map displaying, where upcoming earthquakes are likely to happen in the eastern part of Iraq. The study involves establishing a GIS database (DB) of the previous earthquake in the period (1985 - 2015), identifying the parameters that a map layers of all parameters (factors) which are responsible for occurring earthquakes, and using GIS techniques to identify the locations of the future earthquakes. The previous earthquakes among the periods (1985 -2015) were divided into three sub-periods ((1985-1995), (1996-2005), and (2006 to 2015) to distinguish all regions that affected by past earthquakes easily and precisely. The results show that:

- GIS is a powerful tool that can provide an accurate prediction of upcoming natural phenomena such as earthquakes. This can evaluate earthquake hazards and raise the awareness of the government to save people's lives, properties and infrastructures against the possible future earthquakes.
- The seismic line and the majority of the quakes falling on (Badra-Amarah) fault. This active fault has a major influence on the earthquakes in the study area.
- The number of the earthquakes increased dramatically during the third period (2006-2015) to exceed 4000 quakes as compared with first (1985-1995), and second (1996-2005) periods. This means the seismic activity has increased in the eastern of Iraq during the last few years.
- The prediction accuracy to the final produced map (Fig (5)) was assessed by checking the location of the future earthquakes that occurred at the study area after 2015 (e.g. from 2015 to 2018). The accuracy assessment reveals that about 80% of the coming quakes happened where they expected (very close to the prediction seismic line). Thus, the developed prediction procedure applied using GIS techniques are an efficient and effective procedure to easily distinguish and know most sites affected by earthquakes, as well as to find out more momentum in periods of earthquakes.

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