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Soil Liquefaction Hazard Zonation Map for Kordkuy County, Golsetan Province Using Model SWM

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Abstract

Liquefaction is one of the most determinant factors in the collapse of transportation infrastructures. This is especially true for roads and railroads located on saturated, fine-sand substrates under seismic conditions. The damage and human casualties resulting from liquefaction highlight the importance of understanding and mapping this phenomenon. Soil liquefaction occurs as a natural hazard in saturated, loose sand due to increased pore pressure and low shear strength. The purpose of this study was to prepare a soil liquefaction hazard zonation map for Kordkuy County, located in Golsetan Province, using data collection, basic digital mapping (soil deposits map, ground water depth and earthquake acceleration map), three parametric Stanford Watershed Models (SWM) and ArcGIS software . An empirical liquefaction model as a function of the three studied variables was used to model liquefaction in four hazard classes using ArcGIS software. According to the results, most areas fall into the nonhazardous and moderately hazardous risk classes. A portion of the Eastern County was classified as highly hazardous due mostly to its close proximity to an earthquake focal point.

Keywords: *hazard zonation, soil liquefaction, SWM model, earthquake*

1. Introduction

Iran is one of the areas of the world most prone to earthquakes. Some of the strongest earthquakes ever seen have occurred here resulting in many causalities. Planning programs to address the risks associated with these earthquakes are critical. Of these risks, geotechnical hazards are the most serious. Such hazards often occur as a result of earthquakes depending on site conditions and seismic characteristics and in many cases lead to deformation of the earth and irreparable damage to buildings. On June 16, 1964, Alaska and Niigata experienced destructive 9.2 and 7.5 magnitude earthquakes. Since then, many researchers have become involved in work pertaining to this phenomenon.

The purpose of this study was to prepare a soil liquefaction hazard zonation map for Kordkuy County, Golsetan Province using ArcGIS software and three parametric SWM models. Soil liquefaction is defined as a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, most commonly caused by earthquake shaking or other sudden changes in stress conditions, causing it to behave like a liquid [1].

Liquefaction is one of the most interesting, controversial and complicated phenomenon in the earthquake engineering field. The term liquefaction was first described by Mogami and Kobo in 1953 [2]. Saturated sand exposed to earth vibrations tends to compact. When there is a lack of drainage, this compactions leads to a higher pore pressure. When this pressure equalizes, open pressure is created and the effective stress becomes zero. This results in a loss of resistance and finally liquefaction [3].

Liquefaction is a major geotechnical hazard. [4]. Esmaeili et al (2014) used numerical modeling effectiveness of stone columns in the mitigation of liquefaction during an earthquake. The results showed that the group performance was dominant for (s/ d = 2,3) and that each column acts in a single manner for (s /d = 4 ,5) [5]. Abdolahzadeh et. al (2013) carried out a hazard and risk analysis of soil liquefaction case study for Gorgan, Golestan Province [6]. Criscione et al (2001) zoned liquefaction hazard areas in Nevada and concluded that liquefaction hazard maps are a useful tool for managers and planners in identifying areas of potential risk [7].

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2. Study Area

Kordkuy County, Golestan Province, Iran, is located at 54º 6′ E and of 36º 47′ N in an area approximately 815.5 km^2. At the time of the 2006 census, it was estimated that the county consisted of 17,617 families with a total population of approximately 67,427 people. Overpopulation and convenient access to services in some villages located in watersheds has resulted in some social and physical discrepancies compared to other rural areas. The Kordkuy County position is shown in Fig. 1.

3. Research Methodology

3.1. Mapping factors affecting liquefaction

Generally, mapping the liquefaction hazard process involves the preparation and composition of a series of layers showing those areas prone to liquefaction hazard. Table 1 shows the layout parameters classification standard and their scoring according to the SWM three parametric method.

3.2. Groundwater depth

To prepare this map, data related to ground water depths from 53 pizometric wells over the course of 25 years was collected. An Iso-map for groundwater depth was prepared using Arc GIS.

3.3. Deposition type

Having been digitalized, the soil and deposition map was converted from polygon to rater manner using base map pixels. Each pixel value was prepared from model standard tables and validated [9].

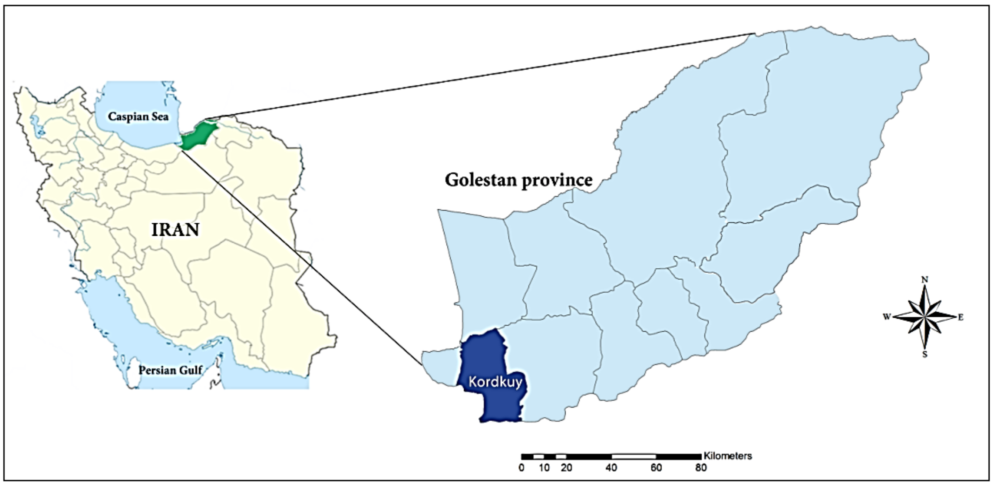

Fig. 1: Position of Kordkuy County, Golestan Province,Iran

Table1. Layout parameters classification standard and their scoring as per the SWM three parametric method [8]

Parameter	Range	Description	Rate Floors
Water depth)m(	**0-3** Meter	High static water level	2
	3-7 Meter	Average static water level	1
	7> Meter	Low static water level	0
Genus sediments	Fine sand and silt	High susceptibility to liquefaction	2
	Clay	Moderate susceptibility to liquefaction	1
	Coarse sand and gravel deposits	Low susceptibility to liquefaction	0
Acceleration amplitude(g(	6.0>	Areas with high seismic potential	2
	0.3-0.6	Areas with average seismic potential	1
	0.3<	Areas with Low seismic potential	0

3.4. Earthquake acceleration magnitude

To obtain maximum earthquake horizontal acceleration, the Joiner and Bour formula (1981) was used.

$$PGA = 10^{\wedge}(0.249 \times M - \log(D) - 0.00255 \times D - 1.02) \quad (1)$$

$$D = (E^{\wedge}2 + 7.3^{\wedge}2)0.5 \quad (2)$$

M represents earthquake magnitude [10], E denotes distance from earthquake focal point [8].

4. Results and Discussion

After the key parameters map was prepared, a rater map was prepared using 30*30 m pixels. Three classes were then created to which appropriate values were assigned using standard tables. A multiplication algorithm was used in three parametric mode in overlay function and data layers in ArcGIS environment. The hazard zonation map resulted in four classes. In Figures 2 to 5, the output map's ArcGIS software environment for this study is shown.

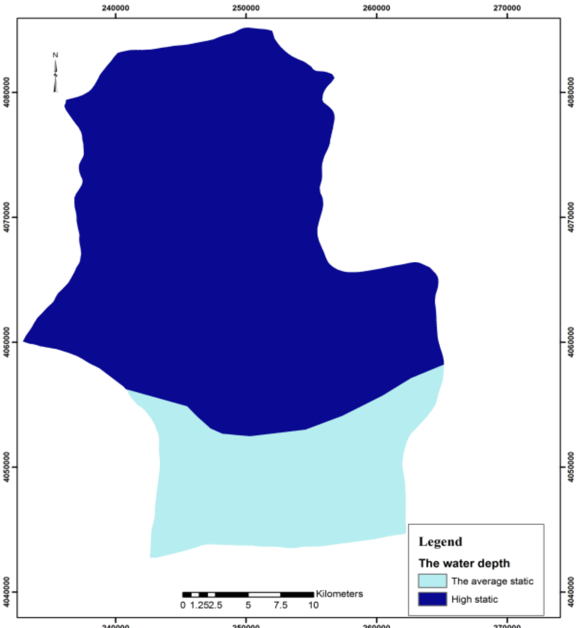

Fig. 2: Map of groundwater depth

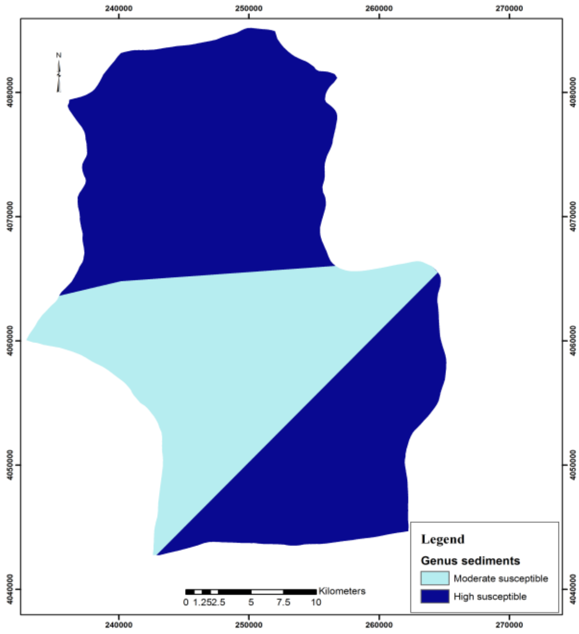

Fig. 3: Map of soil and sediment

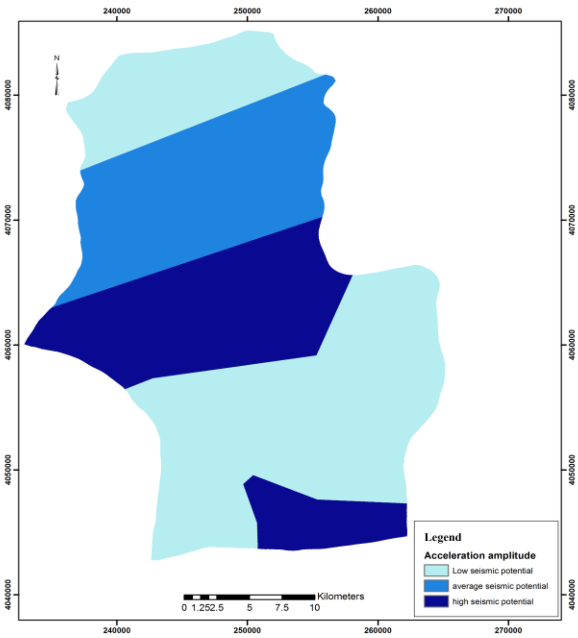

Fig. 4: Map of earthquake horizontal

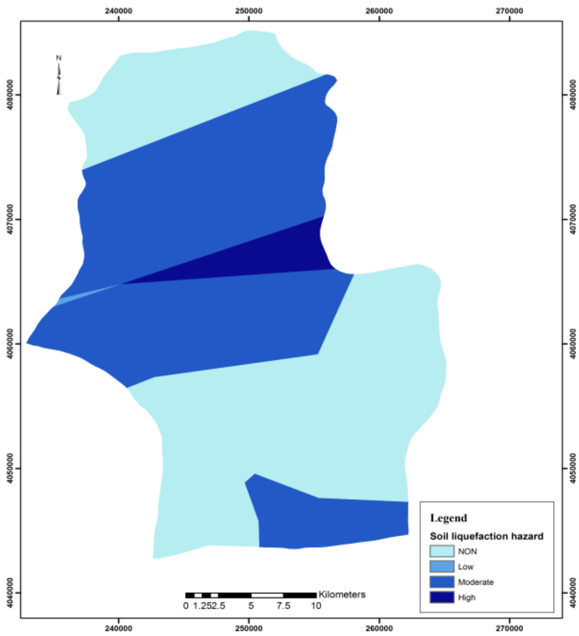

Fig. 5: Soil liquefaction hazard map

The results showed that the hazard potential ranged from nonhazardous to highly hazardous, with nonhazardous accounting for most of the area. Due to its closeness to a focal point, the eastern part of the county is categorized as highly hazardous with a probability of liquefaction mainly because of passing Chel-chai through which. This is in line with Mostafazadeh,s and Ownegh’s findings (2008).

The northern and southern portions of Kordkuy County were classified as nonhazardous due to their long distance from a focal point while the central portions of the county was found to be moderately hazardous. Identification of areas subjected to liquefaction provides an opportunity to avoid damage to residential and industrial areas as well as allowing for the identification of suitable areas for constructions and the prioritization of crisis management in case of emergency.

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