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Shrinking-swelling soil hazard mapping using multi-criteria evaluation techniques in berhoum area (Algeria)

Amar Guettouche[1]

[1] Ferhat Abbas University, Setif 19000, Algeria
guettouche.amar@gmail.com

Abstract. Shrinking-swelling soil are a serious problem for infrastructure in many parts of Algeria. Therefore, the primary objective of this research is to produce the shrinking-swelling soil Hazard Map for Berhoum area (Algeria) so that appropriate shrinking-swelling soil disaster risk reduction strategies can be developed.

In this research, Geographic Information System based Multi-Criteria Decision Analysis method — Weighted Sum Method (WSM) — were applied to scientifically assess the shrinking-swelling soil Hazard areas in Berhoum. The methodology is to create thematic maps by combining in GIS, determining factors (soil types, depth of ground water table, rain) in triggering phenomenon, using the method of Weighted Sum Model (WSM). These maps are then combined to provide a hazard map of shrinking-swelling soil.

The application of this method allows the spatial distribution of different criteria and phenomena in Berhoum area (eastern Algeria). As a result, the study area has been divided into three different areas: (1) areas with no shrinking-swelling soil hazard, (2) areas with low to medium shrinking-swelling soil hazard, and (3) areas with high shrinking-swelling soil hazard.

Keywords: Shrinking-Swelling, Hazard, MCDA, WSM, GIS, Berhoum.

1 Introduction

The north regions of Algeria, characterized by population density and speed of urban growth, are witnessing difficulties in construction caused by problems related to the land movements. This is due to the weakness of knowledge of phenomenon like shrinking - swelling soil. (Guettouche, 2019)

In this research, the Weighted Sum Model (WSM) method was applied. This model is tested in the framework of GIS, and the obtained results have been discussed. The results provide useful information about shrinking-swelling risks mitigation and may serve as guidelines for land use planning in Berhoum area.

The study is part of the contribution to Berhoum area management, which is vulnerable to natural hazards, and also in the context of the production of information and awareness documents.

2 Methodology

Mathematical model has been established, after identification of the parameters involved in shrinking-swelling soil hazard. In order to obtain the model of the study area the method of (WSM) was applied.

The weights values, and classification in (WSM) model, are based on opinions of experts (Sounding views was conducted with a group of experts in the framework of the preparation of the doctoral thesis of the author scientific article) (Guettouche 2015). The application of the proposed model, suggested uses the SIG approach.

The shrinking-swelling soil hazard is given by the following formula:

$$HSS = 0.6\ TS + 0.2\ PNP + 0.2EP \quad (1)$$

Where: TS: soil types; PNP: depth of ground water table; EP: rain.

TS; PNP and EP, were each divided into four categories (Tab.1).

Table 1. Criteria effect on the hazard.

TS	PNP (m)	EP (mm/year)	Grade	Classes
Rock / G / S	$PNP \geq 10$	$EP \leq 300$	1	no effect
Lt / Lp	$5 \leq PNP < 10$	$300 < EP \leq 600$	2	low to medium effect
Ap	$3 \leq PNP < 5$	$600 < EP \leq 800$	3	high effect
At	$PNP < 3$	$EP > 800$	4	very high effect

To make the crossing between the parameters, it is better to segment them into classes according to their degree of effect. The combination of the weighted results of the different criteria, one by one and taking the common factors in each time, gives the level of each phenomenon.

The classification for shrinking-swelling soil is represented in Table 2.

Table 2. Shrinking-swelling soil hazard classification.

HSS	Classes	Hazard Level
$HSS \leq 1.8$	1	no hazard
$1.8 < HSS \leq 2.8$	2	low to medium hazard
$2.8 < HSS \leq 3.4$	3	high hazard
$HSS > 3.4$	4	very high hazard

3 Spatialization by GIS Approach: Application in the Berhoum area.

3.1 Data sources and evaluation

The data sets used in this study can be grouped in four main data sources as lithological map, field survey and geotechnical drilling data and rainfall map. These data have been implemented in GIS program (Arc Gis 9.3) for the primary maps drawing. After the building of a database of the geographic reference, a map of the Shrinking-Swelling soil Hazard that shows the best areas for building.

The lithology map is derived from the geological map of the study area (Guiraud 1971). Nine lithological units were identified include Dolomite, Limestone, Sandstone, Conglomerate, Marls, Clays, Coarse Alluvium Sandy-Clay Alluvium and Fine Alluvium (Fig 1). Dolomite, Limestone, Sandstone, and Conglomerate were classified as rock.

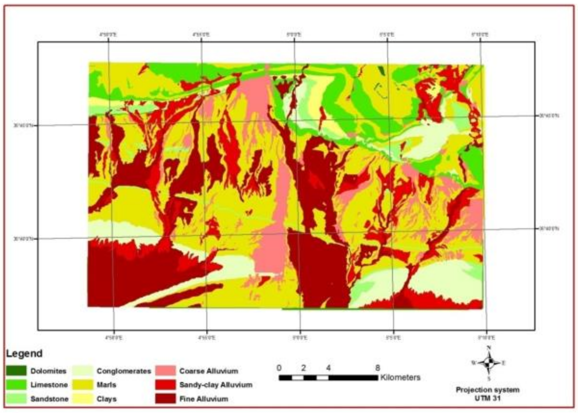

Fig. 1. Lithology map of Berhoum area.

For the Field survey data and geotechnical borehole, three techniques-different but complementary, have been used to complete the database: (a) The relevant data of 49 study geotechnical surveys were reviewed and evaluated, (b) Well field investigation based on direct observations, (c) As well as recordings and field sampling (GPS, images, etc.).

Soil types and the groundwater table layers are prepared using lithology map and geotechnical borehole.

The rainfall map in scale 1/50.000 is used to obtain the rain water layer.

These data were consolidated and evaluated to obtain shrinking-swelling soil hazard map (Fig 2). To implement these steps, we use the machine tool calculator networking (Calculator Raster) of spatial analysis toolbar (Suitability Special) in Arc Gis 9.3. (Dawod 2012)

3.2 Identification and classification of shrinking-swelling soil hazard.

Combining the results (Formula 1), gives the degree of shrinking-swelling Hazard (Hss), we have presented in the form of figure 2.

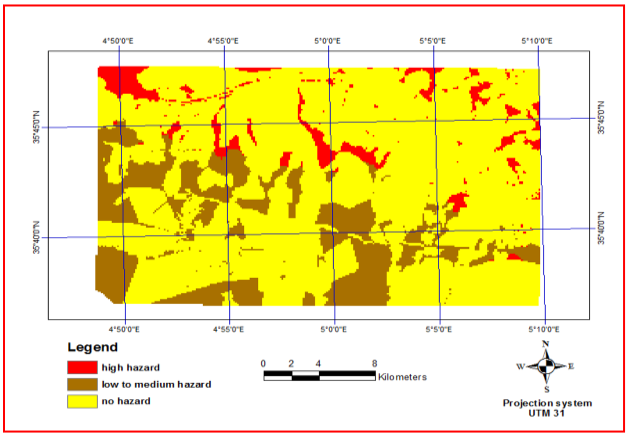

Fig. 2. Shrinking-swelling soil hazard map

4 Validation of Shrinking-Swelling soil Hazard map

Validation of the results was done at two levels. On the one hand, the thematic maps obtained were compared with the field data before their crossing. The perfect match between these field observations (Fig 3) and the medium and high hazard sites revealed by the map made from the GIS allows validating to some extent the final map.

Fig. 3. Field photographs showing the shrinking-swelling soil problems in the study area.

On the other hand, during field missions, the survey conducted (whether through technical offices of municipalities, by the Technical Inspection Agency of Constructions (CTC-EST, Agence de M'SILA) or directly in the field) recorded the presence of some limited damage to buildings (Through Technical Inspection Agency of constructions reports), and are the same observations made by (Belouar, Benaissa & al. 2008) in his research, in each of the municipalities Berhoum and Ouled Addi Gueballa, due to shrinking-swelling soil problems. (CTC-EST 2016).

5 Conclusions

This work on cartography of shrinking-swelling soil hazard, using (GIS) techniques, with a (WSM), shows the interest caused by these methods, which sounds of the multiple forms, opened the way to a very sensitive improvement of the prevention of the natural risks. These tools enable us to express the perception of space and data processing, and consequently the cartography is carried out in an optimal way.

The shrinking-swelling soil hazard map have a great part of importance, especially is a tool for the decision-making aid, by expressing tendencies and orientations. This map is not a means of struggle, but it helps establish an urbanization plan and an adequate control. In addition to managing; the problem of urbanization in hazardous areas, becomes possible and controllable.

In this work, the shrinking-swelling soil hazard map have been prepared for Berhoum area. As a result, and according to the foundations efficiency, the study area has been divided into three different areas: (1) areas with no shrinking-swelling soil hazard, (2) areas with low to medium shrinking-swelling soil hazard, and (3) areas with high shrinking-swelling soil hazard. According to this map, areas with high hazard, presented low density (5.64%) in the study area, areas with low to medium hazard, presented (18.23%) in the study area, and areas with no hazard, presented high density (76.13%) in the study area.

The methodology used in this study can be applied to other places, other procedures for the selection of the site and rebuild the necessary standards appropriately.

The proposed model is simple, and easily used by the geotechnical engineer or otherwise. Thread model is very interesting as it is being built on a small number of geotechnical characteristics according to experts' judgment.

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