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ANALYSIS OF THE VULNERABILITY OF THE CITY OF BATNA (ALGERIA) TO FLOODING

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Abstract: The objective of this research paper is to estimate the vulnerability of the city of Batna to flooding. A multi-criteria analysis has been performed in a geographic information system (GIS) by integrating several features relating to socio-economic stakes with the aim of better understanding, assessing and spatializing the level of vulnerability in the city. Therefore, we have used a customised index approach where each parameter is a numerical index indicating the importance of the stakes, resulting in a code to be used for the modelling.

Key words: flooding, GIS, multi-criteria analysis, vulnerability,

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INTRODUCTION

Vulnerability conveys the importance of potential damages suffered by stakes submitted to a given intensity hazard. The concept of stakes encompasses people, goods and activities that could potentially be affected by the aforementioned hazard (Herman, 2009; Renaud, 2006, p. 15). It is the sensitivity of people and activities located in an area exposed to a hazard (Lacina, 2012, p. 217). According to Leone and Vinet, 2006, pp. 9-25, it is the propensity to exposure to damaging or to dysfunction of various stakes (goods, people, activities, functions, systems) typically part of a territory and a specific society. The vulnerability is the most crucial component of risk in that it determines whether or not exposure to a hazard constitutes a risk that may actually result in a disaster (Yashon et al., 2014, pp. 1515-1545; Sami et al., 2016).

The main direct damage caused by flood hazards is damage to people, buildings and socio-economic activities. In this instance our method uses a multi-criteria analysis, it evaluates the impact of a phenomenon according to several criteria which must be part of, and weighted on, the

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same scale. Multi-criteria analysis allows users to solve complex decision problems where several criteria are taken into account in choosing one or multiple solutions (Solomon, 2001, pp. 413-420). These methods have been applied in several studies since 80% of data used by decision makers is related to geography (Malczewski, 1999).

GIS allows the decision maker to identify a list meeting a predefined set of criteria with the overlay process (Heywood et al., 1993). And the multi-criteria decision analysis within GIS may be used to develop and evaluate alternative plans that may facilitate compromise among interested parties (Malczewski, 1996, pp. 955-971). Vulnerability assessments have been recognized as being crucial to disaster management and are conducted to understand potential for loss, focusing on nature of the hazard and who and what are exposed (Cutter et al., 2001, p. 713-737).

The objective of this paper is to determine the level of vulnerability to floods; the factors involved in estimating the vulnerability consistent with the availability of data are classified according to their importance: the concentration of the population, the urban fabric and the road network.

STUDY AREA

The city of Batna is located in eastern Algeria, between latitude 35°33' North and longitude 6°11' East, covering an area of 11 641 hectares (figure 1). The city represents a variety of urban structures and land use that intensify the level of vulnerability.

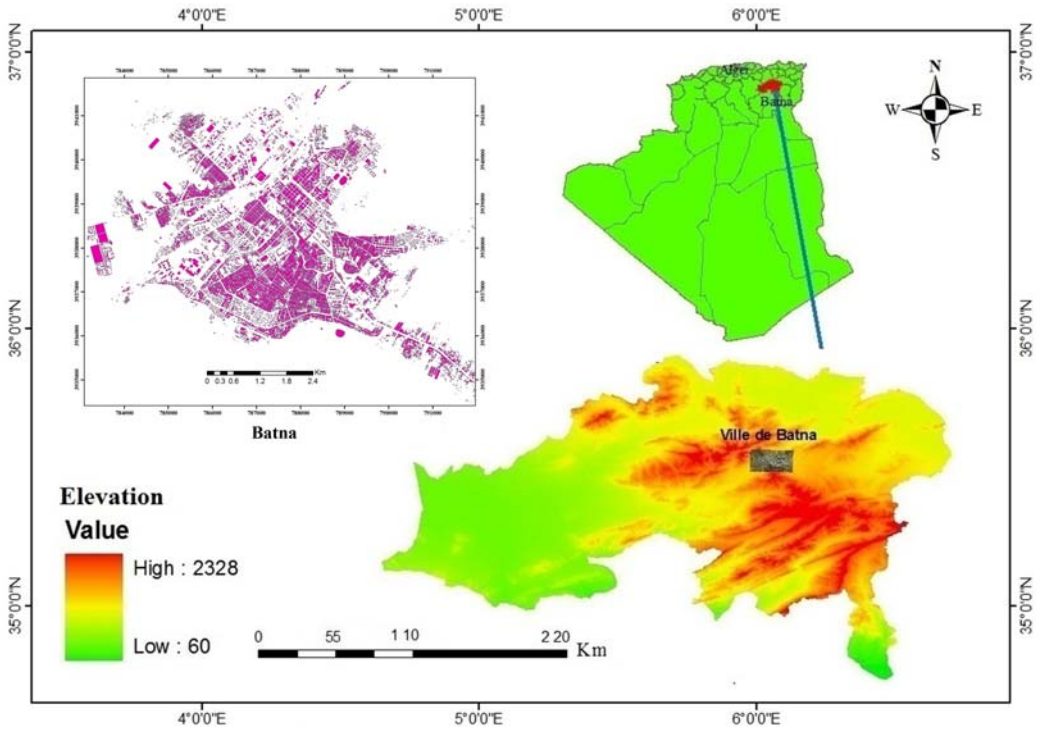

Figure 1. Study area

MATERIALS AND METHODS

Our study is based on a multi-criteria analysis. It is a decision support tool developed to solve complex multi-criteria problems that include qualitative and/or quantitative aspects in a decision making process (Guillermo et al., 2000, pp. 38-79). The method can provide answers to many challenges created by vulnerability assessments (Camille et al., 2007).

The factors in estimating the vulnerability consistent with the availability of data are classified according to their importance as follows:

Population density by district

According to the DPAT (Direction de la Planification et l'Amenagement du Territoire equivalent to the Planning and Territorial Development Authority) the city of Batna's population reached 302 585 inhabitants in 2012.

Figure 2 shows an unequal and uneven distribution of the population of this city with a density exceeding 350 inhabitants per hectare in some districts.

The population density is one of the factors determining high significance vulnerability.

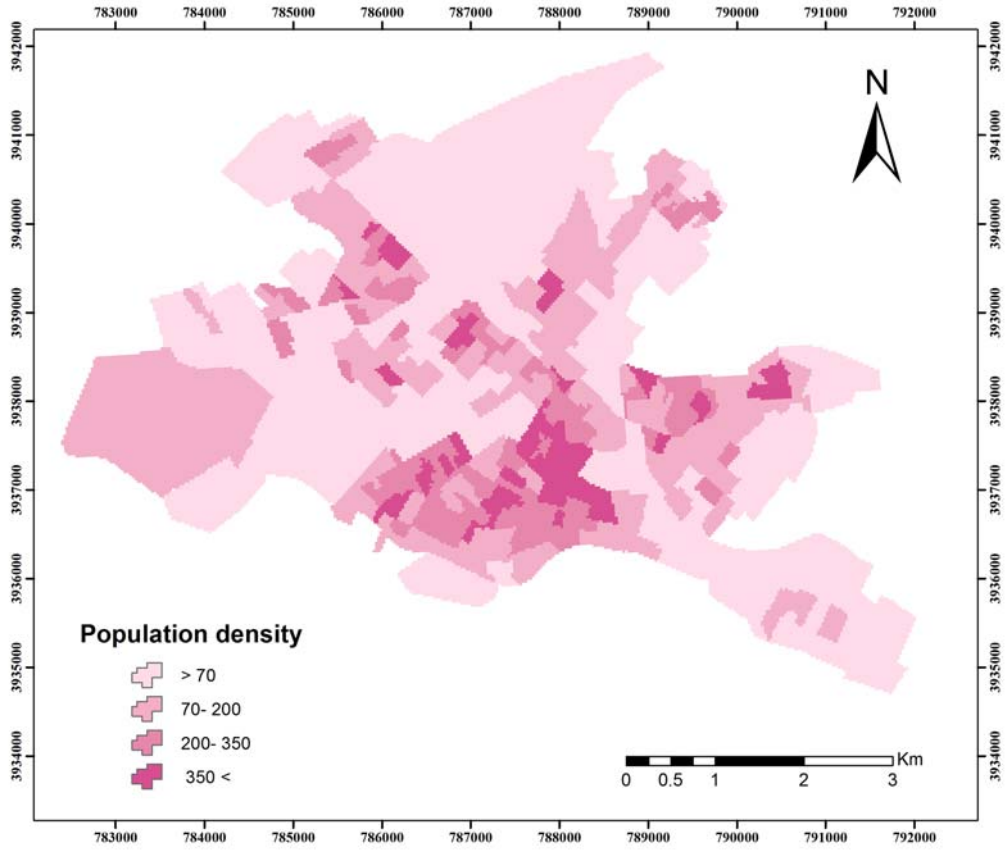

Figure 2. Population density
(Source: DPAT)

Urban fabric

The city of Batna has a variety of urban structures and land use where the spatial correlation of different factors has a significant influence on the degree of vulnerability.

Communal housing is characterized by large building clusters mainly with a residential function involving high-rises that often imply multiple floor levels meaning that the height of these buildings actually protects people and their property despite their high density, as a result, vulnerability to flood risk in this case is reduced, as opposed to individual habitats in which people and property are at ground level height. Urban facilities have a higher vulnerability than housing

areas because of the high public attendance at administration buildings, the importance of the capital goods involved and the services they provide (figure 3).

The industrial zone presents a sizable vulnerability given its economic importance, particularly with the presence of chemical industries which have indirect and adverse effects on the environment. Sources areas such as infrastructures that are highly involved in the management of the crisis; health care facilities and telecommunications, the Army garrisons and the Civil Protection units are areas of extreme vulnerability.

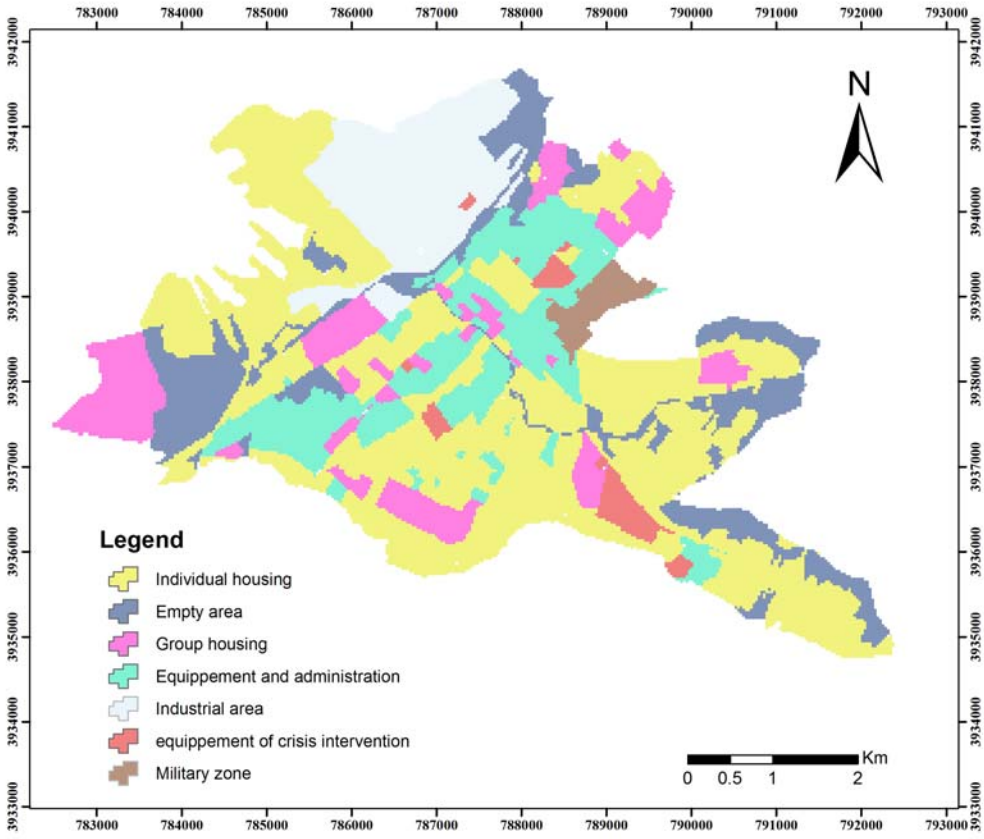

Figure 3. Urban Fabric
(Source: PDAU)

Road network

The road network is one of the factors of vulnerability assessment given its importance in terms of accessibility and traffic.

Several public services in particular those involved in the crisis are associated with this network such as school and public transports.

The vulnerability assessment is based on the identification of socio-economic stakes which importance is transcribed on maps.

Multi-criteria Hierarchical Methods (MHM) have been used to compare the vulnerability of different sites according to socio-economic criteria and relief efforts in relation to flood risks (Graillot et al., 2001, pp. 6-7).

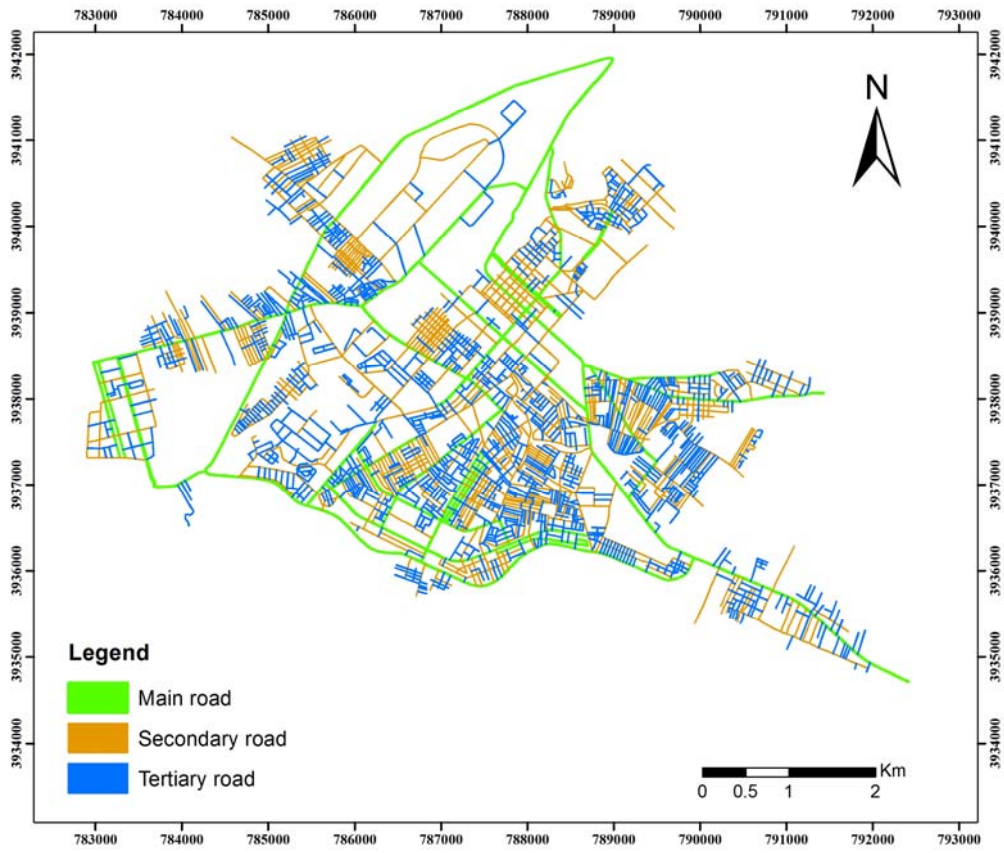

Figure 4. Road network
(Source: PDAU)

We have created vulnerability indices that represent the elements influence level of each factor (table 1).

Table 1. The elements influence level of each factor

Population density hab. /h	Indice	Urban Fabric	Indice	Road network	Indice
70 70 - 200 200 – 350 350<	1 2 3 4	Communal (group housing) Individual housing Equipements and administrations industrial zone Equipements of crisis intervention	1 2 3 4 5	Tertiary road Secondary road Main road	1 2 3

Calculating the vulnerability is done according to the following formula:
Vulnerability = 0.6 Population density + 0.3 Urban fabric + 0.1 Road network (table 2 - 3)

Table 2. The Multi-criteria Hierarchical Methods MHM (part 1)

Population density (0.6) / Urban Fabric (0.3)	(0.15)	(0.3)	(0.45)	(0.6)
(0.06)	0.21	0.36	0.51	0.66
(0.12)	0.27	0.42	0.57	0.72
(0.18)	0.33	0.48	0.63	0.78
(0.24)	0.39	0.54	0.69	0.84
(0.3)	0.45	0.6	0.75	0.9

Table 3. The Multi-criteria Hierarchical Methods MHM (part 2)

PD + UF / Road network (0.1)	0.21	0.27	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.6
(0.033)	0.243	0.303	0.363	0.39.3	0.423	0.453	0.483	0.513	0.543	0.573	0.603	0.633
(0.066)	0.266	0.336	0.396	0.426	0.456	0.483	0.516	0.546	0.576	0.606	0.636	0.666
(0.1)	0.31	0.37	0.43	0.46	0.49	0.52	0.55	58	0.61	0.64	0.67	0.7

0.63	0.66	0.69	0.72	0.75	0.78	0.84	0.9
0.663	0.693	0.723	0.753	0.783	0.813	0.873	0.933
0.696	0.726	0.756	0.786	0.816	0.846	0.906	0.966
0.73	0.76	0.79	0.82	0.85	0.88	0.94	1

Figure 5 shows that several areas of the city are listed as highly vulnerable due, either to their high density, or to their importance and/or the sensitivity of certain infrastructures.

Areas that have been identified as extremely vulnerable must be given special consideration to reduce the damage should a significant hazard occur.

To improve the reliability of this approach, many improvements are still to be made; specifically, we need a better understanding of both current and historical social and territorial characteristics. However, this study can be used as an initial document of decision support for the city's authorities.

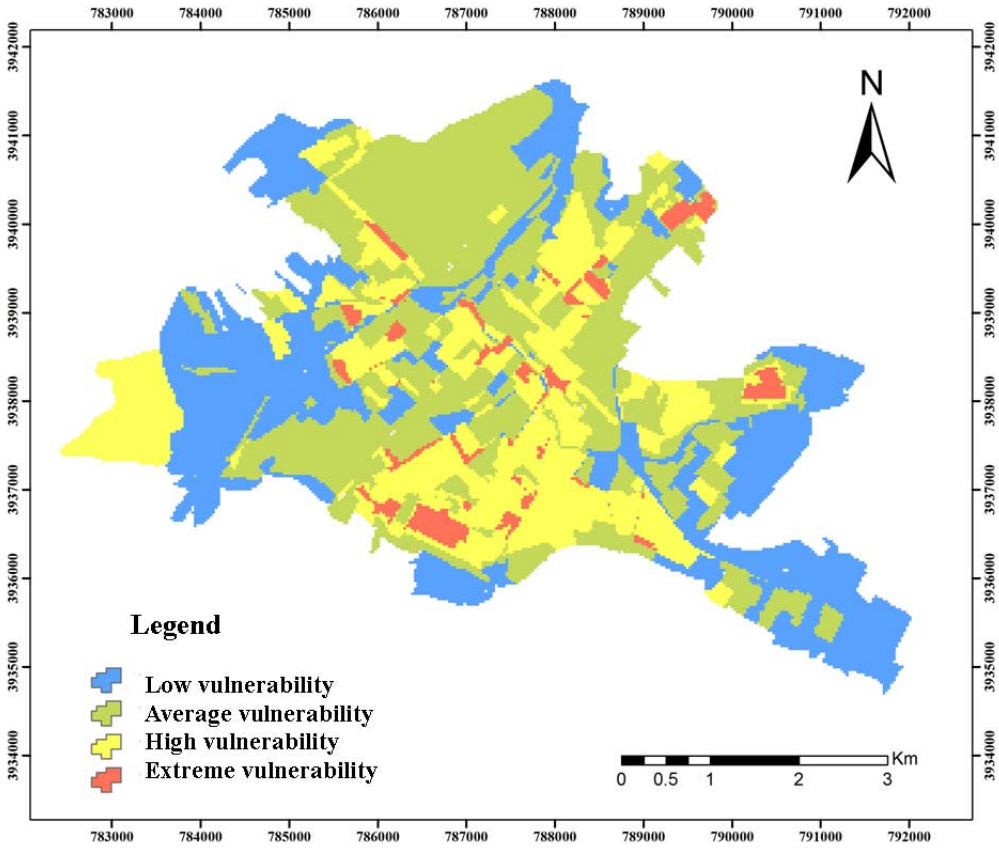

Figure 5. Map vulnerability

CONCLUSION

The development of a flood vulnerability mapping for the city of Batna, in respect of local communities that contribute to target their prevention strategies and the use of multi-criteria analysis in a GIS can be a useful tool for vulnerability spatialisation.

Based on the results of this analysis, decision makers can get access to relevant data needed to assess the risk level.

REFERENCES

Camille Grivault, Aleksandra Barczak (2007), *Evaluation multicritere de la vulnérabilité des territoires aux risques de transport routier de matieres dangereuses*, Rencontre Internationales Géomantique et territoire, SAGEO'2007.

Cutter S. L., Mitchell J. T., Scott M. S. (2001), *Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina*, Annals of the Association of American Geographers, 90, 713-737.

Fand F., Vinet F. (2006), *La vulnerabilite, un concept fondamental au cœur des methodes d'evaluation des risques naturel*, Publications de l'universite Paul-Valery Montpellier III, Coll. Georisques, vol 1 p 9-25 ISBN 978-2-84269-727-3.

Graillot D., Londiche H., Dechomets R., Batton-Hubert M. (2001), *Analyse multicritère spatiale pour l'identification de la vulnerabilite aux inondations*, In Actes du colloques SIRNAT 2001, 6-7 décembre 2001, Sophia Antipolis.

Guillermo A., Mendoza Phil Macoun (2000), *Application de l'analyse multicritere a l'evaluation des criteres et indicateurs*, Manuels de criteres et indicateurs pour la gestion durable des forets, Publie par : Centre de cooperation internationale en recherche agronomique pour le developpement (Cirad) Departement des forets TA 10 – C. Version française© Cirad, Cifor, 2000 ISBN 2-87614-387-9.

Herman G. V. (2009), *Omul şi modificările antropice din Câmpia Someşului [The man and anthropogenic changes in somes Plain]*, Editura Universităţii din Oradea, p. 227 p., ISBN 978-973-759-981-0, Oradea.

Heywood I., Oliver J., Tomlinson S. (1993), *Building an exploratory multi -criteria modeling environment for spatial decision support*, International Journal of Geographical Information Science, 7(4).

Lacina T. (2012, *Analyse des refoulements dans les reseaux de drainage urbain,* Memoire presente a l'Ecole de Technologie Superieure, l'Universite du Quebec, 217 p.

Malczewski J. (1996), *A GIS-based approach to multiple criteria group decision making,* International Journal of Geographical Information Systems 10(8), 955-971.

Malczewski J. (1999), *GIS and Multi-Criteria Decision Analysis*, Wiley: New York, NY, USA, 1999.

Renaud H. (2006), *Analyse d'images satellitaires d'inondations pour la caracterisation tridimensionnelle de l'alea et l'aide a la modelisation hydraulique*, these de doctorat a l'ecole nationale du genie rural, des eaux et forets centre de Montpellier, 15 p.

Salomon V. A. P., Montevechi J. A. B. (2001), *A compilation of comparisons on the analytic hierarchy process and others multiple criteria decision making methods: some cases developed in Brazil*, Proceedings of the 6th ISAHP, Berne, Switzerland, pp. 413-420.

Sami G., Hadda D, Mahdi K. (2016), *Flood hazard map in the city of Batna (Algeria) by hydraulic modeling approch*, Analele Universităţii din Oradea, Seria Geografie Year XXVI, no. 1/2016 (June), pp. 86-93.

Yashon O. Ouma Ryutaro Tateishi (2014), *Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric AHP and GIS: Methodological Overview and Case Study Assessment*, journal of Water, 2014, 6, 1515-1545; doi: 10 3390/w 6061515.

*** (2012), *Direction de la Planification et l'Amenagement du Territoire equivalent to the Planning and Territorial Development Authority* (DPAT).

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