Mapping flood vulnerability. Case study: Tecuci Town (Romania)

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Abstract: Floods represent a natural risk with a very high frequency, which yearly produce important material and human losses. Therefore, developing some detailed maps regarding floods vulnerability imposes. For the accuracy of representation, these must be done at high scales. The present paper aims to present the way the floods vulnerability map was done (using SIG and remote sensing) for an urban space, namely the Tecuci town. This is situated in the north of the Romanian Plain, in the Tecuci Plain, where geomorphologic, climate and especially hydrological factors favoured the occurrence of these phenomena. The most serious floods produced in the year 2007 here proved the high vulnerability to floods. The following types of areas distinguish on the map: areas with low floods vulnerability, areas with medium floods vulnerability, areas with high floods vulnerability and areas with extreme floods vulnerability. The map we propose is based on a qualitative evaluation, firstly done by field research and with an immediate practical utility.

Key words: flood, vulnerability, map, qualitative analysis, Tecuci, Romania

1. Introduction

The mapping of vulnerability is based on its analysis and evaluation. In the international specialised literature, there are numerous papers regarding its analysis and evaluation, but much less papers related to the mapping itself (methods, techniques).
Thus, the most recent papers belong to Aviotti (2011), who presents in his doctoral thesis different analysis methods of floods vulnerability, with

examples for dwellings. Fekete (2012) marks out some particularities of the evaluation methods of floods vulnerability based on some case studies done in Germany. Also, at European level, within the FLOODsite project, a methodology of evaluating the damages produced by floods was developed, having as a basis the multicriterial analysis applied using SIG. The floods' risk management is treated in numerous works as those of Barroca et al. 2005; Lara et al. 2010; Leone et al. 2010; Santangelo et al. 2011; Thakur et al. 2012.

In Romania, the methodological aspects regarding floods vulnerability, or the applying of some already established methods for different spaces, especially for those where the possibility of floods occurence is high, are treated in a few works. Most of the works envisage hasards, their characteristics and their impact.

The papers in which methodological aspects are treated, too, refer to vulnerability evaluation at different types of geomorphologic processes (firstly landfalls), but they can be extrapolated to floods, too. Thus, we mention the paper of Armaş (2006), where vulnerability evaluation methods are divided into three categories: summative, based on probability and factorial analysis.

In Romanian literature, we can notice that floods were given mainly a hydrological attention, namely the occurrence way and development of flood, levels and discharges which generated floods, prognosis measures regarding their occurrence (Chelcea 2011; Pandi 2010; Podani 1981; Stanciu et al. 2005) and less their impact upon the inhabited space.

The analysis and spatial evaluation of floods vulnerability is done on the basis of vulnerability map, on which the degree (intensity) of vulnerability of different areas is emphasized. Usually, several classes ae differentiated, the analysis being qualitative (low, medium, high, very high) or quantitative, depending on the scope of the analysis and the criteria which were taken into account. In order to accomplish these maps, different SIG softs and the data resulted and adapted from the satellite images must be used. For the accuracy of the demarche, the scale the mapping is done is very important.

The aim of this paper is to assess and map the vulnerability to flooding of an area (Tecuci Town) where such phenomena have been present since 2007. The intention behind our effort is to prepare a detailed map (scale 1:5000) of the areas that in September 8th, 2007, suffered serious flooding that resulted in human loss and significant material damage.

The analysis we propose is a qualitative analysis and it is firstly based on the observations and mappings from the field researches.

2. Study area

Tecuci Town lies in the northeastern part of the Romanian Plain (Tecuci Plain), at the junction of Bârlad and Tecucel rivers (*Figure 1*). Its natural setting shows a number of specific features that make it vulnerable to floods. These are related to the geomorphologic, hydrological, meteorological, demographic and socio -economic (included land use) factors, from among these the hydrological factor having the highest importance.

From the geomorphologic point of view, Tecuci town is situated at the junction of Bârlad and Tecucel rivers, in a low, grassland area, with reduced declivities, which favours floods occurrence. The town is situated at altitudes between 50 and 150 metres. The geological sublayer is made up of sedimentary rocks, of different ages (mostly Quaternary), permeable, which determine a rich underground outflow (*Figure 1*).

The analysed space is crossed by Bârlad, which receives Tecucel and Rateş as affluents.

Bârlad river crosses the town on 8 km distance and it characterises by shallow winter waters (reduced quantities of precipitations and their blocking under the form of snow or ice), high waters in March (rains and the melting of snows), shallow waters in April-May, high floods in August and shallow waters in summer-autumn (lack of precipitations). The occurence of high floods, together with floods, as those in 1969, is possible during the period February-May. In order to prevent floods, the riverbed and the grassland were embanked in order to protect the districts situated in the eastern part of the town: Criviţeni, Buda, Peri. Its multiannual capacity is of 8,33m^3/s (Zaharia et al. 2008; Zaharia et al. 2009).

Tecucel river crosses the town on a length of 8,2 km and it has an average annual capacity of 0,38m^3/s. In summer, the beck dries out, but in autumn and in spring it carries a high liquid and solid capacity, due to heavy rains (Zaharia et al. 2008; Zaharia et al. 2009).

Rateş beck crosses Tecuci on a length of 8,4 km, the junction with Bârlad being in the south of the town. This was canalized in 1980, as a measure of defence against floods (Zaharia et al. 2008; Zaharia et al. 2009).

The biggest high flood on the Tecucel river produced in September 2007, when over 60% of the intravilan of the town Tecuci was flooded, 2210 houses were affected, from among which 392 were evaluated as being 100% destroyed, 201 km of roads were declared impracticable, the infrastructure of public utilities was strongly damaged (Zaharia et al. 2008; Zaharia et al.2009).

The damages of human nature were important, 3 persons left their lives, 4887 were seriously affected (11,11% of the town population), 473 wells were cogged up, 150 cars were damaged. The duration of water stagnation was between 8 hours and 3 days, the height of the water column being between 5-150 cm. The total cost of the damages was estimated at 6 million euros (Zaharia et al. 2008; Zaharia et al. 2009).

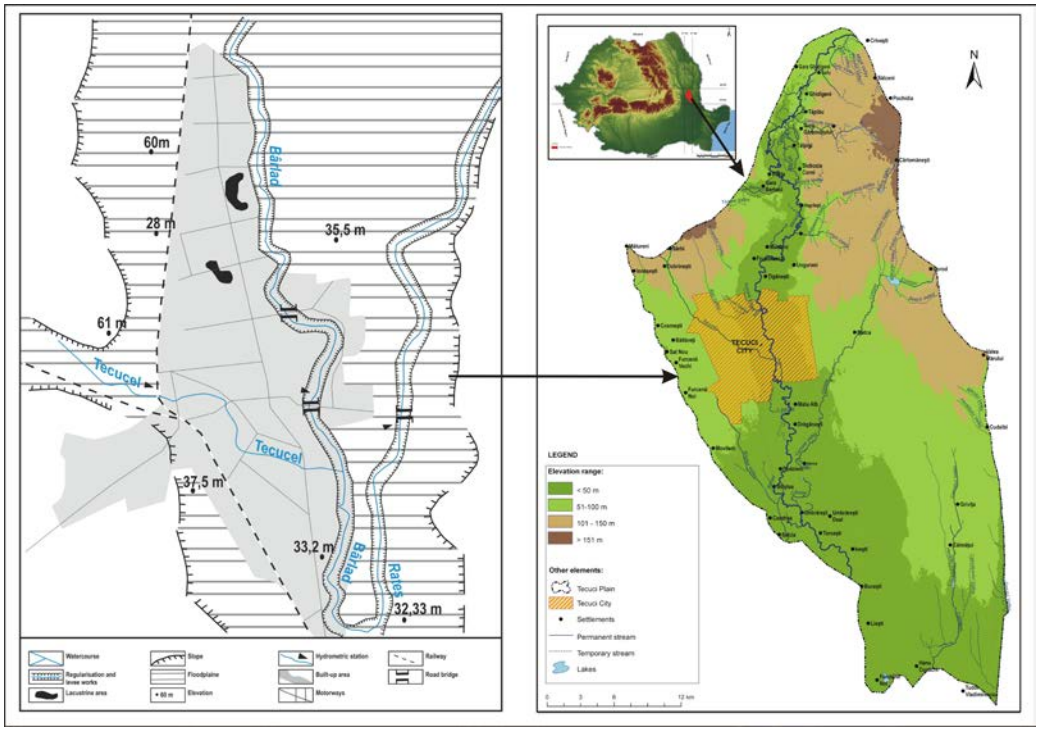

Figure 1. The geographic position of the town Tecuci within Romania and Tecuci Plain (after Zaharia et al. 2008 modified)

3. Methodology

In order to develop the floods vulnerability map, a database must be created, and this should comprise:

- Terrain features, assessed with GIS techniques (altimetry, altitudinal steps, channel dynamics, channel characteristics, hydro technical works);
- Data gathered following some field campaigns (measurements, mappings, observations, questionnaires applying, gathering demographic and socio- economic information);
- Studying the different types of cartographic supports and the bibliographic sources;
- Hydrological characteristics of the Bârlad and Tecucel rivers, based on the data provided by the National Institute of Hydrology and Water Management (mean daily discharges, mean daily levels, rating curves, recorded floods)
- Meteorological conditions, relying on the data collected from the National Meteorological Administration (mean daily precipitation, mean daily temperatures, evapotranspiration)

All numerical data (meteorological and hydrological) were analyzed and interpreted thoroughly, in order to avoid the occurrence of potential errors. The results were processed by using statistical techniques as well, which allowed the computation of a number of indices that emphasize the general evolution trend. Under the circumstances, we were able to use the most accurate datasets for our GIS analyses *(Figure 2)*.

In order to develop the floods vulnerability map, we used the following software and digital outcomes (Ioniţă 2011):

- The digital terrain model provided by the National Agency for Cadastre and Land Registration (N.A.C.L.R.), having an altimetric accuracy of 0.5 m along the main rivers and 0.5 – 2.5 m for the rest of the area;
- The land use map of scale 1:50000 in ArcInfoshapefile format;
- The geological map of scale 1:200000 in ArcInfoshapefile format;
- Orthophotoplans of 0.5 m resolution.

The data processing was done by using SIG (ARCGIS soft). This allows the development of correct, detailed cartographic materials and it offers the possibility of combining the different factors taken into consideration by operations of cartographic algebra, of achieving automatic classifying (Punithavathi et al 2011). Another advantage of using SIG was the possibility to permanently update, in real time, the created and exploited database (*Figure 2*).

The use of the techniques in the field of remote sensing is very important, as it offers, by means of different types of images, from different flights, information firstly qualitative (the extension of flooded surfaces, damages produced etc) in relation with little accessible spaces.

4. Results and discussion

The resulting vulnerability map suggests that Tecuci Town, thorough its geographical position and geomorphological features, lies in an area where flooding is a common phenomenon. Consequently, one can identify the following types of areas: areas never affected by floods, with low flooding vulnerability; areas affected by exceptional floods, with medium vulnerability, and areas often affected by flooding, where vulnerability is high. Every type of vulnerability was mapped differently, by using specific indices *(Figure 2)*.

It can be noticed that in the western part of the town floods vulnerability is much higher than in the eastern part, due to the geographical position and also to the fact that on the Bârlad river important measures against flooding were taken.

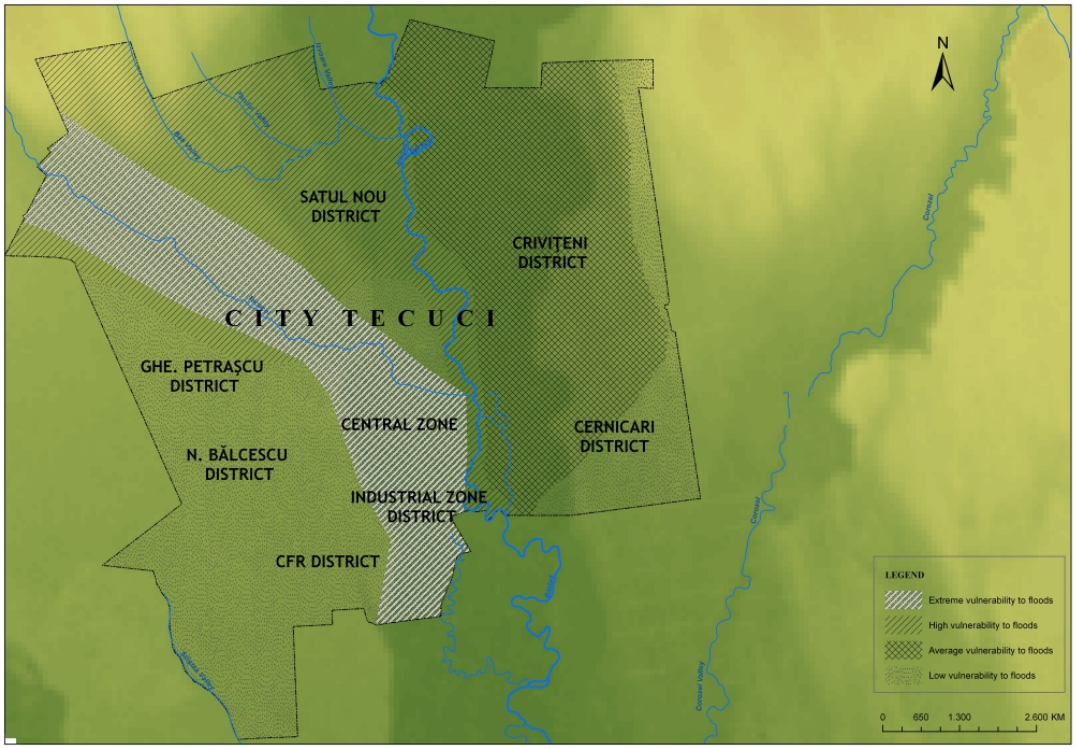

Figure 2 The floods vulnerability of the Tecuci town

5. Conclusions

Tecuci City presents a high vulnerability to flooding, due to its situation in a bottom land, as well as due to the fact that on the area of the locality the rivers Bârlad, Tecucel and Rateş meet. The river Tecucel with low debit, has got a weak development degree, thus presenting a high risk of colmation, being partially covered by vegetation. This was noticed following the hydrological event from September 2007.

The map we propose can constitute a useful instrument for local authorities with the purpose of preventing the occurence of such events in the future, but also for projecting the most correct and adequate structural and non-structural measures.

This map constitutes only the preamble for other cartographic materials, namely the development of a vulnerability map on quantitative basis.

6. Acknowledgement

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7. References

Armaş I (2006) Risc şi vulnerabilitate. Metode de evaluare aplicate în geomorfologie. Ed. Universităţii din Bucureşti.

Aviotti A (2011) Contribution à la caractérisation de la vulnérabilité de l'habitat individuel face à l'inondation. Vers un outil d'autodiagnostic. These de doctorat. MINES ParisTech, Centre de Recherche sur les Risques et les Crises, Sophia Antipolis, 264 p.

Barroca B, Pottier N, Lefort E (2005) Analyse et évaluation de la vulnérabilité aux inondations du bassin de l'Orge ava., Septièmes Rencontres de Théo Quant, janvier 2005, http://thema.univ-fcomte.fr/theoq/pdf/2005/TQ2005%20ARTICLE%2010.pdf

Chelcea M (2011) Resursele de apă de suprafaţă din bazinul hidrografic al râului Bârlad. Teză de doctorat. Institutul de Geografie al Academiei Române.

Fekete A, Marion Damm M, Birkmann J (2010) Scales as a challenge for vulnerability assessment. Nat Hazards 55: 729–747.

Ioniţă Fl (2011) Formarea viiturilor şi delimitarea zonelor inundabile în bazine hidrografice. Teză de doctorat. Universitatea Tehnică de Construcţii, Bucureşti.

Lara A, Saur D, Ribas A, Pavon D (2010) Social perceptions of floods and flood management in a Mediterranean area (Costa Brava, Spain). Nat. Hazards Earth Syst. Sci. 10: 2081–2091.

Leone F, Meschinet de Richemond N, Vinet F (2010) Aléas naturels et gestion des risques. Presses Universitaire de France, 288 p.

Pandi G (2010) Undele de viitură şi riscurile induse. Riscuri şi catastrofe.9, 2: 65-72.

Podani M (1981) *Inundaţii*, Hidrotehnica, Bucureşti.

Punithavathi J, Tamilenthi S. Baskaran (2011) Flood zone mapping of Thanjavur district, Tamilnadu using GIS. Advances in Applied Science Research 2 (2): 437-449.

Santangelo N, Santo A, Crescenzo G Di, Foscari G, Liuzza V, Sciarrotta S, Scorpio V (2011) Flood susceptibility assessment in a highly urbanized alluvial fan: the case study of Sala Consilina (southern Italy). Nat. Hazards Earth Syst. Sci. 11: 2765–2780.

Stanciu P., Nedelcu G., Nicula Gh., (2005), Hazardurile hidrologice din România, Natural and anthropogenic hazards 5 (23): 11-17.

Thakur P.K., Maiti S.C., Kingma N.C., Prasad H.V., Aggarwal S. P., Bhardwaj A., (2012), Estimation of structural vulnerability for flooding using geospatial tools in the rural area of Orissa, India, Nat Hazards, 61, p. 501–520.

Zaharia, L., Catană S., Crăciun E., Toroimac- Ioana G., (2008), *Flood vulnerability of Tecuci city: The rol of natural and socio- economic factors*, Riscuri şi catastrofe, vol. VII, nr. 5: 130-140.

Zaharia, L., Toroimac- Ioana G., Crăciun E., Gogu S., (2008), *Impacts des événements climatiques extrêmes: les crues éclairs. Le cas de la rivière Tecucel (Roumanie)*, Actes du Colloque de l' AIC, Montpellier.

Zaharia L., Catană, S., Popa D., Crăciun, E., Crăciunescu V., (2009), *Synergetic factors of the cathastrophic flood affecting Tecuci City (România) in September 2007*, in *Road Map Towards a Flood Resilient Urban Environment*, Proceedings Final conference of the COST action C22 Urban Flood Management in cooperation with UNESCO-IHP,Paris, 26/27.11.2009