# GIS ANALYSIS OF POPULATION EVACUATION FROM FLASH FLOODS – CASE STUDY, ȚÂȘLA DRAINAGE BASIN, ROMANIA

***A. SIMA[1 2], C. MOLDOVAN[2], H. MELEG[2], ADELA BOLCAȘ[2]***

**ABSTRACT. - GIS analysis of population evacuation from flash floods – case study, Țâșla drainage basin, Romania.** Țâșla watershed, composing sub-basin of the larger Vișeu basin, is a highly anthropic area, with an extremely packed residential and transportation infrastructure, mainly along the Țâșla watercourse. Mining and tourist activities have always been and still are the outcome of a great natural potential, this fact leading to the area always getting ranked as one of the top economic centers in Maramureș County. The high frequency of flash flooding is jeopardizing the socio-economic progress of the area, causing substantial damage. This paper's goal is the adaptation of a GIS tool, proposed by researchers from the U.S. Geological Survey – USGS (Jeanne M. Jones, Peter Ng, Nathan J. Wood, 2014), used in the flash flooding population evacuation analysis, etc. This method is based upon the digital elevation model, land cover, hazard zones and safe zones analysis. The results (evacuation time, evacuation corridors, etc) can be a relevant contribution to the decision making management of the emergency situations.

**Keywords:** GIS, Tâșla, flash flood, evacuation, population.

## 1. INTRODUCTION

Țâșla river's basin is a small, mountain type, drainage basin (103 km²), relatively symmetric, located in the Maramureș Mountains, morphologically complex and also highly anthropic. Țâșla River springs at the altitude of 1600m in Cearcănu Massif and crosses Baia Borșa, the region's most important mining area. Until it's confluence with Vișeu River, in some places, the phenomenon of fissuring waters occurs, mostly concentrated in the old mines, but with significant flows (Fig. 1, Fig. 2).

The morphogeographical characterstics and the atmospheric movement from the west, which generates considerable rainfall, facilitates the emergence of highly hazardous hydrological processes, bringing a negative impact to the inhabited area. Testimony to these phenomena are frequent flash floods, recorded at the Baia Borșa hydrometric station, some of them with significant values (Table 1).

[1] "Babeș-Bolyai" University, Faculty of Geography, Cluj-Napoca, Romania, e-mail: andrei.sima@geografie.ubbcluj.ro

[2] Pro GIS Solutions SRL-D, Cluj-Napoca, Romania, www.pro-gis-solutions.ro, e-mail: pro.gis.solutions@gmail.com

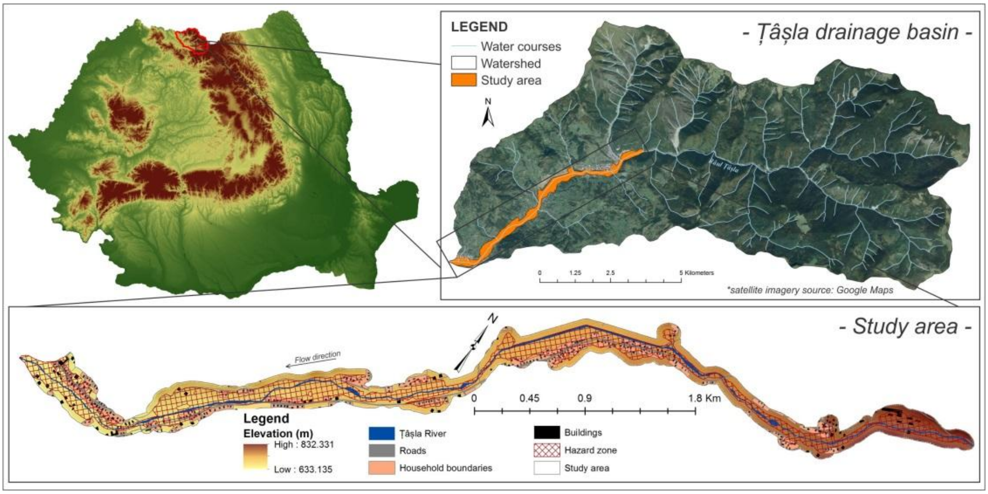


**Fig. 1.** ***Study area location***

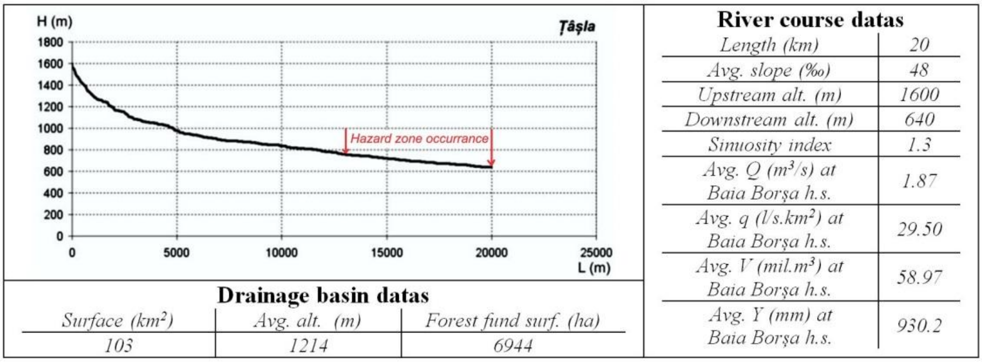


**Fig. 2.** ***Țâșla River and drainage basin characteristics***

**Table 1.** ***The characteristics of the significant flash floods in Țâșla drainage basin (source: "Romanian Waters" National Administration)***

| Flash flood | Q (mc/s) | | T (ore) | | V (mil.m$^3$) | | | hs (mm) | γ |
|---|---|---|---|---|---|---|---|---|---|
| | Max. | base | total | rising | total | basic | drained | | |
| ***Jul. 1974*** | 42 | 3.78 | 120 | 20 | 5.982 | 2.739 | 3.243 | 36.9 | 0.33 |
| ***Dec. 1995*** | 5.9 | 1.12 | 216 | 38 | 2.965 | 1.555 | 1.41 | 16 | 0.65 |
| ***Nov. 1998*** | 9.1 | 3.02 | 168 | 48 | 3.218 | 1.826 | 1.391 | 15.8 | 0.58 |
| ***Mar. 2001*** | 14 | 0.525 | 86 | 59 | 2.61 | 1.08 | 1.53 | 23.8 | 0.35 |
| ***Jul. 2008*** | 86 | 5.71 | 149 | 62 | 12.15 | 3.089 | 9.061 | 102.96 | 0.26 |

## 2. METHODOLOGY AND DATA BASE

***Methodology.*** This software's practicability and the methodology of evacuation time appraisal in the tsunami phenomena, submitted by works in the specialized literature, have convinced us to use them in our case study. The methodology and software shaped by the USGS are available in the work of Jeanne

M. Jones & co, 2014. We didn't go further of creating and analyzing the evacuation surface. The methodology and the tools according to this are presented in Fig. 3.

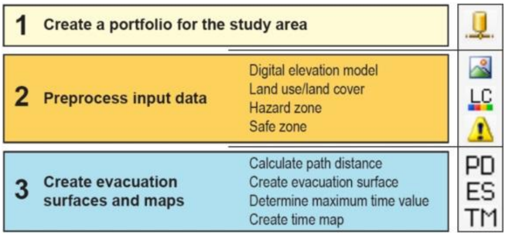


**Fig. 3.** ***Methodology (Jones J.M .& co., 2014)***

***Database***. First of all it was the data preparation. The area upon which the study was made represents the hazard zone of the Țâșla drainage basin. The database we needed for this model was comprised of the basin's DEM raster (Digital Elevation Model) with a 7 meter resolution, the basin's Land Cover shape files which includes the base land-cover (obtained from Corine Land Cover 2006), shape files with digitized roads, buildings, household boundaries and river courses from 1:25000 maps and also the vector shape files representing hazard zones digitized from the 0.1% hazard maps, part of the 207/60/CE Directive, published online by "Romanian Waters" National Administration and INHGA.

## 3. STEPS USED IN PEDESTRIAN EVACUATION ANALYST

The ***Pedestrian Evacuation Analyst software*** determines the evacuation potential assessing variables such as elevation, direction of movement, land cover, travel speed and creates a map showing travel times to safety (a time map) throughout a hazard zone. This tool uses the least-cost-distance (LCD) algorithm, and the simulation's results provide a general, static view of the evacuation landscape at different pedestrian travel speeds and can be used to identify areas outside the reach of naturally occurring high ground. The steps followed in the pedestrian evacuation analyst software are presented below.

***Creating a portfolio for the study area.*** On first using the Pedestrian Evacuation Analyst, we had to create an Evacuation Analyst database in the Portfolio Manager. This database will store and manage all the user's transactions performed using the Pedestrian Evacuation Analyst (Jeanne M. Jones & co., 2014).

***Preprocessing input data.*** *Digital Elevation Model Preprocessing* identifies the projection and the study area for the scenario. In this step the DEM is entered into the tool along with the study area. The basin's DEM includes the hazard zone and a clipped buffer of 50 meters from this hazard-zone.

*Land Cover Preprocessing* combines all inputs related to land cover into a single layer and uses this to create the cost-inverse raster. Beforehand, a correlation between types of land uses, for the Base Land Cover, had to be made (Fig. 4), and lastly adding respectively the values for the default speed conservation index (Soule and Goldman, 1972) (Table 2). As ancillary layers we also added the manually digitized vector shape files containing individual buildings along with household boundaries, roads and watercourses. They had to be entered in a certain order as seen in Table 3.

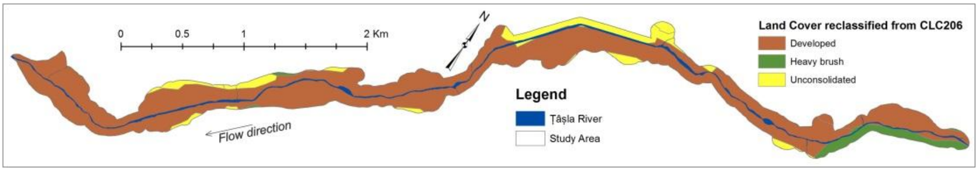


**Fig. 4.** ***Land Cover map of study area***

**Table 2.** ***Default speed-conservation values (SCV) and their corresponding land-cover types***

| Land cover type | SCV |
|---|---|
| Water, buildings | 0 |
| Unconsolidated | 0.5556 |
| Heavy Brush | 0.6667 |
| Developed | 0.9091 |
| Roads | 1 |

**Table 3.** ***Typical land-cover layer ordering for the cost-inverse raster of the Pedestrian Evacuation Analyst***

| Land cover layer | Order |
|---|---|
| Base Land Cover | 1 |
| Water | 2 |
| Roads | 3 |
| Households | 4 |
| Buildings | 5 |

*Hazard-Zone Preprocessing.* The hazard zones were introduced in software. After this, the software generated from the entire study area and those hazard zones a new shape file representing the safe zones. For validation it was important to manually examine the resulting safe zone polygons for correctness and to remove any erroneous polygons

***Creating evacuations surface and maps.*** The *Path Distance Surface Creation* tool calculates the travel distance from every cell in the study area to the nearest safe zone. The resulting path distance raster is ready to be multiplied by the travel speeds that are to be set in the next step.

*Evacuation Surface Creation.* In the next table (Table 4), we set the travel speed categories by which the path distance raster will be multiplied thus, obtaining the evacuation-time surface containing the travel times in minutes to safety.

*Time Map Generation.* This is the last step, in which a time map is generated from every evacuation surface raster by reclassifying the surface into an integer raster at 1-minute increment bands.

**Table 4.** ***Travel-speed names and corresponding values in the Pedestrian Evacuation Analyst***

| Travel speed name | Travel speed value (m/s) |
|---|---|
| Slow Walk | 0.91 |
| Average Walk | 1.22 |
| Fast Walk | 1.52 |
| Slow Run | 1.79 |
| Average Run | 2.68 |
| Fast Run | 3.85 |

## 4. RESULTS

According to the work steps shown earlier there have been attained a number of 12 maps of evacuation time analysis of floods in the 0.1% probability of occurring, 6 of them modeled based upon the natural setting alone (Fig. 5), and the other 6 are modeled based upon the natural and anthropic setting as well (Fig. 6).

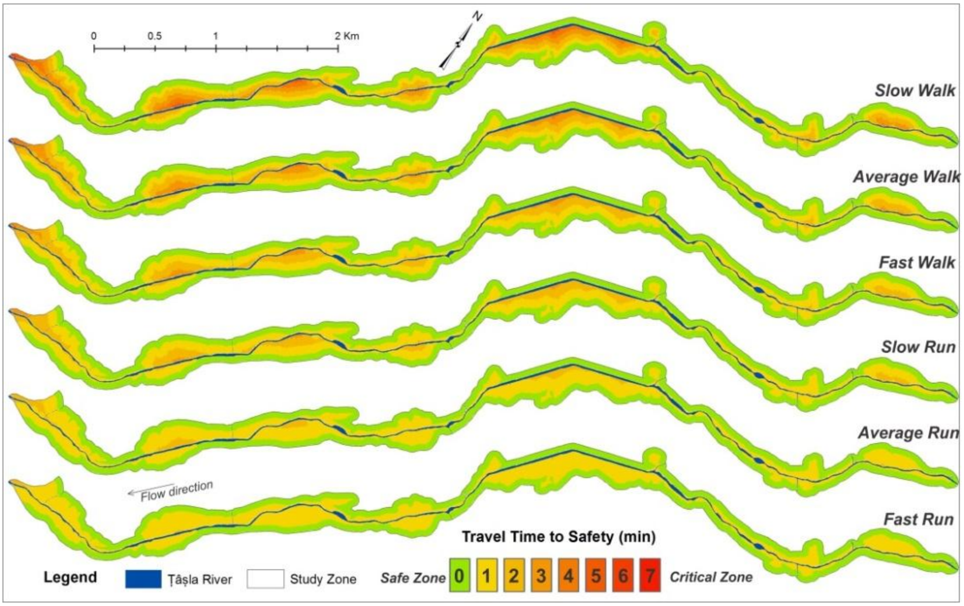


**Fig. 5.** ***Evacuation time maps based on natural setting (base model detail)***

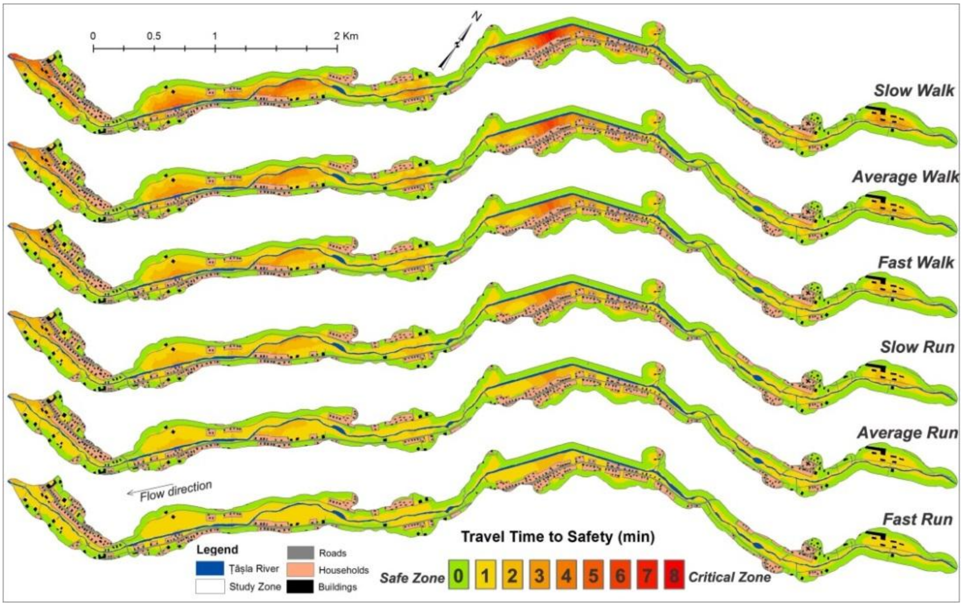


**Fig. 6.** ***Evacuation time maps based on natural and anthropic setting (infrastructure model detail)***

## 5. DISCUSSIONS

An important aspect of our analysis is the correctness of defining our safe zone. That's the reason why so much importance had been given to the process of validating the safe zone. For example the island polygons inside hazard zones were removed because they don't offer a real safe zone for inhabitants.

The determined models represent only theoretical results obtained, upon a series of the study area's internal and external factors. It can easily be noticed the evacuation times' dependence to the terrain's relief, land use and the theoretical travel speeds.

By introducing the resulting set of models based upon the natural setting, we tried to emphasize the anthropic influence over an affected area's evacuation process. This fact can be seen also from the table further lower, by comparing maximum evacuation times to the most fitting models focused on our population. (Table 5).

**Table 5.** ***Correlation between model's details and maximum travel speed***

| Max. travel speed / Model detail | Slow Walk | Average Walk | Fast Walk | Slow Run | Average Run | Fast Run |
|---|---|---|---|---|---|---|
| **Base** | 7 | 5 | 4 | 4 | 3 | 2 |
| **Infrastructure** | 8 | 6 | 5 | 4 | 3 | 2 |

The best evacuation times (maximum 2 min.), had been obtained from the Fast Run model. But in an emergency situation, every individual inside a vulnerable group will be moving by different speeds. These vary by one's age, sex, health, etc. Travel speeds presented in the work steps are just theoretical speeds. Thus, by comparing models, we agreed that the most relevant one for our study area is the Slow Walk model (0.91 m/s) having an evacuation time range of 1-8 min.

By analyzing the Slow Walk model we identified a number of 2 critical zones with the highest evacuation difficulty (red marked zones, 6 – 8 min evacuation time). These areas' correlation with zones characterized by dense infrastructure can easily be observed. Open spaces have no difficulty in the evacuation process, fact found in the smaller values of the time maps (Fig. 7).

## 6. CONCLUSIONS

Even though the method was originally used in the management of tsunami emergency situations, this case study proves its practicability even in areas affected by flash flooding, like Țâșla drainage basin.

This model would have been most practical if an emergency and estimation system for the flood's propagation wave existed from an upstream spot all the way downriver to the study area in case.

The improvement of our results can be achieved using a LIDAR generated DEM or one generated from level curves extracted from much more detailed maps than the ones we used.

For the reduction or even cutting down to half of our evacuation times, some vertical evacuation points could be inserted into the critical areas. These sites can be materialized by buildings or structures taller than the maximum level reached by a flooding at a 0.1% probability of occurring.

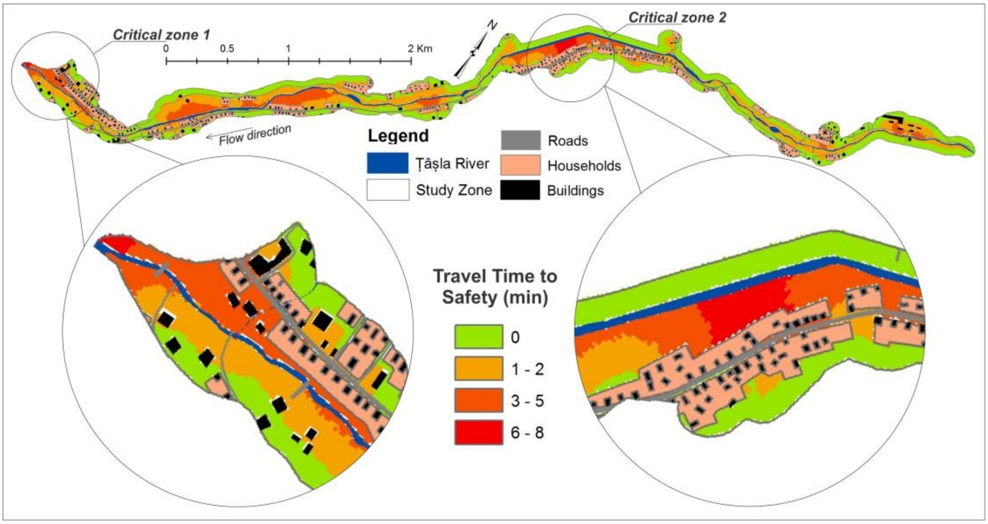


**Fig. 7.** ***Critical evacuation zones***

In critical places where modeled evacuation times exceed the event occurrence time, operators can use the software with emergency supervisors to assess these areas and population, allowing efforts to be concentrated on said vulnerable communities.

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