CHARACTERISTICS OF FLOODS IN PECHEA, GALAȚI COUNTY

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Abstract. Characteristics of the floods in Pechea village, Galați county. This study aims to develop risk analysis methodologies on floods, analyze floods produced on the Suhu River in Pechea village (Galați county), and factors that favor flooding. Flood analysis represents one of the main concerns of researchers in hydrology in the context of climate change. It is increasingly leaving its mark on the frequency of precipitation and, implicitly, on the production of floods. We presented the definitions of floods, and we presented the study area in the first part of the article. The monthly and seasonal frequency of floods were analyzed, and there were calculated specific parameters of a flood produced in the study area. Then, the factors that favor the occurrence of floods were analyzed. The results obtained will contribute to the complete information on floods in small basins in the plain area on the Romanian territory.

Keywords: flood, frequency, analysis, hazard, Pechea.

1. INTRODUCTION

Due to climatic changes, extreme events will intensify and their frequency is difficult to predict (Czigány et al., 2010). Climate change affects flood variables (magnitude and frequency), so an increasing number of studies are focusing on modeling the impact of climate change on floods (Booij, 2005; Gain et al., 2013; Raff et al., 2009).

In insurance contracts flooding is defined as a "temporary covering of land by water as a result of surface waters escaping from their normal confines or as a result of heavy precipitation" (Kron, 2005). Mustățea (2005) defines the flood: "The flood is the significant increase and decrease of water flow through the riverbed."

Floods are risk phenomena that have socio-economic implications, causing great human and economic losses, being the result of the interaction between anthropogenic and natural factors (Diaconu et al., 2021; Popa et al., 2019). River floods are natural hazards that cause among the greatest material damage. Globally, average annual losses are estimated at 104 billion $ and are

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projected to increase with economic growth, urbanization and climate change (Blöschl et al., 2019). There have been a lot of floods in Europe in recent decades with enormous economic damage (Blöschl et al., 2020).

The floods differ according to the size of the affected area and the duration of the event (Bronstert 2003). Floods are favored by the interaction of different processes (meteorological and hydrological processes) (Nied et al. 2014; Fischer et al., 2016). Heavy rainfall is not enough to produce floods. A whole set of morphometric and physical-geographical elements of the hydrographic basin (basin size, topography, slope, orientation, soil moisture, land cover, vegetation) drive to floods (Norbiato et al., 2008; Czigány et al., 2010; Stancalie 2009; Zelenáková et al., 2021, Pandi, 2010, Zaharia et al., 2015; Zaharia et al., 2017; Costache and Zaharia, 2017).

Floods cause most of deaths in Romania, more than any other natural phenomena. They occur in regions with a narrow spatial limitation. Floods in Romania occur in mountainous areas with deep valleys, but also in hilly areas (Stancalie, 2009).

This paper aims to analyze the characteristics of floods produced on the river Suhu, in the area of Pechea village (Galați county) and of the factors that favor flooding there. The work allows completion information on floods in small eastern river basins in Romania, a region less studied from a hydrological perspective.

2. STUDY AREA

The Suhu River is a river located between the plain area (Covurlui Plain) and the low hills area (Covurlui Hills). This is a tributary of the Siret River with which it converges on the South part of Independența village. The river basin belongs to the hydrographic space of Prut - Bârlad (Flood Risk Management Plan. Prut - Barlad Water Basin Administration, 2015).

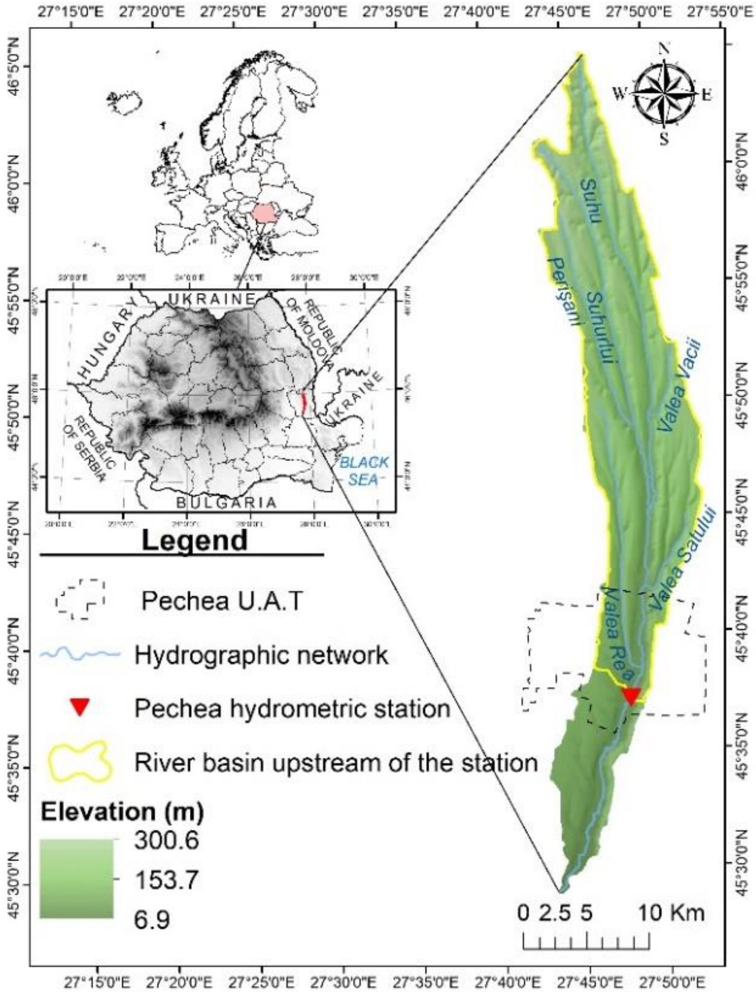
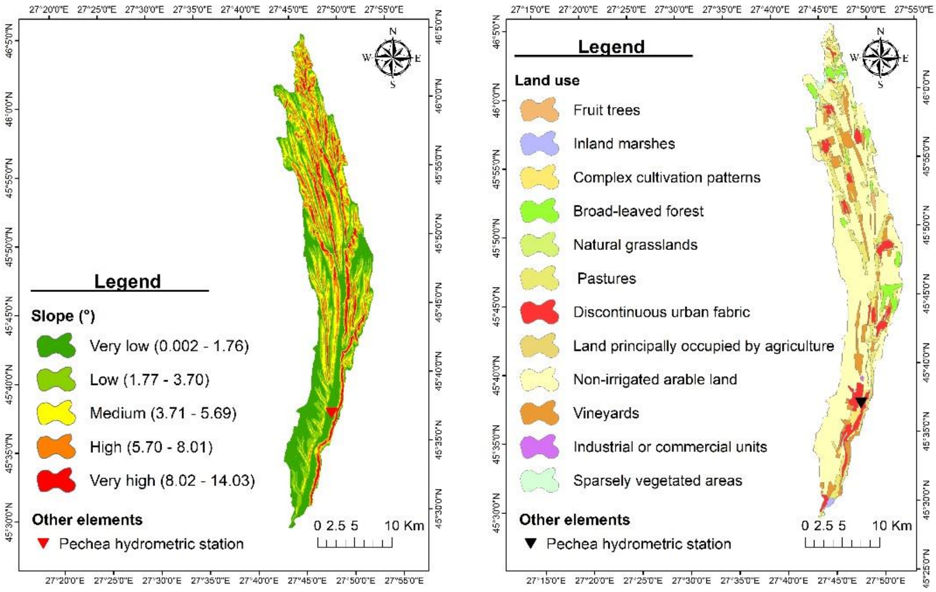


Fig.1. Location of the Suhu River Basin, the Hydrometric Station and Pechea

Suhu River basin has 378 km2 (Anuarul Hidrologic, 1974), an average altitude of 144 m, and an average slope of 3.54 ° (Fig.2 a). It is positioned both in the climatic zone of the plains and in the climatic zone of the low hills, being below the climatic influences of aridity and presenting annual temperature values of 8-10 °C and rainfall of 400-600 mm/year. Because of these climatic aspects, the area does not face floods except after floods. From the point of view of the land use (Fig.2 b) non-irrigated arable land predominates, which favors the drainage of water on the slopes in the absence of a rich vegetal layer.



a b

Fig. 2. Slope (Romania STRM, 90 m) (a) and the land use (Corine Land Cover 2018) (b) in Suhu River Basin

The analysis focuses on the Pechea village in Galați County (Fig.1). The village has an area of 115 020 km², around 10.152 inhabitants, and an agricultural profile (mainly) and industrial profile (secondary) (Environmental Report for the General Urban Plan, 2015). Pechea is located on the lower course of the Suhu river in a sparsely fragmented plain, and it consists of a complex of terraces. The valleys are parallel, they are oriented North-South, and they accumulate water only on floods (Environmental Report for the General Urban Plan, 2015). In its area, there is the hydrometric station Pechea, the only one in the Suhu basin, which allowed the analysis of floods produced on this river.

The Pechea hydrometric station is located at an altitude of 36.4 m. It controls an area of 312 km2 (National Institute of Hydrology and Water Management), representing 82.5% % of the total area of the river basin (378 km2, Anuarul Hidrologic, 1974), and it is located approximately 18 km from the confluence. In the minor riverbed and in the major riverbed, there are 4 hydrometric gauge, depending on the water levels, showing that after heavy rainfall, the level can rise quite a lot.

Fig.3. Hydrometric groom located on the river Suhu, at the Pechea hydrometric station (8.01.2021)

3. METHODOLOGY

For the analysis we used a GIS software (ArcGIS 10.3.1) and a statistical analysis (Excel) software. The first stage included analyzing the maximum annual discharge and exceeding the alert thresholds, the monthly and seasonal floods frequency. The data used for the flood analysis between 2004-2017 recorded at Pechea hydrometric station (Galati Water Management System). The alert rates used are for 2013.

In the second stage, the highest floods produced were analyzed by calculating specific parameters (Pişota, Zaharia, 2003; Pandi, 2010). The parameters that define a flood are initial discharge, maximum discharge, final discharge, base discharge, time of growth, time of decreasing, the total time, the growth volume, the decrease volume, the volume of the flood, the drained water layer, the shape coefficient, the ratios between parameters. These elements are determined on the basis of hydrographs of single flood and were calculated automatically in Excel.

a) Initial discharge (**Q_{in}**) represents the inflexion value of the rising limb base, where abrupt discharge change ratio starts, due to overlapping of surface and underground alimentation (Pandi, 2010). It is measured in m^3/s.

b) Maximum discharge (**Q_{max}**) represents the highest point value between hydrograph rising limb and recession limb (Pandi, 2010). It is measured in m^3/s.

c) Final discharge (**Q_{fi}**) is the inflexion value placed on the recession limb, where the surface alimentation cease and the flow is sustained only by underground alimentation. It is measured in m^3/s.

d) Base discharge (**Q_b**) is the debit flowed under normal drainage conditions which are recorded before and after the flood (Pişota, Zaharia, 2003). It is calculated based on formula (1):

$$Q_b = \frac{Q_{in} + Q_{fi}}{2}\ [m^3]\ (1)$$

where: Q_b-*basic discharge* (in m^3/s), Q_{bi}-*initial discharge* (in m^3/s), Q_{bf}-*final discharge* (in m^3/s).

e) Time of growth (**T_{gr}**) represents the duration (in hours) between the moment of the beginning of the flood and its peak flow (Pişota, Zaharia, 2003).

f) Time of decreasing (**T_{des}**) represents the duration (in hours) of water withdrawal, between the moment of production of the maximum flow and the return to the basic flow. It is usually longer than the increasing time (Pişota, Zaharia, 2003).

g) The total time (**T_t**) or the duration of the flood represents the number of hours in which the water flow was higher than the basic flow. It is determined by summing the partial times of increase (**T_{gr}**) and decrease (**T_{des}**) (Pişota, Zaharia, 2003) (2):

$$T_t = T_{gr} + T_{des}\ \text{[hours]} \qquad (2)$$

h) The growth volume (**V_{gr}**) represents the outline surface between rising limb, the vertical of maximum discharge and delimitation line of initial and maximum moments of discharge (Pandi, 2010). Analytical calculus relation is:

$$V_{gr} = \frac{Q_{in}}{2} + \sum_{2}^{n-1} Q_i + \frac{Q_{max}}{2}\ [m^3]\ (3)$$

where: Q_{in}-*initial discharge (in m^3/s*, Q_i - *discharges placed on the hydrograph delimitation line; n - number of values taken into consideration,* Q_{max} *–maximum discharge (in m^3/s).*

i) The decrease volume (**V_{des}**) represents the area delimited by the recession limb, vertical of maximum discharge and the delimitation line between the moments of maximum discharge and final discharge. With the same reasoning of analytical calculation, can be written (Pandi, 2010):

$$V_{des} = \frac{Q_{max}}{2} + \sum_{2}^{n-1} Q_i + \frac{Q_{fi}}{2}\ [m^3]\ (4)$$

where:Q_{fi}-*final discharge (in m^3/s)*, Q_i - *discharges placed on the hydrograph delimitation line; n – number of values taken into consideration,* Q_{max} – *maximum discharge (in m^3/s).*

j) The volume of the flood (***V***) represents the total volume of water, expressed by hydrograph (in m^3) (Pandi, 2010) (5):

$$V = \sum_{2}^{n} \frac{Q_i + Q_{i+1}}{2} * \Delta t \ [m^3] \ (5)$$

where: *W=maximum volume of flood* (in m^3), Q_{max}= *the peak flow* (m^3/s), T_t= *the total flood time* (in hours), γ= *the shape coefficient of the flood.*

k) The drained water layer (***h***) illustrates the thickness of a uniform layer of water (in mm) obtained by dividing the volume of water of the flash flood (***V*** in m^3) to the surface of the basin (***F*** in km^2) upstream of the considered section (Pișota, Zaharia, 2003). The layer of run-off water is calculated on the formula (6):

$$\mathbf{h} = \frac{\mathbf{V_s}}{\mathbf{F} \times 1000} \ [mm] \ (6)$$

l) The shape coefficient (***γ***) represents the ratio between the volume of the flow wave and the equivalent volume of a rectangle with Q_{max} and T_t as sides (Pandi, 2010). (5)

$$\gamma = \frac{V}{Q_{max} * T_t} \ (7)$$

where *V= volume of the flow* (in m^3), Q_{max}= *maximum discharge* (m^3/s), T_t= *the total time* (in seconds).

m) The ratios between parameters. To characterize the flow hydrographs and in order to check the correctness of delimitation, there are used some ratio computations. These refer to times and volumes (Pandi, 2010):

$$\frac{T_{gr}}{T_t}, \frac{T_{gr}}{T_{des}} \ sau \ \frac{V_{gr}}{V_t}, \frac{V_{gr}}{V_{des}} \ (8)$$

For the rivers of Romania, the ratio value T_{gr}/T_t is about 1/2 - 1/3 for the small hydrographic basins (50 - 100 km²) and about 1/3 – 1/5 for the big ones. The ratio V_{gr}/V_{des} is about 0,5 for the river basins where the flow concentration is very fast and around the unit where the development of the flood is slower (Pandi, 2010).

In the third stage, the factors favoring the occurrence of floods were analyzed as a result of floods produced. Altitudes, slopes, soil, land use, basin form, riverbed development and hydrogeological aspects were analyzed.

4. RESULTS AND DISCUSSIONS

4.1 Analysis of maximum annual flows

Between 2004 and 2017, the maximum annual flows exceeded flow rates corresponding to alert quotas in just four years. Thus, in 2008 the flow of attention (5.35 m3/s) has been overcome, being 7.88 m3/s. In 2017, the flood flow was exceeded (8.66 m^3 /s), registering a maximum flow of 9.24 m^3/s. Floods far exceed the dangerous flow (in 2013, 16.9 m^3/s). In 2013 the maximum flow was 56.2 m^3/s, and in 2016 it was 62.4 m^3/s.

The evolution trend of the maximum annual flows in the analyzed period is increasing, a fact also observed from the increased flows towards the end of the period. The polynomial trend highlights the small increases and decreases from the beginning of the period and a significant increase towards the interval (Fig. 4).

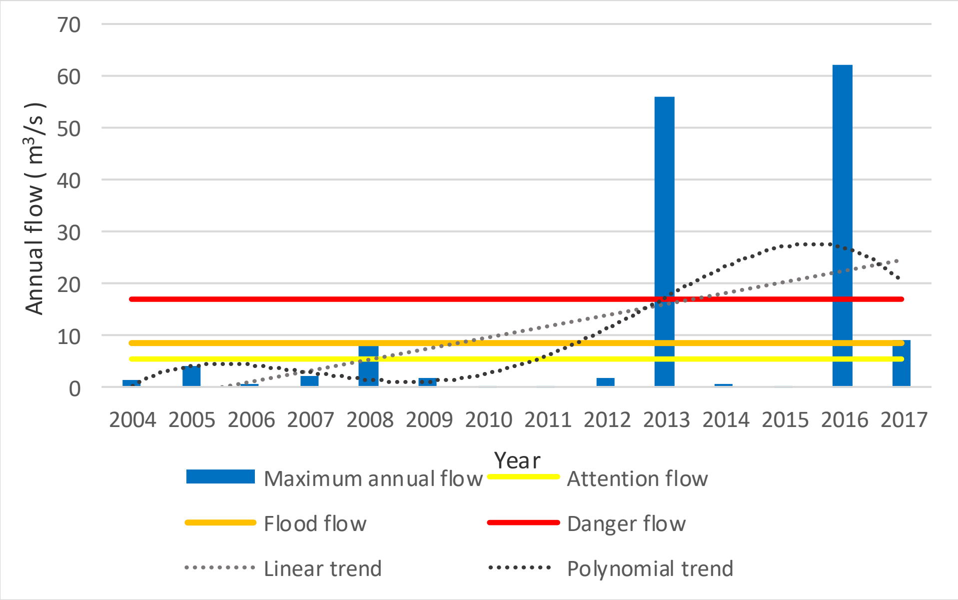


Fig. 4. The maximum annual flows of the Suhu River at the Pechea hydrometric station and those corresponding to the levels of attention, flood and danger

The monthly and seasonal frequencies of flow production were calculated as annual maximums, being expressed as a percentage of the total number of registered cases. The analysis of the monthly frequency shows that most of the yearly floods are produce in April (21.43%), February (14.29%), May (14.29%), and July (14.29). No annual floods were recorded in January, June, and December. The lack in June is caused by low rainfall. February is an exception. It records a high percentage, due to the sudden snow melting and the production of floods coming from snow.

At the seasonal level, spring floods have the highest frequency (46%), followed by the summer and autumn floods, both registering a percentage of 23%. In contrast, the minimum frequencies are recorded in winter, with only 8% of the total annual floods in the analyzed period.

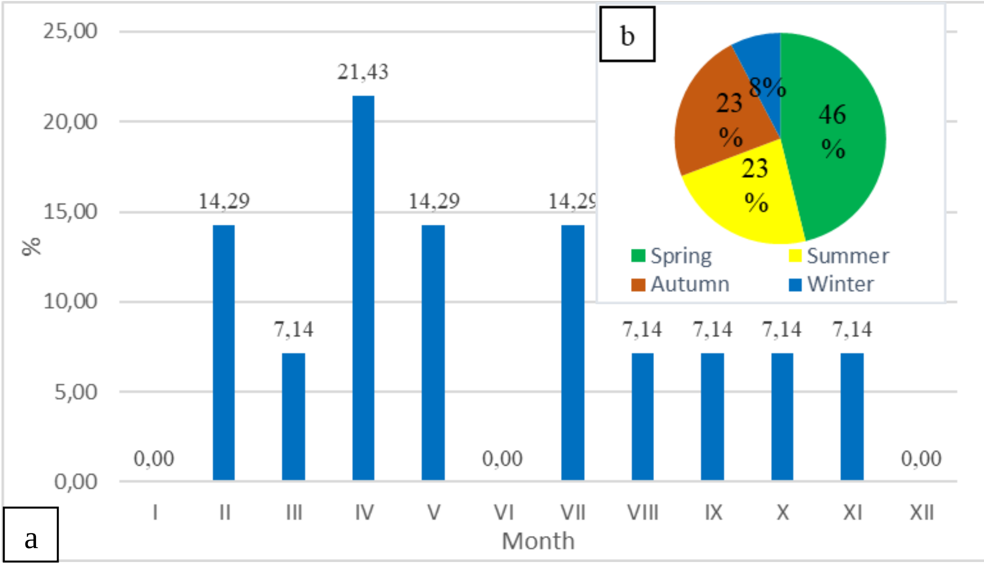


Fig. 5. Frequency (%) monthly (a) and seasonally (b) of the maximum annual river flows Suhu at the Pechea hydrometric station (2004 - 2017)

The high frequency during spring is due to heavy rainfall and melting snow in early spring. In summer, especially in July, the floods arise as a result of precipitation in the form of downpour, on the background of accentuated atmospheric instability during the summer. The autumn floods occur due to autumn precipitation. There is a constant frequency of floods in all three months, and the lowest frequency in the winter (December and January) is a consequence of precipitation in solid form and negative temperatures.

4.2 Analysis of flood waves

During the analyzed period (2004 - 2017), the highest flood occurred in 2016. In 2016, a simple flood was recorded that recorded a peak of 62.4 m^3/s on October 12 (11:00 A.M.).

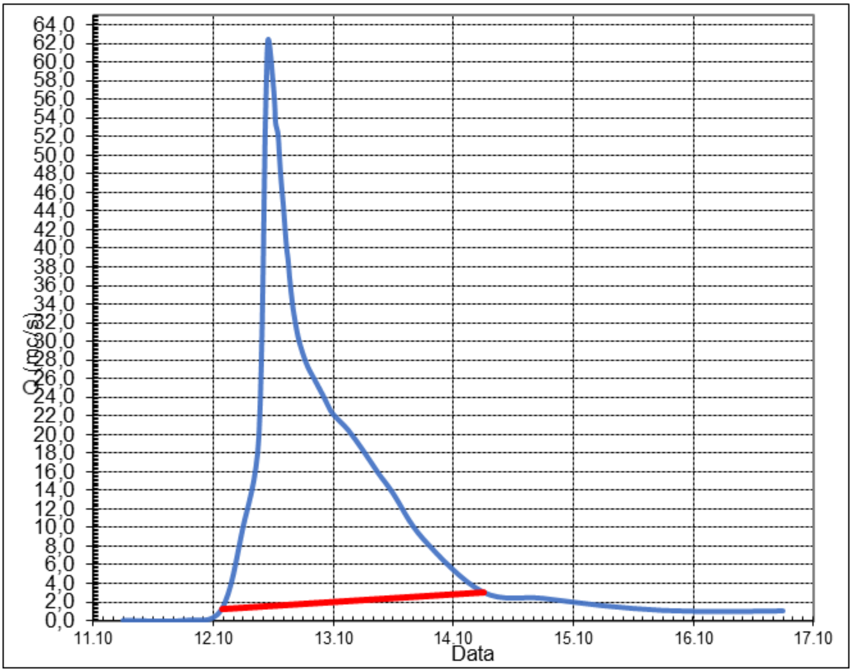


Fig.6. Monographic flood hydrograph produced on the Suhu River at the Pechea Hydrometric Stationin October 2016

Specific parameters of this flood are:
Initial discharge (Qin) was 1.23 m3/s;
Maximum discharge (Qmax) was 62.4 m3/s;
Final discharge (Qfi) 3.1 m3/s;
Base discharge (Q_b) was 2,16 m3/s;
Time of growth (T_{gr}) was 9 hours;
Time of decreasing (T_{des}) was 43 hours;
The total time (T_t) was 52 hours;
The growth volume (Vgr) was 0.82 m3;
The decrease volume (Vdes) was 2.68 m3;
The volume of the flood (V) was 3. 5 mil. m3;
The drained water layer (h) was 9.9 mm;
The shape coefficient (γ) was 0,30.
a.The ratio value T_{gr}/T_t is 0, 17 and the ratio V_{gr}/V_{des} is 0,3.

4.3 Favoring factors in the production of floods in the village of Pechea

The amplitude of floods is influenced by both natural and anthropogenic factors (Mustățea, 2005). The most important factors favoring the occurrence of floods are: the altitude, the slope, the basin form, the edaphic cover, the land use, riverbed development and hydrogeological characteristics.

The relief indirectly influences the flow through the slope. The conditions for the formation of runoff in a plain area are unfavorable due to the weak fragmentation and the low slope of the riverbed (Mustățea, 2005).

The altitude of Pechea is below 150 m, which is located in the meadow area and in the area from the meadow to the plain (Fig.7 a). Besides being located in a low area, the northern entrance of the village Pechea presents an area of hydrographic convergence: the Valea Rea stream meets the Suhu river, which leads to an increase of water volume that accumulates in the riverbed. The basin has an elongated shape that does not allow time for water in case of a flood to extend on the surface of the minor riverbed and thus flood the major riverbed and low terraces.

The slope in the village area is very low, between 0.002 and 5.40 ° (Fig. 7 b), fact which does not allow water to drain, favoring its accumulation and stagnation. Slopes correspond to the terrace fronts and favor the flow to the minor riverbed, where the urban area is located. This is also highlighted in the graphic profile made in the West-East direction (Fig.8).

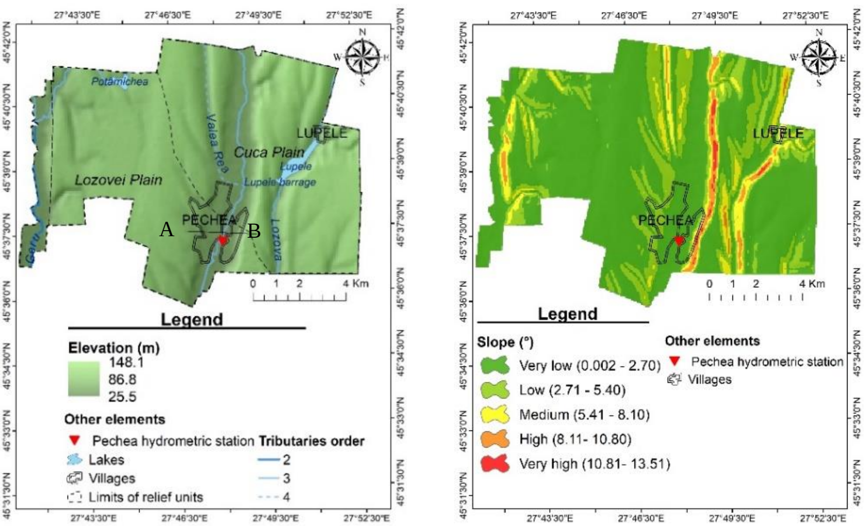


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Fig.7. Altitude (Romania STRM, 90 m) (a) and slope (Romania STRM, 90 m) (b) in the perimeter of Pechea locality

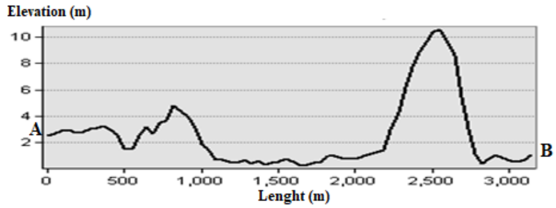

Fig. 8. Graphic profile made in the West-East direction

The soil cover highlights the presence of permeability, but the existence of alluvial soils in the meadow area and the shallow depth of the groundwater saturated substrate that cannot take up the significant volume of water (Fig. 9 a). According to Environmental Report for the General Urban Plan Pechea (2015) in the area there is a groundwater table with variable hydrostatic level on the vertical, starting at a depth of about 1.00 m, in the meadow area of the Suhu river, while in the rest of the territory of the village, the underground water was intercepted between 2.60-5.00 m of depth. The low depth of the groundwater and the low altitudes of the area that favors the accumulation of rainwater and poor drainage lead to flooding.

In terms of land use, the village of Pechea overlaps some urban/rural spaces and areas of complex cultivation (Fig. 9 b) due to aluvisols with high fertility. The built-up areas occupy the low sectors of the valley and it has a lower permeability, favoring the stagnation of water from precipitation and river overflow.

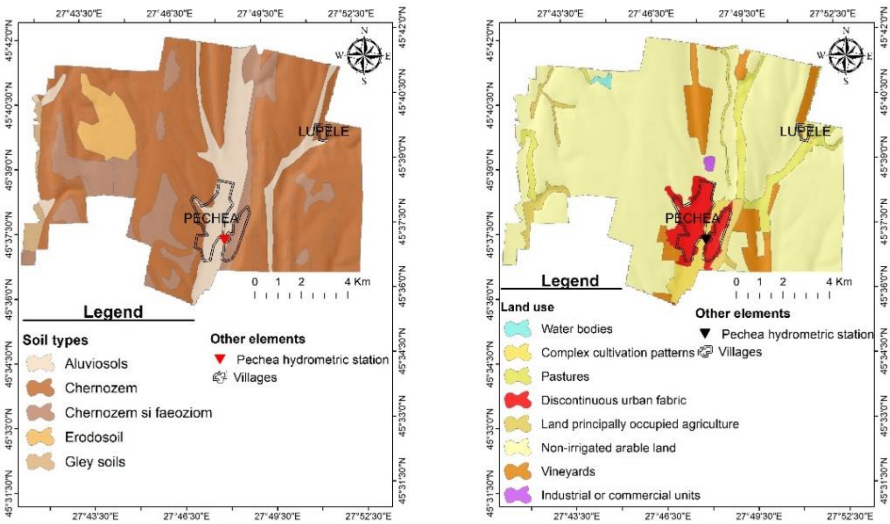

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Fig. 9. Soil cover (Romania Soil Map 1:200.000, SIGSTAR-200) (a) and land use land (Corine Land Cover 2018) (b) within the perimeter of the locality Pechea

5. DISCUSSIONS

Types of floods are differentiated according to weather conditions and previous conditions (Turkington et al. 2016; Nied et al. 2014). For example, Merz and Blöschl (2003) separated floods according to their generating processes in long-rain floods, short-rain floods, flash floods, rain-on-snow floods and snowmelt floods.

The flood registered in 2016 is representative for the territory of Pechea village. According to the classification of Merz and Blöschl (2003) it falls into the category of short-rain floods. The arguments are mentioned: the duration of the storm was from a few hours to 1 day (October 12), the deep rainfall was moderate to substantial rainfall (158.2 mm on October 12, according to the Galați Water Management System), catchment state was wet for flood event, runoff response dynamic was fast response (growth time at flood was 9 hours), spatial coherence was local or regional extension (flood caused damage in Pechea village and neighboring localities).

From the results obtained it can be seen that a very high volume of water was involved, producing floods, highlighted by photos from the village at that date (Fig. 10). It was a moderate flood, the increasing time being relatively short (9 hours).

Fig. 10. Images from Pechea village after the flood produced between October 12-14, 2016 (https://pechea.info/poze-inundatii-pechea-2016/)

6. CONCLUSIONS

Floods are dangerous natural hazards in terms of reaction time, and they trigger a large volume of water. They are very difficult phenomena to manage, both in terms of structural as nonstructural measures as well, because their frequency and the size of the impact is not known. Floods are difficult to predict, and especially in small-sized basins in the plain area, studies does not focus on their analysis.

Studies on floods should draw the implementing authorities' attention a plan of measures, especially structural ones, to reduce vulnerability. The current study aimed to analyze floods in a less studied area in Romania, which corresponds to the river basin of the river Suhu and the village Pechea from Galați county. Although it is a small basin in the plain region, due to the heavy rainfall, floods with high flow took place, which in the specific geographical conditions of Pechea village caused floods with significant damage. The results obtained can help complete information on floods in small basins in Romania's plain area.

The case of Pechea village, where a small river can channel a considerable volume of water and cause immense damage even in a plain area, shows that nature has immeasurable force.

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