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STUDIES REGARDING THE CAUSING OF FLOODING ON THE HYDROGRAPHIC BASIN OF PETRIȘ VALLEY

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Abstract. *Throughout history, humans have tried to change and shape their environment to meet their basic needs, such as food and shelter. Water has always had a special significance in human consciousness, and its perception since ancient times can be understood from two distinct perspectives: the continuity of life on earth and at the same time its destructive power. At the same time, water has also been perceived as an element with significant destructive potential, especially in terms of floods and the natural disasters associated with them. This perspective reflects the violent side of water, which can have devastating consequences when it gets out of control. This duality of water, as a source of life and as a destructive force, has given it a special place in myths, cultures and human thinking over the centuries. Thus, studies and research are carried out to understand and control environmental factors, which under certain conditions can be considered risk phenomena. In the present work, the conditions of flooding production in the Petriș Valley, located in the Mures river basin, a region characterized by geographical diversity and its significant impact on the environment and local communities, are investigated. This article provides a comprehensive analysis of the Mures river basin, highlighting the geographical features, relief, climate, and hydrological infrastructure surrounding it. It also discusses past extreme climatic events and measures taken to protect inhabited areas from flooding.*

Key words*: flooding, hydrographic basin, climate change, flow, runoff*

INTRODUCTION

More and more we are feeling the effects of climate change in recent years. These effects are manifested by dry periods followed by very rainy periods that produce disastrous hydrological phenomena (HÂNCU, 2008) (ȘMULEAC AT ALL., 2020.)

Floods are natural phenomena that involve the presence of a significant amount of water, a short trigger interval and have a negative impact on society and the environment as a whole. In nature, the existence of sources that can rapidly generate a large flow of water, such as mountain glaciers, underground water levels, excessive snow accumulation during winter and upstream reservoirs with large capacities, contribute to the occurrence and spread of floods if adequate flood prevention measures are not taken (SĂGEATĂ ET ALL., 2015)

The main causes of flooding are natural and man-made. Natural causes are manifested by adverse climatic conditions such as heavy rainfall, rapid snowmelt or storms. Anthropogenic causes involve the negative influence of human activities on the water cycle, such as massive deforestation, hydro-engineering or inadequate dam construction (BRAGOI, 2016).

Figure 1 shows the main causes of flooding in Romania.

Several systems of works to protect the population and property are operating in our country. Among these works, we mention dams, with a total length of 9920 km, river bed regulation, 6300 km, a number of 217 non-permanent reservoirs. 1232 permanent reservoirs (National Administration of Romanian Waters, 2023.).

In the last decade, almost every year, Romania has witnessed significant floods, events during which considerable loss of life and material damage occurred. In our country, floods are the most frequent natural disasters, which have had a profound impact on the evolution of human society. These events have led to a change in strategy in order to identify the most appropriate solutions for flood defence and prevention (NEGRU ET AL., 2013).

Causes of floods in Romania	
	the fall of large amounts of precipitation in short intervals of time, on restricted areas;
	damage to some dykes as a result of the accumulation of significant volumes of water in the protected areas or the overflow of water courses
	exceeding the transport capacity of the section of bridges and decks, both due to the undersizing and due to the clogging of the drainage sections with wooden materials and household waste, stored in the river beds or carried from the slopes;
	the clearing of forests and the improper performance of some agrotechnical works that facilitate the erosion processes and lead to the increase of the runoff coefficient on the slopes and the entrainment of large amounts of alluvium;
	the non-existence of gutters and rainwater drainage ditches or the non-maintenance of the existing ones, in many rural localities;
	clogging, undersizing or non-maintenance of locality sewerage networks, which are unsuitable for torrential drainage regimes
	placement of unauthorized objects (houses, outbuildings, etc.) in flood zones;
	building houses, in flood zones, on inadequate foundations and from very poor quality materials;
	clogged, undersized, unmaintained sewer networks, unsuitable for torrential drainage regimes;
	the lack or insufficiency of funds for the realization of the entire set of hydrotechnical arrangements provided for in the framework schemes and for the restoration of all the works affected by the floods produced in previous years, as well as for new works with the role of defense against floods, both in the river beds and on the slopes;
	the lack at the level of local committees for emergency situations and economic agents of stocks of materials and means of operative intervention;
	failure to ensure permanence at some rural town halls, which makes it difficult for the information flow to warn-alarm the population;
	failure to ensure permanence at some town halls in the rural environment, which makes it difficult for the information flow to warn-alarm the population;
	not knowing the measures to be taken in critical situations of floods and dangerous meteorological phenomena

Figure 1. Causes of floods in Romania

Floods usually occur in spring when the snow melts or after heavy rain. In recent years, however, they have occurred throughout the year and sometimes in repeated waves in the same areas. Although floods are predominantly natural in nature, environmental changes brought about by human activities, such as excessive urbanisation, massive deforestation and intensive economic, industrial and agricultural practices, are also contributing to the increasing frequency and severity of floods.

There are numerous flood risk management measures in place, involving prevention, protection of people and property, and preparedness to manage and mitigate the effects of floods. In Romania, the set of public policies, comprising both structural and non-structural measures implemented by the responsible authorities, is the framework for flood risk management, known as Flood Risk Management (ȘMULEAC ET ALL., 2022).

MATERIAL AND METHODS

Located in central Romania, the Mures river basin covers the counties of Mures, Alba, Cluj, Bistrita-Nasaud, Harghita, Brasov, Sibiu, Hunedoara, Arad, and Timis. A vast region that is home to 16 municipalities, 23 towns, 303 communes, and 1,780 villages. With a total population of 1,877,642 inhabitants, of which 1,052,037 live in urban environments and 825,605 in rural areas, the basin is clearly a vital centre of Romanian life.

The geographical diversity of the Mures catchment is remarkable, ranging from plains to mountains. With a minimum elevation of 80 metres at the exit of the country, in the Western Plain, and a maximum elevation of 2509 metres in the Retezat Mountains, the basin hosts numerous relief units, including the Carpathian Mountain Unit, the Transylvanian Plateau Unit, the Piedmont Unit, and the Plain Unit.

The climate in the Mures river basin is marked by seasonal variations. In the upper Mures, the multi-year average temperatures range from 5°C to 6°C in the depression sector and drop to just above 0°C in the mountain sector, with January being the coldest month, with temperatures of -6°C to -7°C, and July the warmest, with temperatures of 12°C to 17°C. This climate changes in the lower Mures in the Western Plain, where average annual temperatures are between 10°C and 11°C. The climate in the basin is arid and summers are generally drier and hotter.

The multi-year average rainfall ranges from 480 mm to 980 mm, with an average of 610 mm over the whole basin. This rainfall forms the region's river network, which comprises 758 watercourses and a total length of 10,861 km. The Mures River, with its source in the Eastern Carpathians, flows mostly through Romania, with a length of 761 km out of a total of 766 km, the rest passing through Hungary. This river and its tributaries, such as the Gurghiu River, the Arieș River, the Niraj River, and the Sebeș River, form the backbone of the river system.

In the Mures river basin, there are 210 dyking works with a total length of about 825 km. These works protect 240 localities, including 55 towns and municipalities, 8,827 houses in urban environments and 60,240 in rural environments, as well as transport infrastructure, including 314 km of railway lines, 242 km of national roads and 313 km of county roads. The total area protected in case of flooding is reported to be about 190,000 hectares.

This flood defence network includes important works such as those at Reghin, Târgu Mureș, and Luduș, as well as the damming of the Niraj and Târnava Mică rivers at Târnăveni. In addition to these, dams such as Zetea, Bezid, and Mihoești were built for storage and flood protection. These are just a few examples of a complex network of hydrological infrastructure designed to ensure the safety of local people and their property.

The Lower Mures corridor is segmented into three distinct divisions and extends in the southern part of the Apuseni Mountains, between Vințu de Jos and Păuliș. This stretch of the river stretches over a distance of 255 km out of the total 716 km of the Mures River in Romania. The commune of Petriș is located in the eastern part of Arad county, close to the Zarandului Mountains, on the right bank of the river Mureș. It is about 106 km from Arad and 52 km from Deva. The commune is well connected both by the national road DN7 and by the railway line 200 Arad-Deva-Sibiu-Bucuresti, which includes CFR stations at Petriș and Ilteu (GYŐRI MARIA-MIHAELA, 2010).

To the north, Petriş is bordered by the communes of Brazi and Gurahonț, to the east by the commune of Săvârşin, to the south by the commune of Zam in Hunedoara county, and to the west by the same commune of Zam, also in Hunedoara county.

Situated at the foot of the Zarandului Mountains, on the right bank of the Mures River, the Petriş commune is crossed from north-west to south by the main watercourse Petriş Valley, which is a 14 km long cadastral watercourse (cadastral code IV-1.139) with two left tributaries:

- Burguieni Valley (cadastral code IV-1.139.2) with a length of 6 km and,
- Red Valley (cadastral code IV-1.139.1) with a length of 18 km which in turn has two right tributaries:
- Valea Corbească (cadastral code IV-1.139.1.2) with a length of 8 km and,
- Timișoaia Valley (cadastral code IV-1.139.1.1) with a length of 7 km.

In addition to registered watercourses, there are unregistered watercourses and streams.

The hydrographic network of Petriş is composed of the Mureş river, which enters the county of Arad through Petriş commune, west of Zam commune in Hunedoara county, and crosses the southern part of the administrative territory of the commune. During its 4 km of the territory of Arad county, the Mures river receives an important tributary called Valea Roșiei, which crosses the Petriş commune from its springs located under the Breaza peak in the village of Obârșia. Valea Roșiei is fed by several tributaries, including Morilor Stream, Izvoarelor Stream, Valea Marcului, Valea Mică, Valea Hănulească, Valea Mare, Lupoaia, Roșuța, Valea Nesi, Timișoaia, Stănilesc Stream in the village of Roșia-Nouă, Valea Corbească, Meșteroaia in the village of Corbești, Valea Sântească and Burdujeni in the village of Petriș.(Mures River Basin, 2023)

The Lower Mures corridor is segmented into three distinct divisions and extends in the southern part of the Apuseni Mountains, between Vințu de Jos and Păuliș. This stretch of the river stretches over a distance of 255 km out of the total 716 km of the Mures River in Romania.

As the river enters the county of Arad, at Petriş, and travels along its route to the town of Păuliș, it crosses 70 km of the total 110 km of the Brănișca - Păuliș Corridor, according to data available for 2010.(2013-03-26-PNABH.pdf)

The Mures River has a multi-millennial history and is known for frequent changes in its course, leading to the formation of beaches and islands, as well as lateral erosion of the banks, especially on the right and left banks. The average annual flow of the Mures at the entrance to the Petriş commune is about 142 mc/sec. In case of prolonged drought periods, the groundwater level drops significantly, which leads to strong drying of the soil and drying up of shallow wells (ŞMULEAC ET ALL., 2020)

Flooding occurs when the water level rises above the land level in a given area, causing that area to be covered by a layer of standing or moving water .

The effective approach to flood management at the river basin level is to apply a set of preventive measures, which aim to:

Runoff control: Implement runoff management systems that allow water to be regulated and directed to established areas to avoid flooding. This may include the construction of dams, reservoirs or drainage channels to keep flows within safe limits.

Reducing the velocity of runoff in rivers: Slowing the speed of water flow in streams to prevent damage to banks and soil erosion. This can be achieved by using bank protection vegetation, so-called borer plants, or by constructing deceleration ponds.

Facilitating flood propagation on natural and agricultural land: Plan and use land in such a way as to allow water to be absorbed into the soil and avoid building on areas at high risk of flooding. Sustainable agriculture and preservation of natural wetlands can play an important role in this approach (CHIRICA, 2016).

Protecting vulnerable infrastructure: Identify and protect critical infrastructure such as schools, hospitals and water and sewage systems through flood-resistant construction measures or relocation to safer areas.

Avoiding flood amplification downstream: Ensuring that floods are not amplified as they move downstream. This may involve managing reservoirs to release water in a controlled manner and avoid flash floods (NECULAU AND STAN, 2016).

These actions are in line with the provisions of the Floods Directive, which promotes an integrated and coordinated approach to flood risk management at river basin level. This approach aims to prevent and reduce the impact of floods on the population, the environment and the economy (TIȘCOVSCHI AND DIACONU, 2004).

One of the significant characteristics that distinguish floods from floods is the time interval between the causal event (heavy rainfall) and the time when it occurs, as well as its duration (Fig. 2).

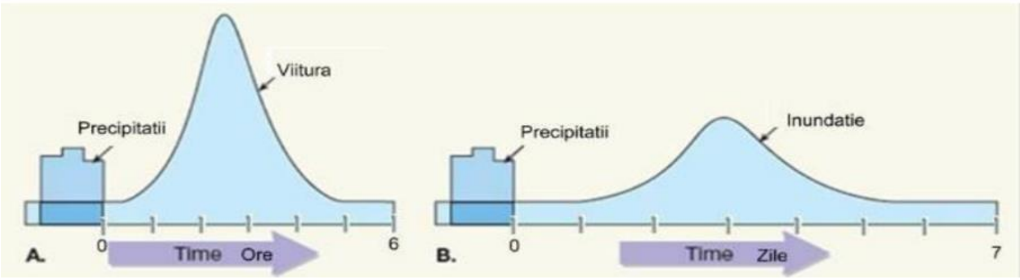


Figure 2. The difference between floods and floodwaters

RESULTS AND DISCUSSIONS

The study of flood production on the surface of the Petris River Basin, in the years 2017-2021, was carried out based on the measurements made at the Petris Hydrometric Station, located on the Petris River, on the surface of the Mures river basin. The measurements of the different parameters necessary for the hydrological description are made according to the standard methodologies and on the basis of the legislation in force (*Guidelines for the work of hydrometric stations on rivers, 2014*).

We followed the evolution of the monthly and annual mean, maximum and minimum flows, the values of the monthly mean water levels, the amount of rainfall, the timing of flood waves and the runoff regime. All the above mentioned elements are determining factors in the occurrence of floods in the study area.

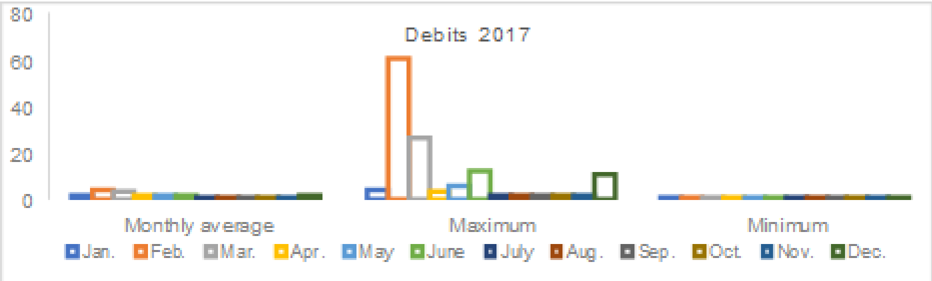
The water level measurements made on the section of the hydrometric station studied were concerned with determining the position of the free surface of the river water in relation to a "zero-peak" plane, expressed in whole centimetres, without decimals.

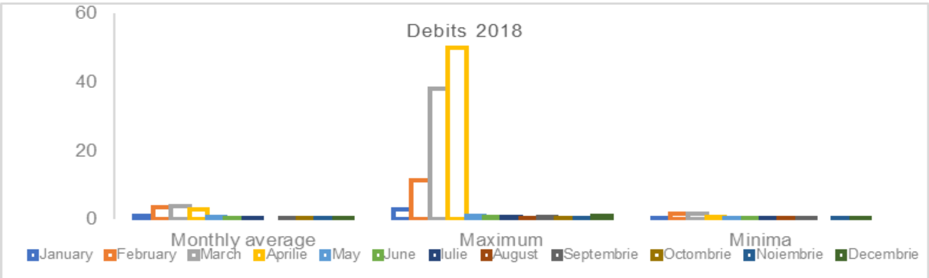
To make these measurements, hydrometric sights were used to monitor changes in water levels over time in discrete values.

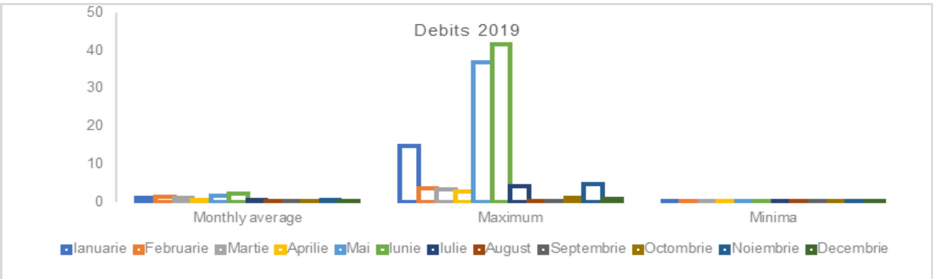
These measurements were made at the standard observation times of 06.00 and 18.00. During periods of high water the measurements were more frequent in order to anticipate special events such as floods and their propagation in the studied catchment (*Guidelines for the work of hydrometric stations on rivers*, 2014).

A key limnimetric correlation was used to derive the streamflow hydrographs based on previous water level data and new streamflow measurements. The frequency at which water flow determinations are made is decided by hydrological station staff, taking into account the state of the flow regime and the requirements for defining limnimetric keys. This is an essential step for water management and flood prevention, provided that water flow values are calculated with an error of less than 10% to ensure adequate data accuracy (*Guidelines for the work of hydrometric stations on rivers*, 2014).

Figure 3 shows the flows, monthly average, maximum and minimum values for the period studied.







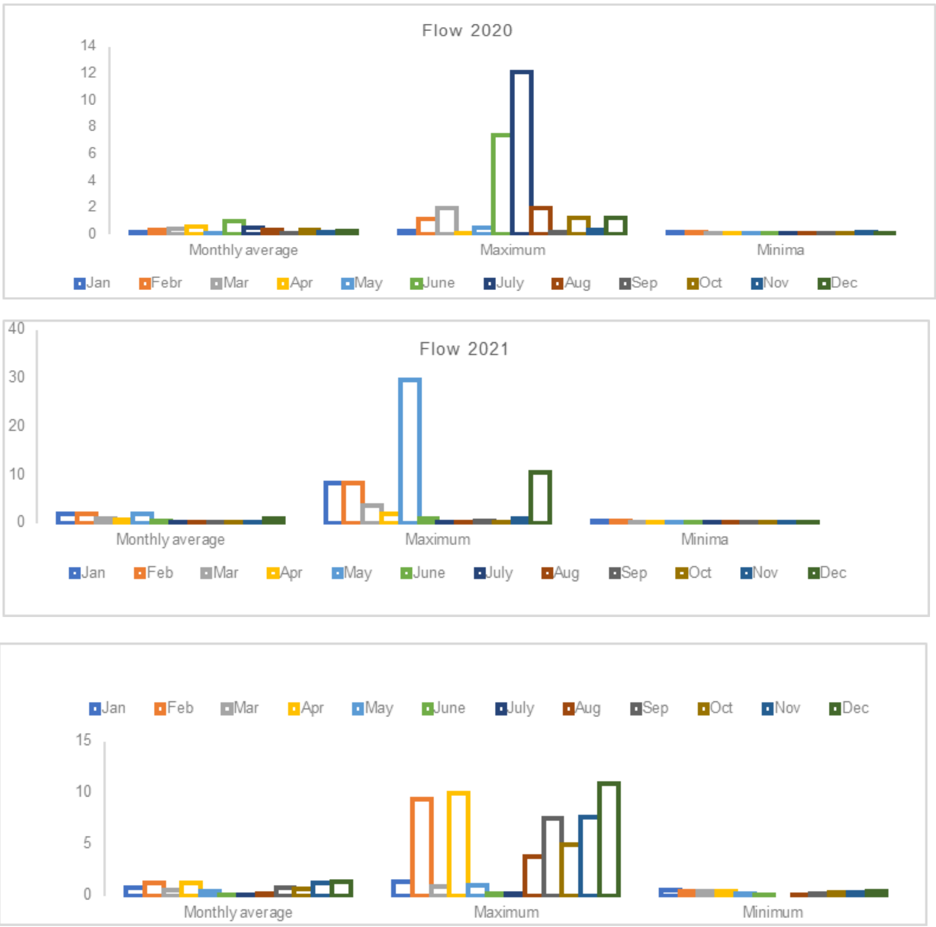


Figure 3. Monthly averages, maximum and minimum flow 2017- 2022

Figure 4 shows the values for the levels for the years 2022. Monthly averages, maximum and minimum levels are shown.

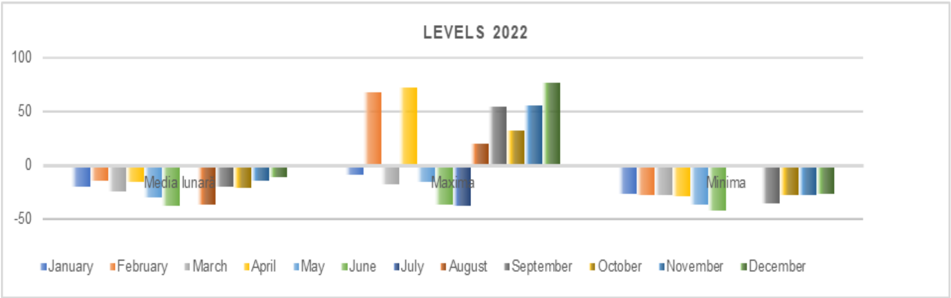


Figure 4. Monthly averages, highs and lows for 2022

The year 2017 was a rainy year from a hydrological point of view, with rainfall of over 30 l/sq.m, leading to flooding. The high amounts of precipitation led to the recording of maximum flows, the maximum flow recorded being 60.8 m3/s.

Table 1

Flood wave 2017

Year	Date	Q(m^3/s)	PP (l/m^2)
2017	17.02.2017 7:00	0,67	
	17.02.2017 17:00	0,670	
	18.02.2017 7:00	0,612	
	18.02.2017 17:00	0,61	1,5
	19.02.2017 7:00	0,67	
	19.02.2017 17:00	0,81	
	20.02.2017 7:00	0,89	
	20.02.2017 17:00	0,96	7,8
	21.02.2017 7:00	1,29	
	21.02.2017 15:00	2,24	
	21.02.2017 16:00	2,35	
	21.02.2017 17:00	2,45	16,1
	22.02.2017 7:00	4,72	
	22.02.2017 8:00	6,50	
	22.02.2017 10:00	9,5	
	22.02.2017 12:00	12,7	
	22.02.2017 14:00	13,6	
	22.02.2017 15:00	14,5	
	22.02.2017 16:00	15,6	
	22.02.2017 17:00	23,4	30,6
	22.02.2017 18:00	29,0	
	22.02.2017 20:00	44,0	
	22.02.2017 21:00	50,0	
	22.02.2017 22:00	56,0	
	23.02.2017 2:00	60,8	
	23.02.2017 6:00	56,0	
	23.02.2017 7:00	50,0	
	23.02.2017 8:00	44,0	
	23.02.2017 12:00	38,0	
	23.02.2017 14:00	32,0	
	23.02.2017 15:00	26,0	
	23.02.2017 16:00	23,40	
	23.02.2017 17:00	23,40	23,8
	23.02.2017 18:00	20,70	
	23.02.2017 22:00	14,50	
	24.02.2017 1:00	11,80	
	24.02.2017 5:00	10,70	
	24.02.2017 7:00	9,50	
	24.02.2017 11:00	7,55	
	24.02.2017 12:00	7,25	
	24.02.2017 17:00	6,50	
	25.02.2017 7:00	5,75	
	25.02.2017 15:00	4,30	
	25.02.2017 16:00	4,16	
	25.02.2017 17:00	3,60	2.1
	26.02.2017 7:00	3,0	
	26.02.2017 17:00	3,60	
	27.02.2017 7:00	3,240	
	27.02.2017 14:00	3,0	
	27.02.2017 15:00	2,890	
	27.02.2017 17:00	3,00	

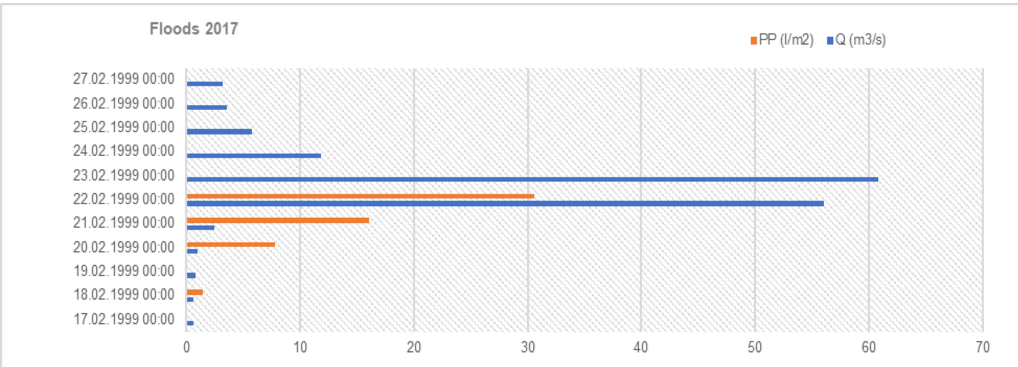


Figure 5. Flood waves produced in 2017

Table2

Flood wave 2018

Year	Date	$Q (m^3/s)$	$PP (l/m^2)$
2018	01.04. 2018 6:00	1,06	
	01.04. 2018 18:00	0,870	
	02.04. 2018 6:00	0,796	
	02.04. 2018 18:00	3,10	11,7
	02.04. 2018 19:00	3,38	
	02.04. 2018 20:00	4,22	
	03.04. 2018 6:00	4,36	
	03.04. 2018 18:00	3,80	
	05.04. 2018 6:00	2,00	
	05.04. 2018 14:00	4,50	
	05.04. 2018 18:00	6,80	13,2
	05.04. 2018 22:00	9,30	
	06.04. 2018 5:00	26,0	
	06.04. 2018 6:00	44,0	
	06.04. 2018 7:00	44,0	
	06.04. 2018 8:00	44,0	
	06.04. 2018 10:00	50,0	
	06.04. 2018 12:00	44,0	
	06.04. 2018 15:00	44,0	
	06.04. 2018 16:00	44,0	
	06.04. 2018 18:00	38,0	25,9
	06.04. 2018 20:00	32,0	
	06.04. 2018 22:00	26,0	
	07.04. 2018 2:00	16,8	
	07.04. 2018 6:00	11,0	
	07.04. 2018 9:00	9,81	
	07.04. 2018 10:00	9,30	
	07.04. 2018 18:00	7,60	
	08.04. 2018 6:00	4,50	
	08.04. 2018 10:00	4,08	
	08.04. 2018 11:00	4,08	
	08.04. 2018 18:00	3,10	
	09.04. 2018 6:00	2,85	
	09.04. 2018 12:00	2,60	
	09.04. 2018 13:00	2,60	
	09.04. 2018 18:00	2,47	
	10.04. 2018 6:00	1,88	
	10.04. 2018 18:00	1,67	
	11.04. 2018 6:00	1,56	
	11.04. 2018 18:00	1,56	
	12.04. 2018 6:00	1,46	
	12.04. 2018 18:00	1,46	
	13.04. 2018 6:00	1,35	
	13.04. 2018 18:00	1,35	
	14.04. 2018 6:00	1,25	
	14.04. 2018 18:00	1,16	
	15.04. 2018 6:00	1,16	
	15.04. 2018 18:00	1,06	
	16.04. 2018 6:00	1,06	
	16.04. 2018 18:00	0,966	
	17.04. 2018 6:00	0,870	
	17.04. 2018 10:00	0,870	
	17.04. 2018 11:00	0,870	
	17.04.2018 18:00	0,870	
	18.04. 2018 6:00	0,870	
	18.04. 2018 18:00	0,870	
	19.04. 2018 6:00	0,870	
	19.04. 2018 18:00	0,870	
	20.04. 2018 6:00	0,796	

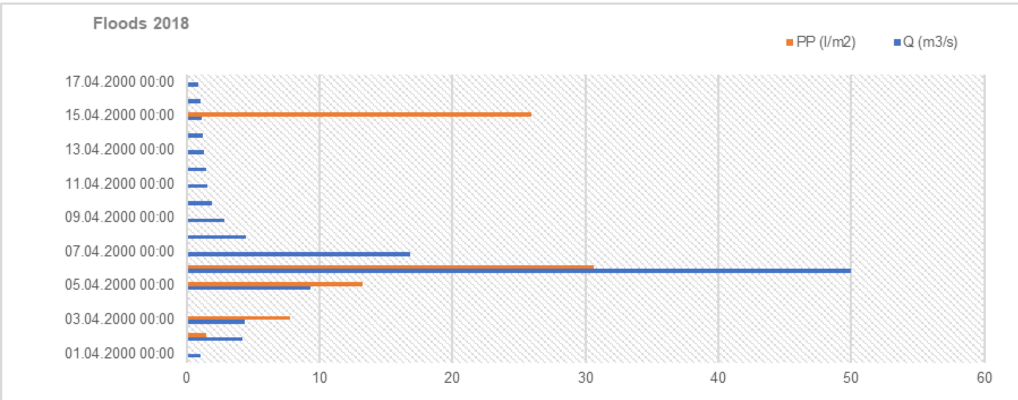


Figure 6. Flood waves produced in 2018

Table3

Flood wave 2019

Year	Date	Q(m^3/s)	PP(l/m^2)
2019	10.06.2019 6:00	0,330	
	10.06.2019 18:00	0,360	7,3
	11.06.2019 6:00	0,499	3,7
	11.06.2019 18:00	0,420	
	12.06.2019 6:00	8,22	35,3
	12.06.2019 12:30	22,4	
	12.06.2019 13:00	34,3	
	12.06.2019 15:00	37,0	
	12.06.2019 16:00	41,6	
	12.06.2019 17:00	27,3	
	12.06.2019 18:00	22,0	15,3
	12.06.2019 22:00	14,6	
	13.06.2019 6:00	8,80	0,7
	13.06.2019 11:30	6,66	
	13.06.2019 12:30	6,42	
	13.06.2019 18:00	5,59	4,5
	14.06.2019 6:00	4,80	6
	14.06.2019 14:30	16,3	
	14.06.2019 15:10	17,0	
	14.06.2019 18:00	14,22	11
	15.06.2019 6:00	12,8	8,5
	15.06.2019 9:20	11,1	
	15.06.2019 10:30	10,0	
	15.06.2019 18:00	5,82	
	16.06.2019 6:00	4,46	
	16.06.2019 9:10	3,82	
	16.06.2019 10:00	3,71	
	16.06.2019 18:00	2,55	
	17.06.2019 6:00	1,70	
	17.06.2019 18:00	1,09	
	18.06.2019 6:00	0,881	1.0
	18.06.2019 18:00	0,810	

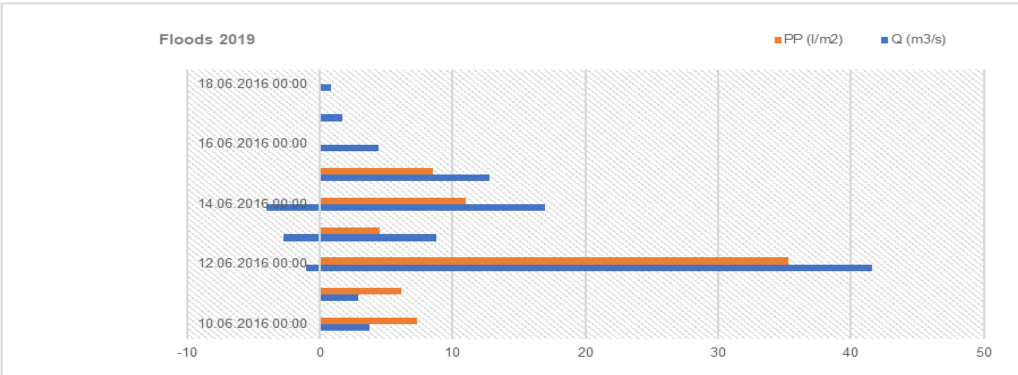


Figure 7. Flood waves produced in 2019

Flows represented in Tables 1,2, 3 are of rainfall nature, reported per time and square meter. Floods form on the studied area in all seasons of the year, but most important in winter, spring and summer.

In the Petriș commune there are no flood protection works caused by the floods on the Mureș river, but there are regularization works on the Petriș valley to limit the damage caused by the floods caused by the heavy rainfall in the Petriș valley basin.

CONCLUSIONS

The Mures river basin is one of the largest and most important river basins in Central Europe. It covers the territory of three countries: Romania, Hungary and Serbia. The Mureș River flows from the Hăşmaş Mountains in the Eastern Carpathians for about 965 kilometres before emptying into the Tisa River.

From the research we concluded that the Mures watershed has the following hydrological characteristics, namely, it is characterized by a variable hydrological regime, its flow is influenced by heavy precipitation, snowmelt and the runoff regime of its tributaries. In summer, the flow can decrease significantly and during periods of heavy rain or snowmelt it can increase rapidly, contributing to flooding.

Due to its location, the Mures river basin records most of the average monthly runoff during spring periods. In the months of March, April, May, the average monthly runoff on the slopes is 37%-47%. In the summer months of June, July and August, 21% to 31% of the annual runoff occurs. In the months: September, October, November the average monthly runoff is 11% - 18%, in the winter: December, January and February between 10 - 23% of the annual runoff.

The highest percentages of the average annual runoff occur in spring with values between 38 - 48%, while the lowest runoff volume is recorded in summer.

Knowledge of runoff is important for characterizing the general variation with altitude and catchment area size, in the sense of increasing values of this parameter as a function of altitude and decreasing with increasing catchment area.

Floods form on the surface of the Mures river basin in all seasons of the year. The most considerable occur in winter, spring and summer. The floods presented above by concrete data were produced by maximum flows with lower values, by the amounts of precipitation significant in quantity.

The Petriș Valley is located in the catchment area of the Mureș River, an area prone to flooding. The geographical characteristics of the Petriș Valley, such as the configuration of the terrain, the slopes and the limited drainage capacity of the Mures River in this area, can contribute to flooding during periods of heavy rainfall or sudden snowmelt.

Flooding in the Petris Valley can have significant consequences for communities, infrastructure and the environment. They can lead to the destruction of homes, agricultural land and road and water infrastructure. Floods can also cause loss of life and affect water quality and the environment through contamination with chemicals or polluting materials.

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