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THE STUDY OF THE VARIATION OF THE HYDROLOGICAL REGIME IN A REPRESENTATIVE HYDROGRAPHIC BASIN DURING A HYDROLOGICAL CYCLE

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ABSTRACT. The Study of the Variation of the Hydrological Regime in a Representative Hydrographic Basin During a Hydrological Cycle. The study of the variation of the hydrological regime in hydrographic basins is a necessity in the context of climate change. Based on the forecast of flow and level variations, water resources management plans are drawn up.

The paper deals with the subject of simulating the phenomenon of rainfall - runoff with the help of the advanced hydroinformatics tool MIKE by DHI. The data used represent the precipitation and flows recorded in the Turnu Ruieni section, on the Sebes river, between the years 1988-1997, 2005, respectively the year 2021. A comparison is made of the maximum discharge values obtained from the simulation in the years 1988-1997, 2005 and 2021 (the difference of 33 years, approximately the duration of a hydrological cycle); a comparison is made between the discharges on the Sebeș River, in the years 1988-1997, 2005 and 2021, respectively between the amounts of recorded precipitation.

The MIKE11byDHI program is used, the Rainfall – Runoff (RR) module, based on the UHM (Unit Hydrograph Model), the CN "Curve Number" method, the SCS (Soil Conservation Service) method.

Keywords: precipitation, discharge, flows, hydrological regime, simulation, Romania.

1. INTRODUCTION

The study of the variation of the hydrological regime in hydrographic basins is a necessity in the context of climate change. Water management tasks and water-related policies can change with climate fluctuations, land use changes, and complex watershed management. (Novaky and Balint, 2013)

The hydrologic regime as the relationship between precipitation inputs and streamflow outputs in a hydrographic basin, measured across a range of temporal and spatial scales. (Post and Jones, 2001)

Hydrological components on hydrographic basin scale are show in Figure 1. (Stagl et al., 2014)

The hydrological regime of water bodies in a hydrographic basin depends to a great extent on climatic factors. Runoff is defined mainly by the seasonal distribution

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of precipitation, its characteristics (height, duration and intensity) on the one hand, and potential evapotranspiration on the other.

Air temperatures near the slope surface regulate precipitation phase and, consequently, snow accumulation, ablation, and runoff resulting from snowmelt.

The hydrological regime can be modified due to climate changes, changes in land use (agriculture, grazing, deforestation) and various human activities related to water (various hydrotechnical works for water accumulation, flood control, flow regulation, water catchments, interception works of surface runoff on hillslopes, etc.). (Novaky and Balint, 2013)

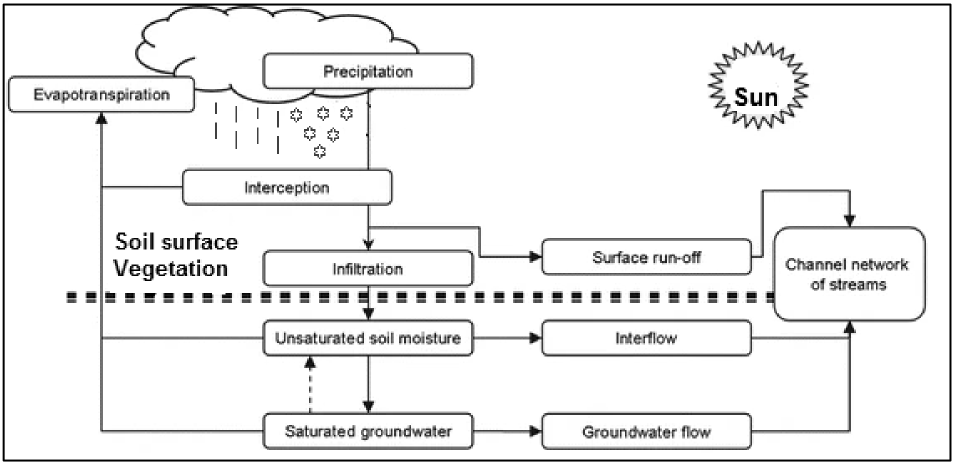


Fig. 1. ***Hydrological components on hydrographic basin scale (source: Stagl et al., 2014)***

Climate change leads to the acceleration of some stages of the water cycle, because the increase in global temperatures increases the rate of evaporation worldwide, which leads to the production of more important precipitations from a quantitative and qualitative point of view.

In general, an increase in temperature increases the moisture holding capacity in the atmosphere. Key changes in the hydrologic system include changes in the seasonal distribution, magnitude, and duration of precipitation and evapotranspiration. (Stagl et al., 2014)

2. ADVANCED HYDROINFORMATIC TOOL MIKE11

MIKE 11 is a professional engineering software package for simulation of one-dimensional flows in estuaries, rivers, irrigation systems, channels and other water bodies. MIKE 11 is a 1-dimensional river model. It was developed by DHI Water • Environment • Health, Denmark.

The UHM methods of Rainfall-Runoff module of MIKE11, simulates the runoff by the use of the unit hydrograph techniques. Unit hydrograph is a hypothetical unit response of the hydrographic basin to a unit input of rainfall.

During a storm a part of the total rainfall infiltrates in the soil, depends on the initial soil moisture and vegetation. Large parts of the infiltration evaporate or reach the river a long time after the end of storm as base flow. In event models it is proper to describe the major part of the infiltration as loss. The amount of rain actually reaching the river, i.e. the total amount of rainfall less the loss is called the excess rainfall. The unit hydrograph module includes four optional methods for calculation of the excess rainfall. They are all lumped models considering each basin as one unit and hence the parameters represent average values for the basin.

SCS Loss Method was developed by U.S. Soil Conservation Service (SCS) in 1972. The basic equation for computing the depth of excess rainfall or direct runoff from a storm by the SCS method is:

$$P_{excess} = \frac{(P - I_a)^2}{P - I_a + S} \tag{1}$$

By study of results from many small experimental hydrographic basins, was developed the following empirical relation:

$$I_a = 0.2 \cdot S \tag{2}$$

Result:

$$P_{excess} = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{3}$$

where: P_{excess} - depth of excess precipitation or direct runoff (mm); P - depth of precipitation (mm); I_a - initial loss before ponding (mm); S - potential maximum retention (mm). The potential maximum retention S is calculated from a dimensionless curve number (CN) using the empirical formula derived by SCS on the basis of rainfall runoff analyses of a large number of hydrographical basins:

$$S = ((1000/CN) - 10) \cdot 25.4 \tag{4}$$

The curve number depends on the soil type, the land use and the antecedent moisture condition (AMC) at the start of the storm. CN varies between 0, resulting in no runoff, and 100 which generate an excess rain equal to the rainfall. For natural basins normally CN is in the range (50, 100).

The SCS Generalized Loss Model corresponds closely to the SCS loss model, but it differs in a few important ways. In this model the initial loss (initial abstraction depth) I_a is given directly as an input parameter. The curve number is an input parameter and is not changed during the simulation as for the SCS loss model. (DHI, 2014)

3. CASE STUDY

The study of the variation of the hydrological regime in a representative hydrographic basin during a hydrological cycle was carried out for the representative Sebes river hydrographic basin.

The representative basins complement the activity undertaken at the experimental stations and basins, thanks to the data they provide, an activity that is much more precise than in the case of large hydrographic basins.

In creating the network of representative basins, account is taken of the possibilities of obtaining information related to average, maximum and minimum runoff, alluvium runoff, the thermal regime of air and water, the regime of precipitation and the evolution of freezing phenomena on rivers. In the location of the representative basin, a number of physical-geographical criteria were taken into account, and not only (diverse physical-geographical conditions, different shapes of the hydrographic basins, insignificant changes in the natural flow, homogeneity of the underground flow, the existence of meteorological stations, the existence of the network electricity up to high altitudes, the existence of human settlements as close as possible to the observation points).

The physical-geographic characteristics and monitored parameters of the representative Sebes hydrographic basin are presented in Table 1 and Table 2. (ABAB, 2021)

Table 1. ***The physical-geographic characteristics (source ABAB, 2021)***

River/Hydrographic basin	Sebes / Sebes
Period of operation of the hydrometric network	1975-present
Geographic coordinates (closing station per basin)	X=436782; Y=290600
Surface in the closing station section	125.3 km²
Average altitude in the closing station section	844.2 m
The type of basin	mountainous
Land use	Pasture 0.32%; Complex cultures 4.7%; Deciduous forests 58.02%; Coniferous forests 10.12%; Natural meadows 6.43%.
Soil	Acid brown Podzolite (brown-limestone) Whitish Luvisols Podzolic (feriluvial brown)

Table 2. ***The monitored parameters (source ABAB, 2021)***

Parameter	Monitoring period	Monitoring frequency	No. stations where the parameter is monitored
Air and water temperature	1975-present	Daily 6^{00} / 18^{00}	8
Precipitations	1975-present	Daily 6^{00} / 18^{00}	4
Wind speed	1975-present	Daily 6^{00} / 18^{00}	8
Water level	1975-present	Daily 6^{00} / 18^{00}	8

The Sebes representative basin is located in the northwestern part of the Muntele Mic massif, which is part of the Tarcu Mountains group (Retezat-Godeanu group, Southern Carpathians). The Sebes River, with a length of 20.1 km in the closing section, drains an area of 142 km², being the right tributary of the Timis River, converging with it in the municipality of Caransebes (Figure 2).

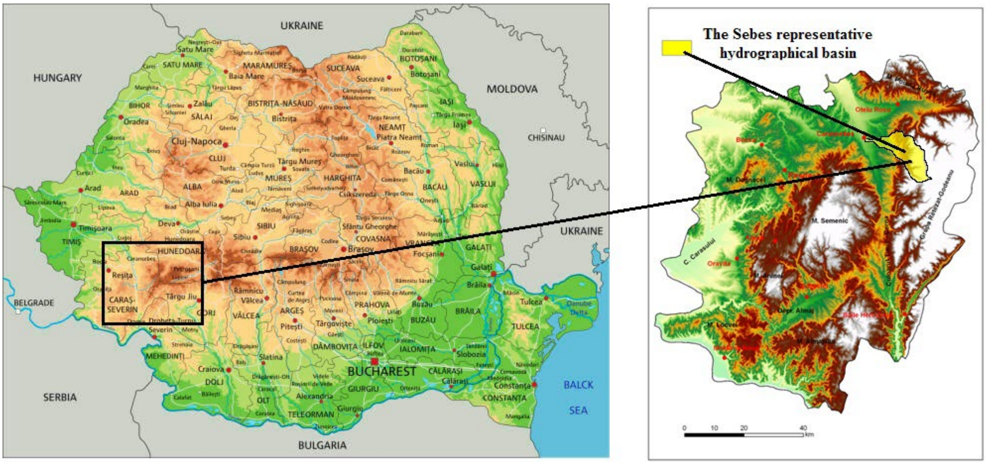
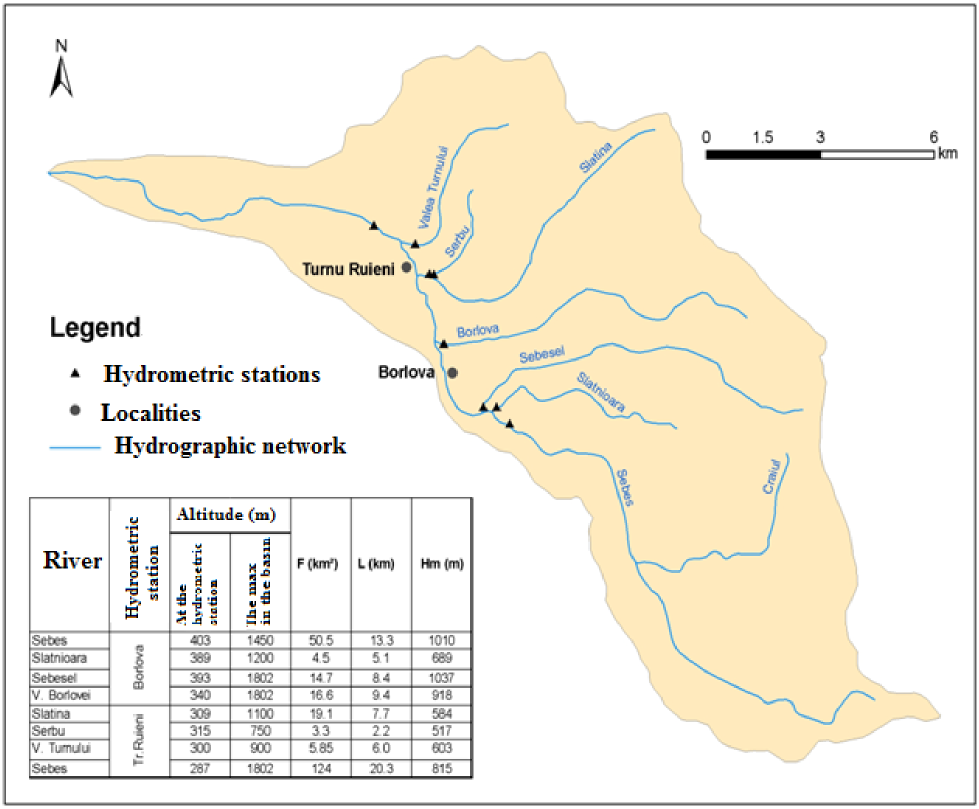


Fig. 2. *The location of Sebes hydrographical basin*



River	Hydrometric station	Altitude (m)		F (km²)	L (km)	Hm (m)
		At the hydrometric station	The max in the basin			
Sebes	Borlova	403	1450	50.5	13.3	1010
Slatnioara		389	1200	4.5	5.1	689
Sebesel		393	1802	14.7	8.4	1037
V. Borlovei		340	1802	16.6	9.4	918
Slatina	Tr.Ruieni	309	1100	19.1	7.7	584
Serbu		315	750	3.3	2.2	517
V. Turnului		300	900	5.85	6.0	603
Sebes		287	1802	124	20.3	815

Fig. 3. *The morphometric data of the studied basin*

Extended in the general southeast-northwest direction, the Sebeş representative basin stretches between 45°17'00" and 45°26'21" north latitude and 22°31'00" and 22°22'21" east longitude.

The morphometric data of the studied basin are represented in Figure 3.

4. RESULTS AND DISCUSSION

In Figures 4, 5, 6, 7, 8 and 9, are show the daily, monthly and annual variations of rainfall and discharges for the years 1988, 1997, 2005 and 2021, recorded in Turnu Ruieni section, on the Sebes river. (Data source from ABAB, 2023)

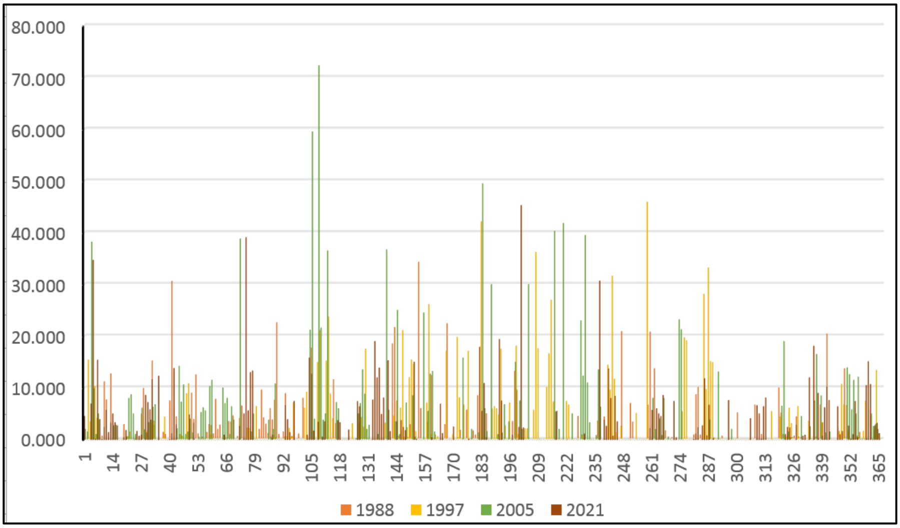


Fig. 4. ***The variation of daily rainfall (l/m²)***

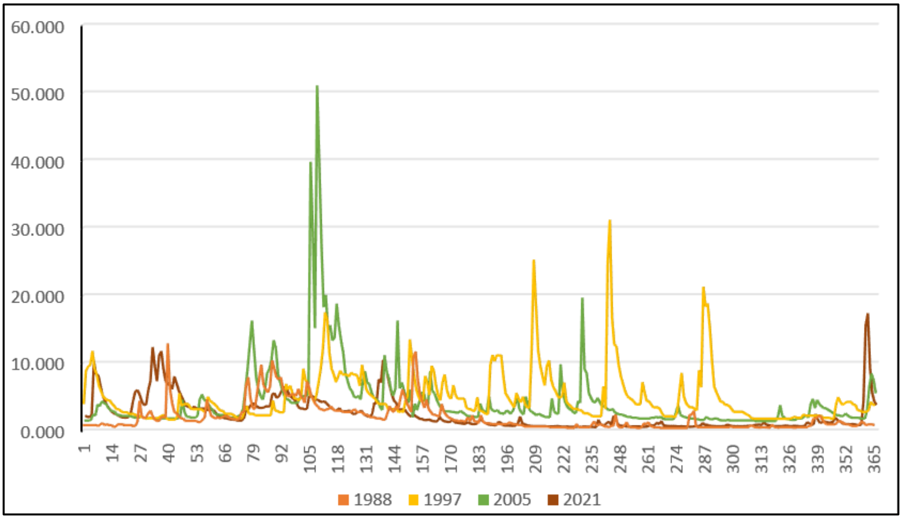
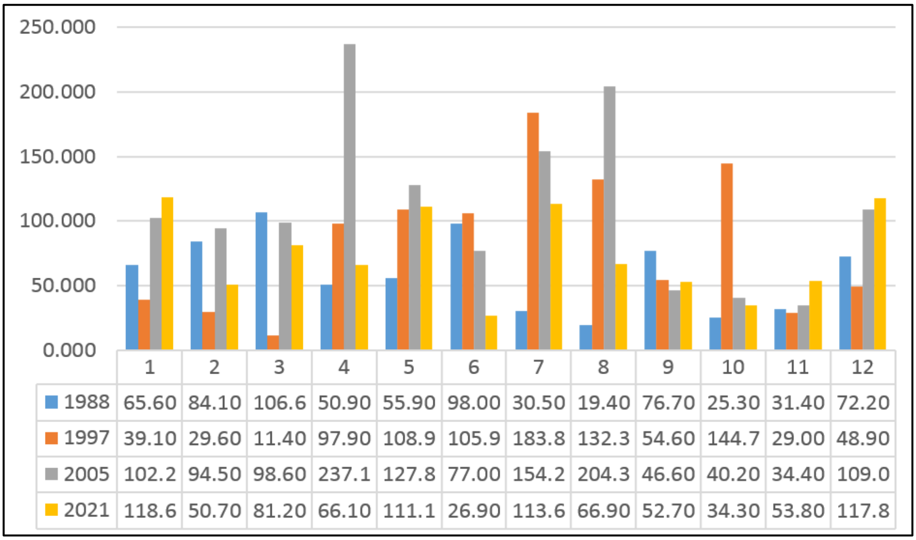


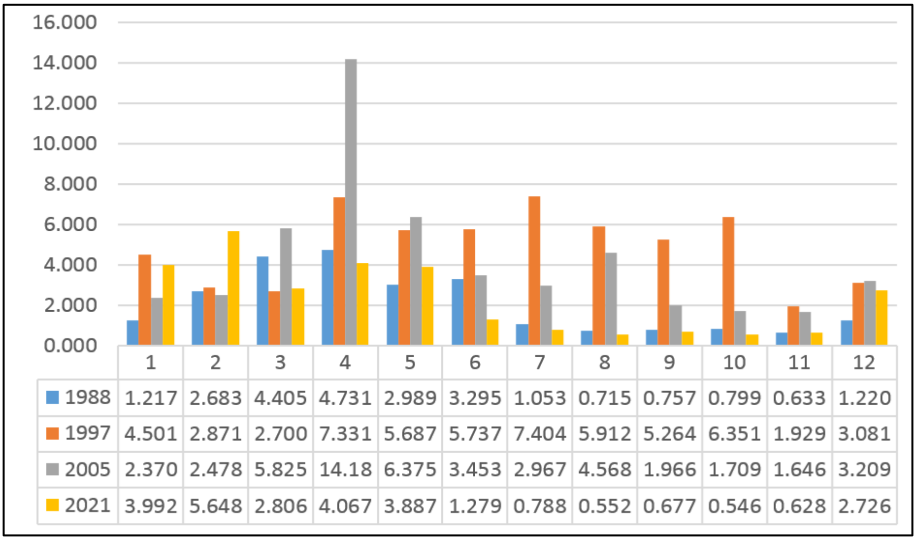
Fig. 5. ***The variation of daily discharges (m³/s)***

From the data analysis, it can be seen that the year with the highest amount of precipitation was 2005, the highest discharges were also observed in 2005, but as an annual average, the highest average annual discharge was in 1997 (among those 4 years analyzed, for which data were available).



	1	2	3	4	5	6	7	8	9	10	11	12
■ 1988	65.60	84.10	106.6	50.90	55.90	98.00	30.50	19.40	76.70	25.30	31.40	72.20
■ 1997	39.10	29.60	11.40	97.90	108.9	105.9	183.8	132.3	54.60	144.7	29.00	48.90
■ 2005	102.2	94.50	98.60	237.1	127.8	77.00	154.2	204.3	46.60	40.20	34.40	109.0
■ 2021	118.6	50.70	81.20	66.10	111.1	26.90	113.6	66.90	52.70	34.30	53.80	117.8

Fig. 6. ***The monthly total rainfall (l/m^2)***



	1	2	3	4	5	6	7	8	9	10	11	12
■ 1988	1.217	2.683	4.405	4.731	2.989	3.295	1.053	0.715	0.757	0.799	0.633	1.220
■ 1997	4.501	2.871	2.700	7.331	5.687	5.737	7.404	5.912	5.264	6.351	1.929	3.081
■ 2005	2.370	2.478	5.825	14.18	6.375	3.453	2.967	4.568	1.966	1.709	1.646	3.209
■ 2021	3.992	5.648	2.806	4.067	3.887	1.279	0.788	0.552	0.677	0.546	0.628	2.726

Fig. 7. ***The average monthly discharges (m^3/s)***

The lowest amounts of precipitation were in the months of February, March, respectively September, October and November, with the exception of October 1997. The highest monthly amount was in April 2005, which corresponds to the highest discharge. The poorest year in precipitation was 1988. The month with the highest average flow was April, with the exception of 2021.

Since 1997, a trend of decreasing of discharges can be observed, in the months July, August, September, October and November, increasing in the following months. The year 1997 was the year with the highest average monthly flows, in most of the year.

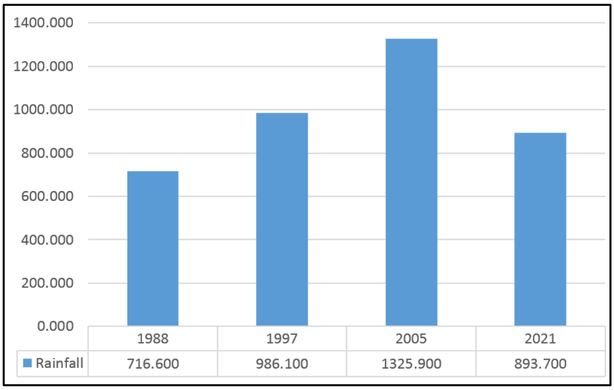


Fig. 8. ***The annual total rainfall (l/m^2)***

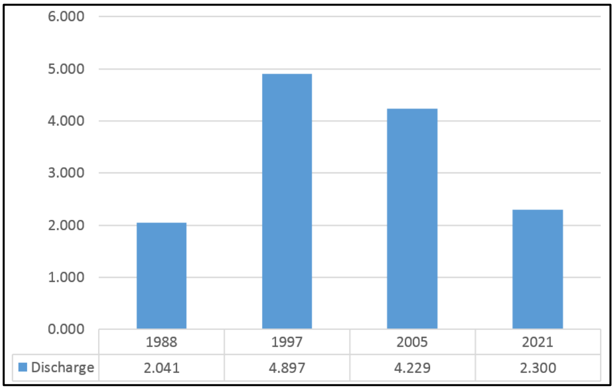


Fig. 9. ***The average annual discharges (m^3/s)***

For a more detailed analysis of the rainfall-runoff phenomenon, it is necessary to realize a numerical simulation of the phenomenon, a simulation that gives values related to runoff mainly, but also about net rain, loss rain and excess rain, values that are determined by the characteristics of the soil (texture, initial humidity, hydrological group), the type and condition of the vegetation in the studied hydrographic basin.

The simulation of the rainfall-runoff phenomenon was realized on the Sebeș hydrographic basin, for the Turnu Ruieni section, in the years 1988, 1997, 2005 and 2021 (the difference of 33 years, approximately the duration of a hydrological cycle). The advanced hydroinformatics tool MIKE11 was used.

Input data (ABAB, 2013), (ABAB, 2023): data about the hydrographic basin – area, average slope, land use, length of the main water course (Sebeș River) in the Turnu Ruieni section; data for the years 1988, 1997, 2005 and 2021 were used for modeling (daily precipitation and average daily discharges); the time step chosen for TIME SERIES – 1 day; time step for simulation 30 seconds; soil hydrological group C; land use – deciduous forests; CN number 79; base flow 0.450 m^3/s; average slope of the watershed 0.3365; area 125.3 km^2; initial abstraction 0; hydraulic length 20.3 km.

The results obtained after the model calibration can be seen in the Figures 10, 11, 12, 13 and 14.

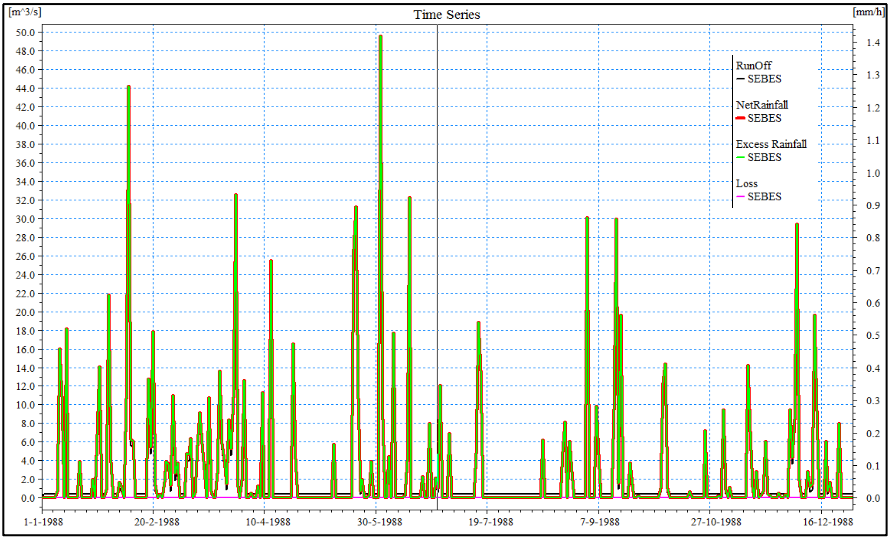


Fig. 10. ***Runoff, net rainfall, excess rainfall and loss for 1988***

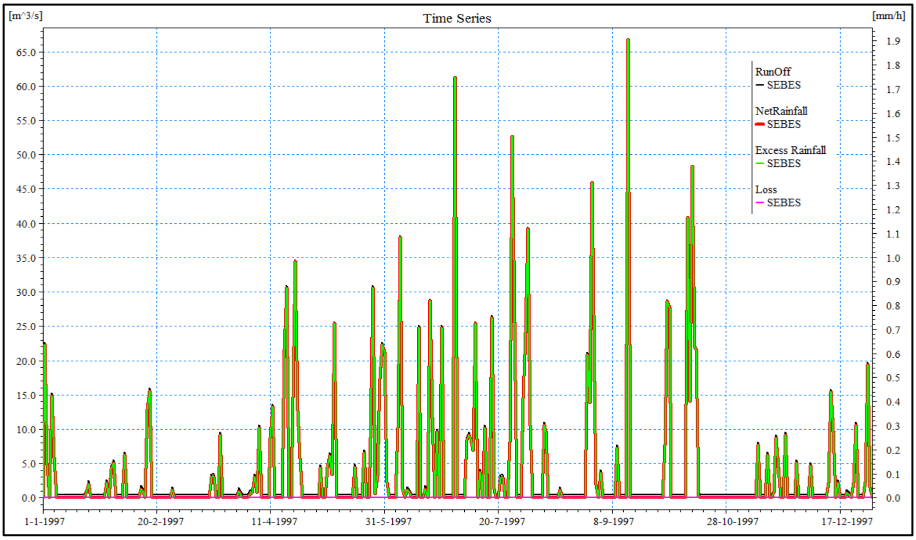


Fig. 11. ***Runoff, net rainfall, excess rainfall and loss for 1997***

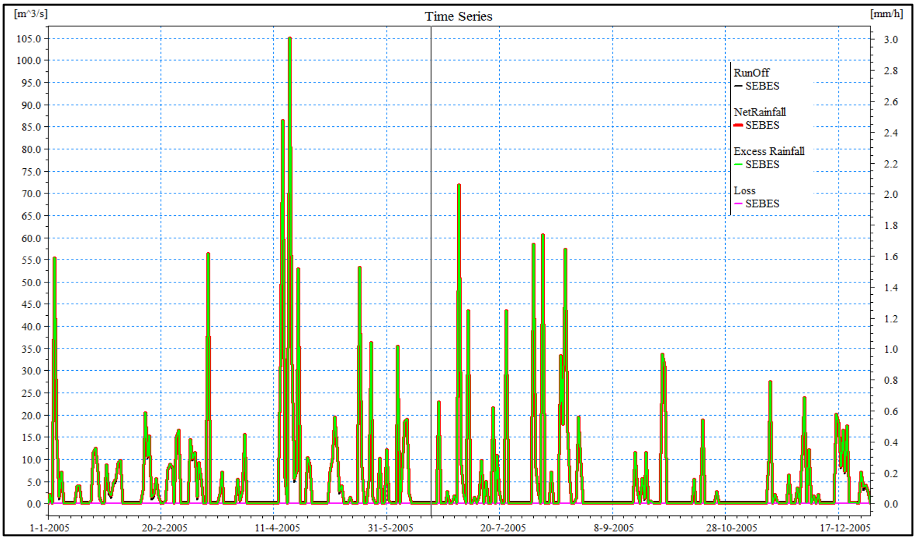


Fig. 12. ***Runoff, net rainfall, excess rainfall and loss for 2005***

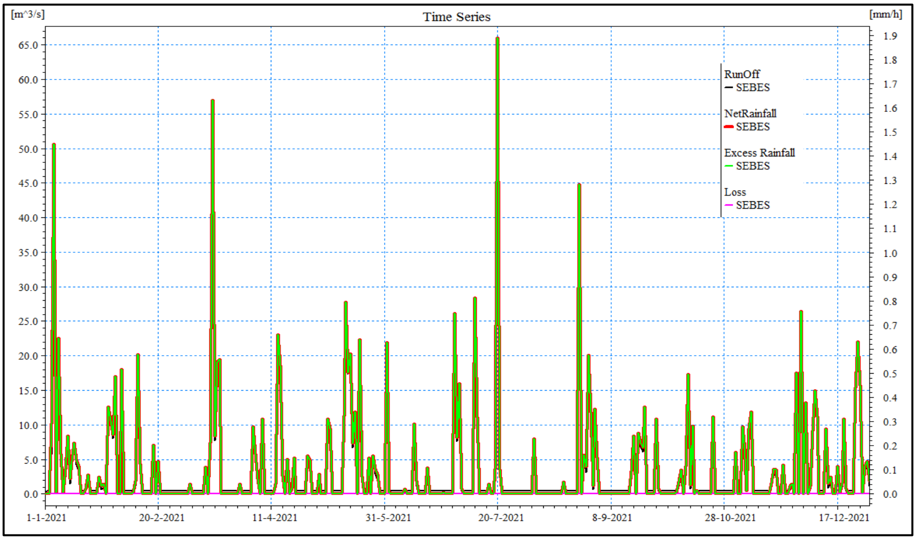


Fig. 13. ***Runoff, net rainfall, excess rainfall and loss for 2021***

From figures 10, 11, 12 and 13 it can be seen that from the total amount of precipitation, only a very small part infiltrates into the soil, contributing to the supply of aquifer layers, the greater part reaches through surface and hypodermic runoff in the beds that drain hydrographic basin.

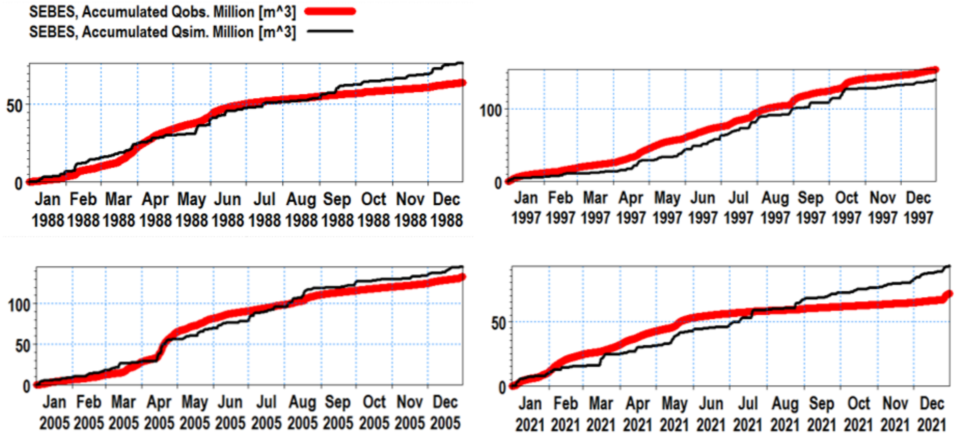


Fig. 14. ***The integral flow rate curve after model calibration***

The differences between the measured values and those obtained by simulation can be due to several causes: incorrect measurement or incorrect recording of precipitation or discharges, respectively the fact that the Sebeș river basin has a very developed hydrographic network, in the simulation only the length of the main course is taken into account. Also, the average slope of the hydrographic basin is quite high, 33.65%, the surface is also quite large, 125.3 km^2, and one of the assumptions on which the unitary hydrograph method is based, that the rain is evenly distributed over the territory of the hydrographic basin for which the hydrograph is constructed may not be met.

For a satisfactory accuracy of the simulation results, measurements performed as accurately as possible and data as updated as possible about the hydrographic basin studied are needed.

For this, it is necessary to carry out or update the studies regarding to topography of basin, studies of processes referring to geomorphology, climate, soil, erosion, hydrology, hydrogeology, vegetation and socio-economic development of analyzed territory.

5. CONCLUSIONS

The study of the variation of the hydrological regime in hydrographic basins is a necessity in the context of climate change.

Water, during its transformation from an input quantity (rain) to an output quantity, goes through different stages involving the processes of accumulation, delay, propagation and loss of part of its mass. Scheming the physical model of the rain-runoff process can the logical model of this process has been obtained, within the system the inputs are represented by precipitation and solar energy, and the outputs from the system by the flow of water and evapotranspiration.

The simulation of the phenomenon of precipitation - runoff provides data on the characteristics of floods downstream of the closing sections of small hydrographic basins (disharges, levels). On the basis of these data, the necessary measures can be established for the protection of the population and the socio-economic assets in the area where flash floods occur. The data resulting from the simulation of the precipitation-runoff phenomenon are used as input data for the hydrodynamic module of the MIKE11 program, thus allowing the modeling of the propagation of flood waves on the main watercourses in the hydrographic basins.

Also, the use of advanced hydroinformatic tools contributes to increasing the degree of precision of the results and greatly facilitates the work of specialists in the field in the development of a sustainable river basin management plan, water resources management plan and flood risk maps, and flood defense plans, respectively in establishing structural and non-structural measures for reducing flood flows, implicitly reducing their negative effects.

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