”BABEŞ-BOLIAY” UNIVERSITY
FACULTY OF GEOGRAPHY
GEOGRAPHY DOCTORAL SCHOOL

# PHD THESIS

*Abstract*

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**Cluj-Napoca**

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# RIVER WATER FLOW IN SUCEAVA HYDROGRAPHIC BASIN

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# SUMMARY

## KEY WORDS

regime, Suceava,hydrographic basin, Eastern Carpathians, Suceava Plateau, water flow, floods, low water, seasonal, monthly, daily, rainfalls, temperature, snow cover, perception, effects, flood prevention, control, seasonality, drought

# CHAPTER I. INTRODUCTION
## I.1. CONTEXT AND JUSTIFICATION

The effects of climate change on the hydrological component of the environment can be observed around the world, being documented and analyzed in various specialist works. Nowadays, excess and hydrologically deficient periods seem to be more and more frequent and increasingly rising.

In addition, river drainage and water resource management depend on the normal behavior of the river basins and the average seasonal variability of runoff (Pardé, 1933), which are and those affected by environmental changes.

The Suceava River made no exception to these variations. The increase in intensity and frequency of precipitation and dry periods caused strong variations in the amount of water drained in this river basin, and the occurrence of very high peak periods (culminating in exceptional floods from 2005-2010), interspersed with periods with very low minimum drainage (a part of the '80s and '90s).

To this end, I have attempted to make a study to analyze these variations and to present the current, current and possible future evolution of the water drainage regime in the Suceava River Basin.

## I.2. RIVER WATER FLOW REGIME. DEFINITION OF THE HYDROGRAPHIC REGIME

Knowing the drainage water regime in the rivers is of great importance at this time, climate change and anthropogenic intervention strongly altering it. The regime is defined in the English literature: "*the difference in the discharge of the river over the year*" (source: http://www.s-cool.co.uk / GCSE / geography / rivers / REVISE-IT / Hydrology).

The analysis of the water regime deals with problems related to the rhythms, the characteristic periods, the parameters used and the territorial distribution of the water regime. Among the parameters used in the flow analysis are the duration, the period of occurrence, the frequency, the variability and the extremes of the flows (maximum and minimum).

## I.3. TERM HISTORIC OF WATER FLOW REGIME RESEARCH

Within this chapter we tried to centralize the studies on the world drainage regime achieved over the years to the present day, presenting the evolution of the term of the regime and the way it was seen from beginnings until today ..

In the international literature, studies on the hydrological regime have a long history, references to such aspects still emerging from ancient Greece. In the medieval period, Perrault P. (1674) publishes a scheme of the Seine hydrological balance in Paris, entitled "De l'origine des fontaines", laying the basis of hydrological calculations in quantitative geography and hydrology.

The work done during the early study of the river water regime (until the 1940s) focuses on defining the water regime and the elements that are its integral part with a general analysis of them as part of larger works. These works appeared in the Russian and German schools. From the 1940s to the late 1980s, the drainage water regime became a topic most often debated by researchers, the study being conducted by three different hydrology schools (German school, French school and English school). After 1990, a new period begins for studies in the water regime, extending to other sub-areas, study directions and countries studying it, leaving the influence of the three schools. Thus, studies are directed both to the analysis of the regimes specific to certain rivers and to the analysis of the hydrological - environment regime relationship.

In Romania, there have been many concerns over the drainage water regime over time. The first to explore this area is Emm. De Martonne (1926), followed by V. Mihăilescu (1936) and later by Lăzărescu, D. and Panait, I. (1957), who analyze the types of regime in Romania. The most important author is Ujvari, I. (1957, 1965, 1972), who carried out a detailed analysis of the types of water drainage regime in Romania. He was followed by authors such as Mociornița, C. (1963), C. Diaconu (1962, 1973, 1988), Dumitrescu S. (1958, 1964), Sorocovschi, V. (1996, 2002, 2005, 2008, 2010 ), etc ..

## I.4. GEOGRAPHIC POSITION AND LIMITS OF SUCEAVA HYDROGRAPHIC BASIN

The basin of the Suceava River, a tributary of the Siret River, lies on the territory of Romania between the following geographical coordinates: 47°31 'and 47°59' north latitude and 25°05 'east longitude and 26°33' east. This hydrographic basin is asymmetric with a strong development on the right and drains the eastern edge of the Nordic Carpathian Group. The northern boundary of the study basin is given by the state border between Romania and Ukraine, the course of the Suceava River being the natural border between these two states between Baineţ and Ulma. To the west, the boundary follows the northern edge between Obcina Mestecanisului and Obcina Feredeului, which delimits the hydrographic basins of the rivers Suceava and Moldova. Then the border crosses Obcina Feredeului and Obcina Mare, following the line of the highest peaks between the rivers Suceava and Moldova (Fig.1). The southern boundary follows the line of the highest peaks between the rivers Suceava and Moldova from the exit of Obcina Mare, continuing with that between the Suceava river basin and the basins of Şomuzul Mare and Şomuzul Mic rivers, reaching the confluence point with the Siret River downstream by the city of Liteni. The eastern limit is the clearest, overlapping on the

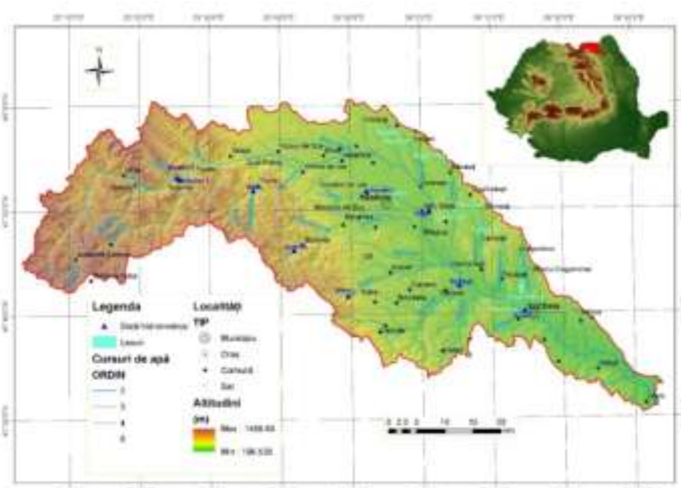


***Fig. 1.*** *Location of Suceava hydrographic basin*

interfluvial between the Suceava River Basin and the Siret River, superimposed over the highest hills of the Dragomirna Plateau.

## I.5. ELEMENTS OF GEOGRAPHICAL REGIONALIZATION

From the point of view of the altitude, in the basin of Suceava River are distinguished three distinct physico - geographic units with multiple implications on the hydrological processes of the rivers that drain them: the mountain sector - which includes Obcinile Bucovinei (the north and northwest of the basin) (including the Obcinile Bucovinei and the Suceava Plateau) - includes Piedmont Marginea - Ciungi (is located in the central part of the basin), the plateau sector - includes the western part of the Dragomirne Plateau, the Suceava River valley, Radauti Depression, Horodnic Depression, Iaslovăţ Depression and the northern part of the Fălticeni Plateau (Fig. 2).

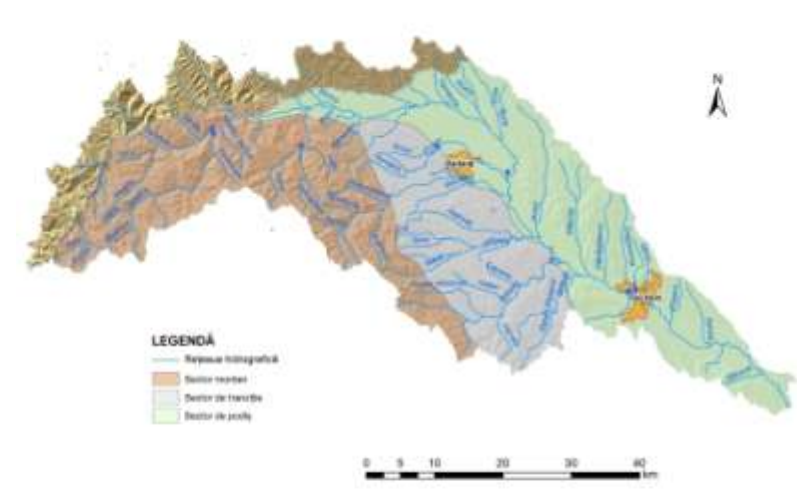



***Fig. 2.*** *Suceava river basin – sectors and hydrometric stations*

## I.6. DATA BASE

In order to analyze the peculiarities of the river water drainage regime during the period 1961-2010 within the Suceava basin, data on the physico-geographic characteristics of the land of this basin, of several types were used: cartographic data, geospatial and remote sensing maps, satellite imagery, etc.); hydrological data representing the reconstituted (annual, monthly and daily) flows in the period 1961-2010 and the hourly flow rates of the 2005-2010 floods for the 8 hydrometric stations in the basin, 3 of which are on the main course and 5 on the main tributaries (Figure 3); climatic data; socio-economic data.

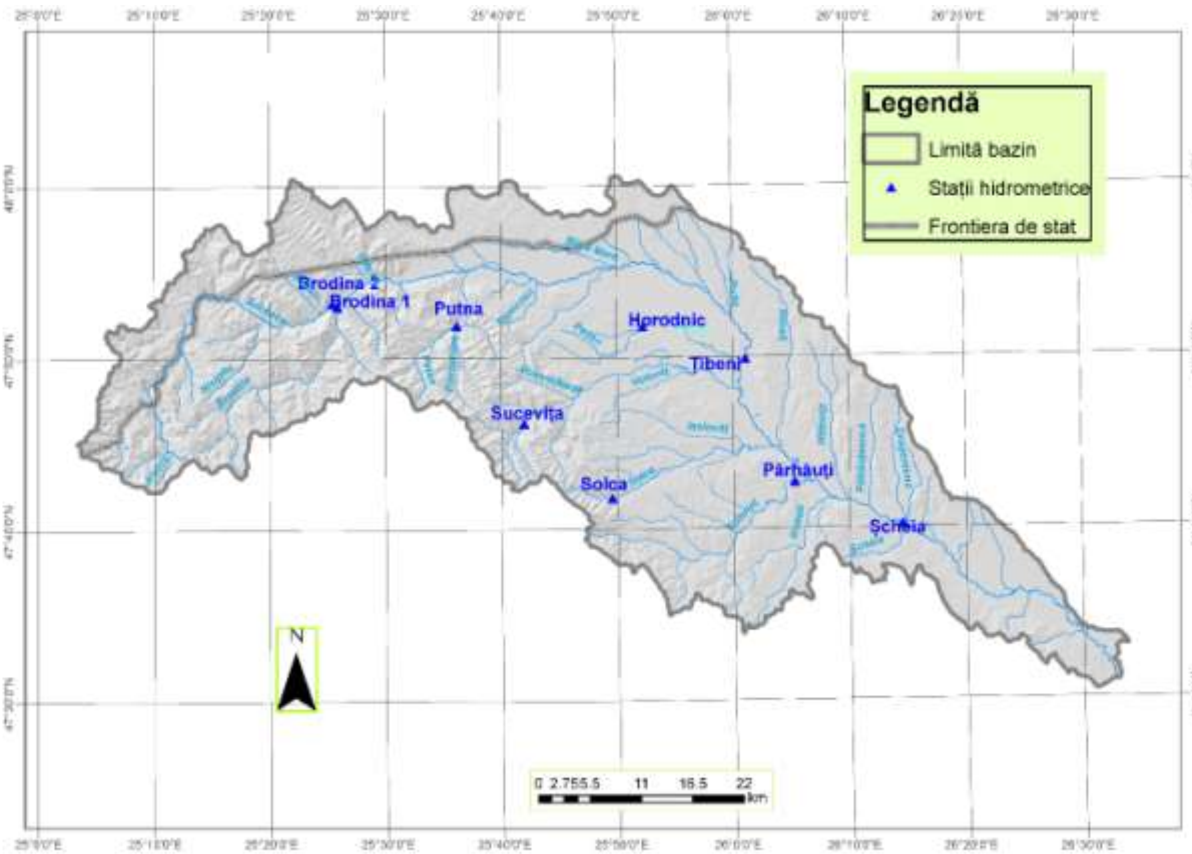



***Fig. 3.*** *Hydrometric stations' repartition in Suceava river basin*

## I.7. METHODS AND TECHNIQUES APPLIED

The quantitative data obtained and used in this paper have been processed using several working methods, which are specific to both geography and other sciences, conferring an interdisciplinary character to the present paper. Several methods were used to accomplish this work as follows:

General, specific and other methods: **the analysis method** (cause-effect analysis, statistical analysis and correlation of the data string, quantitative analysis of data strings), **the observation method** (the important elements in the field, accompanied by functional relations analysis – to analyze comparatively the static and temporal differences in the manifestation of geographic relief phenomena, climate and water), **the method of synthesis** (used for the centralization and final analysis of the data obtained from the natural and anthropic elements of the basin) land and data processing from hydrometric and climatic stations); **the questionnaire method** (social statistical method, which involved interviewing over 200 subjects in the face-to-face pool, by telephone, email, or electronic questionnaires under formats such as www.surveymonkey.com or www.google /survey.com), etc ..

Methods specific to geography: **statistical method** (for calculating statistical indicators of climatic and hydrological parameters, using programs such as Microsoft Excel 2010, CAVIS, HydroOffice, TLM extension, diagrams used to represent cathattic data by building different types of diagrams using Microsoft programs Excel 2010, CAVIS, HydroOffice, TLM extension), **geospatial mapping and geospatial analysis in GIS** (for spatial representation of the data obtained above).

# CHAPTER II. GEOGRAPHIC CONDITIONS AND THEIR ROLE IN WATER FLOW REGIME FORMATION IN SUCEAVA RIVER BASIN

## II.1. GEOLOGICAL CONDITIONS

The geology of a territory has a major role in its evolution, its degree of resistance to erosion and the composition of rocks; through their properties - physical (porosity, permeability, solubility) and mechanical (perforation resistance), with an important impact on the evolution over time of a hydrographic basin and its response to climatic factors.

In the tectonic structure of the Suceava River basin there are two major geostructural components: the orogenic area and the platform area, between which a contact area, which we have called a transition area.

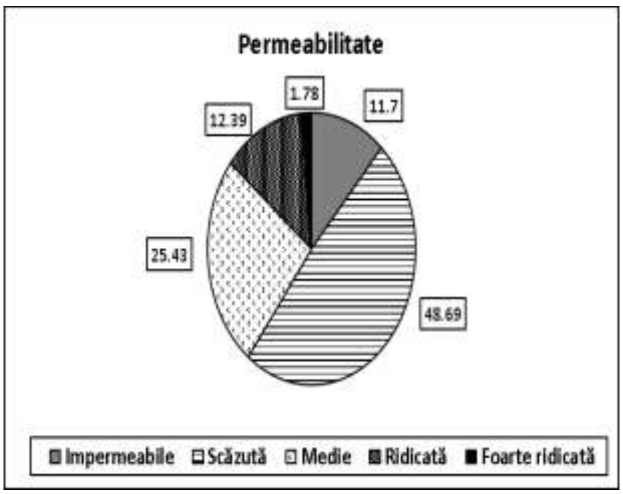



***Fig. 5.*** *Permeabilitatea (în %) a rocilor din bazinul hidrografic Suceava*

The rocks entering the geological composition of this basin have distinct characteristics that influence flow through water absorption and ability to allow water to pass through them to the lower soil layers, thus helping or not to increase the drainage velocity in basin and the development of certain areas prone to floods. From the point of view of permeability, almost 50% of the rocks in the Suceava basin have a low permeability, which is determined by the presence of loose and clayey rocks, which make it very difficult to infiltrate the water (Figure 5). These types of rocks overlap the basin transition sector where they occur cele mai multe inundații din bazin.

25% of the surface of the basin has medium permeability rocks, consisting of a greasy fly, located in the horogenic mountainous sector, where it is in intercalations with a shale, waterproof, which represents 11.7% of the basin surface. The highest permeability is found in the collector river and main tributaries, and includes river beds and terraces formed by recent sands and gravel. In the Suceava River Basin, an area with a high compact permeability is distinguished, this being Rădăuţi depression, developed almost exclusively on pebbles and sand.

## II.2. RELIEF

The relief has a strong impact on the formation of the river water flow regime, its morphometric peculiarities, and indirectly through the vertical zoning of the main climatic elements, the vegetal associations and the edifice.

From the point of view of the altitude, one can notice the decrease of the heights from the west to the east, from the upper mountainous sector represented by Obcinile Bucovinei, towards the plateau, formed by the Dragomirna Plateau, causing an absolute altitude difference of 1241 m. Following the share of the main steps of altitude, it can be seen that the highest percentages of the entire studied region have altitude ranges between 301 - 400 m (30.7%), followed by 401 - 500 m (24.1% ). The percentage of relief areas at altitudes less than 300 m is about 6%, and those with altitudes above 1100 m is 7% for each relief step.

The slope of the relief is one of the most important factors in surface and underground liquid flow control. The areas occupied by the five classes of delimited slopes are different. Thus, the highest share belongs to slopes with values between 5.1 and 15º, which hold 31.9% of the area of the region. Then, with close values, the classes are between 0 and 2º (27,2%), respectively 2,1 and 5º (25,5%) respectively. Areas with large slopes over 15º have lower weights (15%), while very large slopes (over 35º) have insignificant weights (0.1%).

The relief energy (depth of fragmentation or vertical fragmentation of the relief) is a morphometric parameter dependent on the petrographic composition, which reflects the different stages of deepening of the riverbed, depending on the change in the basic levels. At sector level, the largest depths of fragmentation are found in the mountain sector, which includes over 97% of basin areas with a fragmentation depth of more than 150 m, most of which have an energy of relief between 150 and 300 m. The transition and plateau sectors contain only surfaces with a relief depth of less than 150 m, 88% and 92% of the area of these sectors with relief energies of less than 100 m.

Density fragmentation of the relief illustrates the degree of evolution of the relief, offering the possibility of a detailed analysis of the way of organizing and evolution of the river water drainage process from the incipient stages of river formation to the most advanced ones.

The distribution of the horizontal fragmentation classes of the relief in the basin of the Suceava River is varied, the whole range of values being recorded, with weights ranging from one basin to another, the largest share of the total basin area belonging to the interval 1-1.5 km / km2 (24.8%). There are the intervals of 1.5 - 2 km / km2 (17.9%) and 0.5 - 1 km / km2 (16.6%). These are followed by values ranging from 2 to 2.5 km / km2 (12.9%) and 0.5-1 km / km2 (12.4%). Surfaces with slope fragmentation values between 2.5 and 4 km / km2 have values less than 10%, while those with more than 4 km / km2 have subunit values. This shows the variety of relief of this basin and its deployment on its deployment on two distinct relief sectors: mountain and plateau.

The exposure of the slopes is an important factor that induces differentiation in the duration of the sun, contributing to the formation and nuance of the caloric regime, influencing the moisture content in the soil by its cumulative effects, the configuration of the vegetative ovum characteristics, the soil peculiarities, the suitability for different ways of using the land, current geomorphological processes affecting the relief, etc.

The slope exhibition in the Suceava basin is very varied, with some exposure categories having slightly higher values. Flat surfaces have the lowest percentage, with 6.4% of the total basin area, but they have a fairly large area in some subbasses, due to the appearance of low gravel and sand sectors. The NE (17.4%) orientation is the highest, followed by E (15.7%), representing the main directions of the orientation. Then there are SE and SV directions, with 12% each, and N, E and S directions, with values between 9.5 and 9.9%.

In the mountain sector, located in the northwest of the study basin, the weight of the slope exhibition types is relatively equal in all directions and the flat surfaces are almost non-existent. With the exit from the mountain sector in the Voitinel basin, the exhibition changes, with NE → SE exhibits predominant, with an increase in the percentage of flat surfaces. Towards the bottom of the basin, the orientation moves slightly towards S.

## II.3. CLIMATIC CONDITIONS

### II.3.1 Climate genetic factors

The action of climatic factors is complex and simultaneous, playing an important role in the formation of the drainage regime of a river. The genetic factors of the climate are grouped into three categories, consisting of the radiation factors (solar radiation), the dynamic factors (the air masses represented by the barric centers), and the physico-geographic factors (relief, vegetation, soils).

### II.3.2. Analisis of main climatic elements

#### II.3.2.1. Rainfalls

The main feature of the atmospheric precipitation regime and its distribution is its variability and discontinuity in space and time. These are the result of the interaction of the genetic factors of the climate with the local environmental factors.

With regard to the seasonal rainfall, it can be noticed that most of the precipitations fall during the warm season, with a 4/1 ratio between the two periods of the year in the entire river basin without exceptions. This shows the very cool and dry nature of the cold season.

At an seasonall level, the precipitations are relatively homogeneous in the Suceava basin, with the largest quantities occurring in the whole pool during the summer (around 44% of cases) (Figure 19). The second season as a frequency is spring (25%), the last place being in winter (12%).

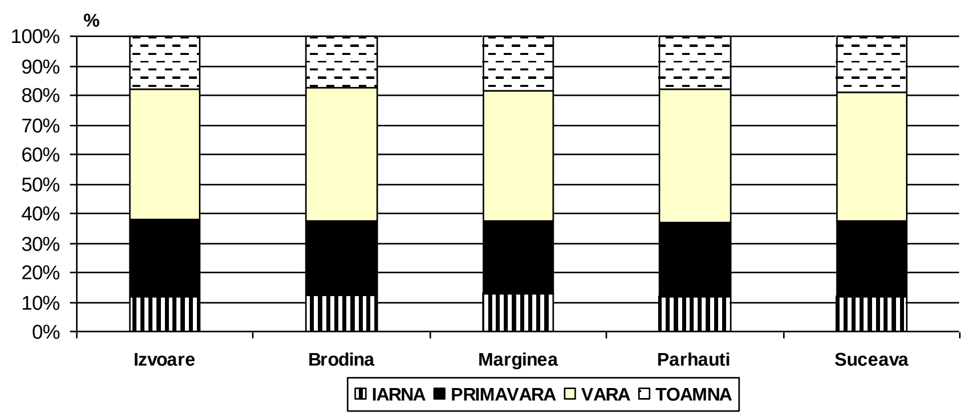



***Fig. 19.*** *Seasonal rainfall quantities (%)*

Monthly average precipitation in the entire basin of the Suceava River shows the highest values in July, with the maximum reaching in the mountain sector (Izvoarele Sucevei - 158.14 mm) (Table 19). These values decrease to the plateau sector, reaching a minimum of 102.9 mm in Suceava this month. The highest rainfall values are recorded between May and August, declining strongly in the other periods. The smallest values are recorded during January (22.94 mm at Părhăuţi), when the lowest atmospheric temperatures occur in this basin.

***Table 19.*** *Montlhy average rainfall quantities (in mm) from 1961-2010*

| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brodina** | 33,0 | 39,8 | 43,6 | 71,4 | 109,5 | 138,0 | 146,4 | 112,3 | 73,1 | 44,0 | 35,2 | 34,1 |
| **Izvoarele** | 33,6 | 41,8 | 53,8 | 80,8 | 119,9 | 153,6 | 158,1 | 120,2 | 80,7 | 54,4 | 43,5 | 42,2 |
| **Marginea** | 28,2 | 30,6 | 37,4 | 57,0 | 86,4 | 114,6 | 116,5 | 87,3 | 59,0 | 41,1 | 34,5 | 33,1 |
| **Părhăuți** | 22,9 | 24,1 | 29,2 | 50,0 | 74,7 | 98,7 | 103,0 | 76,2 | 49,2 | 32,8 | 28,2 | 24,3 |
| **Suceava** | 23,1 | 24,2 | 32,4 | 53,6 | 76,6 | 98,0 | 102,9 | 73,2 | 51,9 | 36,2 | 30,0 | 27,3 |

***Trend analysis using the linear regression method***

In order to analyze the rainfall trend during 1961-2010, the rainfall trend was calculated using the first degree equation for intervals of different lengths (one month, three months - seasons, six months - seasons, year), the values obtained in based on the ratings obtained (Table 26).

***Table 26.*** *Values and thresholds used for quantity trend of precipitation in the Suceava basin (after Croitoru, 2006)*

| Mark | Threshold value | Mark | Threshold value |
|---|---|---|---|
| +++ intense increase | ≥ 10 mm/10 years | -/0 very small decrease | -1.0…'-0.1 mm/10 years |
| ++ moderate increase | 9.9…6.0 mm/10 years | - small decrease | -5.9…'-1.1 mm/10 years |
| + small increase | 5.9…1.1 mm/10 years | -- moderate decrease | -9.9…'-6.0 mm/10 years |
| +/0 very small increase | 1.0…0.1 mm/10 years | --- intense decrease | ≥ -10 mm/10 years |

Trends were calculated for the entire interval, determining the overall rainfall trend, as well as for 10-year periods, analyzing the evolution of precipitation in each decade. As an example, there is a trend of precipitation in the period 1991-2000 (Table 30).

***Table 30.*** *Ratings according to the value of monthly, seasonal and semestrial rainfall trends between 1991-2000*

| | **1991-2000** | | | | |
|---|---|---|---|---|---|
| **Station/Analysed period ză** | **Brodina** | **Izvoare** | **Marginea** | **Părhăuți** | **Suceava** |
| **January** | + | + | + | + | +/0 |
| **February** | + | + | + | + | +/0 |
| **March** | + | + | +/0 | -/0 | - |
| **April** | + | + | + | + | + |
| **May** | -- | -- | -- | -- | -- |
| **June** | +/0 | +/0 | - | - | - |
| **July** | - | + | - | - | - |
| **August** | + | + | + | +/0 | +/0 |
| **September** | + | + | + | + | + |
| **Octomber** | -/0 | - | +/0 | + | + |
| **November** | - | - | - | - | - |
| **December** | +/0 | + | +/0 | +/0 | +/0 |
| **Spring** | - | - | - | -- | -- |
| **Summer** | + | ++ | - | - | - |
| **Autumn** | - | - | +/0 | + | + |
| **Winter** | + | + | + | + | + |
| **Warm seson** | +/0 | + | -- | -- | -- |
| **Cold season** | + | + | + | + | + |

***Trend analysis with the Mann-Kendall non-parametric test***

The Mann-Kendall non-parametric test (Mann, 1945; Kendall, 1975) was used to calculate rainfall and seasonal and extreme weather patterns with Excel MAKESENS (Mann-Kendall test for trend and Sen's slope estimates) created by researchers from the Finnish Institute of Meteorology (Salmi et al., 2002). The application of this test made it possible to identify the type of trend (positive or negative), and Sen's nonparametric method (Gilbert, 1987) allows estimation of the trend slope. The variation over the precipitation analysis period is determined by the atmospheric air circulation above the basin in the study, with local peculiarities influenced by the relief factor. These differences have also strongly influenced the drainage flow of the river basins with long-term effects (Table 31).

***Table 31.*** *Seasonal and extreme rainfall trend (in mm / year) and net change rate (in%) between 1961-2010 at the studied stations*

| ASeason | Hydro. station / Parameters | Brodina | Izvoarele Sucevei | Marginea | Părhăuți | Suceava |
|---|---|---|---|---|---|---|
| **Winter** | Trend | -0.65 | -0.80 | -0.22 | -0.43 | -0.52 |
| | Rating | SU | SU | S | S | SU |
| | Slope | -0.05 | -0.10 | -0.04 | -0.05 | -0.05 |
| | Net change (mm) | -2.70 | -5.21 | -2.25 | -2.33 | -2.50 |
| | Rate of net change (%) | -7.99 | -13.30 | -7.35 | -9.80 | -10.07 |
| **Spring** | Trend | 0.43 | 0.18 | -0.13 | -0.65 | -0.60 |
| | Rating | S | S | S | SU | SU |
| | Slope | 0.07 | 0.04 | -0.04 | -0.11 | -0.17 |
| | Net change (mm) | 3.61 | 2.23 | -1.89 | -5.41 | -8.33 |
| | Rate of net change (%) | 5.34 | 2.63 | -3.14 | -10.56 | -15.38 |
| **Summer** | Trend | 0.85 | 0.97 | 1.02 | 1.05 | 1.15 |
| | Rating | CU | CU | CU | CU | CU |
| | Slope | 0.23 | 0.33 | 0.30 | 0.30 | 0.28 |
| | Net change (mm) | 11.67 | 19.99 | 18.35 | 18.32 | 17.06 |
| | Rate of net change (%) | 9.3 | 37.3 | 14.2 | 16.2 | 15.3 |
| **Autmn** | Trend | 2.14 | 2.48 | 1.86 | 1.56 | 1.47 |
| | Rating | CM | CM | CM | CU | CU |
| | Slope | 0.42 | 0.57 | 0.33 | 0.25 | 0.25 |
| | Net change (mm) | 21.06 | 28.42 | 16.58 | 12.59 | 12.42 |
| | Rate of net change (%) | 40.61 | 47.75 | 36.98 | 34.30 | 31.52 |
| **January** | Trend | -0.52 | -0.62 | -0.85 | -0.87 | -0.70 |
| | Rating | SU | SU | SU | SU | SU |
| | Slope | -0.07 | -0.11 | -0.13 | -0.13 | -0.10 |
| | Net change (mm) | -3.62 | -5.73 | -6.58 | -6.32 | -4.78 |
| | Rate of net change (%) | -5.19 | -7.00 | -10.88 | -12.37 | -9.12 |
| **July** | Trend | -0.02 | 0.23 | 0.12 | 0.38 | 0.54 |
| | Rating | S | S | S | S | CU |
| | Slope | -0.02 | 0.22 | 0.03 | 0.22 | 0.26 |
| | Net change (mm) | -1.09 | 10.85 | 1.38 | 10.83 | 12.80 |
| | Rate of net change (%) | -1.57 | 13.25 | 2.27 | 21.20 | 24.42 |

### II.3.2.2. Snow cover

In the development of river water flow, an important role is played by the contribution of the melting of the snow layer. As with any other climatic element, the snow layer is characterized by several parameters: temporal - the duration of the snow layer (%, days), the date of the snow cover, the date of disappearance of the snow layer, the quantity of the snow layer (%).

Depending on the altitude, the snow layer persists more in the higher areas, with shorter hill and plain times. This is due to the longer persistence of negative temperatures at high altitudes. Table 37 presents the variations of these parameters in the basin of the Suceava river calculated for the period 1961-2010.

***Table 37.*** *Date of occurrence and disappearance of the first or last layer of snow*

| Station | Altit. (m) | First snow cover | | | Last snow cover | | |
|---|---|---|---|---|---|---|---|
| | | First date of appearence | Average | Last date of appearence | First date of appearence | Average | Last date of appearence |
| **Brodina** | 1016 | 14.10.2008 | 06.XI | 16.12.1985 | 22.03.2009 | 21.IV | 04.05.2010 |
| **Izvoarele Sucevei** | 910 | 28.09.1976 | 03.XI | 17.12.1999 | 23.03.2009 | 25.IV | 07.06.2010 |
| **Marginea** | 446 | 24.10.1990 | 15.XI | 20.12.1999 | 03.03.2010 | 26.III | 24.04.1996 |
| **Părhăuți** | 300 | 26.10.1990 | 23.XI | 26.12.1985 | 18.02.1989 | 24.III | 18.04.1996 |
| **Suceava** | 296 | 26.10.1990 | 24.XI | 26.12.1985 | 9.02.1976 | 18.III | 18.04.1996 |

Between the quantitative parameters of the snow layer, the most important is its thickness, with important implications both in the hydrological regime of the water flow in the basin (influenced by the intake of water from the melting of snow, but also the reserve of water accumulated in the soil), but also on the economy (agriculture), hydro-technical facilities, water supply, etc. The thickness of the snow layer varies depending on altitude, in mountain areas it is possible to maintain a higher thickness of the layer due to favorable weather conditions.

Monthly average thickness. Although the highest snow cover is recorded in January, the highest thicknesses are recorded in February (even March in the mountain sector) (Table 40). This is due to the maintenance of negative temperatures until March, which favors the massive accumulation of snow. The highest values of the thickness of the snow layer are registered at the Izvoarele of Suceava, where in February - March, the grace is maintained at values of 45 and 47 cm of snow respectively. With the decrease of the altitude, the thickness of the snow layer decreases, reaching up to 9 cm in the lower section. The variations in mean snow thickness are lower in the plateau sector (6.5 cm), but these increase significantly but they increase significantly with the transition to the mountain sector, reaching 34 cm in the highest part of the basin.

***Table 40.*** *Monthly average thickness (cm) of snow cover*

| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brodina** | 27.474 | **39.701** | 37.506 | 7.224 | 0.044 | 0.004 | 0.00 | 0.00 | 0.001 | 0.412 | 4.547 | 15.018 |
| **Izvoarele Sucevei** | 32.309 | 45.314 | **47.431** | 11.979 | 0.106 | 0.005 | 0.00 | 0.00 | 0.006 | 0.672 | 5.525 | 18.434 |
| **Marginea** | 17.949 | **21.585** | 15.491 | 1.039 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.084 | 2.887 | 9.706 |
| **Părhăuți** | 8.067 | **9.527** | 6.415 | 0.213 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.014 | 1.173 | 3.903 |
| **Suceava** | 7.419 | **8.795** | 5.972 | 0.209 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.014 | 1.133 | 3.585 |

### II.3.2.3. Temperature

Air temperature is a climate element directly related to solar radiation, which directly influences the climate of a region and, at the same time, the drainage regime of the rivers in that region. In terms of seasonal temperatures, the highest temperatures occur in the hot season. The temperatures in the warm season (April - October) increase with altitude, the highest values being recorded in the plateau sector (15.5 ° C - Suceava), and the lowest in the mountain sector

(9.7 ° C - Izvoarele of Suceava). The deviations of the extreme values recorded this season reflect these variations but are higher in the mountains, ranging between 10.9 and 15.3% (maximum) and -11.4 - -19.1% (minimum).

Throughout the Suceava River basin, the average temperatures of the seasons are directly related to the altitude variation (Figure 33). In the winter season, average temperatures are negative throughout the pool, the highest values being recorded in the plateau sector. Spring temperatures are positive, reaching a peak of 8.43 ° C in the plateau sector. Highest heat values are recorded during summer, when average temperatures vary between 12.38 and 18.31 ° C. During autumn, temperatures return to springtime, being equally sensitive in the plateau sector, but higher in the middle and upper sectors.

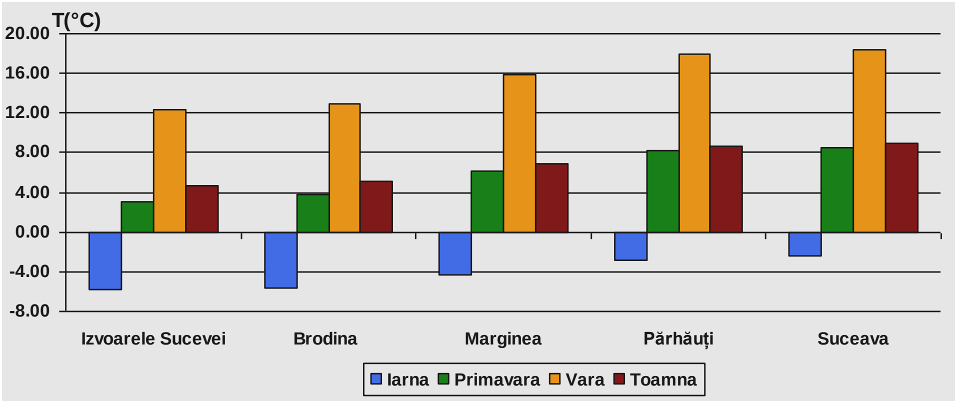



***Fig. 33.*** *Variația anotimpuală a temperaturilor medii multianuale (în °C)*

**Trend of temperatures.** Following the values obtained for the period 1961-2010, a positive trend of temperatures in the entire Suceava river basin was observed, a tendency which varied from stationary in winter to all stations, a marked increase during spring and autumn at all stations 51). An analysis of the temperature trend was also carried out on each of the cynical decades of the analyzed period.

***Table 51.*** *Trend of seasonal temperatures (in ° C / year) and net change rate (in%) for air temperatures during 1961-2010 at the studied stations*

| Season | Hydro. station / Parameters | Brodina | Izv. Sucevei | Marginea | Părhăuți | Suceava |
|---|---|---|---|---|---|---|
| Winter | Trend | 2.46 | 2.34 | 2.49 | 2.58 | 2.66 |
| | Rating | CM | CM | CM | CM | CM |
| | Slope | 0.04 | 0.03 | 0.04 | 0.05 | 0.05 |
| | Net change (mm) | 1.83 | 1.59 | 2.03 | 2.39 | 2.37 |
| | Rate of net change (%) | 37.70 | 27.83 | 47.39 | 85.06 | 96.22 |
| Spring | Trend | 2.09 | 2.14 | 2.41 | 2.56 | 2.48 |
| | Rating | CM | CM | CM | CM | CM |
| | Slope | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 |
| | Net change (mm) | 1.17 | 1.18 | 1.36 | 1.74 | 1.71 |
| | Rate of net change (%) | 22.88 | 37.67 | 22.12 | 21.31 | 20.04 |
| Summer | Trend | 4.82 | 4.65 | 4.55 | 4.53 | 4.45 |
| | Rating | CA | CA | CA | CA | CA |
| | Slope | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| | Net change (mm) | 2.12 | 2.61 | 2.57 | 2.54 | 2.56 |
| | Rate of net change (%) | 14.61 | 21.20 | 16.17 | 14.14 | 13.91 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Autumn | Trend | 0.00 | -0.25 | 0.07 | 0.12 | 0.02 |
| | Rating | S | S | S | S | S |
| | Slope | 0.00 | -0.01 | 0.00 | 0.00 | 0.00 |
| | Net change (mm) | 0.01 | -0.26 | 0.06 | 0.08 | 0.02 |
| | Rate of net change (%) | 0.10 | -5.62 | 0.87 | 0.89 | 0.20 |
| January | Trend | 2.06 | 2.06 | 2.11 | 2.26 | 2.23 |
| | Rating | CM | CM | CM | CM | CM |
| | Slope | 0.058 | 0.054 | 0.062 | 0.073 | 0.077 |
| | Net change (mm) | 2.91 | 2.72 | 3.12 | 3.66 | 3.84 |
| | Rate of net change (%) | 48.65 | 41.84 | 56.29 | 90.42 | 104.87 |
| July | Trend | 3.95 | 3.93 | 3.96 | 4.02 | 4.02 |
| | Rating | CA | CA | CA | CA | CA |
| | Slope | 0.050 | 0.051 | 0.053 | 0.053 | 0.054 |
| | Net change (mm) | 2.51 | 2.57 | 2.64 | 2.67 | 2.71 |
| | Rate of net change (%) | 16.59 | 19.86 | 15.87 | 14.36 | 14.19 |

## II.4. VEGETATION

Vegetation has different roles in the formation of rivers. Thus, by increasing the water infiltration capacity in the soil, it helps to increase the amount of water stored in the underground water resources, helping to supply surface water during low drain periods (autumn, winter).

It can be noticed that the forests are unfolded within the basin, determined by the distribution of relief factors and climate, but also by the strong antropic intervention, materialized by very strong deforestation produced especially in the last part of the 20th century and in the first decade of of the 21st century, especially in the transition and plateauing sectors, where forests have been replaced by agricultural land, pastures (for livestock farming) and civil engineering. The forests of the Suceava basin are surrounded by four vegetation floors: coniferous forests, mixed forests, deciduous forests and mixed deciduous forests. From the west to the east, with the descent in the altitude, the following vegetation floors are distinguished in the basin of the Suceava River (Geography of Romania, 1987, 1992).

## II.5. EDAFIC FACTOR

The soils appearing in the basin (Figure 35) belong to 7 soil classes, which vary from one sector to another as a surface, these being the classes of argilvvisols, cambisols, spodosols, molisols (cernisols), hydromorphic soils (hidrisols) and non-evolved soils (protosols).

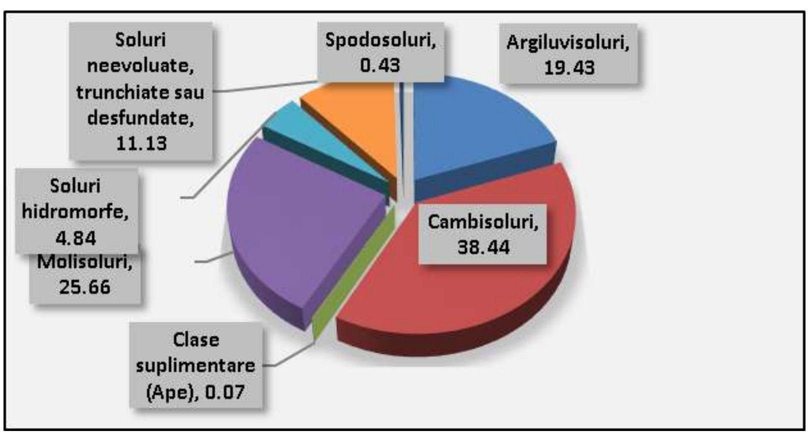



***Fig. 35.*** *Share (in %) of soil classes in the Suceava basin*

If we analyze the **texture** of these soils, which is the one that influences the degree of infiltration of a soil type, it is possible that the soils with silky texture (76,5%) prevail in the basin (Fig. 37), which are conducive the infiltration of water into the soil and helps to drain it, reducing the risk of flooding. Most of the soils have loose texture (31.5%) and luteonite (16.8%). At high distance there are soils with clayey texture (19.4%), which have a low water infiltration rate, being conducive to floods.

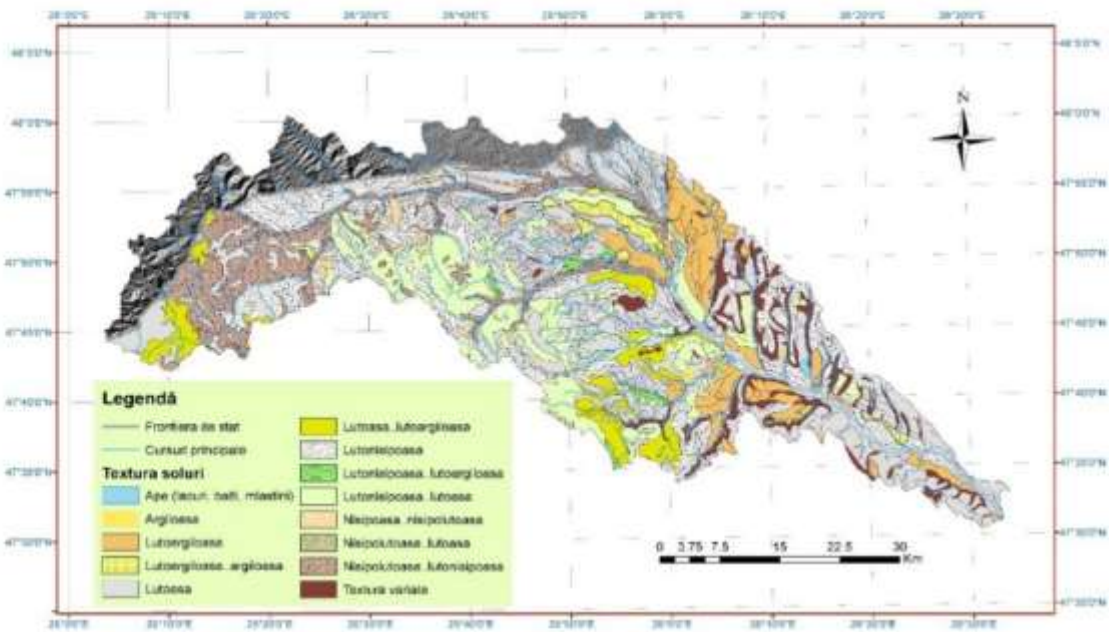


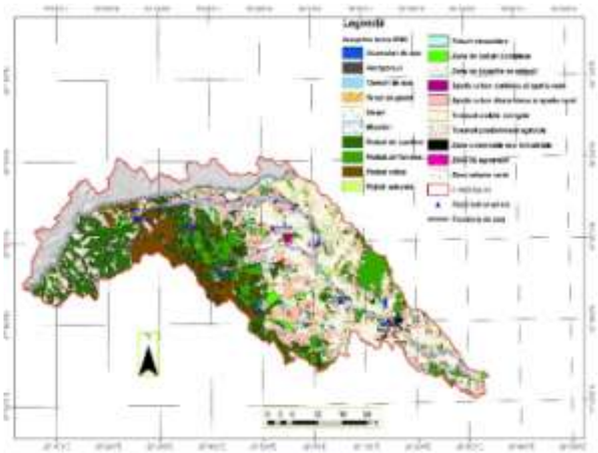

***Fig. 37.*** *Soil texture in Suceava river basin*

## II.6 ROLE AND INFLUENCE OF HUMAN FACTOR

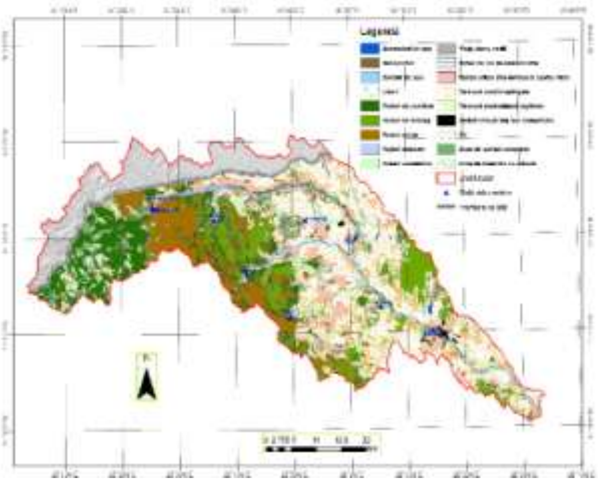
The man makes a considerable contribution to the modification of the drainage water regime of a river through its own presence in the vicinity of the river, by the actions it takes on the water and the ground in the basin, the constructions that it raises in the riverbed and the entire basin, etc. This contribution may have a positive or negative influence on the formation and evolution of the water drainage regime (in most cases negative), manifested in the way the river behaves and reacts to environmental changes (especially climatic). Therefore, when considering the drainage regime of a river, one must also take into consideration the role of man in the river, which can greatly change the natural regime of a river.

### II.6.1. Land use

Suceava County, and including the Suceava River Basin, has been for hundreds of years, one of the most afforested areas of our country. However, the rapid increase in the number of inhabitants during the communist period has also led to an increase in the network of settlements and communication channels. As a result of this, the percentage of land occupied by civil and agricultural land increased, all gained at the expense of land occupied by forests and pastures (Figure 38).



(a)



(b)

***Fig. 38.*** *Comparison of land use in the Suceava river basin in 1996 (a) and 2012 (b) (maps after Corinne Landcover)*

## II.6.2. Hydrotechnical facilities in Suceava river basin

Permanent or non-permanent hydro-technical accumulations in the basin Permanent or non-permanent hydro-technical accumulations may have different roles in a hydrographic basin, one of the most important being the defense and mitigation of floods, but also the influence of flow values river water during the low water period.

In the Suceava River Basin there are eight permanent and non-permanent accumulations managed by SGA Suceava, with mixed functions, mostly fish farming, water supply of the cities of Suceava and Solca, and protection against floods. The largest of these are Solca (56.24 million m3) on the river Solca, Dragomirna (V = 19.22 million m3) on the Dragomirna river, Şerbăuţi (V = 1.59 million m3) on Hătnuţa, Grăniceşti V = 1.36 million m3) on Horaiţ, and Mihoieşti (0.31 million m3) on Suceava. Only the accumulations of Şerbăuţi, Grăniceşti and non-permanent ones Horodnicu 1, 2 and 3 were built for the mitigation of the floods, after the floods, in response to their negative effects.

## II.6.3. Hydrotechnical works for embankment, regulation and bank consolidation

Prior to the historical floods from 2005-2010, there were dams and other hydro-technical works with more than 30 years of age in the Suceava river basin. The only minor works are in the localities of Salcea, Mihoveni, ACET Suceava and Frătăuţi Noi (20 years old) and in the localities of Straja and Vicovu de Sus (since 2004) (Table 60). It can be noticed that not all dams are subordinated to the Romanian Waters Directorate, but they belong to

CFR Iaşi Regional, S.C. F.E.E. E.ON Moldova, various local councils and private companies, which makes their maintenance more difficult due to the various owners. Most of the lengths are located on the Suceava River in Suceava (12.06 km) and Vicovu de Jos (9.5 km), on the Pozen river at Frătăuţii Vechi (9.48 km) and at Horodnicu de Sus 7.37 km); on the Voitinel river in Gălăneşti (7,15 km). This was determined by the absence of phenomena with very strong negative effects in some parts of the basin, while others, where the dams were almost absent, were severely affected.

## II.6.4. The network of localities

The network of settlements in the studied area (with an area of 2278.46 km2) comprises 50 administrative-territorial units, of which 8 are towns and 42 communes with the associated villages (a total of 143 settlements), resulting in an average density of 15, 93 localities / km2 (Fig. 41). Of these localities, 4 communes have extended only part of their surface in the territory of the Suceava basin. Altogether 8 villages from these communes are extended to the Siret and Sosuzul Mic basins, being located in the southern and eastern parts of the basin.

However, if it analyzes the three sectors delineated in this basin, it appears that in the mountain sector there are 23 localities (5 communes), in the transition 40 (4 cities and 36 communes) and in the 80 (4 cities and 76 communes) (59.7% of the total of the localities in the basin), resulting in a density of 2.51 localities / km2 in the mountain sector, 7.24 localities / km2 in the transition zone and 9.86 localities / km2 in the plateau.

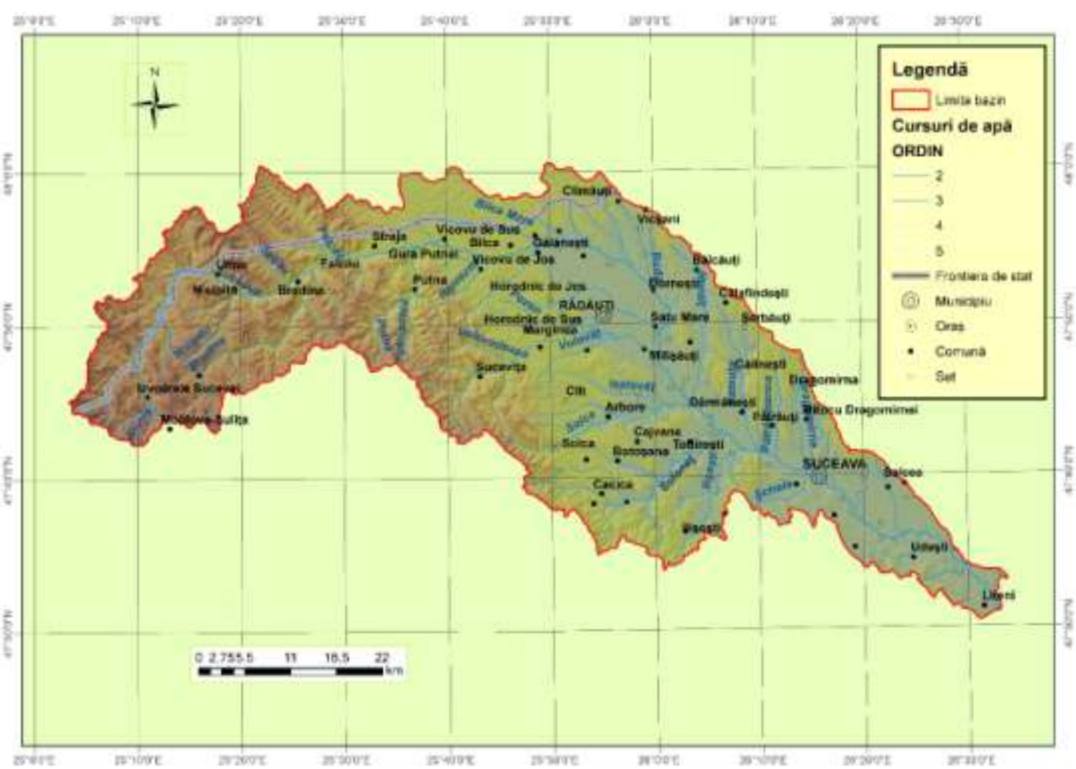



***Fig. 41.*** *The network of localities from Suceava river basin*

# CHAPTER III. RIVER WATER FLOW IN SUCEAVA HYDROGRAPHIC BASIN

The study of the water drainage regime of a river involves the knowledge of the variation of the flow and of the sources of supply, depending on the climatic factors regime and the physico-geographic conditions of the river basins, which terminate the complexity of the regime.

## III.1. RIVER SUPPLYING SOURCES

The river regime is influenced by local and regional climate conditions, which determine its characteristics. The river is supplied both from surface sources (surface liquid flow) and / or from underground sources, depending on the characteristics of the physico-geographic and geological factors. Of the surface sources, the most important are the rains and snow melting, followed by the melting of glaciers and permanent snow.

Separation of power supplies from a hydrographic basin can be done with the help of the daily average flow chart. Thus, by means of a curved line, the winter and summer minima and the final valleys of the floods are combined, resulting in the flow from the groundwater sources. The separation between rain and snow is done by analyzing meteorological factors (precipitation, temperature, snow cover) at the basin stations.

In this, the sources of supply for all the basin stations were analyzed, obtaining the percentage of each source in the total flow of the river (Table 61).

***Table 61.*** *Sources of water supply (%) for rivers Suceava basin*

| Stație | Subteran | Surse de suprafața | | Tip de alimentare |
|---|---|---|---|---|
| | | Zăpadă | Ploi | |
| Brodina 2 | 15,5 | 34,79 | 65,21 | Sp |
| Țibeni | 24,86 | 33,7 | 66,3 | Sp |
| Ițcani | 11,13 | 25,48 | 74,52 | Sp |
| Brodina 1 | 16,13 | 29,59 | 70,41 | Sp |
| Putna | 7,01 | 33,7 | 66,3 | Sp |
| Horodnic | 22,22 | 22,19 | 77,81 | Sp |
| Părhăuți | 18,89 | 18,9 | 81,1 | Sp |
| Șcheia | 66,66 | 11,78 | 88,22 | Up |

Based on the analysis at the stations in the Suceava basin (Figure 42), it can be said that the supply in the basin is predominantly of the surface, with preponderant feed (over 60%) of the rainfall (Sp), specific for the lower mountainous sector of the Eastern Carpathians, making the Scheia station, where the power is Up.

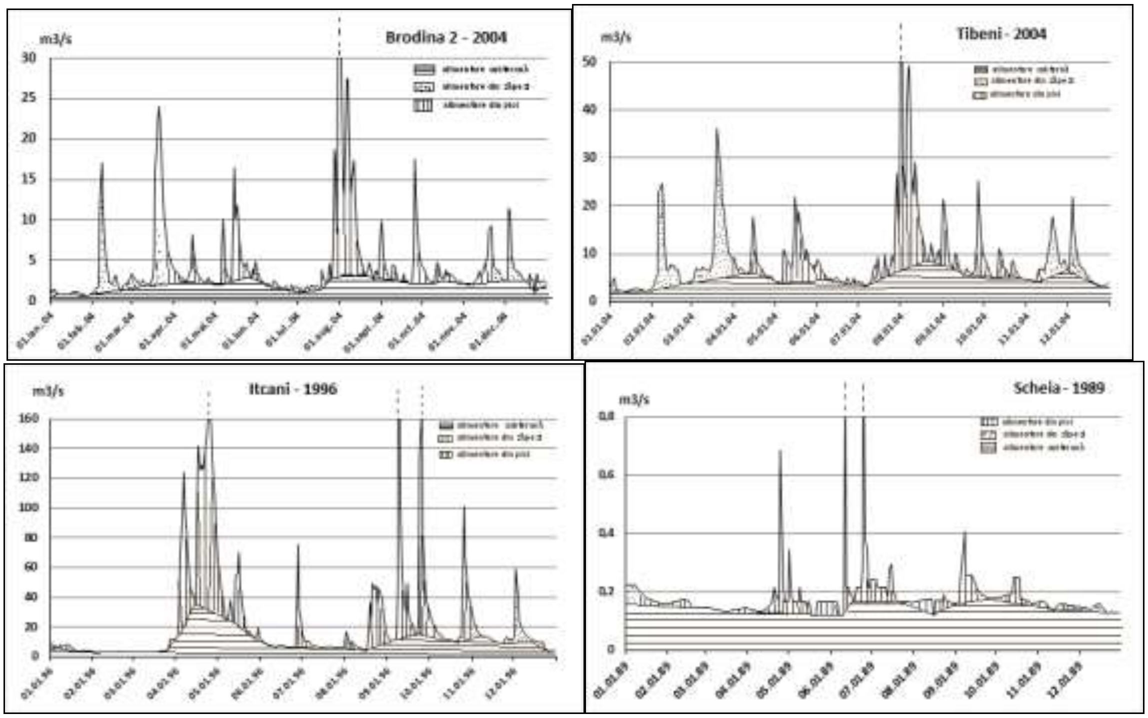



***Fig. 42.*** *Hidrografele pentru anii medii și sursele de alimentare ale râurilor din bazinul hidrografic Suceava*

*

# III.2. RIVER WATER FLOW IN SUCEAVA HYDROGRAPHIC BASIN

## III.2.1. Seasonal flow regime

The distribution of the river water run-off in the studied region (Figure 62) is closely related to the climatic conditions, resulting in local differentiation due to physico-geographic conditions.

***Table 62.*** *Valorile procentuale ale scurgerii anotimpuale a râurilor din bazinul hidrografic Suceava*

| | Winter | Spring | Summer | Autumn |
|---|---|---|---|---|
| **Brodina 2** | 8,5 | 35,4 | 39,7 | 16,4 |
| **Țibeni** | 9,9 | 36,5 | 38,6 | 15,0 |
| **Ițcani** | 10,6 | 36,3 | 37,9 | 15,2 |
| **Brodina 1** | 8,5 | 34,0 | 41,3 | 16,2 |
| **Putna** | 10,2 | 33,2 | 40,8 | 15,8 |
| **Horodnic** | 14,8 | 34,5 | 34,4 | 16,3 |
| **Părhăuți** | 13,6 | 36,1 | 35,0 | 15,3 |
| **Șcheia** | 16,9 | 32,8 | 33,3 | 17,0 |

In the Suceava River Basin, winter represents the season with the lowest value of flow on rivers during the year, with rivers in the mountain sector showing very low flow values. The lowest values of winter run-off (8.5% of the annual volume) are recorded at Brodina 1 and 2 stations at the highest altitudes of all stations. Compared to the average situation, there are both positive and negative deviations. The highest positive values occur in the years 2002 (at the highest altitude stations - Brodina 1,2, Putna) and 1982 at the main courses in the plateau (Ţibeni, Iţcani, and Şcheia) (Table 63). The relative maximum deviations exceeded 200% at all stations. The lowest values were registered in 1964, at many stations the flow values approaching 0, with relative deviations that even exceeded -30%.

***Table 63.*** *Maximum and minimum values of winter and spring spillage*

| Râu | Stația hidro. | Qi med ($m^3/s$) | Valori extreme | | | | Qp med ($m^3/s$) | Valori extreme | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Max | | Min | | | Max | | Min | |
| | | | Abs. | An | Abs. | An | | Abs. | An | Abs. | An |
| **Suceava** | **Brodina 2** | 1.462 | 3.43 | 2002 | 0.45 | 1964 | 6.093 | 14.63 | 1970 | 1.28 | 2002 |
| **Suceava** | **Țibeni** | 4.764 | 12.12 | 1982 | 1.35 | 1964 | 17.612 | 44.74 | 1970 | 3.28 | 1990 |
| **Suceava** | **Iţcani** | 7.192 | 19.34 | 1982 | 1.85 | 1964 | 24.682 | 61.29 | 1970 | 5.43 | 1990 |
| **Brodina** | **Brodina 1** | 0.591 | 1.44 | 2002 | 0.18 | 1964 | 2.352 | 6.83 | 1970 | 0.61 | 1994 |
| **Putna** | **Putna** | 0.258 | 0.66 | 2002 | 0.06 | 1964 | 0.838 | 2.21 | 1984 | 0.19 | 1990 |
| **Soloneț** | **Părhăuţi** | 0.679 | 1.94 | 2008 | 0.14 | 1964 | 1.805 | 5.83 | 1970 | 0.30 | 1990 |
| **Pozen** | **Horodnic** | 0.315 | 0.82 | 1998 | 0.06 | 1964 | 0.733 | 2.29 | 1978 | 0.20 | 1987 |
| **Şcheia** | **Şcheia** | 0.111 | 0.27 | 1982 | 0.02 | 1964 | 0.215 | 0.50 | 1978 | 0.04 | 1974 |

*The spring (III - V)* is the second season after the summer as the value of the flow, the only hydrometric stations with Horodnic (34.5%) and Parhăuţi (36.1%). Spring spring values represent over 30% of the annual amount. The maximum spring percentage (36.5%) is recorded at the Ţibeni station. At the rest of the stations, the values are approximately equal, varying slightly around 35%.

***Table 64.*** *Maximum and minimum values of summer and autumn flow*

| River | Hydro. Station | Qv med ($m^3/s$) | Extreme values | | | | Qt med ($m^3/s$) | Extreme values | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Max | | Min | | | Max | | Min | |
| | | | Abs. | An | Abs. | An | | Abs. | An | Abs. | An |
| **Suceava** | **Brodina 2** | 6.84 | 15.10 | 2010 | 2.04 | 1990 | 2.82 | 6.85 | 1997 | 0.89 | 1961 |
| **Suceava** | **Țibeni** | 18.59 | 57.45 | 1969 | 4.53 | 1987 | 7.22 | 17.31 | 1972 | 1.86 | 1963 |
| **Suceava** | **Iţcani** | 25.71 | 78.71 | 1969 | 6.01 | 1990 | 10.33 | 28.67 | 1996 | 2.54 | 1963 |
| **Brodina** | **Brodina 1** | 2.86 | 7.12 | 2010 | 0.62 | 1993 | 1.12 | 2.75 | 1997 | 0.35 | 1987 |
| **Putna** | **Putna** | 1.03 | 3.44 | 2008 | 1.71 | 1987 | 0.4 | 1.14 | 2001 | 0.08 | 1990 |
| **Soloneț** | **Părhăuţi** | 1.75 | 6.50 | 2006 | 0.25 | 1990 | 0.77 | 2.01 | 2007 | 0.15 | 1990 |
| **Pozen** | **Horodnic** | 0.73 | 3.22 | 2010 | 0.11 | 1964 | 0.35 | 1.01 | 1996 | 0.08 | 1963 |
| **Şcheia** | **Şcheia** | 0.22 | 1.24 | 2010 | 0.03 | 1964 | 0.11 | 0.27 | 1981 | 0.02 | 1963 |

The smallest flow values in this season have been recorded over a number of years with variations from one station to another (distancing 1990 to four stations), but with relatively lower deviations than in winter, the smallest the value being recorded in 1994 at the Brodina 2 station (-25.9%). The highest values of the spring flow occurred in two years - 1970 and 1978, in 1970 one of the largest floods occurred on the Romanian territory, at Brodina 1 and Brodina 2 stations, some of them being recorded higher historical flows, and at the stations Brodina 2 and Părhăuţi the highest values of the maximum relative deviation were recorded - 290.6%, respectively 323.9%.

*The summer (VI - VIII)* represents the season with the highest value of the year-round flow at almost all stations (except Horodnic and Părhăuţi stations), close to the one during the spring. At all basin stations, summer flow values exceed 30% (Table 64). In the mountain sector, these values exceed even 40% (41.3% at Brodina 1 station, 40.8% at Putna station). The lowest values are recorded at the stations in the Suceava Plateau (Şcheia - 33.3%, Horodnic - 34.4% and Părhăuţi - 35%).

Maximum summer flow rates were recorded in the first decade of the 21st century in the years 2008 and 2010 (Table 64), when the largest floods in this basin were recorded, with the highest deviations from the flow average of 441.1% (Horodnic) and even 563.6% (Şcheia). Exceptions are made by the stations of Tibeni and Iţcani, where the highest maximum summer flows were recorded in 1969. The years when summer flow rates were recorded vary from one station to another, but concentrated in very dry years , such as 1964, 1987 and 1990.

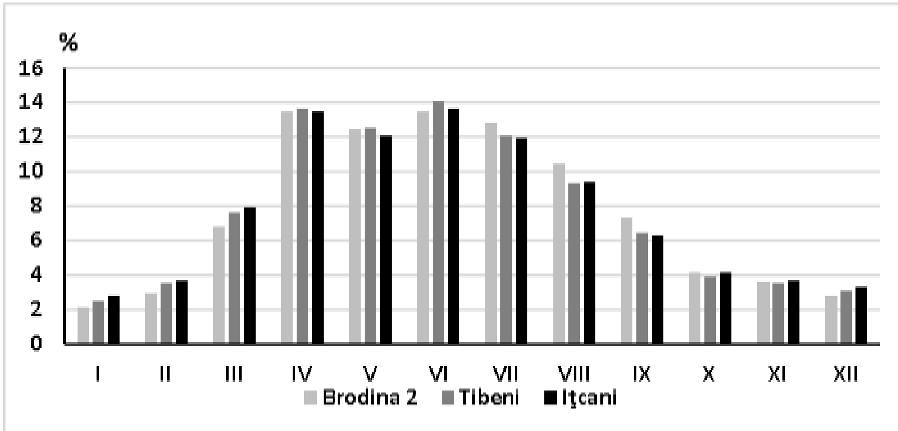
Values recorded during *autumn* at all basin stations vary between 15 and 17% of the annual value. The highest values are recorded at mountain stations (Brodina 1, Brodina 2), gradually decreasing with the entry into the plateau. Higher values are recorded at the Scheia station, where the reduced size of the basin causes a faster reaction to the autumn rainfall. The leak recorded positive and negative deviations, with no evidence of a year, showing the irregularity of this season at all stations, with minimum values ranging from -18.2% (Şcheia, 1963) and -31.6% (Brodina 2, 1961), and the maximum between 239.7% (Ţibeni, 1972) and 288.6 (Horodnic, 1996). However, it can be noticed that the lowest values were recorded at the beginning of the analysis period, and the highest values towards the end of the period, showing the slightly or even more pronounced increasing trend of the flow trend in this season.

## III.2.2. Monthly flow regime

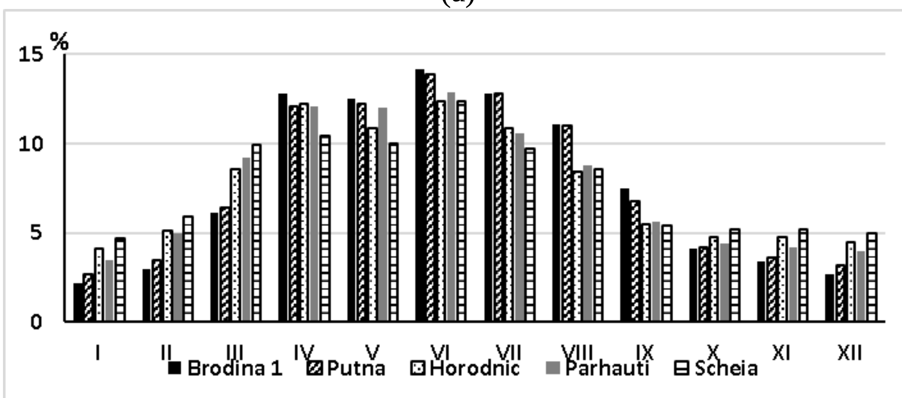
In the basin of the Suceava River, the monthly discharge shows a uniform variation in the whole basin, having a unitary character, with small territorial differentiations determined by local factors. Thus, peak leaks appear on all rivers, with three exceptions, in June, followed by April and May. Exceptions make the rivers in the mountain sector, which show another succession of the maxims: Brodina 1 and 2 - June, April, July; Putna - June, July, May.

All the minima recorded in the basin occur during January, the values exceeding only 3% of the annual total values in the case of Pozen, Soloneţ and Şcheia rivers. Then December, February and November are the minimum values.

The main course of the Suceava River is the one that synthesizes the evolution of the flow in the basin, showing from the springs to the spill the transition from the mountain sector to the plateau (Figure 44). It can be seen the strong difference between the drainage in this basin and the drainage types in the Transylvanian Depression, where the winter flow has a much higher weight due to the higher temperatures of this season, and the one in the summer has a lower weight.




(a)




(b)

***Fig. 44.*** *Scurgerea medie lunară (%) la stațiile de pe cursul principal (a) și de pe afluenți (b)*

## III.2.3. Daily flow regime

In the basin of the Suceava River, the monthly discharge shows a uniform variation in the whole basin, having a unitary character, with small territorial differentiations determined by local factors. Thus, peak leaks appear on all rivers, with three exceptions, in June, followed by April and May. Exceptions make the rivers in the mountain sector, which show another succession of the maxims: Brodina 1 and 2 - June, April, July; Putna - June, July, May.

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The main course of the Suceava River is the one that synthesizes the evolution of the flow in the basin, showing from the springs to the spill the transition from the mountain sector to the plateau (Figure 44). It can be seen the strong difference between the drainage in this basin and the drainage types in the Transylvanian Depression, where the winter flow has a much higher weight due to the higher temperatures of this season, and the one in the summer has a lower weight.

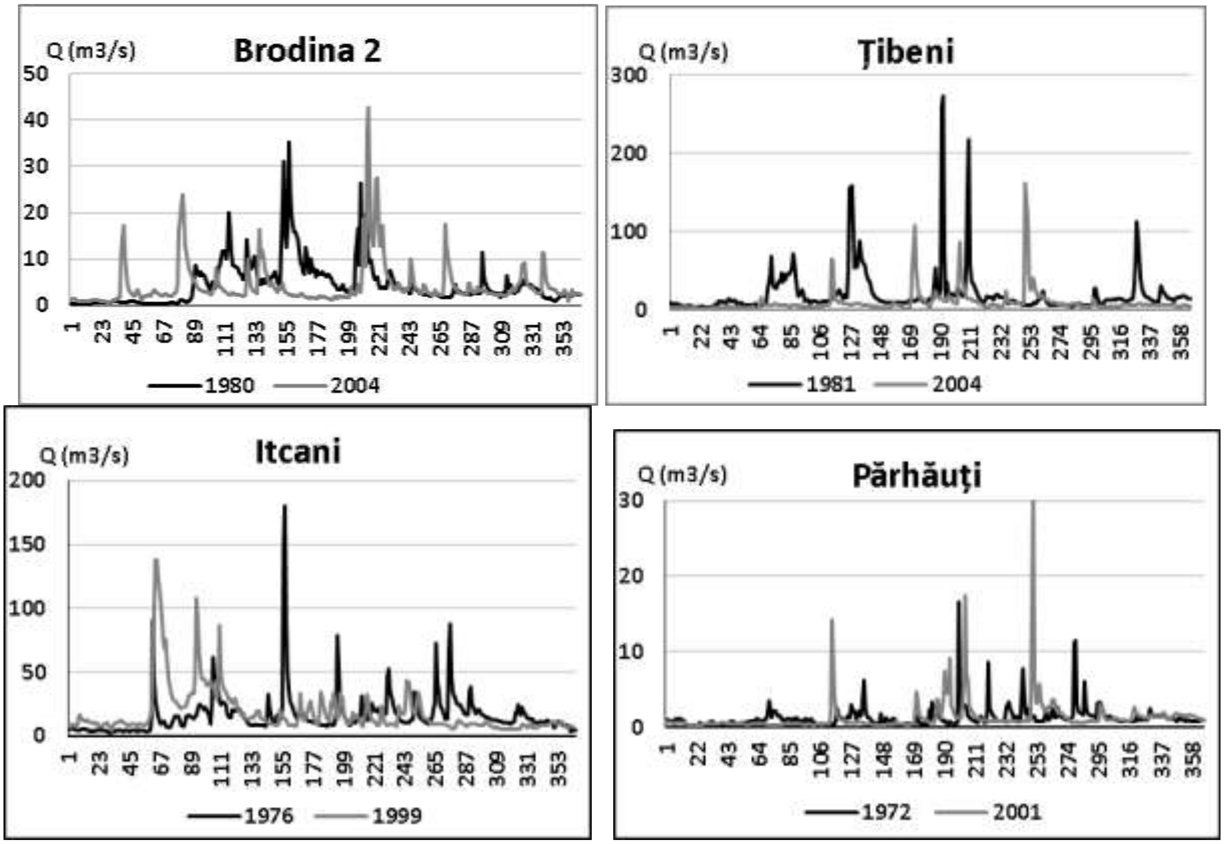


***Fig. 45.*** *Hidrografele tipice pentru anii medii la stațiile din bazinul râului Suceava*

A distinction can also be drawn between the typical riverbike specific to the first part of the study period and the end of the period. At most stations, flow increases, increasing the amount of water drained in all seasons, especially during the winter, with an increase in autumn high water caused by a faster melting of snow. Also, one can see a shift in summer and autumn highs due to an increase in flow values towards the end of these seasons as a result of the average temperature increase in these seasons.

## III.2.4. Seasonal and extreme months flow oscillation

The variation in time of flow can be emphasized by means of variation coefficients. The lowest values of this parameter within the Suceava river basin meet during the spring, followed closely by the winter, ranging from 0.38 spring at Brodina 2 station and 0.9 summer at Şcheia station.

The lower values (between 0.40 and 0.50 at Brodina 1 and 2 stations) show a more uniform character of the distribution and evolution of flow in the entire basin of the Suceava River, except for the larger plots in the plateau sector (Pozen, Soloneţ and Şcheia), which have a more uneven character during the winter and especially during the spring (Fig.46).

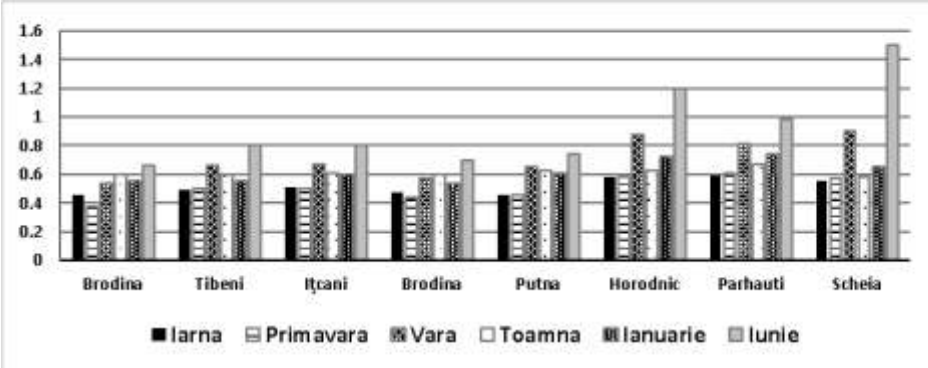


***Fig. 46.*** *Variaţia valorilor Cv anotimpuale și din lunile extreme ale scurgerii*

## III.2.5. Seasonal flow trend

The tendency of water flow from a hydrographic basin can be analyzed by several methods. among these are the method of coefficient of variation, the linear tendency method, the Mann-Kendall test method and the Sen slope, etc. For the analysis of the flow tendency, the linear trend and the Mann-Kendall test method were used in this paper.

Analysis of flow trend using the linear trending method

***Table 67.*** *Tendinţele liniare ale scurgerii anotimpuale*

| River | Hydrometric station | Winter | Spring | Summer | Autumn |
|---|---|---|---|---|---|
| Suceava | Brodina 2 | St | St | Cu | Cu |
| | Ţibeni | Cu | St | Cu | Cu |
| | Iţcani | Ca | St | Cu | Cu |
| Brodina | Brodina 1 | Cu | St | Cu | Cu |
| Pozen | Horodnic | Ca | St | Cu | Cu |
| Soloneţ | Părhăuţi | Ca | St | Cu | Ca |
| Putna | Putna | Ca | Cu | Ca | Ca |
| Şcheia | Şcheia | Ca | Cu | Cu | Ca |
| | | St - Stationary | Cu – Small increase | Ca – Accentuated Increase | |

The multi-annual trend of water flow was mostly growth (Table 67). While in the spring, the trend stayed at a stationary level at most stations (except for Putna and Scheia stations where the trend was slightly increasing), the other seasons show slight and even increased increases. The highest increases were recorded in winter, except for the Brodina 1 and 2 stations in the mountain area, where the trend was stationary or slightly increasing, with climatic variations in this season being lower in the mountain sector.The multi-annual trend of water flow was mostly growth (Table 67). While in the spring, the trend stayed at a stationary level at most stations (except for Putna and Scheia stations where the trend was slightly increasing), the other seasons show slight and even increased increases. The highest increases were recorded in winter, except for the Brodina 1 and 2 stations in the mountain area, where the trend was stationary or slightly increasing, with climatic variations in this season being lower in the mountain sector.

**Analyze the flow trend using the Mann-Kendall test method**

In the period 1961-2010 there was an increase in the tendency from mild to moderate at all the stations in the Suceava river basin, except for Iţcani and Ţibeni stations, where it was stationary. If an anotype analysis is performed, some differentiations can be observed from one season to another and from one station to another (Table 68).

***Table 68.*** *The values of the seasonal trends (in mm / year) and of the net change rate (in%) for the flows drained during 1961-2010 at the hydrometer stations in the Suceava river basin*

| Season | Hydro. Station/ Parameters | Brodina 2 | Putna | Horodnic | Ţibeni | Părhăuţi | Iţcani |
|---|---|---|---|---|---|---|---|
| Winter | Trend | CM | CM | CA | CU | CA | CM |
| | Slope | 0.00 | 0.00 | 0.01 | 0.03 | 0.01 | 43.32 |
| | Net change (mm) | 0.22 | 0.11 | 0.28 | 1.31 | 0.53 | 43.32 |
| | Rate of net change (%) | 4.58 | 41.19 | 81.89 | 26.94 | 72.25 | 43.32 |
| Spring | Trend | S | S | S | SU | SU | SU |
| | Slope | 0.02 | -0.002 | -0.002 | -0.001 | -0.008 | -0.128 |
| | Net change (mm) | 1.13 | -0.08 | -0.11 | -0.07 | -0.39 | -6.38 |
| | Rate of net change (%) | 23.96 | -9.33 | -14.23 | -0.38 | -20.49 | -24.50 |
| Summer | Trend | CU | CM | CU | S | S | S |
| | Slope | 0.06 | 0.01 | 0.00 | 0.13 | 0.01 | 0.18 |
| | Net change (mm) | 2.90 | 0.65 | 0.24 | 6.55 | 0.61 | 9.11 |
| | Rate of net change (%) | 58.09 | 59.55 | 30.25 | 33.43 | 33.17 | 33.57 |
| Autumn | Trend | CM | CM | CM | CM | CM | CM |
| | Slope | 0.02 | 0.00 | 0.00 | 0.06 | 0.01 | 0.10 |
| | Net change (mm) | 1.25 | 0.23 | 0.24 | 2.76 | 0.42 | 5.00 |
| | Rate of net change (%) | 24.58 | 55.80 | 63.69 | 37.10 | 51.78 | 46.65 |

To make it easier to analyze the factors that influenced flow during flow, a flow analysis was performed in each of the five decades of the period, with results relevant to the area under study.

**The decade 1961-1970** was imposed by a stationary spring tendency of the spring seasons and a slight increase in winter at all stations. During the summer and especially in the autumn there was a slight and even moderate increase in almost all the stations.

**The 1971-1980** decade showed a leak with a general, stationary and even downward trend at some stations, due to the stationary rainfall trend and slight temperature drops.

**The decade 1981-1990** was characterized by the highest decrease in river flows in the Suceava basin, the tendency of flow being at all stations and in all negative seasons. The trend varied between stationary and slight fall during winter and autumn, and a slight decrease to moderate decrease in summer and spring, reaching a minimum of -1.97 mm / year at Horodnic station.

**The decade 1991-2000** was characterized by a different evolution of the flow trend from one season to another. The wintertime recorded a moderate, even increased increase, reaching a maximum of 3.04 mm / year at the Zibeni station.

**Decade 1991-2000** was different from the previous ones, during winter there was a slight decrease in flow rates at stations on small rivers with higher altitudes, while at main or lower altitude stations the trend is stationary or even moderate growth. During the spring and summer months there was a steady increase and a slight increase, manifested in very high summer flow rates ranging between 32.87% (Putna) and 214.29% (Şcheia). In autumn, the trend was steady, with a slight drop.

## III.2.6. Seasonal flow repartition types

The types of seasonal distribution of flow were determined according to the sequence of seasons in descending order of their contribution to the annual flow. It was found that the dominant type is V.P.T, appearing in almost all the rivers in the basin, except for the Pozen and Soloneţ rivers where P.V.T appears, although the percentage differences between summer and spring values are very low (below 1%) (Figure 49).

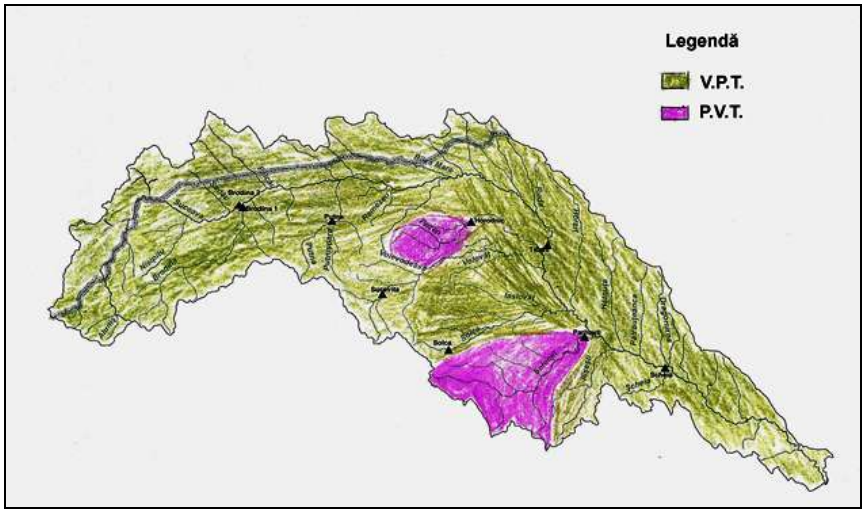


***Fig. 49.*** *Spatial distribution of the types of seasonal drainage in the Suceava basin*

## III.2.7. Monthly flow repartition types

The monthly distribution types of flow were established according to the share (% of the total number of cases) of the premiums and the second richest months and the poorest outflows (Table 75). Generally, one can not grouping of stations with the same characteristics of the monthly regime, especially for the richest months of drainage of the warm period, while the poorer flow months are more compact in weight. These differentiations are determined by the average altitude of the basin and its surface.

***Table 75.*** *The richest and poorest months in flow to comparatively between 1961-2010*

| Hydro. Station | The richest months (cases) and their frequency (%) | | | | The poorest months (cases) and their frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | First Month | % | Second Month | % | First Month | % | Second Month | % |
| **Brodina 2** | V | 22 | IV | 25 | I | 45 | II | 29 |
| **Țibeni** | V | 20 | IV | 36 | I | 40 | II | 24 |
| **Ițcani** | IV | 30 | V | 24 | I | 44 | XI | 24 |
| **Brodina 1** | VI | 33 | VII | 35 | I | 42 | II | 29 |
| **Putna** | IV | 23 | VI | 26 | I | 31 | II | 21 |
| **Horodnic** | IV | 29 | VI | 26 | I | 26 | II | 19 |
| **Părhăuți** | V | 24 | IV | 26 | I | 30 | X | 20 |
| **Șcheia** | IV | 21 | III | 26 | I | 26 | X | 16 |

## III.2.8. Daily flow repartition types

For the analysis of the types of daily distribution of flow, which determine the type of river regime, criteria such as the period of occurrence and the duration of large waters, floods and lowwaters, the distribution of the flow time and the sources of supply .

Brodina 1 and 2 stations have a similar distribution of flow, with lowspring waters starting in April, with floods occurring predominantly in July - June, those in July exceeding 30%. At the end of summer, large waters occur, with even higher weights than in the spring, exceeding 45%. Lowautumn waters are installed by October, and the longest periods of lowwater appear in winter. Feeding is predominantly superficial in the rain.

The distribution of the flow at Zibeni is similar to that of the previous stations, with lowdifferentiations. Floods have the highest weights in June, July and September, the share of lowwinter waters (45%) and autumn decreases, but the share of large summer waters (50%) is increasing.

The Iţcani station, situated at the closure of the basin, in the plateau sector, has distinct characteristics from the other mains stations, determined by the combination of the flow characteristics of the entire basin. Large spring waters (45%) appear more quickly since March, followed by floods in May and July. Large waters at the end of summer have a high, but lower, weight than spring. The share of lowwinter waters is maintained at 49%.

Pools with preponderant development in the transition and plateau sectors have distinct characteristics due to their small size.

The Putna station has a similar feature to Brodina 1 and 2 stations, but the summer floods occur in May and July, and the share of low winter waters decreases to 36%, increasing the spring water.

The flow at Horodnic and Părhăuţi stations is similar to that of Iţcani, decreasing the low winter waters and increasing the share of summer and spring. Sometimes there are cases of high water in the winter.

Şcheia Station has completely distinct features from the other stations in the basin, due to the low flow, the small dimensions of the basin and its positioning exclusively in the plateau sector, in a strongly anthropized environment. Large spring waters have the highest share (35%), occurring during March, followed by large summer (31%) and autumn (20%), sometimes also in winter. Floods occur in June and July. Low waters have the highest share in summer (31%) and autumn (28%), due to strong evaporation, as well as the use of pool water for the supply of the population and for agriculture. Low winter waters decrease by 23%. A specific element at this station is the underground power supply, which reaches 66.6% of the total.

# CHAPTER IV. CHARACTERISTIC PHASES OF RIVER WATER FLOW IN SUCEAVA HYDROGRAPHIC BASIN

The main phases of water flow from a river are maximum flow (high water and flood periods) and low water periods.

## IV.1. MAXIMUM FLOW PERIODS

Flow periods are manifested by large waters and floods that occur with different times and frequencies in the temporo-spatial profile. There is a lower frequency of overlapping periods over floods.

Large waters are the phases in which daily, decade and even monthly flows are high, exceeding the multiannual average flow (Sorocovschi, 2002). They occur as a result of the slow melting of snow at the beginning of spring, following less intense but long-lasting rain during the warm season, or as a result of overlapping the two causes. Sometimes, floods can overlap with large waters, with catastrophic effects on the population, high water periods causing an increase in the surplus water stored in the groundwaters and in the vegetation mat.

Floods are a flow concentration at the time, with a rapid increase in flows to a peak, followed by a slower and longer lasting decline.

In order to be able to delimit the maximum drainage water flow from the average drain, it is necessary to find a certain threshold over which the flow must increase to achieve the maximum flow. This threshold can be set in several ways, according to the needs of the study. In this study we took as a threshold the 80% percentile threshold of the flow rate, which is more appropriate to this study.

### IV.1.1. High waters

In the basin, large waters have a reduced frequency of the number of cases compared to floods, this being determined by their length. Large waters are the least common in the mountain sector, where such phenomena have rarely occurred during the analyzed period (1 case), increasing in the plateau sector (7 cases). The highest frequencies occur for large spring and summer waters when precipitation and overlapping of the two factors is more common, ranging between 15% (Horodnic summer) and 30% (Brodina 2 summer) (Table 77).

***Table 77.*** *The annual (absolute and relative) frequency of high waters*

| Station | Winter high waters | | Spring high water | | Summer high waters | | Autumn high waters | |
|---|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | No | % |
| **Brodina 2** | 1 | 1,5 | 27 | 41,5 | 30 | 46,2 | 7 | 10,8 |
| **Țibeni** | 1 | 2,4 | 17 | 40,5 | 21 | 50,0 | 3 | 7,1 |
| **Ițcani** | 2 | 3,3 | 28 | 45,9 | 24 | 39,3 | 7 | 11,5 |
| **Brodina 1** | 1 | 2,0 | 21 | 42,9 | 22 | 44,9 | 5 | 10,2 |
| **Putna** | 1 | 1,8 | 21 | 37,5 | 25 | 44,6 | 9 | 16,1 |
| **Horodnic** | 6 | 10,9 | 21 | 38,2 | 15 | 27,3 | 13 | 23,6 |
| **Părhăuți** | 6 | 8,7 | 24 | 34,8 | 24 | 34,8 | 15 | 21,7 |
| **Șcheia** | 7 | 13,0 | 19 | 35,2 | 17 | 31,5 | 11 | 20,4 |

## IV.1.2. Floods

### IV.1.2.1. Theoretical aspects concerning floods

Floods represent a sharp increase in river flows, followed by a relatively slower decline. There are a number of criteria where floods can be characterized, each with its destination and purpose, differing from one author to the other, depending on the purpose of the study. The main criteria to be taken into account when considering floods are: genesis, hydrographic form, location, severity, mode of manifestation, return period, associated effects, etc. (Sorocovschi, 2002).

From the quantitative parameters that can be found on the flood map, we can mention: the basic flow, peak or peak flow, duration (total time 0, duration (growth time), duration (decrease) base, due to underground supply) total, growth, decrease, flow water, shape coefficient, flow coefficient, peak coefficient.

### IV.1.2.2. Chronology of extraordinary floods in Suceava river basin

In the present paper there was a centralization of historical records of floods and floods in the study basin. The first notes of this phenomenon were found in the time of Stephen the Great, with the names of floods in 1504. Other years in which such phenomena were mentioned were 1635, 1670, 1706, 1775. From the 19th century, detailed of the events that took place, in the 20th century passing to a presentation through their measured data.

### IV.1.2.3. Analisis of floods from Suceava river basin

For the analysis of the flood characteristics in the Suceava River Basin, only the first two floods (called normal floods), with the highest recorded flows in one year, for the period 1981-2010, were taken into account. Of these we have separated the floods that have exceeded the maximum multi-annual average flow threshold, thus forming the major floods in the basin.

The significant floods show the highest percentage at the stations in the upper basin of the Suceava River - Brodina 2 - 43.75%, Brodina 1 - 37.7%. These stations have altitudes above 950 m. The least significant floods were recorded at Putna (18.18%) and Horodnic (20.45%).

From the point of view of the form, the floods produced in the basin show, in more than half of the singular cases, the highest values being recorded on tributaries, with 79.5% at Horodnic station (Table 16). Composite floods occur mainly on the main course, reaching 45.8% at Zibeni and Iţcani stations, due to the large number of young tributaries that receive the main course.

From the point of view of genesis, the flood waves that occur within a hydrographic basin are strongly influenced by the amount of precipitation in the basin before and during floods, as well as by the high temperatures that cause sudden snow melting. Thus, in the basin of the Suceava river, mostly overwhelming of pluvial origin (over 90%), with the exception of the Pozen river, which has a slightly lower value (88.64%) (Table 82). This shows that spring floods are heavily delayed, and snow meltdowns do not have intensities to influence flow.

**Table 82.** *Frequency (in%) of normal basin floods after genesis and form*

| River | Station | Surface (km2) | Basin altit. (m) | Form | | Genesis | |
|---|---|---|---|---|---|---|---|
| | | | | Simple | Composed | Pluvial (V-X) | Mixt (XI-IV) |
| **Suceava** | **Brodina 2** | 366 | 990 | 62,5 | 37,5 | 97.92 | 2.08 |
| **Suceava** | **Țibeni** | 1228 | 730 | 54,2 | 45,8 | 93.75 | 6.25 |
| **Suceava** | **Ițcani** | 2377 | 613 | 54,2 | 45,8 | 93.75 | 6.25 |
| **Brodina** | **Brodina 1** | 142 | 989 | 63,9 | 36,1 | 97.92 | 2.08 |
| **Putna** | **Putna** | 53 | 847 | 65,9 | 34,1 | 97.73 | 2.27 |
| **Pozen** | **Horodnic** | 67 | 488 | 79,5 | 20,5 | 88.64 | 11.36 |
| **Soloneț** | **Părhăuți** | 204 | 467 | 64,6 | 35,4 | 93.75 | 6.25 |

Frequency (in%) of normal floods in the basin after genesis and formIn the floodgraph of a flood there are the temporal and quantitative parameters of a flood. These include: the base rate, the peak or peak flow, the total duration (time), the growth time, the (decrease) duration (time), the volume (excluding the basic one due to the underground supply) growth, decreasing, flow water layer, shape coefficient, flow coefficient, peak coefficient.

The most important temporal parameters of a flood are the growth time and total time. The rise time of a flood shows its degree of danger. The faster a flood is, the less warning time for the affected population is shorter and the preventive measures that can be taken immediately before production and during the flood are much less. In the Suceava River Basin, the high values of the growth time are registered at the stations in the mountainous tributaries (Brodina, Putna), with a maximum of 20.8% at the Brodina 1 station (Table 87), where the higher average altitude of the basin makes the floods trigger very quickly, defending the flash-floods.

**Table 87.** *The increasing time (in hours) of the floods in the Suceava River Basin*

| River | Station | 0-6 hours | | 7-12 hours | | 13-24 hours | | 25-48 hours | | > 48 hours | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. cases | % | No. cases | % | No. cases | % | No. cases | % | No. cases | % |
| **Suceava** | **Brodina 2** | 3 | 6.25 | 7 | 14.58 | 21 | 43.75 | 14 | 29.17 | 3 | 6.25 |
| **Suceava** | **Țibeni** | 1 | 2.08 | 0 | 0.00 | 12 | 25.00 | 17 | 35.42 | 18 | 37.50 |
| **Suceava** | **Ițcani** | 2 | 4.17 | 3 | 6.25 | 14 | 29.17 | 14 | 29.17 | 15 | 31.25 |
| **Brodina** | **Brodina 1** | 10 | 20.83 | 9 | 18.75 | 16 | 33.33 | 5 | 10.42 | 8 | 16.67 |
| **Putna** | **Putna** | 7 | 15.91 | 6 | 13.64 | 15 | 34.09 | 8 | 18.18 | 8 | 18.18 |
| **Pozen** | **Horodnic** | 4 | 9.09 | 6 | 13.64 | 16 | 36.36 | 11 | 25.00 | 7 | 15.91 |
| **Soloneț** | **Părhăuți** | 3 | 6.25 | 7 | 14.58 | 21 | 43.75 | 13 | 27.08 | 4 | 8.33 |

From the analysis of the data obtained, it can be noticed that the total flood time is higher on the main course than on the tributaries (Table 86), a normal phenomenon due to the much higher flow of water leaked on it and due to the combination of incoming floods affluents, which prolongs the flood, reaching a peak at the Țibeni station, where 58.3% of the normal floods recorded had a total duration of more than 96 hours. There were no floods of total duration less than 24 hours at stations on the main course, with no flash floods at these stations.

***Table 86.*** *Total time (in hours) of the floods in the Suceava River basin*

| River | Station | 0-24 hours | | 25-48 hours | | 49-72 hours | | 73-96 hours | | >96 hours | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. cases | % | No. cases | % | No. cases | % | No. cases | % | No. cases | % |
| **Suceava** | **Brodina 2** | 3 | 6.25 | 11 | 22.92 | 12 | 25.00 | 10 | 20.83 | 12 | 25.00 |
| **Suceava** | **Țibeni** | 0 | 0.00 | 0 | 0.00 | 7 | 14.58 | 13 | 27.08 | 28 | 58.33 |
| **Suceava** | **Ițcani** | 0 | 0.00 | 3 | 6.25 | 9 | 18.75 | 13 | 27.08 | 23 | 47.92 |
| **Brodina** | **Brodina 1** | 0 | 0.00 | 9 | 18.75 | 11 | 22.92 | 11 | 22.92 | 17 | 35.42 |
| **Putna** | **Putna** | 2 | 4.55 | 17 | 38.64 | 8 | 18.18 | 6 | 13.64 | 12 | 27.27 |
| **Pozen** | **Horodnic** | 4 | 9.09 | 9 | 20.45 | 13 | 29.55 | 9 | 20.45 | 8 | 18.18 |
| **Soloneț** | **Părhăuți** | 3 | 6.25 | 12 | 25.00 | 12 | 25.00 | 10 | 20.83 | 11 | 22.92 |

## Parametri cantitativi

The maximum flow rate (Qmax), increasing volume (Wc), total volume (Wt), flow layer (Hs), and maximum level reached are among the quantitative parameters of a flood. The average values of these parameters for the Suceava River Basin can be seen in Table 88.

***Table 88.*** *Average values of maximum flows, volumes and strains elapsed during floods in the Suceava river basin*

| River | Station | Qmax (m3/s) | Wc (mil. m3) | Ws (mil. m3) | Wt(mil. m3) | Hs (mm) |
|---|---|---|---|---|---|---|
| **Suceava** | **Brodina 2** | 70,100 | 3,159 | 7,781 | 13,533 | 29,861 |
| **Suceava** | **Țibeni** | 165,129 | 10,318 | 22,054 | 32,372 | 26,360 |
| **Suceava** | **Ițcani** | 225,268 | 13,010 | 28,577 | 41,503 | 17,603 |
| **Brodina** | **Brodina 1** | 53,903 | 1,841 | 4,751 | 6,582 | 45,935 |
| **Putna** | **Putna** | 14,739 | 0,634 | 1,120 | 1,753 | 33,117 |
| **Pozen** | **Horodnic** | 17,012 | 0,594 | 0,961 | 4,293 | 23,232 |
| **Soloneț** | **Părhăuți** | 36,044 | 0,800 | 2,001 | 2,800 | 13,733 |
| **Șcheia** | **Șcheia** | 4,326 | 0,161 | 0,291 | 0,452 | 13,730 |

Maximum levels hit by a river during a flood may exceed certain thresholds (Attention (CA), Flood (CI) or Hazard (CP)), with values varying from one station to another and over time. conditioned by the flow rate and the geomorphological conditions of the river bed. Analyzing the frequency of the maximum levels of water reached during the floods in the Suceava basin, one could notice that some stations are detached from the other. Thus, at the stations of Ţibeni, Brodina 1 and Părhăuţi, the flood and danger levels were exceeded in over 50% of cases with normal floods (Fig. 47).

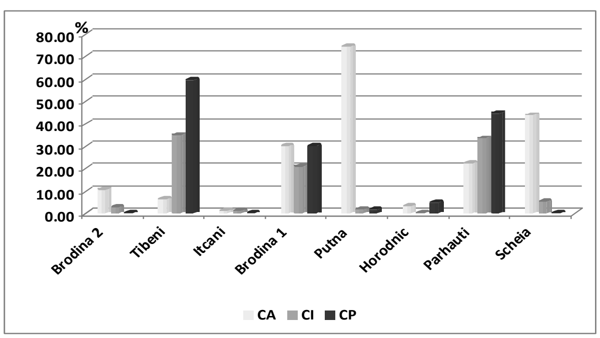


***Fig. 47.*** *Number of cases and frequency (%) of floods that exceed the attention, flood and danger*

From the analysis of debits and absolute maximum levels recorded in the Suceava river basin, it can be noticed that most values were recorded during the July 2008 flood (Table 20).

***Table 84.*** *Average and absolute maximum values of floods recorded during the period 1981-2010*

| River | Hydro. station | Qmax med ($m^3/s$) | Hmax med (cm) | Qmax abs. ($m^3/s$) | Hmax abs. (cm) | Date |
|---|---|---|---|---|---|---|
| **Suceava** | **Brodina 2** | 79.17 | 177.76 | 426 | 341 | 26.07.2008 |
| **Suceava** | **Ţibeni** | 199.18 | 361.71 | 1118 | 500 | 26.07.2008 |
| **Suceava** | **Iţcani** | 291.94 | 430.90 | 1710 | 1561 | 27.07.2008 |
| **Brodina** | **Brodina 1** | 55.83 | 186.44 | 292 | 362 | 28.06.1995 |
| **Putna** | **Putna** | 19.77 | 174.78 | 143.64 | 410 | 26.07.2008 |
| **Pozen** | **Horodnic** | 20.95 | 226.18 | 192 | 530 | 28.06.2010 |
| **Soloneț** | **Părhăuți** | 55.42 | 316.21 | 382 | 740 | 26.07.2008 |

## IV.1.3. Effects induced by maximum flow periods‘ apparition

Floods are a common hydrological hazard on the surface of the globe and over millions of years of Earth. They can have natural and anthropogenic effects on the environment, as well as negative effects, being one of the only natural risks with positive effects on the environment.

Negative effects of floods are called floods, occurring when river flows and levels exceed the storage capacity of the bed. They act on multiple levels, both socially and psychologically, economically and ecologically.

For a more accurate analysis of the effects and due to the lack of statistical data on the floods in the Suceava River basin during the study period, it was taken into account the period 2005 - 2010, when there were catastrophic historical floods in the basin, with well-documented data.

**Social Effects**. Between 2005 and 2010, the floods in the Suceava River basin caused 22 deaths, most of them in 2006 when 11 people (including a baby) died in the case of spontaneous floods produced in Arbore (30.06-01.07.2006), which showing the rapidity of this flood in a well populated and poorly hydrographic area. The remaining 11 people died in Liteni (1 deceased person - 2005), (2 deceased - 2005), Cacica (1 deceased person - 2006), Satu Mare (1 deceased person - 2008), Brodina - 2010), Marginea (1 deceased person - 2010), Şerbăuţi (3 deceased persons - 2010), Todireşti (1 deceased person - 2010).

**Economic effects**. It can be noticed that at the level of the whole basin, the largest total damages were caused by floods in 2008 and 2010, which together amounted to over 475 million lei, which accounted for 85% of the total damages recorded during this period. If we do a sectoral damage analysis (Figure 52), it can be noticed that the greatest damage occurred in the transition sector, the smallest in surface area, but also the most dynamic in terms of geographic features.

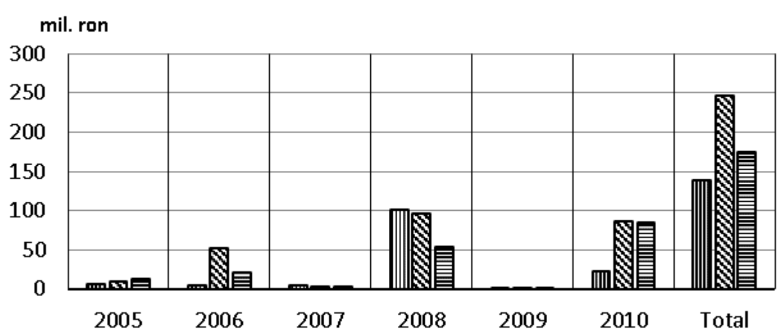


***Fig. 52.*** *Distribution of total damages (in million lei) on the three sectors of the basin in 2005-2010*

*Damage to households.* The value of damages to households in this period amounted to 16.5 million lei (Table 21), over 80% of these damages being registered in 2010 and 2008, followed at a great distance from 2006. An interesting fact is that the damage was higher in the plateau sector, driven by the larger and denser population in the plateau sector, where the number of households is higher than in other sectors.

***Table 21.*** *Distribution of total damages (in lei) in the period 2005-2010 in the Suceava river basin*

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
|---|---|---|---|---|---|---|---|
| **Mountain Sector** | 2.100 | 600 | 0 | 1.476.000 | 0 | 306.870 | 1.785.570 |
| **Transition Sector** | 50.050 | 3.201.123 | 14.300 | 2.212.000 | 26.890 | 1.693.677 | 7.198.040 |
| **Plateau Sector** | 50.820 | 90.880 | 0 | 2.876.820 | 605.846 | 4.429.848 | 8.054.214 |
| **Rural** | 68.670 | 3.249.553 | 14.300 | 5.519.020 | 26.650 | 6.269.488 | 15.147.681 |
| **Urban** | 34.300 | 43.050 | 0 | 1.055.800 | 606.086 | 189.907 | 1.929.143 |
| **Total** | 102.970 | 3.292.603 | 14.300 | 6.079.820 | 632.736 | 6.432.800 | 16.555.229 |

Damage to the transport infrastructure. If a comparison is made between the three sectors, it can be noticed that they have been affected in a variety of ways, depending on the share of roads in the three sectors, with values for the main years with floods. Roads were more strongly affected in 2008, followed by 2010 and 2006, with different values from one sector to another (Figure 57). If in 2008 the roads were affected mainly in the mountain sector (including the railway network from Gura Putnei - Nisipitu), in the upper basin of the Suceava and Putnei, in 2006 and 2010 the roads in the sector were affected but at values similar to those of the year 2008.

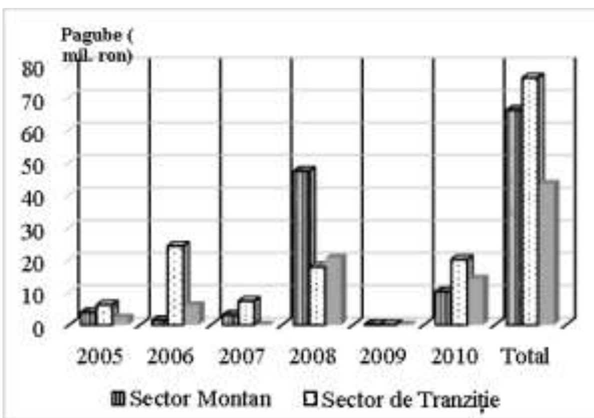


***Fig. 57.*** *The value of damages (in millions of lei) produced by the roads in the three sectors*

**Ecological effects.** The most affected areas were the Mihoieşti mobile dam on the Suceava River, upstream of Iţcani, the lake of lakes and ponds on the Dragomirna river (Dragomirna reservoirs 1, 2, and several private fish ponds such as the pond Dragomirna 2 in Dragomirna), and on the Hânnuţa river (Calinesti pond in Şerbăuţi), especially the Călineşti pond, with damages of 30000 lei, and the Dragomirna Monastery Lake, with successive clumps, being later drained and prepared for a total cleaning.

*Land landslides*. During 2005-2010 there were numerous landslides in the entire Suceava river basin, in all sectors, the most affected area was Suceava, where in 2006 a sloping slope in the Zamca area caused damages of 3,513 .448 lei, and in 2010 a slope slip affected the Sports High School in the locality, with damages of 3,600,000 lei. Also in the same year were affected by landslides in this locality 1650 m of slopes, but without material damage.

## IV.1.4. Prevention, protection and relief measures from the effects of maximum flow

*Structural measures.* The most dangerous floods from 2005-2010 in the Suceava River basin (ie from June to July 2006, July 2008, June 2010) were flash floods, which made the warning time very short, almost non-existent in some cases. For this reason, the defensive actions that took place during the floods were limited in number. The areas that could best be defended were the cities on a higher relief and the downstream areas where the upstream water concentration time was longer, giving more time for authorities and locals to save what could be saved.

Residents were helped by the authorities to restore and reconstruct the affected households by removing water with motor pumps, physical aid to reconstruction, providing material aids (wood, other masonry materials) for reconstructions. The sanitation of clogged wells, which are in danger of contamination with toxic substances, has been carried out (in this basin, where half of its population is in the countryside, there was also the cleaning of water sources for urban areas, especially for Suceava. made bridges of temporary pontoons in the place of severely affected bridges (such as the bridges over the Suceava River connecting Rădăuți and Dornești, Suceava between Verești and Udești, Sucevița in Marginea, etc.).

Non-structural measures include local defense plans and population education actions. Such actions took place during the period 2005-2010 and thereafter, in the Suceava County, respectively in the Suceava river basin, the older persons have more experience, therefore more knowledge about the way they should action in case of floods. But younger people have far less knowledge, so they are less prepared to cope with floods. In 2009, following strong floods in previous years, UNICEF, together with CRISP (Resource and Information Center for Social Professionals), carried out a project called "The Teaching Staff Training Project in Flood-affected Communities," which targeted this category of people and "aimed to improve the situation of children affected by psychological floods in 48 communities in the counties of Neamţ, Bacau, Botosani, Suceava, Iaşi and Maramureş" (UNICEF, 2009, p.6).

## IV.1.5. Flood perception in Suceava river basin

Between May and July 2016, the author of this paper drew up a study on the perception of floods and their effects in the Suceava river basin, called the Flood Perception Questionnaire, in order to be able to see how the inhabitants of the basin regard this risk phenomenon after all the unpleasant experiences between 2005 and 2010 and the one that followed. In order to follow the perception of the inhabitants of the basin over the floods, a comparative analysis of the perception of floods by rural and urban residents was attempted.

Following this questionnaire several conclusions were drawn regarding the perception of the floods in this basin. Thus, there is a clear difference between rural and urban residents, with rural residents having more knowledge of floods and other risk phenomena that could affect their locality. This is due to the fact that the last years were very rich in extreme natural phenomena, which affected mainly the rural areas where, although the level of studies should be and is slightly lower than the one from the city, so the level of the theoretical knowledge the floods should be lower, the recent experience of floods in rural areas has made people in the village have deeper knowledge about floods and how they are unfolding. Also, rural people are more open to helping others, their troubles during floods making them more open to the troubles of others.

The 2005-2010 floods have had a very strong impact on the inhabitants' awareness of the pool, from the youngest to the elderly, each of them keeping in mind their very recent effects. The high share of people leaving their home in case of floods and those who would move if they were offered acceptable conditions on the part of the state, which shows that the inhabitants are aware of the seriousness of the risk they pose in case of production of a flood. Subjects have brought some interesting answers to the causes of the floods, indicating among them, in addition to abundant rains, factors such as deforestation, increasing wind intensity and dam failure.

## IV.2. MINIMUM FLOW PERIOD

Minimum drainage is a phase of river spill, of real economic interest for the economy and ecology of a river basin. The low water phase of a river drainage regime represents that period of the year where the flow and level of the river water is well below the multiannual average flow rate.

***The genesis of lowwaters***

At our country level, lowwaters occur during the summer-autumn period, as a result of the decrease of atmospheric precipitation and the increase of soil evaporation, and in winter, as a result of falling fallen rainfall, mostly in solid form, and the phenomenon of frost on the rivers. During these times, rivers are fed solely from underground water resources.

Among the causes that can generate periods of lowwater, we mention: rainfall, human activities (land erosion, deforestation, irrigation), dry seasons (tropical latitudes), El Nino phenomenon, climate change, etc.

***Parameters of low water periods***

In order to analyze the lowwater characteristics (persistence, tendency, frequency, duration and severity) and their mode of manifestation in time and space, the quantitative threshold method was used (Hisdall et al., 2000).

Lowwater parameters depend on the decrease of the river water flow rate below a certain threshold. Depending on this threshold, the characteristics or parameters of the drought are determined as follows:

Temporal parameters: duration (number of days in which the average daily flow falls below the low water threshold, cumulative maximum values), the frequency (percentage of the total number of cases in which the duration of events was within certain limits), the recovery period (T) .

Quantitative parameters: the severity of lowwater (the volume required for regularization at the daily average flow threshold), the minimum flow, the date of lowwater production (the date of the underflow threshold, the average between the start and end date of the lowwater episode , minimum flow date)

The length of periods of low water on the rivers in the Suceava river basin vary from one case to another. Table 103 shows that the most common ones are those with a short duration (less than 10 days), with values between 59.5% at Horodnic station and 91.8% at Putna station. The high value recorded at the Putna station is due to the fact that at this station the flow variations were very rapid, the flow varying around the 80% threshold, here also the largest number of lowwater days (329 ). It takes 10-20 days, but at a great distance (between 5% at Putna and 20% at Horodnic station). More than 70 days are more rarely encountered in this basin, occurring only in very dry hydrological and climatic periods.

***Table 103.*** *Percentage of the total number of days with lowwaters (%) for certain time intervals (in days) recorded between 1981-2005 at the stations in the Suceava river basin*

| Station | < 10 | 10 - 20 | 20 - 30 | 30 - 40 | 40 - 50 | 50 - 60 | 60 - 70 | 70 - 80 | 80 - 90 | 90 - 100 | > 100 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brodina 1** | 72 | 17 | 5 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 100 |
| **Brodina 2** | 71 | 13 | 5 | 5 | 1 | 2 | 0 | 1 | 0 | 0 | 2 | 100 |
| **Putna** | 92 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| **Horodnic** | 60 | 20 | 7 | 5 | 5 | 0 | 0 | 1 | 0 | 1 | 1 | 100 |
| **Ţibeni** | 68 | 14 | 4 | 6 | 0 | 4 | 0 | 2 | 0 | 0 | 2 | 100 |
| **Părhăuţi** | 72 | 14 | 7 | 3 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 100 |
| **Iţcani** | 79 | 9 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 100 |
| **Şcheia** | 81 | 11 | 4 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 100 |

### Seasonal frequency of periods of low water

Lowwaters can appear at any time of the year, in any season, but they are especially suited to winter and autumn.

In the water catchment area of the Suceava River, periods of lowwater appear on average the most frequently in winter, when the amount of precipitation is reduced, and the very low temperatures of the air help to reduce the amount of running water through the frost. In this situation, the rivers are fed only from the underground water reserves, causing the appearance of lowwater. 69.3% of the total number of lowwater days recorded at Brodina 2 station during 1981 - 2005 occurred in this season, while at Brodina 1 there were 54% of the cases, at these two stations being recorded 40% of total cases with low water during this season. As the transition to the transition sector and the plains of the basin, the values recorded in this season decrease, reaching a minimum of 22.8% at Şcheia Station, due to the higher rainfall and higher temperatures recorded in these sectors, making the freezing of rivers occur less frequently, thus increasing the flow of water spilled on these rivers.

***Table 105.*** *The average seasonal frequency of low water periods in 1981-2005 and the maximum number of recorded cases*

| Station | Winter | | | | Spring | | | | Summer | | | | Autumn | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No | (%) | Max | Year | No | (%) | Max | Year | No | (%) | Max | Year | No | (%) | Max | Year | Max | Year |
| **Brodina 2** | 42 | 60,0 | 4 | 1988 | 11 | 15,7 | 2 | 1996 | 4 | 5,7 | 2 | 1987 | 13 | 18,6 | 3 | 1987 | 7 | 1987 |
| **Ţibeni** | 33 | 45,8 | 3 | 1990 | 11 | 15,3 | 3 | 1986 | 11 | 15,3 | 4 | 1986 | 17 | 23,6 | 3 | 1990 | 11 | 1986 |
| **Iţcani** | 42 | 48,8 | 4 | 1990 | 12 | 14 | 4 | 1990 | 10 | 11,6 | 2 | 1987 | 22 | 25,6 | 3 | 1994 | 10 | 1990 |
| **Brodina 1** | 49 | 56,3 | 4 | 1986 | 13 | 14,9 | 2 | 1990 | 9 | 10,3 | 2 | 1990 | 16 | 18,4 | 3 | 1990 | 10 | 1990 |
| **Putna** | 44 | 36,4 | 5 | 1994 | 25 | 20,7 | 4 | 1990 | 19 | 15,7 | 4 | 1987 | 33 | 27,3 | 4 | 1994 | 15 | 1994 |
| **Horodnic** | 20 | 31,3 | 3 | 1991 | 8 | 12,5 | 3 | 1987 | 19 | 29,7 | 3 | 1987 | 17 | 26,6 | 3 | 1983 | 10 | 1987 |
| **Părhăuţi** | 22 | 31,4 | 3 | 1990 | 7 | 10 | 3 | 1990 | 20 | 28,6 | 3 | 1995 | 21 | 30,0 | 3 | 1992 | 10 | 1990 |
| **Şcheia** | 25 | 22,7 | 4 | 1995 | 19 | 17,3 | 4 | 1995 | 35 | 31,8 | 5 | 2001 | 31 | 28,2 | 5 | 1994 | 13 | 2001 |

If an analysis is made of the total number of days with lowwater recorded in the basin, it is noticed that during the 25 years of analysis, 1200 such days were recorded at the Brodina 2 station, followed by Brodina 1 by 987 days , the least days being at Scheia Station - 353 (Table 105). But the station where most of the lowwater days were recorded in one year is the Tibeni station, with 90 days in 1986.

**Monthly Frequency**

At the stations in the upper mountain basin (Brodina 1, Brodina 2), the month with the most low water periods is January, followed by December and February, with over 60% of cases reaching even a maximum of 84% in December at station Brodina 2. This phenomenon is determined by the lower temperatures in the winter months. A similar situation occurs in the Iţcani station, where the watercourse is regulated by the reservoir lake upstream of this station.

**The daily frequency** over the 1981 - 2005 period (Fig. 80) of the low water periods at the Suceava river basin shows a higher frequency (over 13 cases per day) at the mountain stations (Brodina 2, Brodina 1) in January and February respectively. Values of 10 to 12 cases are also recorded at Iccani station in January, February, March and December, due to the short cut and the regularity in this sector (Figure 89). Also, there is a small number of cases recorded during the spring season, when rainfall is the highest.

At stations in the middle and lower basin there is a decrease in the daily frequency and a more even distribution of the periods with lowwaters during the year, especially at Putna, Ţibeni, Horodnic and Părhăuţi stations.

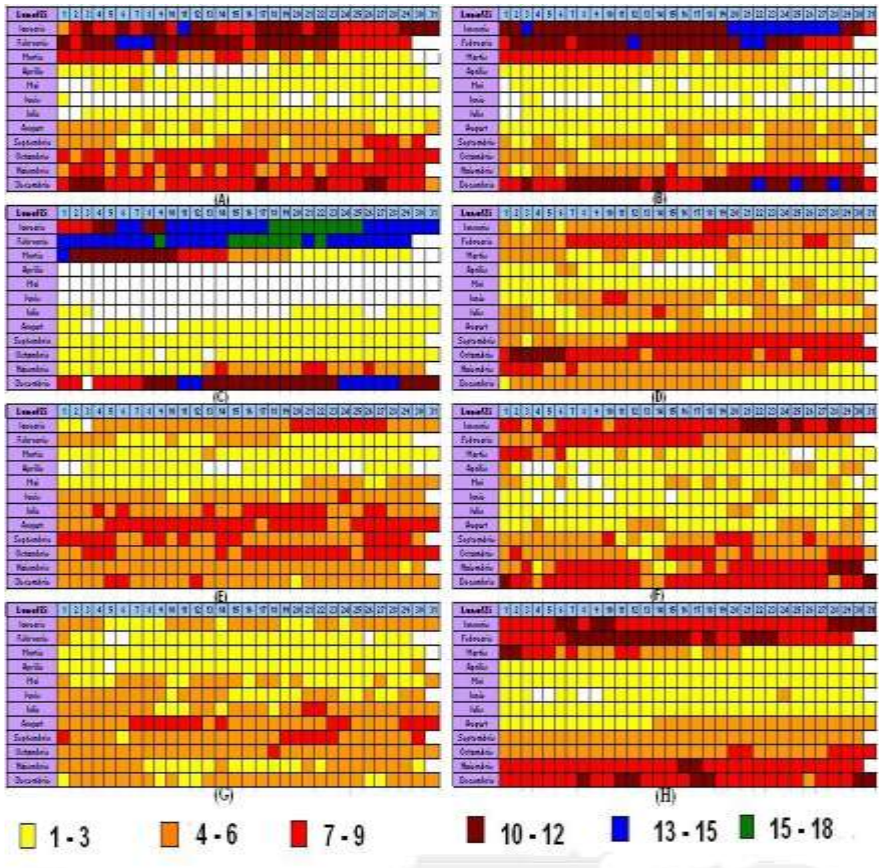


***Fig. 80.*** *The daily number of small water cases recorded between 1961-2010 at Brodina 2 (A), Ţibeni (B), Iţcani (C), Brodina 1 (D), Horodnic (E), Părhauţi (F), Putna ) and Şcheia (H)*

**Quantitative parameters**

From the quantitative parameters analyzed, we can note the minimum volume and the minimum flow along with the maximum deviation of the flow values (Fig. 110), which very well records the evolution of the minimum flow values during the analyzed period.

***Table 110.*** *Some parameters of the minimum flow at stations in the Suceava River Basin*

| Station | Q min. | Year | Average cumulated deficit | Maxium cumulated deficit | Year | Maximum deviation |
|---|---|---|---|---|---|---|
| **Brodina 2** | 2.12 | 2001 | 0.38 | 6.86 | 1984 | -0.89 |
| **Ţibeni** | 0.01 | 1987 | 1.54 | 46.31 | 1987 | -2.69 |
| **Iţcani** | 0.2 | 1995 | 1.06 | 26.72 | 1990 | -3.78 |
| **Brodina 1** | 0.14 | 1991 | 0.08 | 1.13 | 1987 | -0.31 |
| **Putna** | 0.027 | 2002 | 0.02 | 0.75 | 1987 | -0.14 |
| **Horodnic** | 0.088 | 1987 | 0.05 | 0.72 | 1987 | -0.13 |
| **Părhăuţi** | 0.103 | 1990 | 0.11 | 2.48 | 1990 | -0.31 |
| **Şcheia** | 0.03 | 1987 | 0.15 | 0.55 | 1999 | -0.08 |

*The maximum deviation* is in direct correlation with the maximum flow rate, representing the deviation from the multi-annual flow rate recorded at a particular station. Compared to the maximum deficit, it can be seen that the maximum deviation is highest at the Iţcani station, not at the Tibeni station, which shows the power of improvement of the minima imprinted by the presence of the Mioveni mobile dam and the lake salt on the river Dragormirna, carried out around Suceava, demonstrating the anthropic character of the regime at this station.

### IV.2.3. Effects induced by mimum flow period apparition

Lowwater periods have important, sometimes devastating effects on agriculture and human society. Reducing the amount of water drained into a river can cause it to wither, a phenomenon that occurs when underground resource supply ceases or becomes temporary, so it can not sustain flow. With the growth of a river basin and the supply of the river, the needles of a river are quite rare due to its size or extreme phenomena.

In the basin of the Suceava River, between 1961-2010, there were no periods of complete seeding of any of the main tributaries. However, there were periods when levels were very low, such as 1987-1988 and 1990, even 2000, when the atmospheric drought caused a very large reduction in the amount of water from rainfall entering the basin.

# CONCLUSIONS

In the present paper, structured in four chapters, a detailed analysis of the drainage regime was carried out in the Suceava basin. In the first chapter were presented the theoretical bases of the concept of water regime and the history of research in this field, presented the working framework and the database, as well as the techniques and methods used for the work.

In the second chapter we analyzed how geology, the relief through its characteristics, the climate especially through rainfall, snow cover and temperature, vegetation, soils and human factor influenced during 1961-2010 the evolution and the variation during the year and over the years of the drainage regime, applied to the Suceava River.

In chapter three, starting from these physico-geographic and anthropic elements, the drainage regime of the Suceava River was analyzed in the above-mentioned period. Being a hydrographic basin with predominantly surface water supply in the rain, the underground water supply of the river was not taken into account.

The flow regime was analyzed at both anotimpular and monthly and daily levels. At wintertime, the lowest flow values (8.5% of the annual volume) were recorded at the Brodina 1 and 2 stations at the highest altitudes of all stations. On the main course, downstream of the Zibeni station, the percentages of flow in this season exceed 10% of the average annual value. Spring is the second season after the summer as the value of the flow, the only hydrometric stations at which this spring season is the maximum spring drain being Horodnic (34.5%) and Părhăuţi (36.1%), the highest values of flow spring was recorded in the 1970s and 1978s, and the smallest in many years, including 1990. The summer (VI - VIII) is the season with the highest value of the flow during the year at almost all the stations, the flow values exceeding 30%, in the mountain sector exceeding even 40%. Maximum summer flow rates were recorded especially in the first decade of the 21st, 2008 and 2010, with the years varying from one station to the next, which shows, but in very dry years, were the years 1964, 1987 and 1990. In autumn, flow values are lower than in summer and spring, but exceed those in winter. During this period there are periods of high water (up to 10 days), and sometimes even floods.

At decadal level, a correlation between the rainfall trend and the flow of river water can be observed. Thus, the decade 1981-1990 is distinguished, when the tendency of flow was at all stations and in all the negative seasons. Net change rates were also negative, with the smallest values being recorded during the autumn at Putna (-207.11%) and in the summer at Şcheia (-179.36%). These extreme values were due to the fact that these rivers have the lowest flow rates, which has a very rapid reaction to sudden climate change. At the opposite end there is the decade 2001-2010, during the winter there is a slight decrease in flow rates at stations on small rivers with higher altitudes, while at the main or lower altitude stations the trend is stationary or even moderate growth (Shcheia - 1.61 mm / year).

The monthly flow regime in the study baseline peaked in June (between 12.4-14.1%), followed by April and May, the lowest being recorded in January.

Analysis of the daily run has used the hydrograph of the typical year. It can be seen from the analysis that the basin of the Suceava River is included in the general type of East Carpathian regime with lowwinter waters, large spring waters and floods that occur later in May, floods during the summer and early autumn, which continues with high autumn waters, prolonged until the beginning of October. Differences are determined by the altitude and the size of the receiving basin, and a transition from the mountain sector (Brodina 2) towards the plateau (Părhăuţi) occurs. In the high mountain sector, large spring waters appear later, and floods towards the end of spring. Summer frosts occur in June-July, followed by large autumn waters early September, ending with lowautumn waters, stretching back to early November. Lowwinter waters are kept at low levels at most stations. Also, it can be noticed that over the years, the summer floods moved later in the summer, increasing in frequency the autumn floods, as well as the values of the winter spill.

Between 1961-2010, there was a slight to moderate increase in the flow trend at all stations, with the exception of Iţcani and Ţibeni stations, where the tendency was stationary. In winter, an average increase was observed

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