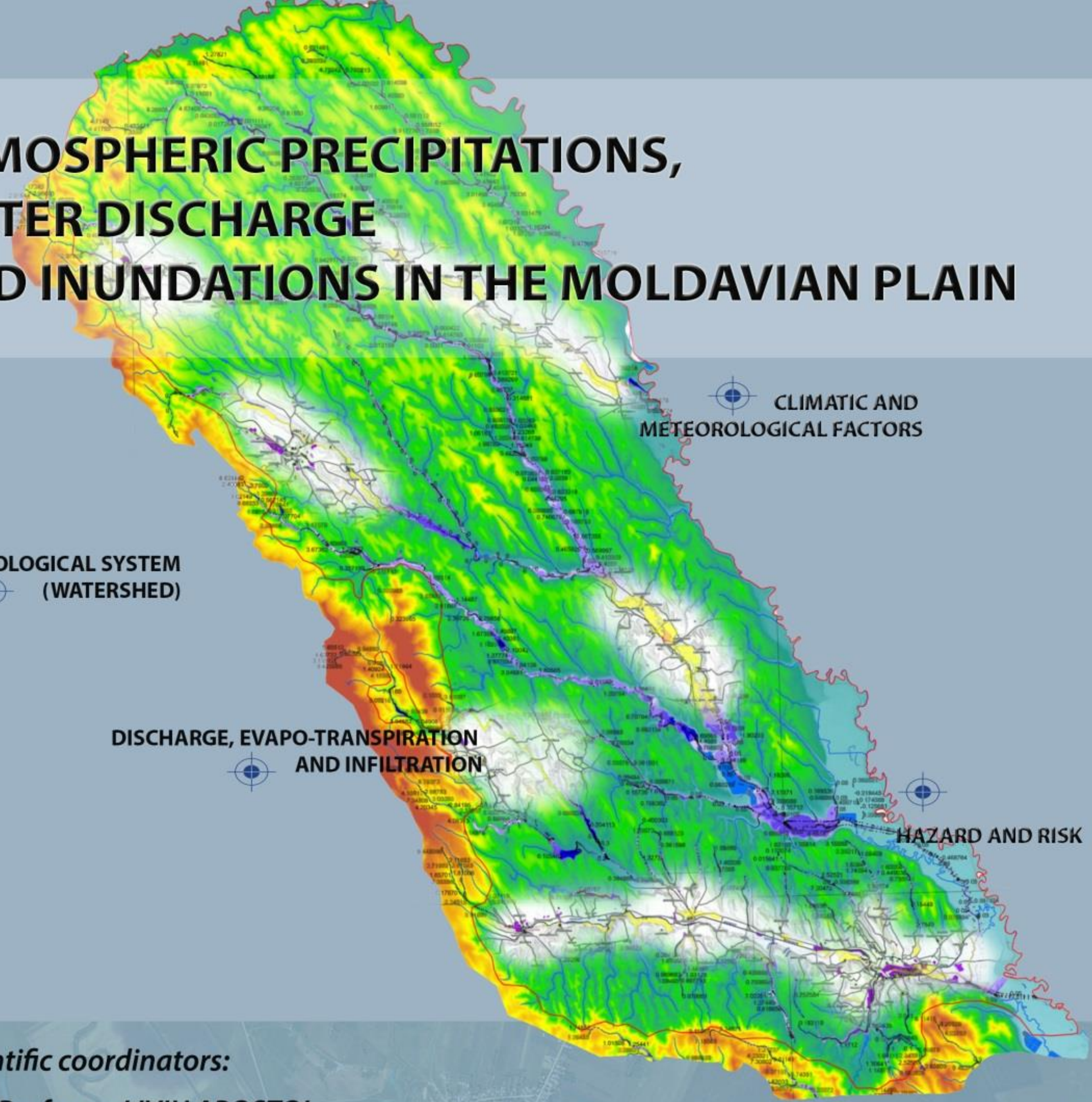
UNIVERSITY OF "ALEXANDRU IOAN CUZA", IAŞI
GEOGRAPHY AND GEOLOGY FACULTY
CHEMISTRY, LIFE AND EARTH SCINECES DOCTORAL SCHOOL

UNIVERSITÉ DE LORRAINE
DÉPARTEMENT DE GÉOGRAPHIE ET AMÉNAGEMENT
ECOLE DOCTORALE FERNAND-BRAUDEL

ATMOSPHERIC PRECIPITATIONS, WATER DISCHARGE AND INUNDATIONS IN THE MOLDAVIAN PLAIN



Scientific coordinators:
PhD Professor LIVIU APOSTOL
UNIVERSITY OF "ALEXANDRU IOAN CUZA"
PhD Professor IONEL HAIDU
UNIVERSITÉ DE LORRAINE

Doctoral student:
geographer DAN BURUIANĂ

2015

UNIVERSITY OF “ALEXANDRU IOAN CUZA”, IAŞI

GEOGRAPHY AND GEOLOGY FACULTY

CHEMISTRY, LIFE AND EARTH SCINECES DOCTORAL SCHOOL

UNIVERSITÉ DE LORRAINE

DÉPARTEMENT DE GÉOGRAPHIE ET AMÉNAGEMENT

ECOLE DOCTORALE FERNAND-BRAUDEL

DOCTORATE THESIS IN CO-TUTELLE

ATMOSPHERIC PRECIPITATIONS, WATER DISCHARGE AND INUNDATIONS IN THE MOLDAVIAN PLAIN

Scientific coordinators:

PhD. prof. LIVIU APOSTOL
UNIVERSITY OF “ALEXANDRU IOAN CUZA”
PhD. prof. IONEL HAIDU
UNIVERSITÉ DE LORRAINE

Doctoral student:

geographer DAN BURUIANĂ

SUMMARY

The elaboration and the scientific groundwork of a Philosophiae Doctor thesis become possible, indubitably, through a qualitative scientific guidance accompanied by exigency and professional routing. In this respect, I would like to express my special appreciation and thanks to my advisor, University Professor dr. Liviu Apostol, not only for the scientific guidance but also for the moral support in the rounding of the present thesis and for his ample experience share along with a wide and valuable bibliographic sheaf support.

I also want to express sui generis thoughts unto University Professor dr. Ionel Haidu, as scientific coordinator on behalf of the Université de Lorraine, France, for his generosity, professional support and reliability during the scientific work. In this context, I would also like to express my regards and thankful thoughts to the colleagues from the Laboratoire LOTERR-EA7304, Mr. director Michel Deshaiessi Emmanuel Gille, the doctoral school Fernand-Braudel and the de Géographie et Aménagement – Mr. director Gregory Hamez.

In the same time I would like to express my frank thanks to the colleagues and friends at the CHEMISTRY, LIFE AND EARTH doctoral school within the Geography Department of the Geography and Geology Faculty at the University of Alexandru Ioan Cuza in Iaşi pointing out that their advice, observations and support empowered my scientific endeavour and allowed the overcoming of inherent drawbacks along the way. My special thanks are also addressed to professors Dumitru Mihăilă, Ionuţ Minea and Ovidiu Machidon for the pertinent observations provided at the presentation of the delivered papers, inside the preparation stage and for the amability of enhancing my scientific efforts as contents of the present Ph.D. thesis.

I would especially like to thank the commission members for the thesis evaluation and for the honour of analyzing the paper work as well as for the permission to attend the commission's works.

Kind regards to the meteorologists at the Moldova Meteorological Centre and the colleagues at the Prut-Bârld Water Basinal Administration as contributors to the data fund included in the study and as support in the achievement of a better oriented scientific enterprise.

Last but not least, I would like to thank my family, with all my heart, for the support I felt along all this stage period, for the patience and understanding for when I was not there and for their trust and stimulation in this time span.

Introduction

One of the major challenges of this century is represented by climatic changes and their influence upon the environment. In the case of Romania, the orographic barrier plays the most important role in the delineation of surplus or deficient areas as refered to humidity. In the western and central regions of Romania, with oceanic influences, there is an surplus of humidity, while in the southern, south-eastern and eastern regions, with continental influences, there is a deficient humidity that generates dryness phenomena and drought. Non-the-less, we notice, in the last years, contrast situations with particularities in those regions affected by dryness and drought where there is an surplus of humidity.

Climatic change at global or local level represent a major problem and induce concern among researchers from various disciplines (meteorology, climatology, geomorphology, ecology, hydrology, biology, medicine, sociology etc.) in consideration of change that might produce major setbacks in all the life domains and the socio-economic activities. In this respect, knowledge, research and investigation at detailed level of local and regional meteorological conditions that induce triggering situations for atmospheric hazards generating risks, human and economic losses, sometimes hard to estimate, develop in significant and full of concern attitudes in contemporary times.

In the Moldavian Plain, due to the torrential character of most of the rivers, maximum discharge risk management is still difficult for the tributary/secondary streams. Even if the Jijia watershed, with the main stream of the Moldavian Plain, dispalys numerous water storages since 1960 to 1990, being one of the most systematized hydrographic basins, with tens of kilometers of dams and enbankments, the risks of maximum channel discharge and hillside discharge is still present. The intention of realizing a doctoral study on the *Atmospheric precipitations, water discharge and inundations in the Moldavian Plain* comes as a result of concerns in this respect and need to identify the natural risks and to evaluate the human activities as a perspective of risk – benefit for the efficient management of natural resources or in the attempt to favour sustainable development. Although floods are natural phenomena, with time repetability, as discharge processes along riverbeds, inundations represent, in modern times, one of the main causes of human and material losses.

1. Terminological and methodological aspects on the study of risk phenomena

The great non-periodic climate variability at global level which sets on ceratin air masses of different origins (tropical, polar or arctic) determines a various range of perilous climatic phenomena, as risks, which by genesis, manifestation manner and consequences results in economic prejudice and deprives people of the life neccesary resources.

The climatic risks pertain to natural risks. In addition, the whole range of natural phenomena considered as extreme natural phenomena (earthquakes, volcanic eruptions, tsunami, catastrophic floods, extended droughts, etc.) show that, in the histroy of humankind, while the civilization degree and economy developed, the vulnerability level of population toward various risks and the increased risks' frequency resulted in material losses and human lives losses in an intensified manner. This happened for two reasons: on one hand, certain extreme natural phenomena are enhanced by the anthropic impact on environment and, on the other hand, the global economic development, at high rates in the second half of our century attracted the risks of its own technologies (Bogdan, 1999).

Toward the end of the 20th century the humanking became more and more concerned of such phenomena which generate massive material losses inspite of civilization arguing on better general living conditions. The criteria to assess such consequences are diverse, yet a great majority evoke less the material losses andmore, the human lives losses.

The specialized literature uses different terms to measure and quantify the amplitude and to measure material losses generated by perilous natural phenomena: hazards, risks, records, calamities, disasters, catastrophes etc. The introduction of such notions gave birth to extended discussions on their content. At the moment, there is still no unanimous view point to be accepted regarding the inherent meaning and the fittest term in relation to the physical phenomenon *per se*. Even if the sphere of the respective notions is manifold, yet it contains a common feature, the propagation of material and human lives losses, sometimes incalculable that generate disequilibrium in the geosystems organization manner.

1.1. The Hazard

The Romanian Language Explicative Dictionary (DEX, 1975) states that the hazard is a set of circumstances of unknown cause, an unpredictable and unexpected happening (game of hazard), from the French, *Hasard*.

In the *Grand Larousse*, volume five, cited by Zăvoianu and Dragomirescu (1994) the term is shown to have Arabian origins, *az-zahar* (dice game, as a symbol of chance) and is defined as accidental interface, generally unpredictable between two ore more causal series with interchangeable relations, at each moment, with strict determination but with apparently relative independence in human interpretation.

According to the ONU Terminological Dictionary and the IDNDR Secretariat, with English, French and Spanish versions (cited by Zăvoianu, Dragomirescu 1994 and Grecu 1997) the hazard is a threatening event or the probability of its occurrence in a region and in a certain period of a given natural phenomenon with destructive potential.

In conclusion one can affirm that the Hazard represents an casual phenomenon, of great expansion, unpredictable and undetermined in time and space, a qualitative bounce, a bench or threshold in the system's evolution which discharges tremendous energies and induces disorder, disequilibrium at the common environmental evolution scale as conducting to a new equilibrium state (Bogdan, 1999).

In the case of climatic hazard we refer to a random climatic phenomenon of great extension which appears more as a result of its random genetical conditions (while the consequences are to be substracted), something unexplicable and then hard to predict (typhoons, hurricanes, tropical cyclons etc.)

1.2. The Risk

The Romanian Language Explicative Dictionary (DEX,1975) shows that the term is of French origins, *risque* and explains the posibility to be exposed in a danger situation, to face an undesired situation, to suffer a loss or a posible peril situation. We cand substratct that there is no risk in the absence of natural phenomena (to induce grave consequences) and the human society, mankind (to endure the consequences).

The risk has undefined character of prognosis, set to render a probability character or the certain possibility of a phenomenon appearance, rather unexpected, with grave consequences, upon a passive human position (in general these consequences are endured in the environment also in passive manner).

The same thing applies to the climatic risk also, where humanking bears the consequences of certain inevitable meteorological/climatic phenomena, as uncontrolled and happening in more or less unknown conditions, as foreseen and expected like, for example, the flooded areas or the risk of agricultural segment at severe climatic conditions, which often results in material and human losses.

In other terms the risk implies two sides, consequently: the physical phenomenon taken *per se* as the hazard, on one hand (implicitly) and the potential for the hazard to produce disasters (material and human lives losses) with different degrees, supported by the environment and the society (Bogdan, 1999).

The IDNDR dictionary states that the risk signifies precisely the second feature, as quantifiable, refering to potential character of the hazard to create disasters: the possible number of human lives losses, injured persons, losses of properties and interruption of economical activities in significant moments in a given region as a result of a particular phenomenon and, as consequence it is the by-product of the specific risk and the risk elements. In accordance with this definition the risk rests in the degree of vulnerability of a – population, building, construction, economic activity, public service etc. which become elements exposed to risk – as a result of a devastating phenomenon to be quantified through human and material losses per time unit as a product of annual disasters number and the deceased/disaster numbers (Zăvoianu, Dragomirescu 1994, Grecu 1997).

In the field of climatology the use of these notions is more detailed, yet as general rule one can affirm that all the climatic risks cause losses, not strictly large in every case but with gradual consequences. In important role is given by the climatic zone where the phenomenon takes place (Bogdan, 1994).

Of all climatic zones, the temperate zone represents the most diversified pallete of climatic risks. The phenomenon is explained by the fact that this zone represents the interference or transformation zone of polar air in tropical air and of the tropical air in polar air. It is the domain where susceptability of very cold and dry masses of air of Arctic origin or Polar origin is permanent and attracts with it all the winter climatic risks (cold air waves, frosts and early or late brumes) or invasion of hot tropical air which result in summer climatic risks (heat waves, canicular weather and prolongued droughts).

In the cases of interference of such air massses spectacular phenomena may appear in different seasons, during the year, with certain manifestation modes and consequences (heavy rians or snows, violent blizzards). These phenomena are more perilous as they happen outside their characterisitc season, affecting the vegetation periods. The seasonal and multi-annual evolution of such phenomena have an non-periodic character and hence, not always predictable and avertable (Bogdan, 1999).

2. The progression and present state of knowledge for the study area

The territory of the Moldavian Plain went under study and research, as far as the meteorology, climatology and hydrology are concerned, since Middle Ages. In 1640, Grigore the Ear publishes the ''Moldavian Country Chronicle" where he refers to the great floods of 1504: "during summer there were heavy rains and pouring of water and there lots of drowning" or about the drought of 1585, during the reign of Peter the Gimp: "at the reign of Pătru – the Ruler, in the Moldavian country a great drought took place, when all the spring became exhausted, the valleys, the mires, and where before it was fishing and hailstone in many places, the trees were dry of drought, the domestic animals had no grass to feed on and piles of dust where upon hedges and holes like snow drifts …". These two spectacular meteorological phenomena (the floods of 1504 and the drought of 1585) so eloquently related by the author figure out the pluviometric contrasts that are frequent in Moldavia.

The researcher and ruler of Moldavia, Dimitrie Cantemir (1673-1723) compiles in 1716, in „Descriptio Moldaviae" where he wrote "About the Moldavia landscape, about its old and new frontiers and about the climate" (chapter 2) and "About the Moldavia's waters" (chapter 3). Dimitrie Cantemir becomes, in this respect, the first researcher to describe the uneven character of the climate in Moldavia as a result of outside climatic influences.

The first instrumented observations in our country and in the Moldavian Plain were performed in August 1770 in Iaşi by the Russian military doctor, Lerch, upon the values of air temperature.

The publication *"Observazioni storiche, natural e politiche intorni la Valachia e Moldavia"*, of Steven Raichevich, from 1778, edited in Napoli contains numerous meteorological references and climatic references. Some climatic records about the weather of Iaşi town are given in the Andreas' Wolf publication (1805). The author shows that the four seasons succeed normally and there are distinctive weather states during the year. Andreas Wolf also refers at Iaşi town climate, analyzing the sudden changes of weather as a result of the local physical-geographic conditions and furthermore as a result of the wide opening to the east and west, but also as a result of the Bahlui river. The author state, in the same publication, that the winters a harsh, the springs display wind intensifications and the dominant wind are from east and north.

Later, in 1884 the Romanian Meteorological Institute is established, under the management of Şt. Hepites and, to the end of the 19th century and the beggining of the 20th centruy St. Hepites, publishes pluviometric interpretations on the basis of accumulated data, where references of precipitations regime in Iaşi city are included.

In 1886 the first meteorological station of order 2 is established in Iaşi in the Military School yard.

In 1895 the network of stations and pluviometric posts in the Moldavian Plain grows with the establishments in Dorohoi, Botoşani, Cotnari, and Iloaia's Bridge and later, 1956 the Avrămeni station, 1963 Răuseni and in 1987 Darabani station.

The apparition of an efficient hydrometric network that is able to perform complex observations and measurements for precise registrations of the hydrologic regime parameters is marked in 1932, after the floods on the Bahlui, Jijia and Prut rivers.

In the next period the accumulated data for the rivers in North-eastern Moldavia and the apparition of certain extreme situations in the hydrologic regime, conditioned the necessity of hydrographic systematization on some watersheds (Bahlui, Miletin, Sitna, Başeu) and, furthermore, in the entire Moldavian Plain. For each analyzed problem the goal was to describe the causes of variation at local level. Among the authors to publish specialized studies, there are: M. Niţulescu (1965), L. Mustaţă (1967), M. Schram (1963, 1964) and M. Pantazică (1958, 1963, 1964, 1967, 1968, 1971, 1974).

To the end of the nineteen eighties more and more studies on climatic and hydrologic hazards and risks were published. Hence, in 1992, D. Bălteanu elaborates an analysis on the natural hazards in Romania, where climatic hazards have an important share. In the same year, Octavia Bogdan and Elena Niculescu, refer to the same thematic of climatic risk phenomena in Romania for the 20th century. M. Podani and I. Zăvoianu went to details in “Causes and effects of floods in July 1991 in Moldavia”.

In the same year, 1992, the volume 4 of “Romania’s Geography” refers to the peri-Carpathian regions with an ample study on the conditions and climatic manifestations of the Moldavian Plateau and the Moldavian Plain, where a complex analysis that includes the geographic conditions of these relief unit and subunits is performed by Elena Erhan.

In 1995 Octavia Bogdan, Gh. Neamu and Elena Niculescu present, in Warsaw, a study on the climatic hazards particularities in Romania and, in 1996, Octavia Bogdan performs the regionalisation of climatic risk phenomena in Romania.

The year of 1999 in marked by the apparition of the most comprehensive work in the specialized literature of Romania “ Climatic risks of Romania” published by Octavia Bogdan and Elena Niculescu.

In the last two decades many research papers on the climatic and hydrologic thematic for the Moldavian region or the neighbouring regions, that are relevant for our study, were published: Liviu Apostol (1987 and 1990 *the regime of atmospheric precipitations in the Moldavian Plateau*), Mihăilă (1997 and 2002, *climatic aspects of the Moldavian Plain*), Elena Soare (1997, *the regime of atmospheric precipitations in Moldavia*) and Musteaţă (2005, exceptional floods in Romania territories).

3. Geographic location

The Moldavian Plain lies in the north-east of the Moldavian Plateau, between the Prut River corridor and the plateau of Suceava and Bârlad (Figure 3.1). With an average altitude of 125 meters and a maximum altitude of 265 meters in Cozancea Hill, the Moldavian Plain was studied by distinguished geographers over time: I. Rick (1931) names it the *Jijia Depression*, I. Simionescu (1934) calls it the *Moldavish Plain*, M. David (1993) calls it a part of the *Middle Prut Depression*, V. Tufescu (1942) calls it the *Moldavian Plain*. The *plain* denomination refer to its' agricultural land-use, low altitude, cernoziomic soils, Steppe vegetation and it's regime of water discharge. The sense of depression denomination is imposed by its' lower altitude in relation to the neighbouring table-lands which dominate, through 100 m dislevelments. In reality the Moldavian Plain is a low altitude plateau with field-like features, built on marl and clay deposits, with mono-cline character that results in numerous geomorphologic discontinuities.

The relief of the Moldavian Plain dispalys wide sinuosities with hilly or low altitude table-shaped interfluvial features which figure out a former homogenous surface fragmented by rivers' scouring. The average altitude of this relief is around 15 meters, the average local relief's energy is 60-70 meters and the average interfluvial width is 700 meters (Figure 3.2 A).

This major relief unit was detailed by V. Băcăuanu (1968) as comprising three main subdivisions: 1.*The Plain of Upper Jijia and Başeu Rivers*; 2. *The Plain of Lower Jijia and Bahlui Rivers* and 3. *The Prut River Meadow*

1.***The Plain of Upper Jijia and Başeu Rivers*** includes the Northern half of the Moldavian Plain and iits' limit, to the south, crosses the Bălcescu, Chiţoveni, Prisăcani, sud Hlipiceni, Rânghileşti cu Ilişeni sttlements. This sub-unit is entirely superimposed on wide deposits of lower Sarmatian represented by a clay-sandy facies. The characteristic relief displays low altitude plateaus and sculptural knobs with wide interfluvial surfaces at average altitudes of 160-180 meters.

In the east, the relief is more lofty as a result of Buglovian recifal clacareus deposits with lenticular aspect or apexes which are present at the surface. These deposits induce a local karstic releif with small caves, bare rocks, fissures, lapies etc.

In the central part the relief consists in hills, knobs and small plateau formed on the sandy-clays covered by eluvial loams. This characteristic is cvasi-general for the entire above mentioned zone.

In the west, the releif, as an assembly is 20 to 40 meters lower, compared to the east as a result of the presence of alternant thick Sarmatic sands and gravels. The presence of marhy flat areas and knobs gives the aspect of a contact depression, more obvious in the Cristeşti-Coşula sector. The relief here is, in high extent , covered by coluvial sandy loams.

2. ***The Plain of Lower Jijia and Bahlui Rivers*** consists in clay-marl deposits and sandy deposits of the Middle Sarmatian and includes the Southern half of the Moldavian Plain.

The relief is sinuous, with wide valleys, usually subsequent with one versant developed on terraces and the other with cuestas. The sculptural interfluves are more intensely fragmented and covered, in most of the cases by eluvia and coluvial loams. The accumulative reliefs (plains, terraces and glacises) have a much larger extension compared to the north part.

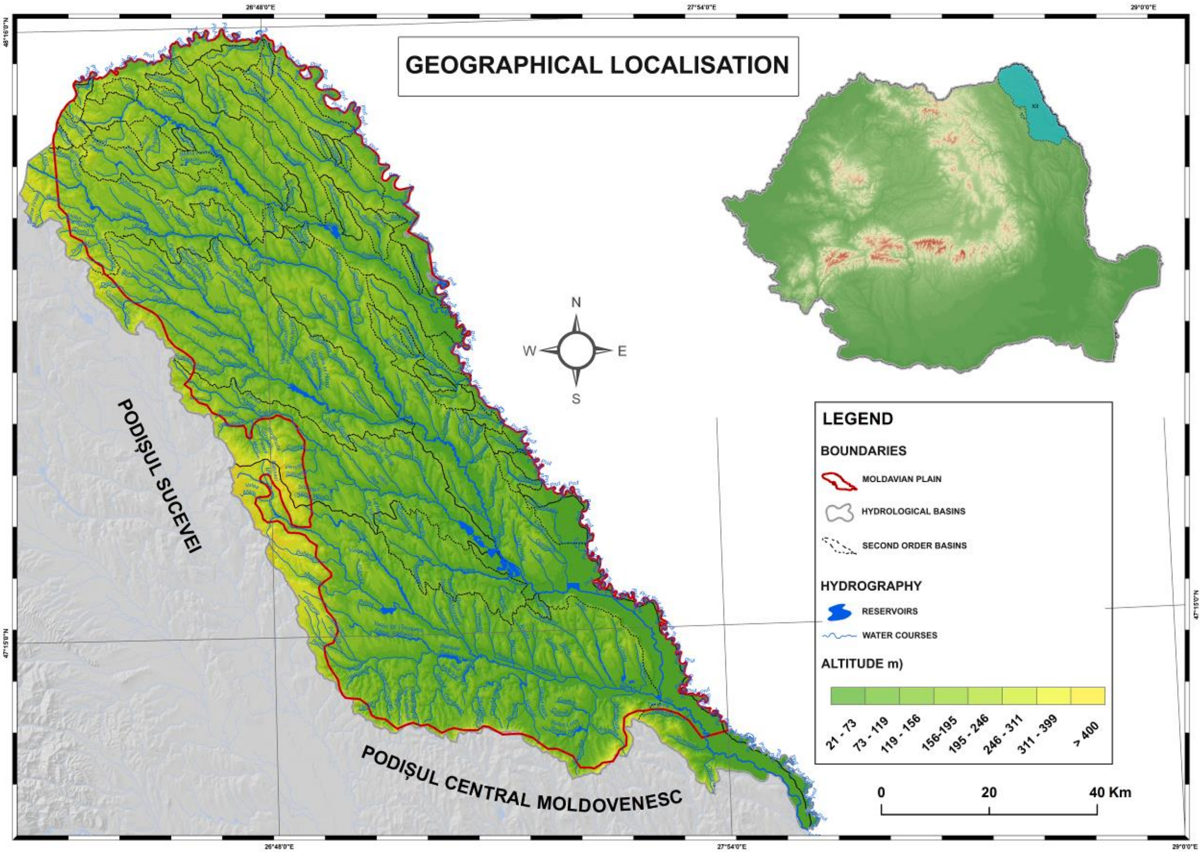


Fig. 3.1 Geographic location of the Moldavian Plain at national level

The medium altitudes predominate with averages between 100 and 150 meters, consequently with 50 meters lower than the *Upper Jijia Plain*. The local relief energy oscillates between 50 and 60 meters. In this landscape the present geomorphologic processes of degradation are more intense and diverse with a higher land - slide incidence.

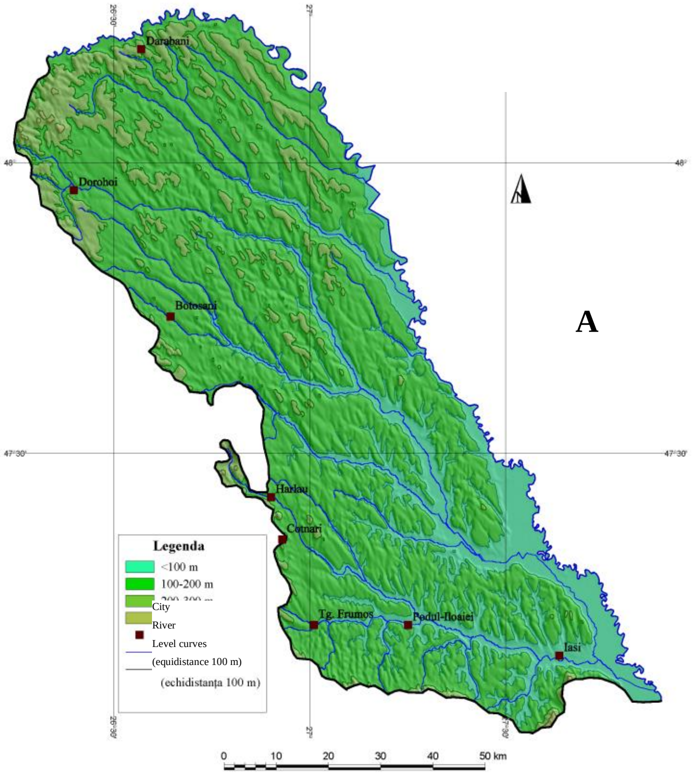
On the sides, at the contact with the plateau hights, on the west and south margins, the relief developed in a row of depressions, more evident in the vicinity of the massif hights and lessened next to saddles.

Considering the age of the surface deposits research pointed out that the first hydrographic network and the first streams appeared in the Northern part at the end of the lower Sarmatian and, in the Southern part, at the end of the Middle Sarmatian. Even if erosion started later in the Southern part, the abundance of clay deposits here and the lower erosion-base level, resulted in denser streams the with more developed releif aspect. In conslusion, the hydrographic network developed from NW to SE along with the retreat of the Sarmatic Sea.

3. ***The Prut River Meadow*** is the third sub-unit to be distinguished in the Moldavian Plain.

The Prut Meadow aggraded during the Holocene epoch as a result of alluvial accumulative processes. The Prut Meadow dispalys thick sandy - gravel deposits covered by sandy-clays alluvial packs and pure clay alluvial packs.

Laying in North-estern Romania, the Moldavian Plain is drained by 5 river systems: Ghireni, Volovăţ, Başeu, Corogea şi Jijia (Figure 3.2 B).



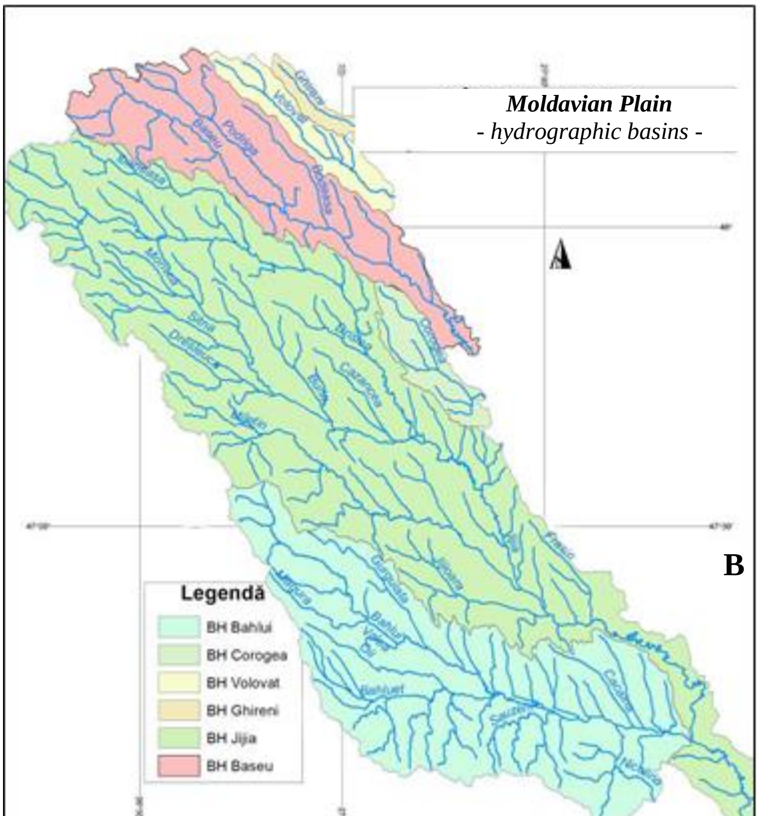


Fig. 3.2 The hypsometric map of the Moldavina Plain (A) The hydrographic basins of the Moldavian Plain (B)

The rivers of Corogea, Volovăţ and Ghireni dispaly their hydrographic basins inside the Moldavian Plain entirely, while Başeu river has 10% of its upper basin in the Suceava Plateau. The Jijia river has 80% of its watershed in the central, Western and Southern parts of the Moldavian Plain. The rest of the watershed, respectivly 20% is fed from the Eastern part of the Suceava Palteau and the Central Moldavian Palteau.

From the hydrographic view point all the rivers in observation pertain to the right part of the larger Prut watershed, developed in the much larger unit of Eastern Moldavian Plateau. In the south and in the west these rivers are separated by the rivers in the Siret watershed, across 225 kilometers, along the Urus Hill, Hăpăi, Bucecea, Great Hill, Strunga, Three Coins Hill, Toader's Hill, Mogoşeşti, Repedea and Peacock Hills with their hights. To the south and east the region is bordered by the Prut river which is the main stream that collects the rivers of North-eastern Moldavia.

4. Physical-geographic characteristics of the study area

The Moldavian Plain is a geomorphological subunit markedly individualized by the Moldavian Plateau with a lower relief altitude compared to the neighbouring units around, widely ondulated, with knob shaped interfluves where the versants are modelled by intense deluvial processes.

The Moldavian Plain stretches along 8.000 km^2 and is superimposed on the Jijia watershed and on other smaller watersheds in the north-eastern Moldavian Plateau. To the south, west and north-west, there is a high altitude rim with a relief energy between 200-300m and slopes between 10-20° while, to the east and north-east the subunit is bordered by the Prut River.

From the geo-structural view point, the Moldavian Plain pertains to the Moldavian Platform that dispalys an inferior Precambrian tier and a superior post-Proterozoic tier of 1000 m thickness.

After the Huronian orogenesis that folded the Precambrian deposits and put in place a mountain relief, highly fragmentised, the bedding finished its geosynclinal cycle and became a platform. The intense activity of the external modelling factors and the long period of their action resulted in a *peneplain* – the peneplain of the crystalline Precambrian basement which, afterwards, only suffered tilt movements. This peneplain became fossilized and covered by the sediments from the Ordovician and Silurian seas.

In present times, after a sub-aerial evolution of almost 10 million years, the relief of the studied region takes the shape of a structural plain. The superior part of the knob shaped interfluves and hilly forms, with slightly inclined surfaces, that form the general profile of this plain finds itself lower (150-200m) than the Central Moldavian Plateau surface or the Great Hill-Hârlău which border the Moldavian Plain to the south and west.

The most important features of this territorial assembly started to appear in the Upper Sarmatian and reached the final shape in Pliocene and Quaternary. During this long period the older relief forms were replaced, gradually, by newer forms and the evolution continues nowadays (V. Băcăuanu,1968).

The extreme altitudes reach 271 meters in the Bodron Hill, in the north and 32 meters in the Prut meadow, to the confluence of the Bahlui and Jijia rivers. A general decreasing altitude trend is to be observed from NW to SE. In this respect, in the north, the average altitudes reach 150-200 meters (175 m), while to the south altitudes reach 100-150 m (125 m) with altitudes differences of 50-100 m between the two sides.

The relief's energy has maximum values of 100-150 meters and average values of 50-70 meters; the horizontal fragmentation oscillates usually between 500 and 1000 m; the average slopes of the interfluves dispaly between 2 and 3°; the valleys' versants, with decreased energy have 5°, while the main valleys, more often, the *cuestas* have 10-15°. Fig. 4.1.

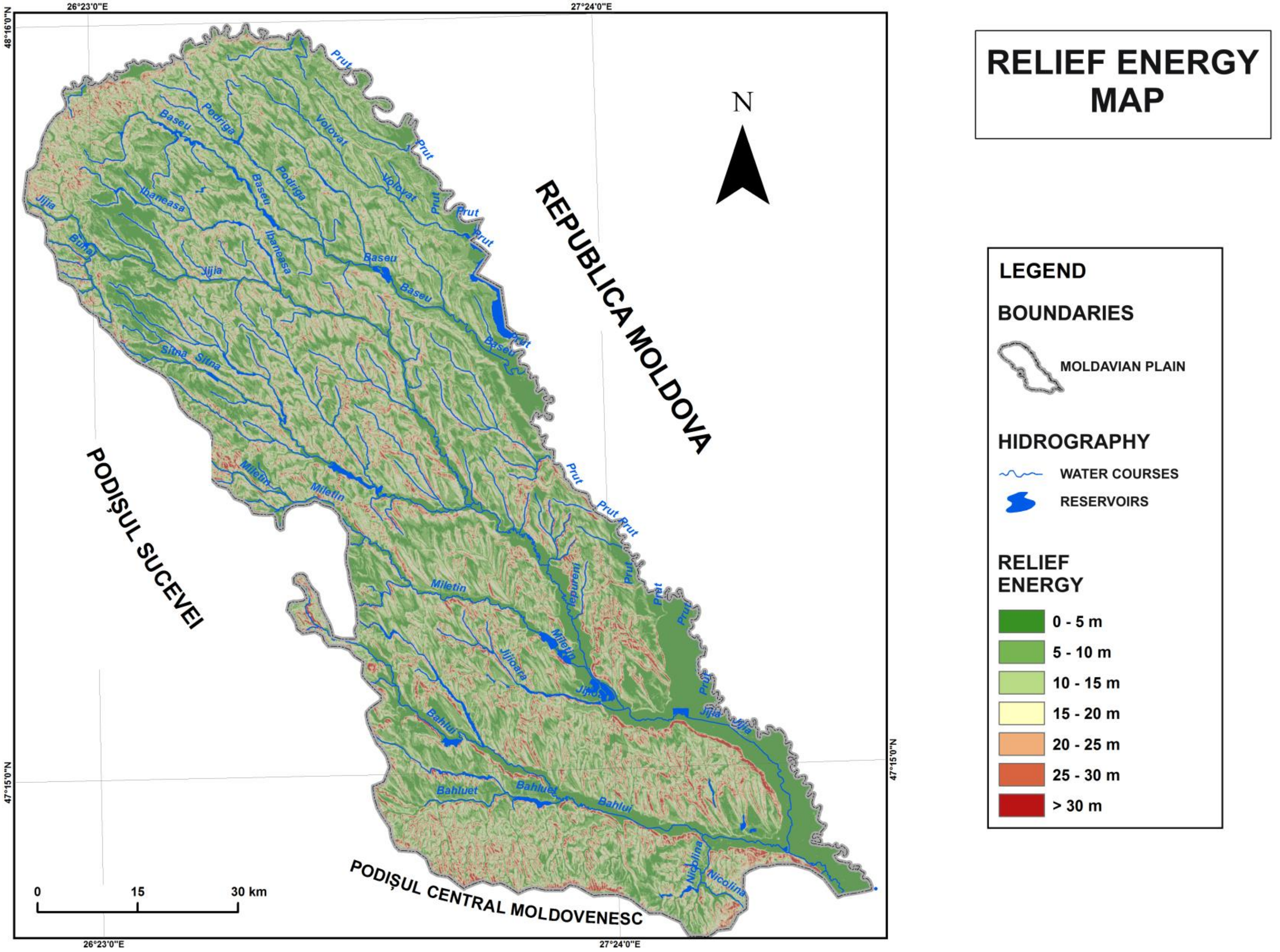


Fig. 4.1 Map of relief energy in the Moldavian Plain

The structural relief covers 70 to 80% of the total territory in the study, yet the marls and the clays do not always appear at the surface. Many times the Sarmatian deposits, at the surface, were transformed in eluvial loessoid loams or lutes of 3 to 4 meters thickness.

The present aspect of the Moldavian Plain relief is the result of selective denudation in relation to the rock types and the general structure and the evolution of the various orders watersheds. Consequently, we have here a single denudation surface of Pliocene to Quaternary age. This surface displays a general NW-SE inclination with absolute altitudes of 200 to 500 meters in the north and 125 to 150 meters in the south.

The natural conditions in this part of Romania allowed the development of a large palette of geomorphological processes and of a deluvial micro-relief on the majority of slopes. By extension, the most important process is the areolar erosion which appears on all the slopes with inclination higher then 3°. This areolar erosion is accompanied by corrasion and deflation and has higher rates in the Northern half of the territory.

The torrential erosion processes with all its various shapes, ditches, gullies, ravines and torrents are widespread, characterizing the inclined surfaces on the clay-Sarmatian complex deposits. A particular type of linear erosion, associated with surface failure and suffosion is to be observed on the versants with salinized Sarmatian marls at the surface. Here we meet microforms resembling those on lime-stones, yet more blurry developed – lapies, kettles, subterranean galleries, sink-holes, suspended crosses, small chimneys etc. (V. Băcăuanu, 1968).

The accumulative relief represented by flat areas, terraces, accumulative cones and glacises is proper to partially reconstruct the paleo-geographic evolution of the hydrographic network and the morphology of the entire region. In the same time there are very good conditions for the agricultural activities, communication routes and settlements.

The most recent accumulative forms are the meadows (flat areas) which appeared in the Holocene epoch. Regarding dimensions these flat areas differ from a valley to another, yet they have common genesis, structure, petrographic content and micro-relief.

The thickness of alluvial deposits in the major meadows of the Moldavian Plain oscillates between 3 and 20 meters, depending on the evolutive phase, and have, in general, two paces (meadow terraces of 1-3 meters and 4-6 meters) with additional bars with meanders bends and dried channels, ponds etc. The flat areas also encompase positive forms like hammocks and smaller heaps where meanders changed their direction and they can be completly individualized or in course of detachement from the versants.

The same relief category includes the terraces. These go along the important valleys in the Moldavian Plain and also in some secondary valleys (Nicolina, Voineşti Valley, and Cârjoaia Valley). Their formation and evolution is the result of tectonic slow transgressions of the Moldavian Platform, the deepening of the baseline erosion level of the sea in Pliocene and Quaternary phases and the climatic oscillations in this period. Generally speaking there are 7 to 8 terraces systems with relative altitudes of 10 – 15 m, 20 m, 30 m, 60 m, 100 m, 120 m, 140 m and 170 m. The most representative are the terraces in the lower course of the sub-sequent valleys. In these sectors they are more extended displaying a fan shape along kilometres and they were not destroyed by the denudation.

The most complete series of terraces is situated in the lower Bahlui valley. On the right bank of the Prut River, the lower Jijia, Bahlueţ and Miletin the 170 terrace is missing, while on other valleys only the low altitude terraces appear (110 m on Sitna Valley, 95 m on Voineşti Valle and 60 m on Başeu Valley).

Considering the altitudes, the number and the age of the fluvial terraces in the Moldavian Plain one can substract that the main hydrographic network is settled since the Upper Pliocene and the beginning of the Quaternary period. This network kept its discharge direction with only few kilometres deviations. The most important deviations in the streams network are at the contact with the higher region of the Suceava Plateau, to the west, where numerous interceptions are in place.

In the same time with the phases of terraces alluvial deposition, to the margins of the Moldavian Plain there are contact accumulative deposits, partially destroyed or fragmented in periods with more intense, afterwards, denudation processes. Some of these accumulative forms appear in the shape of local terraces or they were cross-cut and appear in the form of knobs or hills. On the whole, these old and new accumulative forms give shape to the contact glacis unit at the base of abrupt forms to the west and south of the Moldavian Plain.

5. The climatic geographic factors to influence the discharge regime of the rivers in the Moldavian Plain.

The geographic location of the region influences, in direct manner, the hydrologic regime. The accumulation of water reserves and their variation in time and space is influenced by the geographic factors, their complexity and the dimensional elements of the hydrographic systems and the source watersheds.

The climate, through its components (temperature, humidity, precipitations, and air masses dynamics) manifestation in the regional natural conditions has a direct influence. Thus, the quality of the dominant precipitations, in the hydrographic basins, results in distinct types of water intake; the precipitations quantity influences the regime of liquid discharge; the air's temperature regime influences the water temperature and the evolution of different ice formations in the winter; the humidity and air dynamics intensify or loosens the water consumption through evapo-transpiration while the annual precipitations repartition, their intensification degree and the snow melt pace influence the regime of solid discharge.

The other natural environment components, the relif, the petrographic constitution, the vegetation and the soil, as well as the dimensional elements like the length of the hydrogrpahic networl, the confluences angle, the sinuosity degree, the major bed depth, the watershed surface, control the necessary time for the water to arrive from the dropping point to the collector point and the out of the watershed.

Situated in the north-eastern Romania with weaker Atlantic and Mediterranean influences, the studied region has a stronger influence from the east-European zone. The climate of Moldavian Plain pertains to the transitory temperate climate and the sub-sector of external Carpathian arch (Apostol, 1987). This situation is primarily given by the predominance of the western air masses circulation (over the Carpathians and from the north, avoiding the Carpathians), a relative dominance of the old polar maritime air and the annual moderate quantities of precipitations. Moreover the southern and western air masses to descent from the higher plateau regions suffer, frequently, from foehnization diminished precipitations, usually around 500 mm per year (Băcăuanu, 1992).

The relative uniform lithology with weak subterranean accumulative potential or water input for the rivers the atmospheric precipitations constitute the main source of delivery for the aquatic basins and the underground waters of the Moldavian Plain. The extreme spatial and temporal variability results in the pronounced heterogeneous state of the other components of the hydric balance (evapo-transpiration, discharge, infiltration) which increases the difficulty of quantitative determinations on narrow surfaces and short time intervals.

Consequently the liquid discharge volume is low, the turbidity is high and the freezing regime is more stable, with longer time span compared to the western and south-western watersheds.

On the relative narrow surface of the Moldavian Plain the spatial variations of annual precipitations quantity are significant. The solar radiation and the general atmospheric circulation dominated in the western sector, mainly in the first part of the warm season and in the eastern sector in mid-winter as correlated with the local geographical factors (relief, vegetation, water basins, excess humid zones in valleys or depressions, large settlements, Iaşi city with more active thermo convection and increased pollution with condensed urban-cores) evolve in pluviometric irregularities at watershed level (Mihăilă, 2006).

5.1. Air temperature

The geographic repartition of the annual average air temperature is relatively constant with uniform tendencies on wide spaces. The characteristic isotherms describe extended territories. The highest temperatures, usually over 9, 5°C are specific to the south-eastern areas of the Moldavian Plain while the lowest temperatures, below 8°C are specific to the north and north-western areas. The NW-SE differences are notable and explain the latitudinal interval (1°15'), the altitudinal interval (over 150m) and the climatic influence of the neighbouring areas (the northern area is closer to the high plateaus and mountains to the west). There are also thermic differences between the west and the east, in the Moldavian Plain, yet these are less notable (0, 4 °C in average) and are the result of altitudinal differences between two study area compartments.

The central part of the Moldavian Plain displays temperatures in the 8,5 and 9°C interval where the annual average isotherms impress a sinuous route (given by the isotherms elongations toward the upper valley) and a general NE to SW orientation.

The annual average ait temperatures decrease from south to north (9,6°C at Iloaia's Bridge, 8,2°C at Avrămeni, 7,8°C at Darabani) and increase, in general, from west to east (8,6°C at Botoşani, 9,2°C at Stânca; 8,9°C at Cotnari, 9,5°C at Iaşi) as the continental climatic characteristics become more obvious and the altitude decreases (Mihăilă, 2006).

Temperaturile maxime absolute din aer înregistrate în Câmpia Moldovei, pentru perioada 1960 - 201, s-au încadrat între 36,0°C (Cotnari – 6.VII.1988) şi 40,0°C (Iaşi – 27.VII.1909), iar cele de pe suprafaţa solului între 61,3°C (Dorohoi – 26.VIII.1994) şi 66,6°C (Iaşi – 8.VII.1969).

The absolute maximum temperatures recorded in tha Moldavian Plain between 1960-2011 are the following: 36,0°C (Cotnari – 6.07.1988) and 40,0°C (Iaşi – 27.07.1909) at 2 meters high while at the soil surface the maximums were 61,3°C (Dorohoi – 26.VIII.1994) and 66,6°C (Iaşi – 8.VII.1969).

In the September – May interval the temperature can go below 0°C when the total frost days exceeds 120, in the north and 110 in the south and the winter days oscillate between 35 in the south and 45 in the north. The total frost nights are 15 in the south and 25 in the north of the Moldavian Plain.

5.2. Atmospheric precipitations

Atmospheric precipitations represent, along with the other climatic elements, one of the important control factors for the individual character of the climate of a region since they influence the geographic landscape assembly. Furthermore, due to their wide spatial and temporal variability, atmospheric precipitations, control the social and the economic activities, mainly: agriculture, transportations, tourism, constructions etc.

5.2.1. Spatial distribution of precipitations

In order to account for a comprehensive analysis of the spatial distribution of precipitations' quantities the study relies on pluviometric data in the 1960-2011 period recorded at 32 meteorological stations and pluviometric posts (9 meteorological stations and 23 pluviometric posts) inside the Moldavian Plain and the surroundings (Fig. 5.1).

Given the non-homogenous distribution of the data at the above mentioned posts we applied an extension of the data series. Furthermore, for a fair analysis and as a consequence of some post and stations dismantling since 1990 or the settling other posts and stations far from 1961 we analyzed the data on two common intervals: 1961 – 1991 and 1981 – 2011. The spatial distribution of the posts and stations enhanced the implementing of a regular network of points (including points in the neighbouring areas of the Moldavian Plain) and supported the development of spatial distribution maps for the annual average precipitations.

The analyses of the obtained maps regarding annual precipitations quantities in the Moldavian Plain reveal the decreasing trend from west to east, along with the decrease in overall altitudes and lower frequencies of humid air masses to the east (drier air masses), compared to more humid, Atlantic, air masses to the west. In addition, the foehnization process of the western side accounts for the reduction of the western and eastern precipitation quantities differences. In the same time, the distribution maps (Fig. 5.2, 5.3) indicate that:

1. The high altitude zones register an increased pluviometric input (Ibăneşti Hills or Darabani Hills, to the north: Pomârla - 623, 9 mm; Copălău - Cozancea – Guranda range, to the central part: Cristeşti - 585, 3 mm, Nicolae Bălcescu - 564, 8 mm). The Bahlui hydrographic basin deserves special attention in the context. The Iaşi *Rib-front*, a 350 meters high relief obstacle in front of the north-western air masses movement generates increased precipitation quantities in the lower Bahlui watershed (where the masses of air start to ascend). The situation becomes obvious when comparing with the other important valleys (Jijia valley, north of Iaşi – at Victoria, 476 mm).

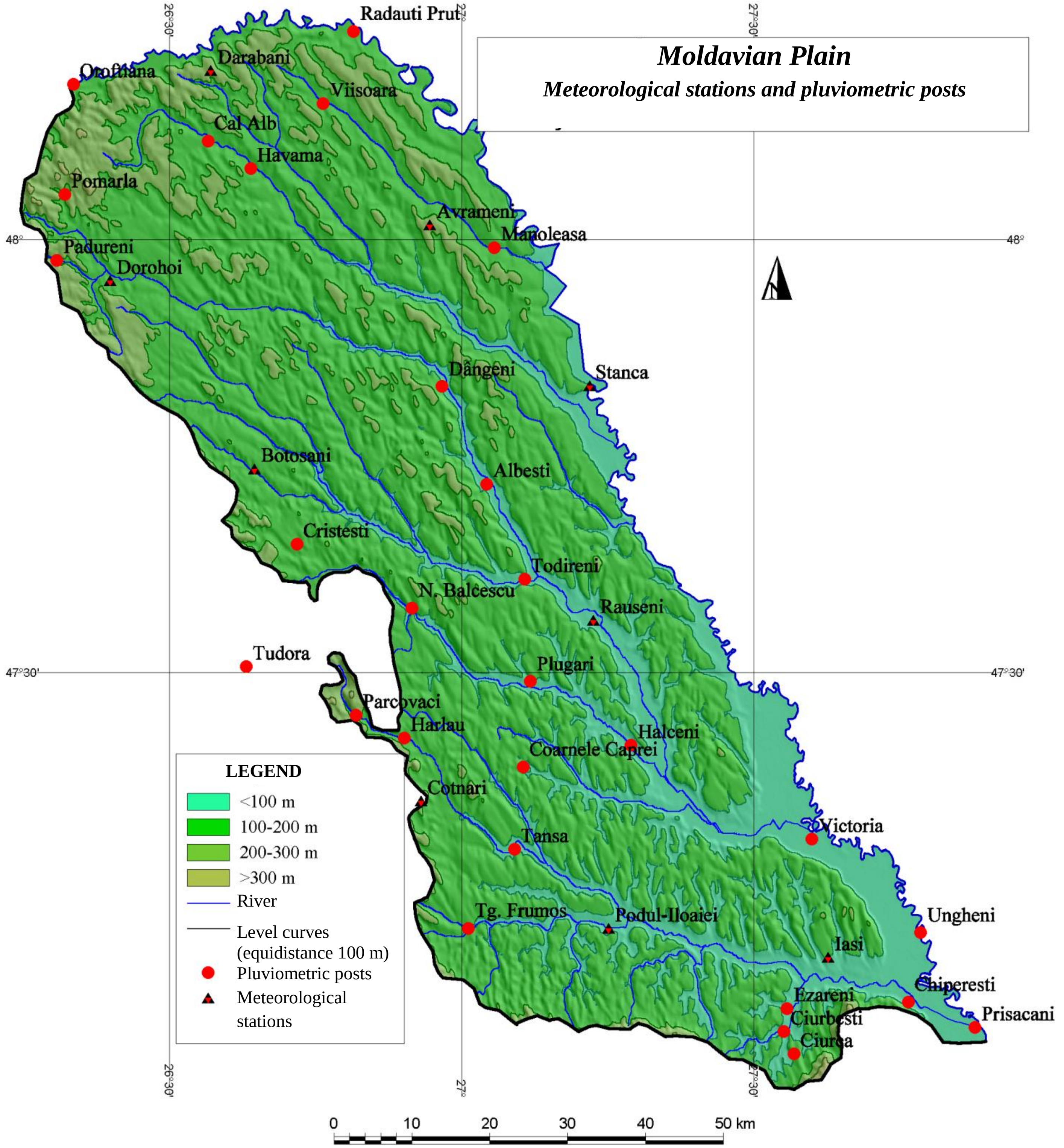


Fig. 5.1 Meteorological stations and pluviometric posts in the Moldavian Plain

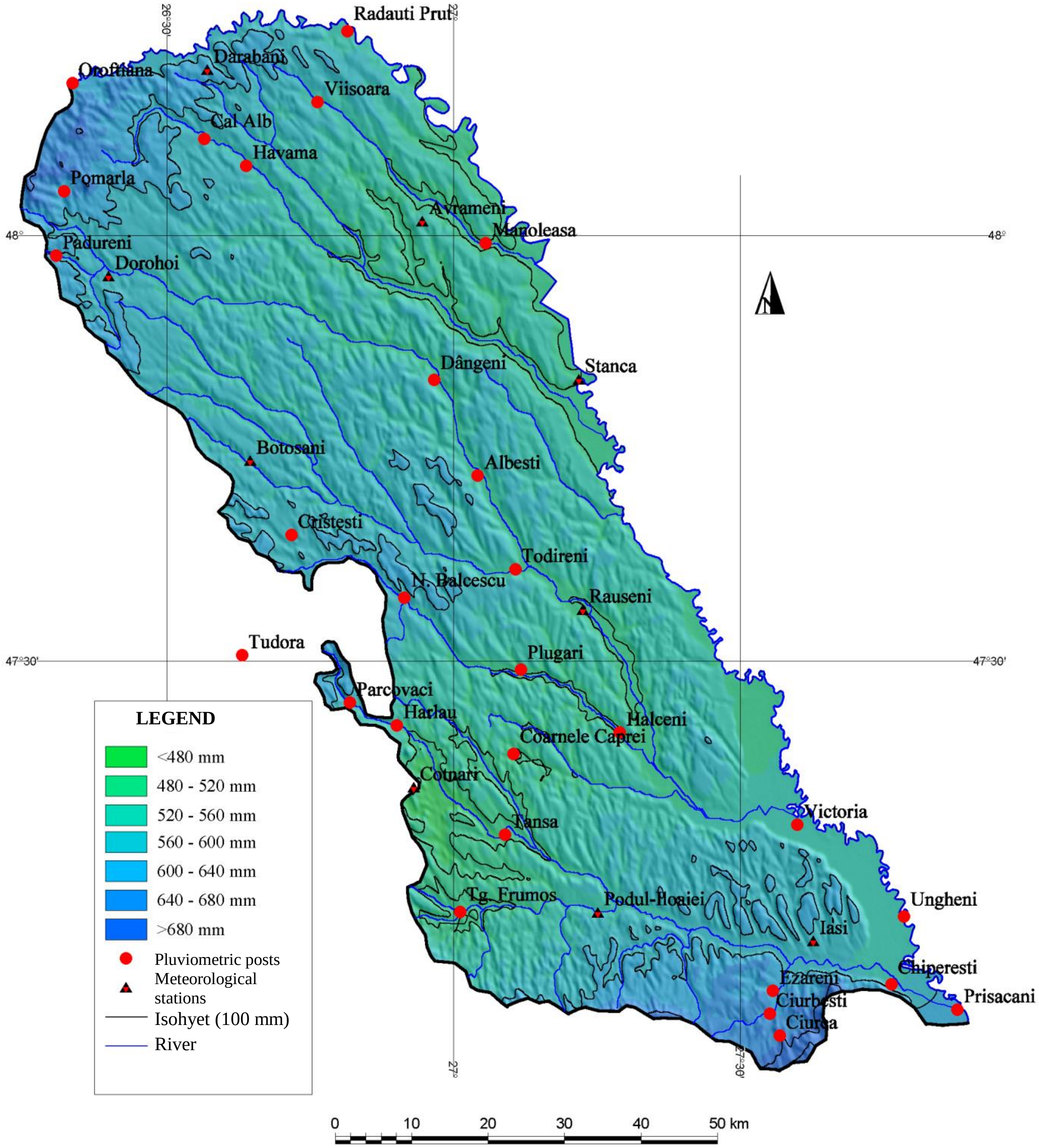


Fig. 5.2 Spatial distribution of the average multi-annual precipitation in the Moldavian Plain between 1961 and 1991

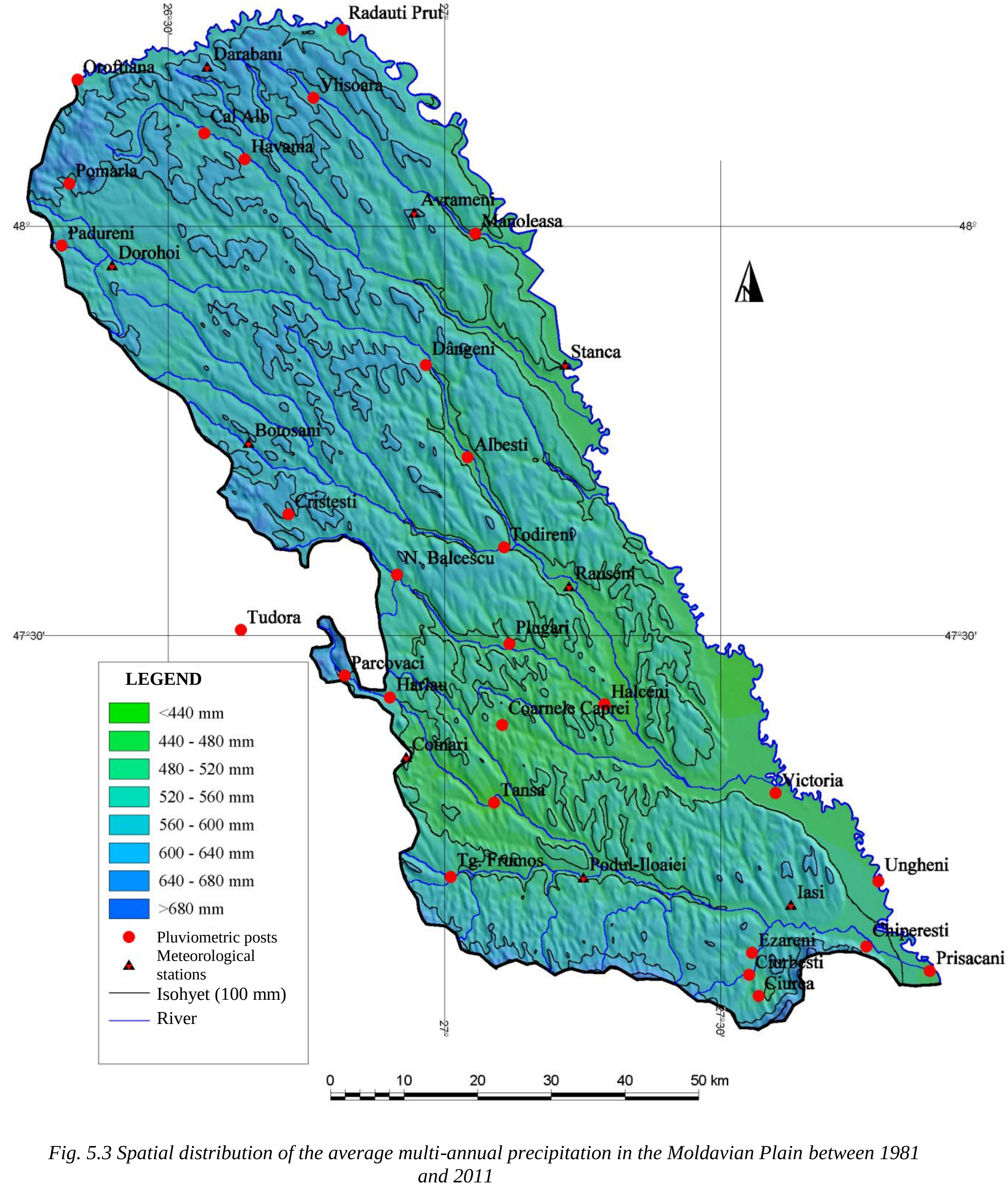


Fig. 5.3 Spatial distribution of the average multi-annual precipitation in the Moldavian Plain between 1981 and 2011

The Iaşi city generates increased numbers of condensation nucleus in conjunction with *thermic chimney* (given by high relative altitudes differences) develops slightly greater precipitations quantities (Iaşi, 573 mm). To the west of Iaşi city there are two *orographic funnels* that entrap, drive and boost the air flows resulting in their ascent. To the south, the opening toward the Prut River and the High Forest Hills (Republic of Moldavia) induce a slight increased precipitation quantity over the year, while in the Ciurea watershed, where the *funnel* is blocked to the south (by the Bârnova Hill) precipitations are very high for this area (compared to the rest of the country, Ciurea 646 mm, Bârnova 775 mm at 354 meters; the quantity is comparable to the mountain area at 700 meters altitude).

II. The lower altitude zones also display the lower annual precipitations quantities. Among them we notice the north-eastern side of the Upper Jijia Plain ac. White Horse 456 mm; the Cliff, 459 mm and the south-western side, in the *shadow* of the Great Hill – Hârlău (Tansa, 467,20 mm; Goat's Horns, 473 mm). A third low precipitation area appears on the Prut River valley.

Aside from the, above mentioned, pluviometric differences there is also an alternative zone of high altitude spots with increased precipitations and low altitude spots with decreased precipitation quantities with a well evidenced trend from north-west to south-east. The versants exposed to the humid air masses from the NW are subject to increased rain input, while the versants exposed to SE drier air masses are subject to decreased rain input. Both air masses categories are subject to foehnization with greater differences between the versants that are opposed to air ascent and those exposed to air ascent, especially when the air masses are of maritime origin.

5.2.2. Spatial distribution of the semestral precipitation quantities

The semestral precipitation quantities describe an uneven distribution along the year, as well as in-between the years and the evolution of the semestral sums display increases and decreases in correlation with the annual precipitation sums evolution. As a rule, the more humid years are characterized by the same genetic phenomena and processes for both the warm and the cold seasons, with the specific value differences. The long term evolution emphasizes a stable tendency, while per assembly; the increase in annual precipitations is a result of greater quantities in the warm season.

In the warm season (1st of April and 30th of September) the air masses dynamics, very active as a western component and the thermic and dynamic convections with maximum annual values determine, for the warm period, that two thirds of the annual precipitations take place (Fig. 5.4).

The spatial distribution of the atmospheric precipitations in the warm semester (Fig. 5.5, 5.6) resemble the annual distribution with notable differences as referred to the recorded values. The greater values are specific to the north and north-west of the study area, to the contact with the Suceava Plateau (Pomârla 413, 3 mm, Darabani - 409, 6 mm).

In the central, higher, zone Copălău - Cozancea – Guranda the precipitation quantities, in the April-September interval exceed the warm semester average: Nicolae Bălcescu (371, 6 mm), Botoşani (402, 6 mm), Cristeşti (418, 6 mm). The higher altitudes to the south induce higher precipitation quantities. The thermo-dynamic ascent, over the Iaşi city, along with the active atmospheric dynamics in the warm season result in increased precipitations quantities: Iaşi (388, 5 mm), Iloaia's Bridge (387, 5 mm), Ungheni (374, 5 mm), Bârnova (512, 84 mm).

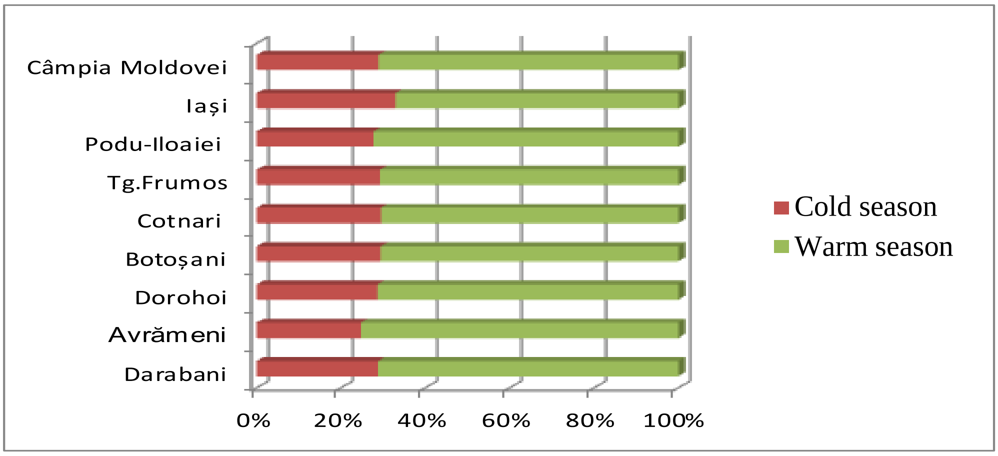


Fig. 5.4 Semi-annual distribution of precipitations quantity in the Moldavian Plain

The Moldavian Plain average is not met in the same two sides as in the case of the annual precipitations sums and display pluviometric deficiency.

In the cold semester (1st of October – 31st of March) the precipitations quantities are lower, with only 165, 9 mm as an average of the Moldavian Plain. This happens as a result of higher frequencies of anti-cyclonic air masses and inefficient thermic convections. In this interval the atmospheric dynamic is dominated by drier and colder continental air masses that originate from the north and north-east of Europe or from north-west and west of Siberia.

The annual repartition of precipitations in the cold semester (Fig. 5.7, 5.8) resembles the annual repartition and the warm semester repartition with certain areas that exceed the average in this interval: in the extreme north-west (over 180 mm), in the central and central-western area (Cristeşti - 175,9 mm) and in the south and south-east (Iaşi - 190,7 mm).

The atmospheric dynamics, the relief and the presence or absence of the forest vegetation or the large urban agglomerations contribute to the seasonal spatial repartition of the atmospheric precipitations (Mihăilă, 2006).

The higher relief favours more abundant precipitations. In the south, along Bahlui river corridor and in the south-east, at the confluence with Jijia and Prut rivers, the cold season the cyclonal ascents from the south, with warmer and more humid air enhance more abundant precipitations even if they have a low frequency.

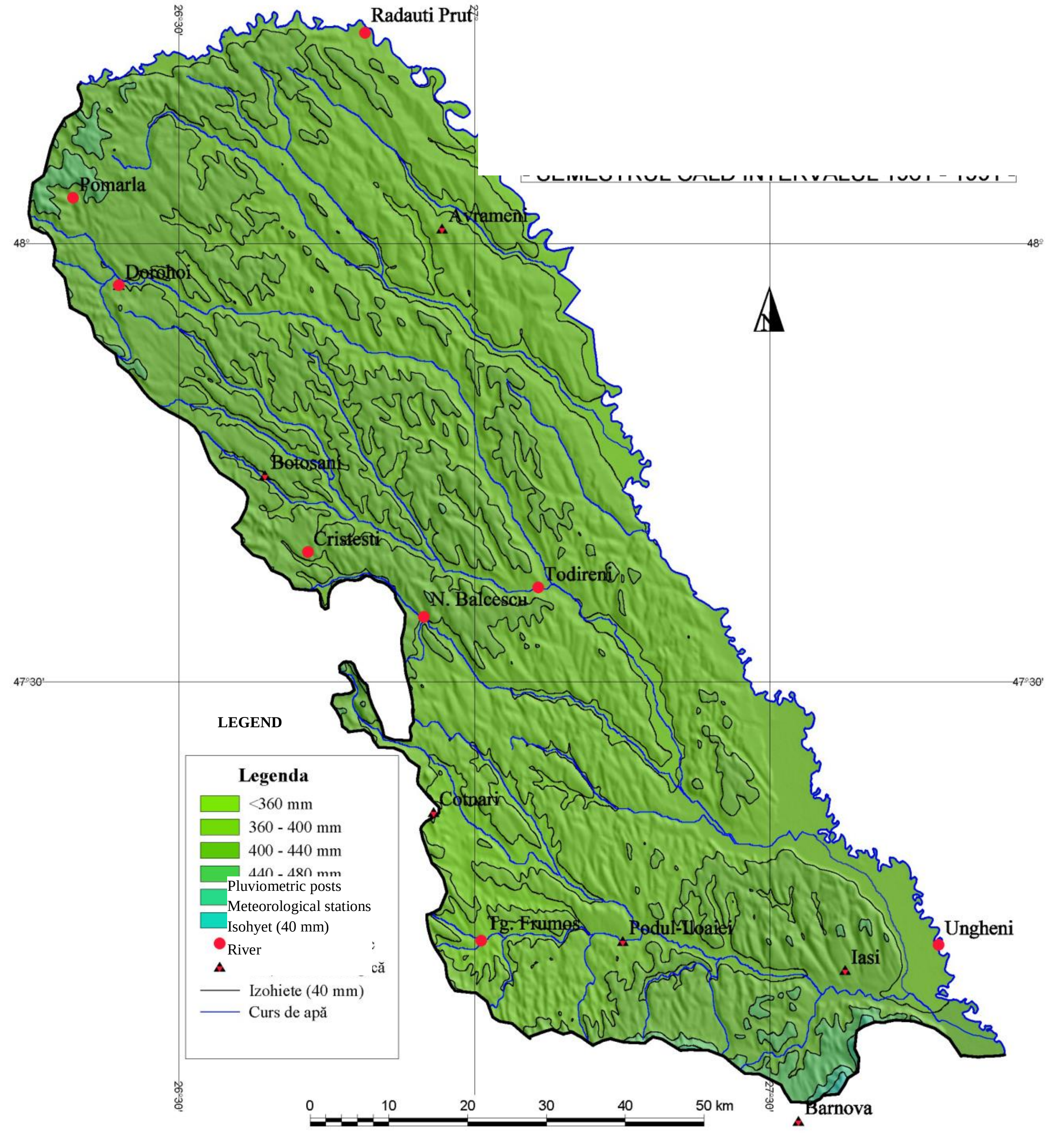


Fig. 5.5 Spatial distribution of multi-annual precipitation quantities in the estival season for the 1961-1991 interval in the Moldavian Plain

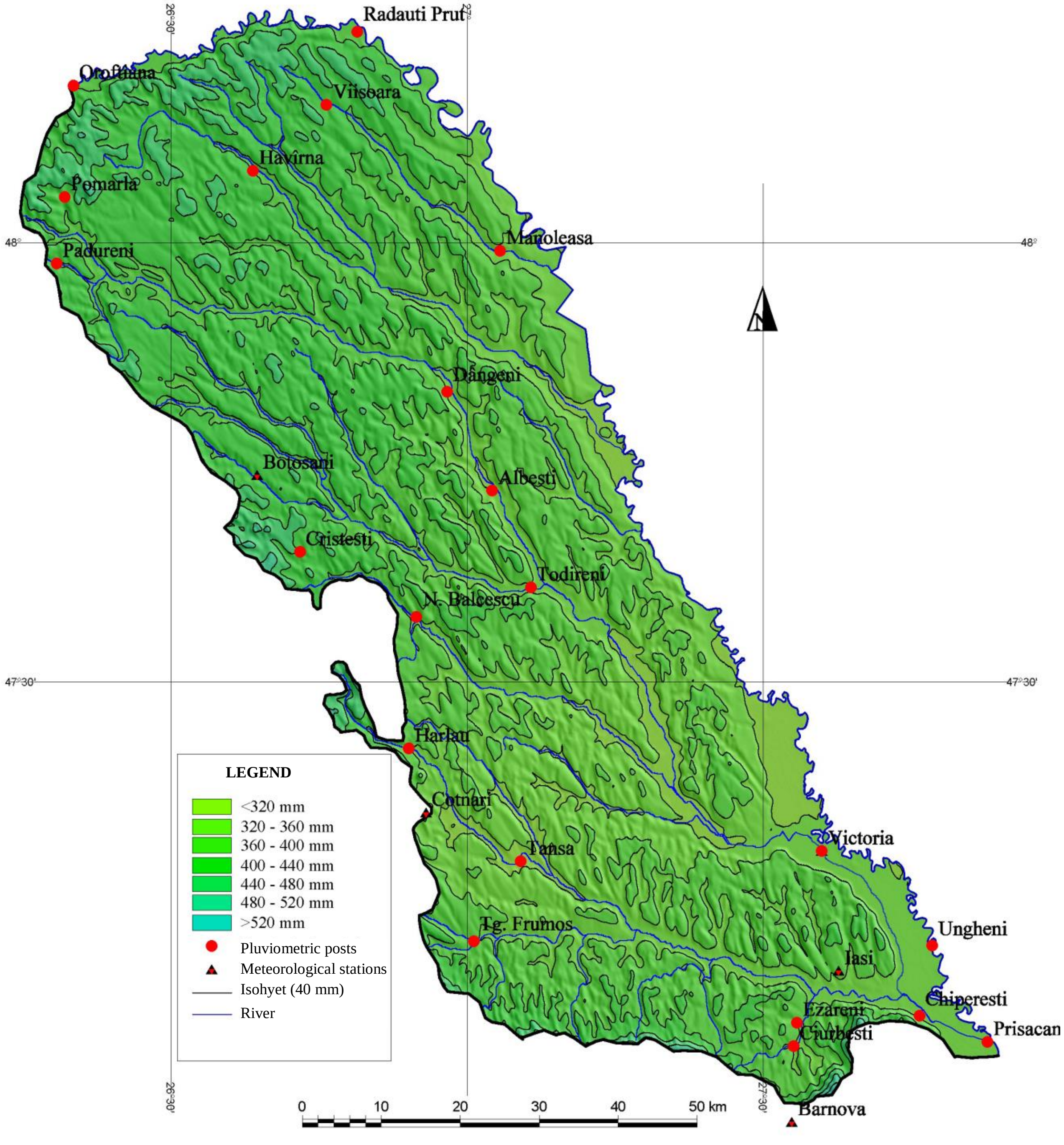


Fig. 5.6 Spatial distribution of multi-annual precipitation quantities in the estival season for the 1981-2011 interval in the Moldavian Plain

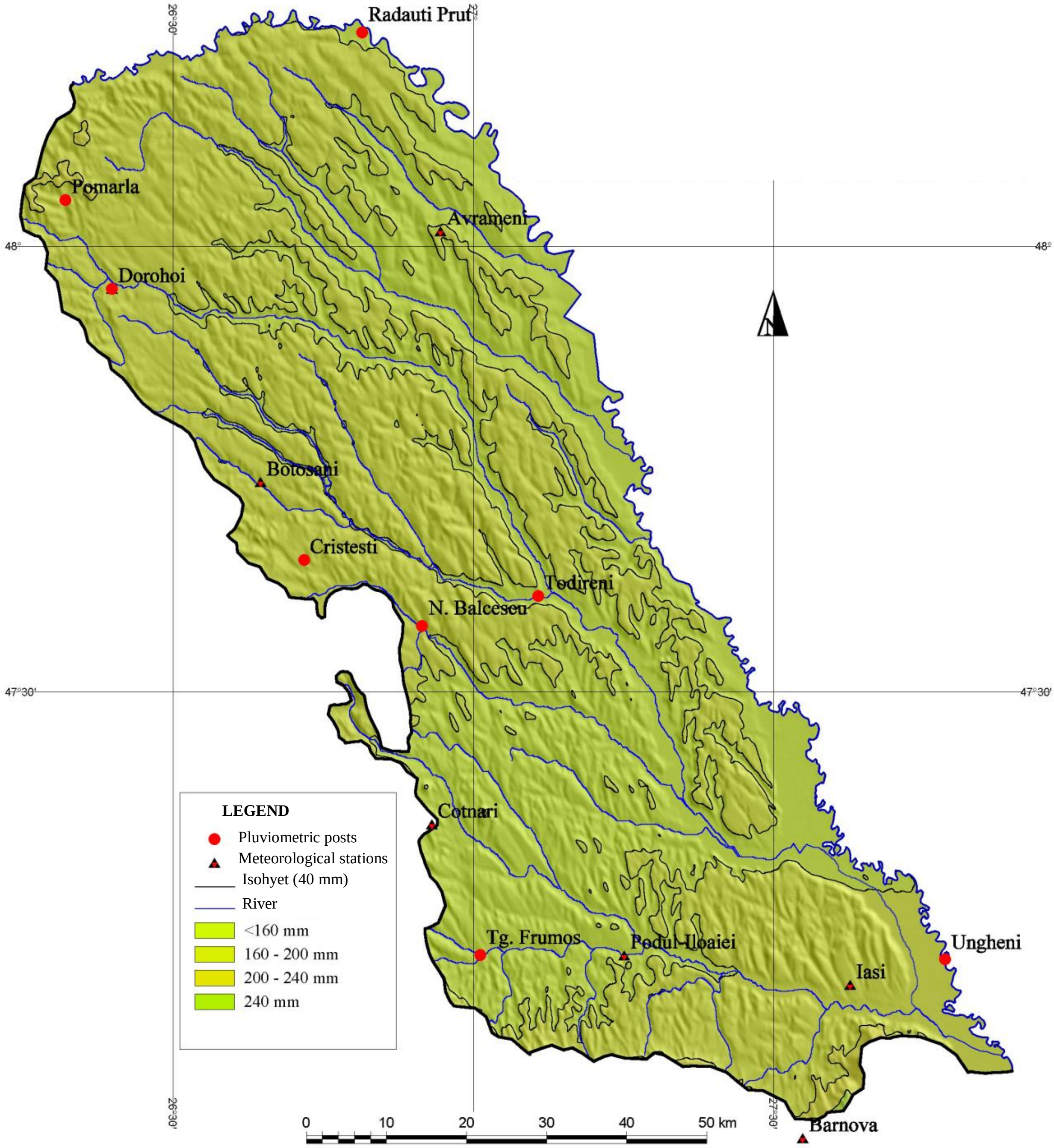


Fig. 5.7 Spatial distribution of multi-annual precipitation quantities in the winter season in the 1961-1991 interval for the Moldavian Plain

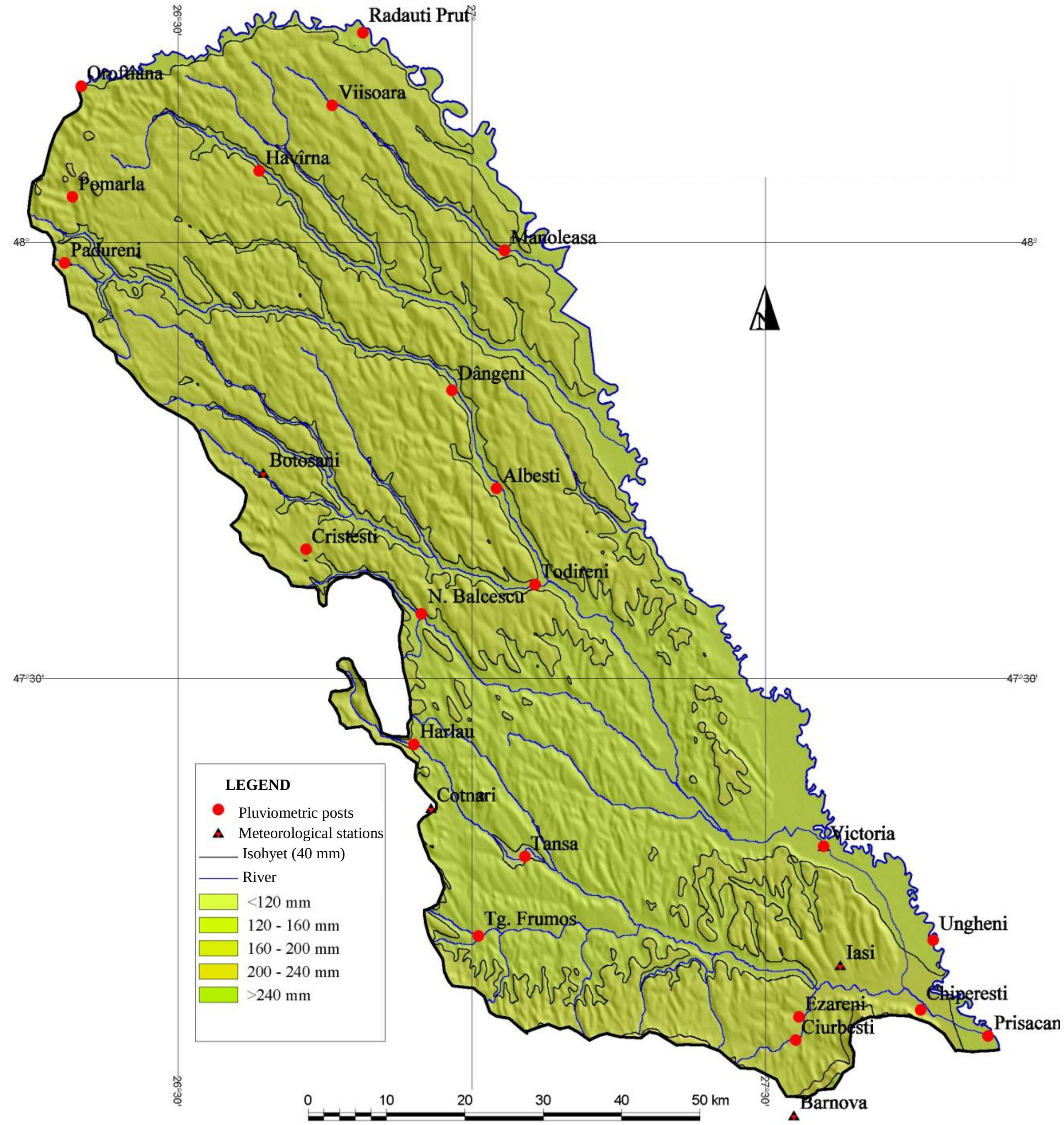


Fig. 5.8 Spatial distribution of multi-annual precipitation quantities in the winter season in the 1981-2011 interval for the Moldavian Plain

5.2.3. Spatial distribution of the seasonal precipitation quantities

The direction and intensity modifications of the annual atmospheric dynamics, display an approximately repetition in-between the years and induce a relative monotony and a characteristic predictable deployment of the precipitations in-between seasons. Yet, the local factors with multiple spatial combinations together with the solar radiation values result in important modifications of the manner, quantities, duration, frequencies and intensities of the precipitations, on short time intervals and small surfaces. In consequence the seasonal precipitations rarely take the same characteristics and quantities from one year to another (Mihăilă, 2006).

Relatively constant, the summer is the seasons of the greatest precipitations quantities (42%), followed by spring (25%), autumn (20%), while in winter there the lowest precipitation quantities (13%). Approximately the same temporal distribution is to be found for the absolute values of the seasonal sums of precipitations at each meteorological station and pluviometric post (Fig. 5.9).

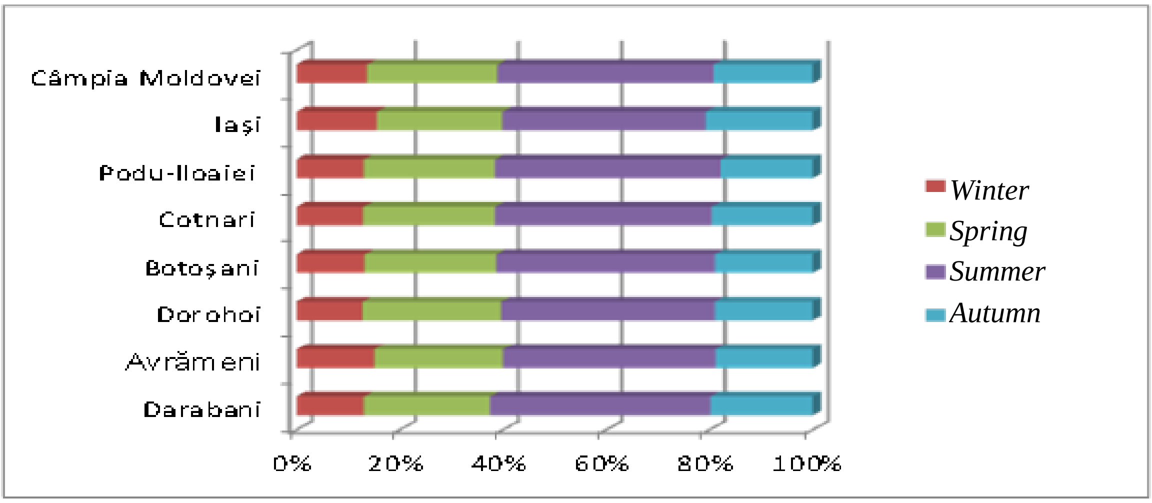


Fig. 5.9 Distribution of seasonal precipitation quantities in the Moldavian Plain

The spatial repartition of the precipitations quantities at seasonal level emphasizes three areas of higher quantities values (the north and north-west, the central and central-western part, plus the southern part) and two geographic zones of deficient precipitations (one in the north and one in the south) (Fig. 5.10 - 5.17).

For the precipitations recorded at the meteorological stations of the Moldavian Plain we calculated the Musset - Gaussen (IM-G) index given by the order of the four seasons initials as a decreasing trend of the precipitation quantities. For the analyzed IM-G index interval the formula is rendered by S.S.A.W which confirms that the more abundant precipitations are in summer and the less abundant precipitations are in winter.

In the middle Bahlui river and the lower Bahlueţ – Sheep Valley, during spring (Fig. 5.23) we have a lower precipitation area as an effect of foehnization of the air to descent from NW to SW and S. In this area there is also a *precipitation shadow* phenomenon, as the one in the Transilvania Plateau, yet to a more reduce scale (Pantazică, 1974).

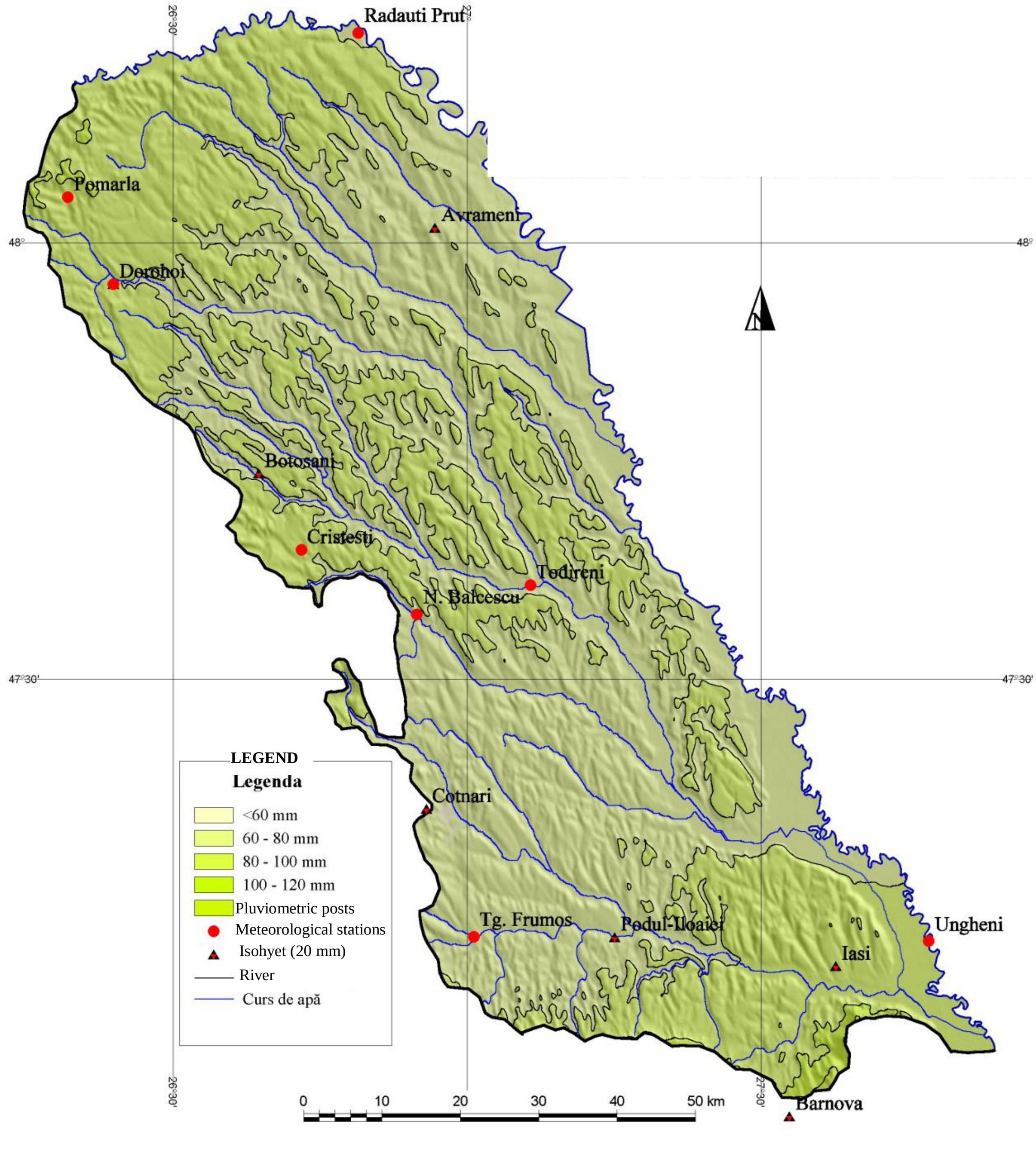


Fig. 5.10 Spatial distribution of multi-annual precipitation quantities in the winter season in the 1961-1991 interval for the Moldavian Plain

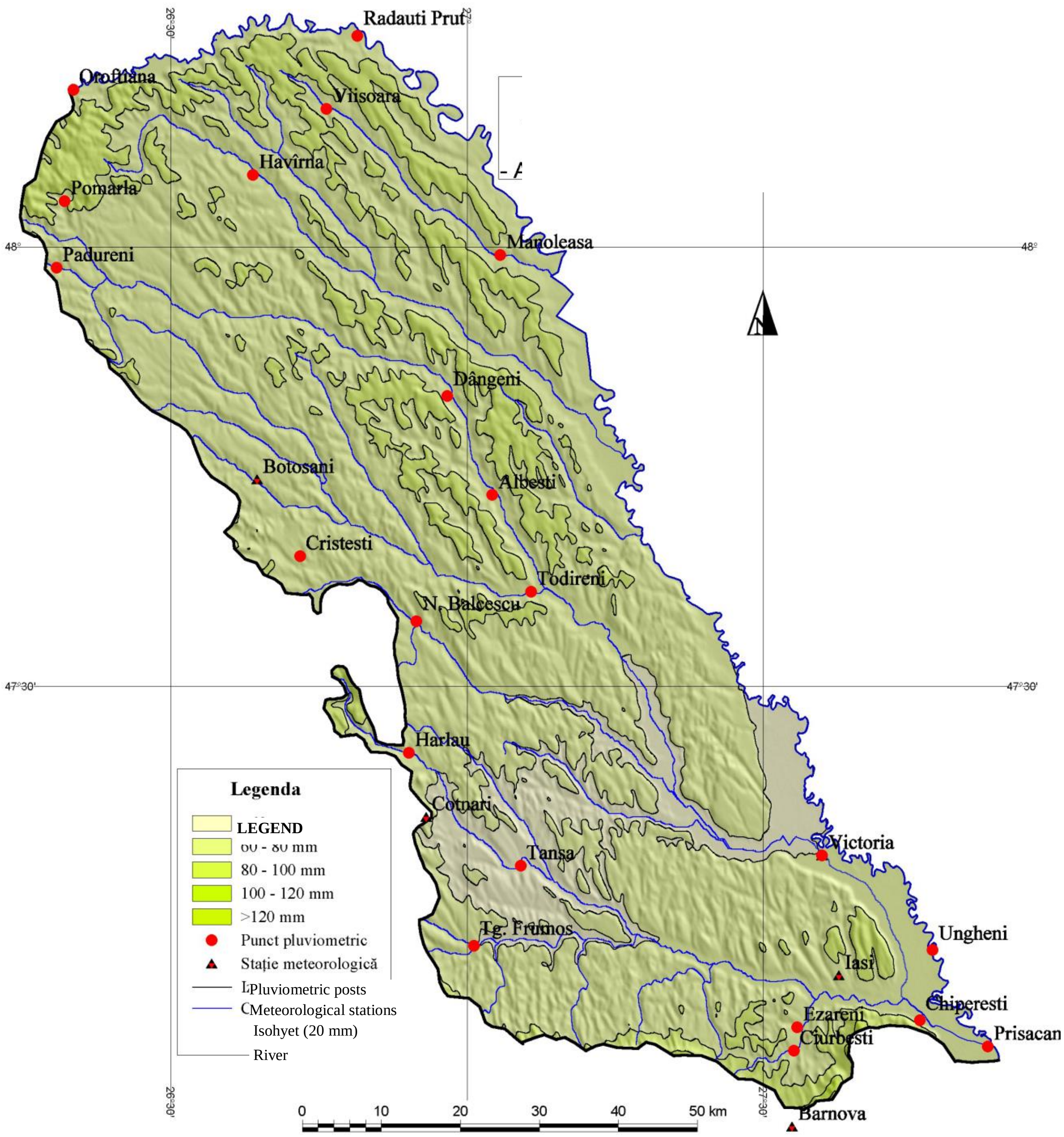


Fig. 5.11 Spatial distribution of multi-annual precipitation quantities in the winter season in the 1981 – 2011 interval for the Moldavian Plain

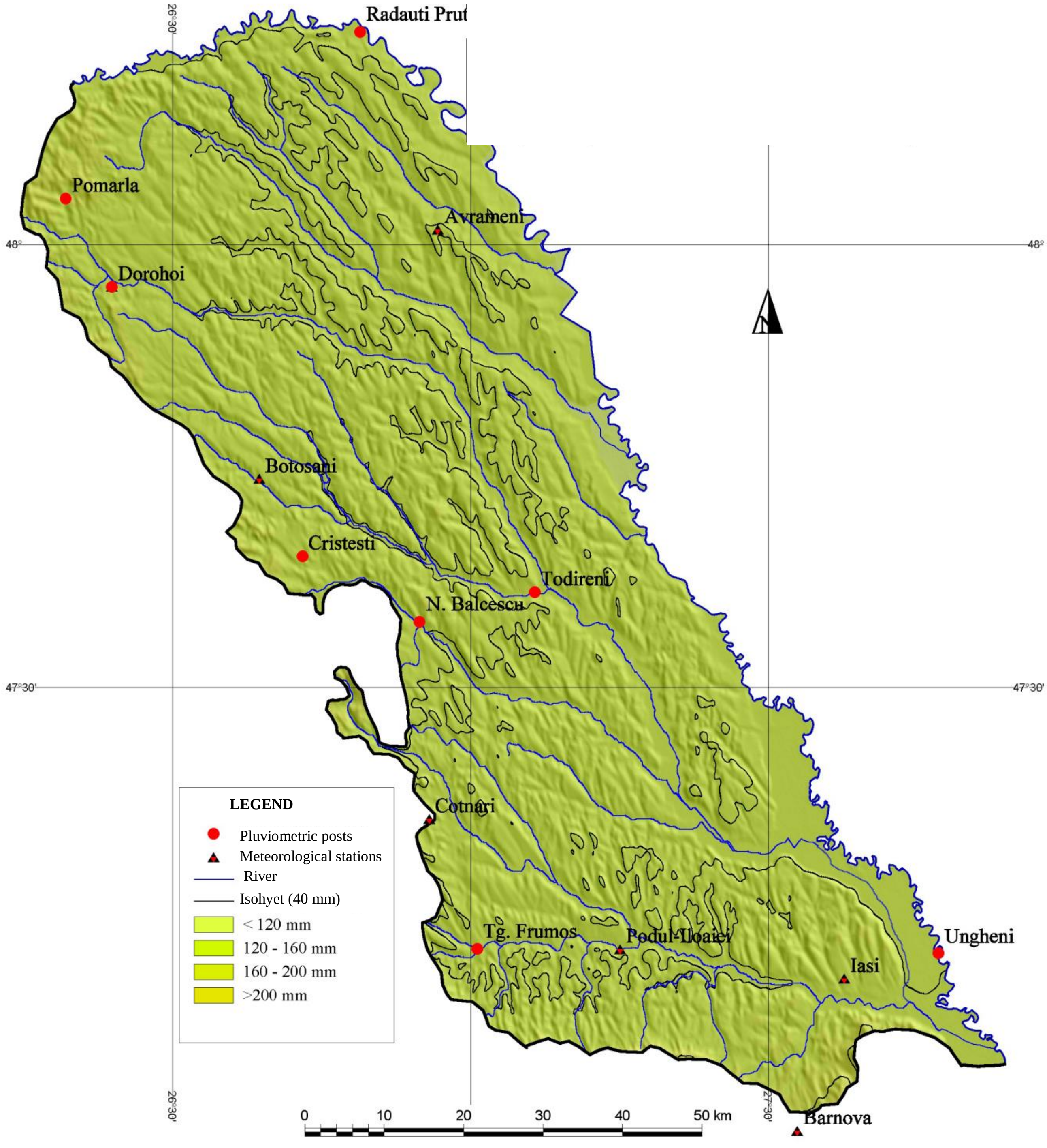


Fig. 5.12 Spatial distribution of multi-annual precipitation quantities in the spring season in the 1961-1991 interval for the Moldavian Plain

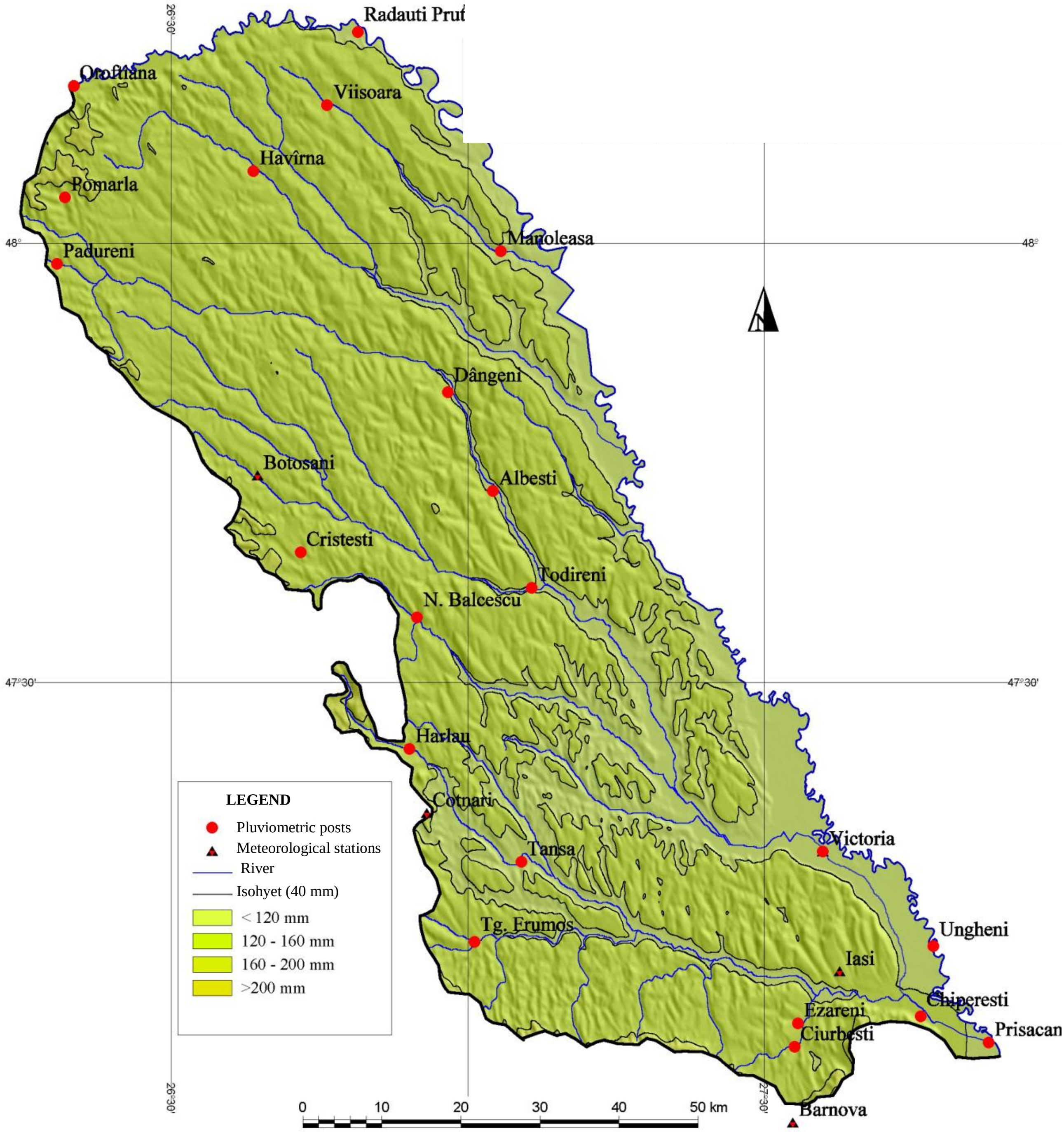


Fig. 5.13 Spatial distribution of multi-annual precipitation quantities in the spring season in the 1981 – 2011interval for the Moldavian Plain

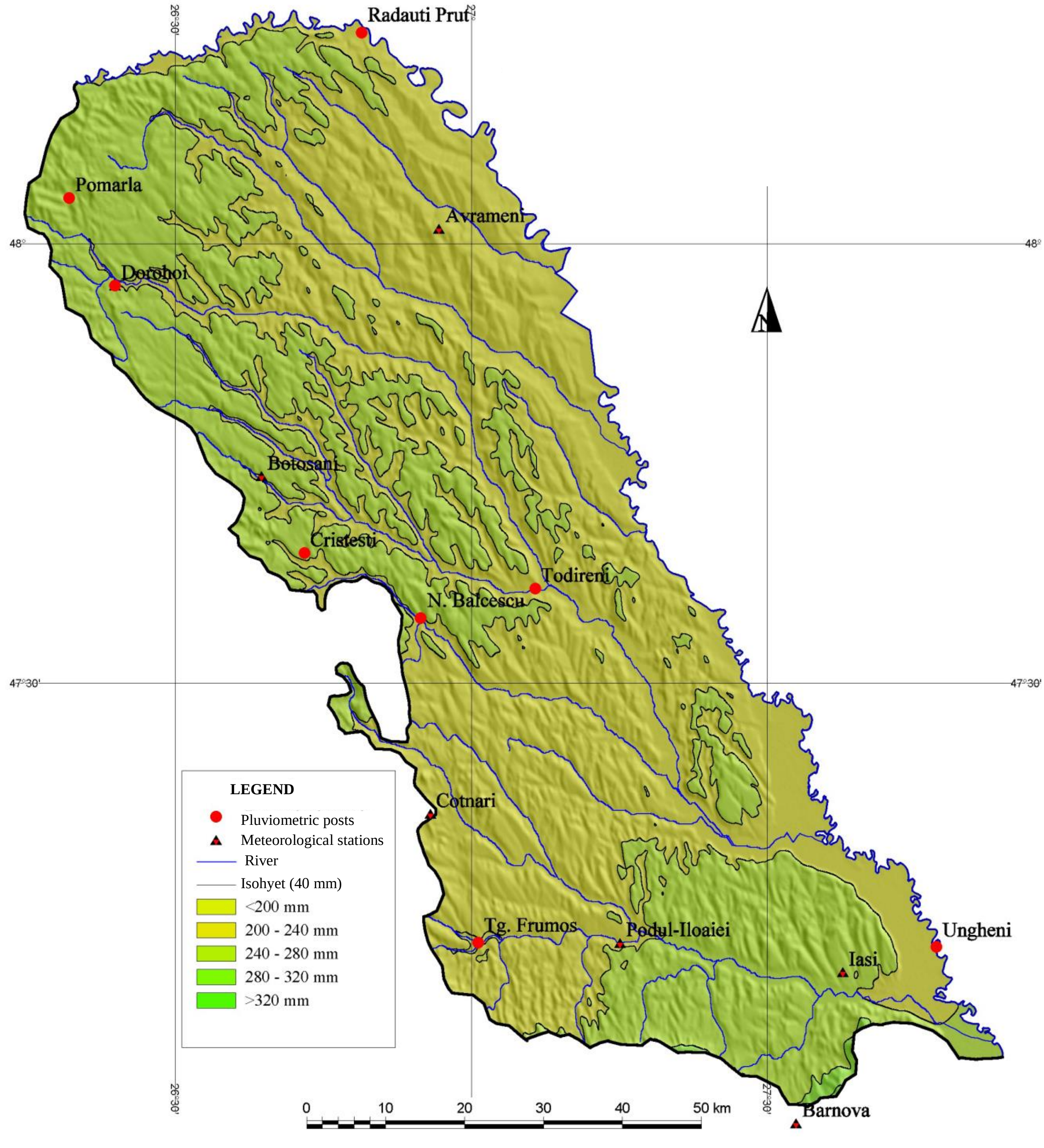


Fig. 5.14 Spatial distribution of multi-annual precipitation quantities in the summer season in the 1961 – 1991interval for the Moldavian Plain

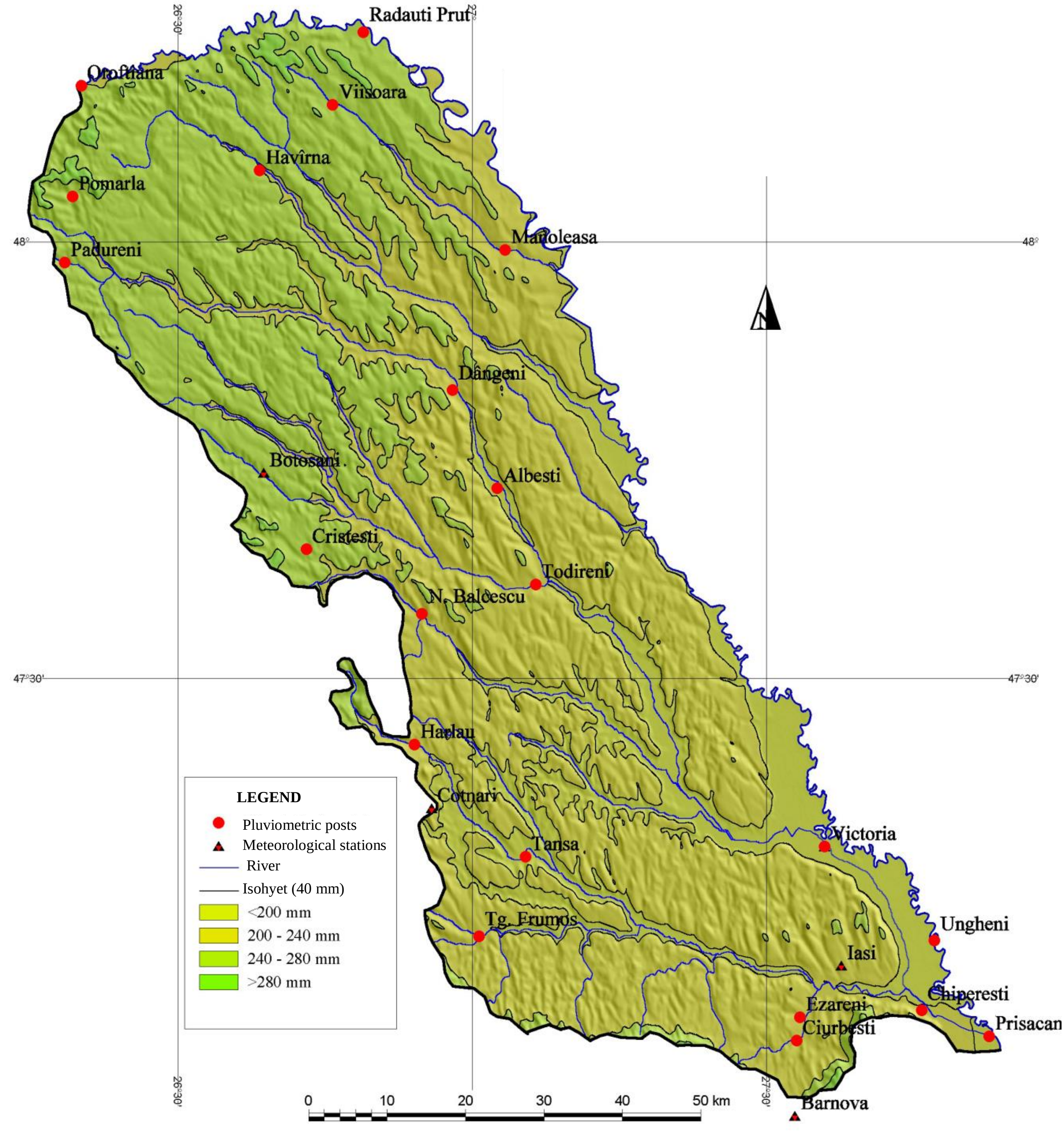


Fig. 5.15 Spatial distribution of multi-annual precipitation quantities in the summer season in the 1981 – 2011interval for the Moldavian Plain

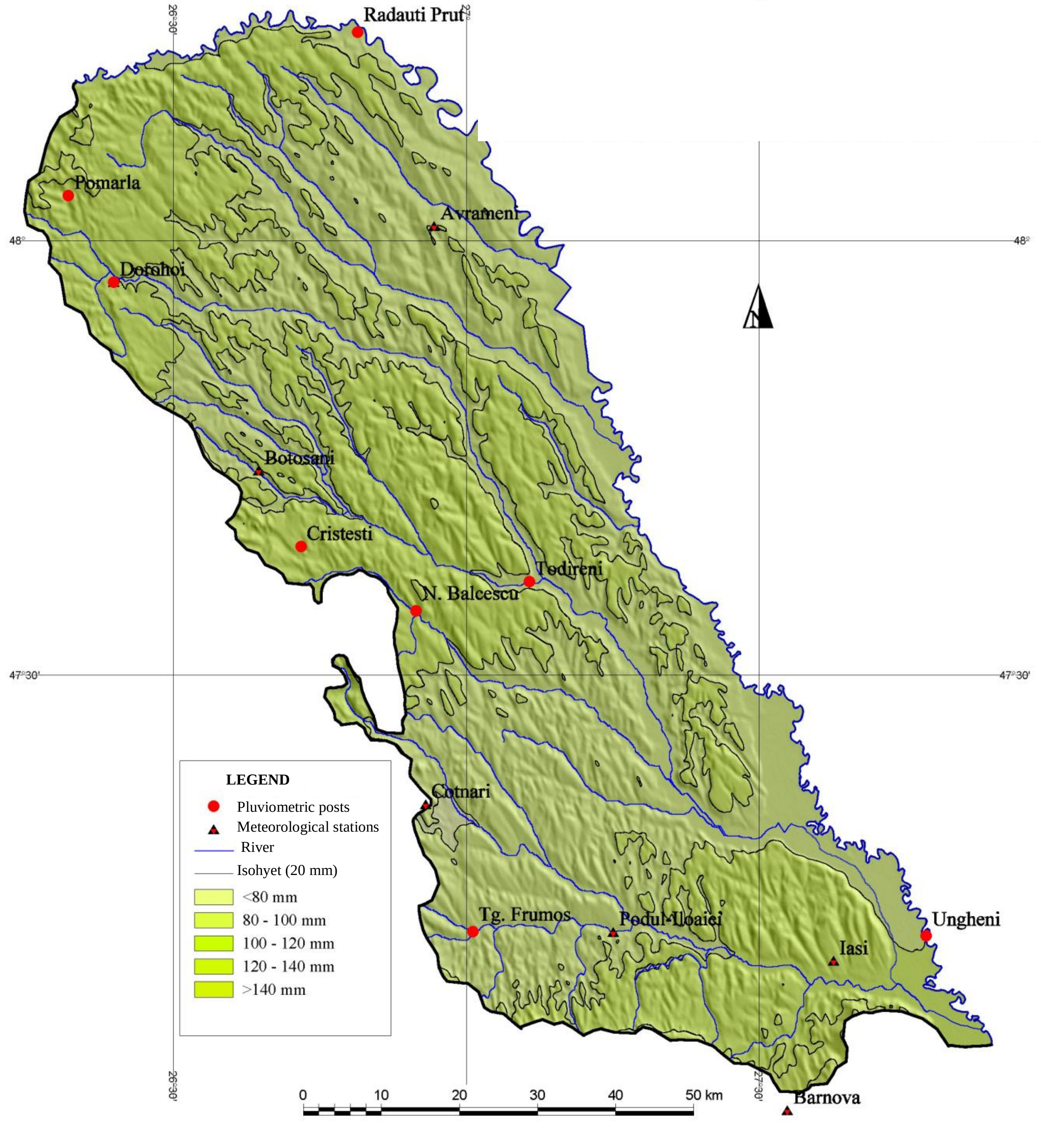


Fig. 5.16 Spatial distribution of multi-annual precipitation quantities in the autumn season in the 1961 – 1991interval for the Moldavian Plain

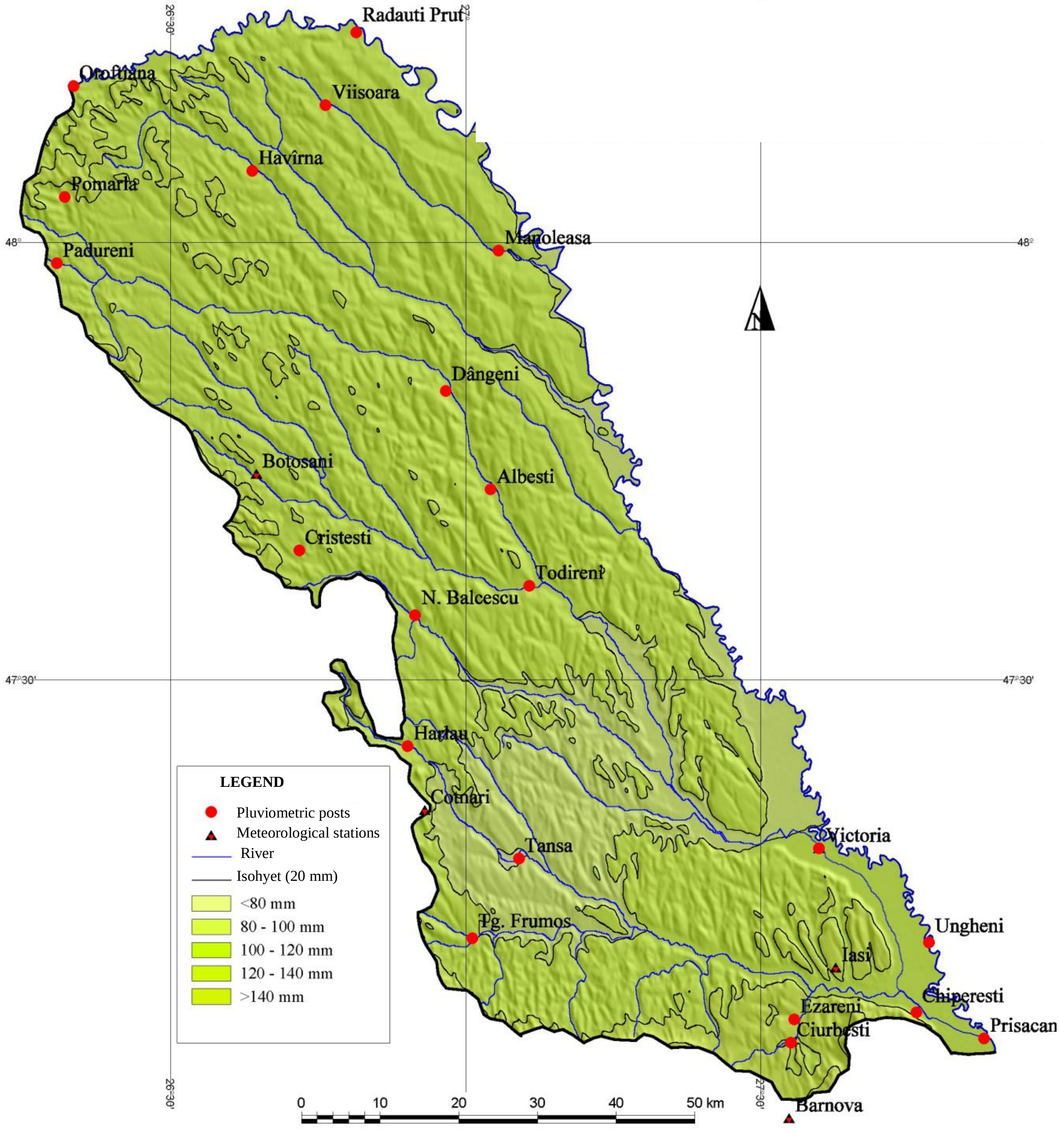


Fig. 5.17 Spatial distribution of multi-annual precipitation quantities in the autumn season in the 1991 – 2011interval for the Moldavian Plain

5.2.4. Spatial distribution of the monthly precipitations quantities

The monthly succession over the year present different values of precipitation quantities, resembling the specific season they traverse, but also depending on the frequency and intensity of air masses ascent with humid or dry character. Moreover, the distribution analysis on the watershed surface, on each month, shows that the values dispersion is tightly bound to the local factors, especially the relief, even if, in some situations the morphology is not very fragmented and spectacular. This explains that even in short distances the pluviometric posts and meteorological stations record various monthly precipitations sums.

Along the year the average annual precipitations record an increase from March to June and a decrease until February. For the whole region, the most abundant precipitations take place in the warm semester with a maximum in June, in 19 cases (59,3%) and July, only 13 cases (41,7%).

In the cold season, more evident to the western part of the region, we note a second a pluviometric maximum in the December-January interval. This second maximum with values below the annual average is determined by the spontaneous entrance of the humid Atlantic air masses to the north of the Moldavian Plateau. The increase of the precipitation quantities during winter is better observed in Tudora, Cristeşti and less obvious at Dorohoi, Botoşani and Iaşi.

The pluviometric minimum, for the whole region, is recorded in the second half of the winter, more frequently in February, with 23 cases (71,8%) and January with 9 cases (29,2%).

The percentage differences of the average monthly, consecutive precipitations indicate the fact that, the most significant average increase of the monthly sums along the year is recorded between May and June, while the decrease is between August and July. The continental character of the Moldavian Plain climate is very well emphasized by the temporal distribution of the annual maximum values in the June-July interval when the humid air invasions from Atlantic are most frequent and the thermo-connective rains increase the moisture input.

Analyzing the temporal distribution of the yearly precipitations evolution as monthly quantitative sums for the rainiest years we draw the following detailed conclusions regarding the precipitations' annual regime. In the case of the rainiest years the monthly pluviometric maximums appeared, more frequent, in July, 22%, and September, 22%, while in June (the rainiest month) we only register 19% of the cases. According to this argument we can conclude that, statistically, the greatest risk of floods occurance is in July and September, followed by June, August and May.

5.2.5. The non-perodic variations of the annual precipitations quantities

The average monthly, seasonal, semestral and annual sums of precipitations resulted after the processing long series of data, registered with dedicated instruments enhance synthetic and global assessments, yet they do not indicate the climatic element variability which, in the context of the transitional temperate-continental climate can reach maximum and minimum records very distant to the average values.

It is very rarely that the monthly and annual precipitations quantities, registered in the system are identical or close to the average values; in general, they go above or below these averages. The overplus and the deficit are due to the atmospheric circulations characteristics where an array of variables adds to the process, especially the evolution of temperatures in time and space and the natural environment with the complex combination of its elements which trigger different manifestations in distinct places and at distinct moments.

From one year to another, the precipitations to fall in the narrow Moldavian Plain, display wide variation between the limits. The variability of the annual quantities and the deviations from the median values is rendered below fig. 5.18.

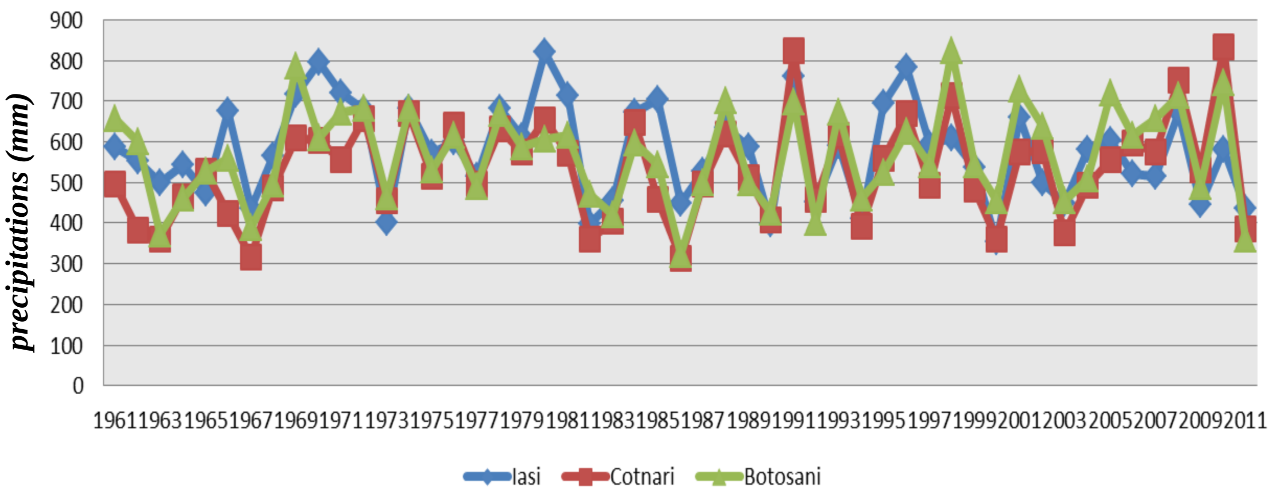
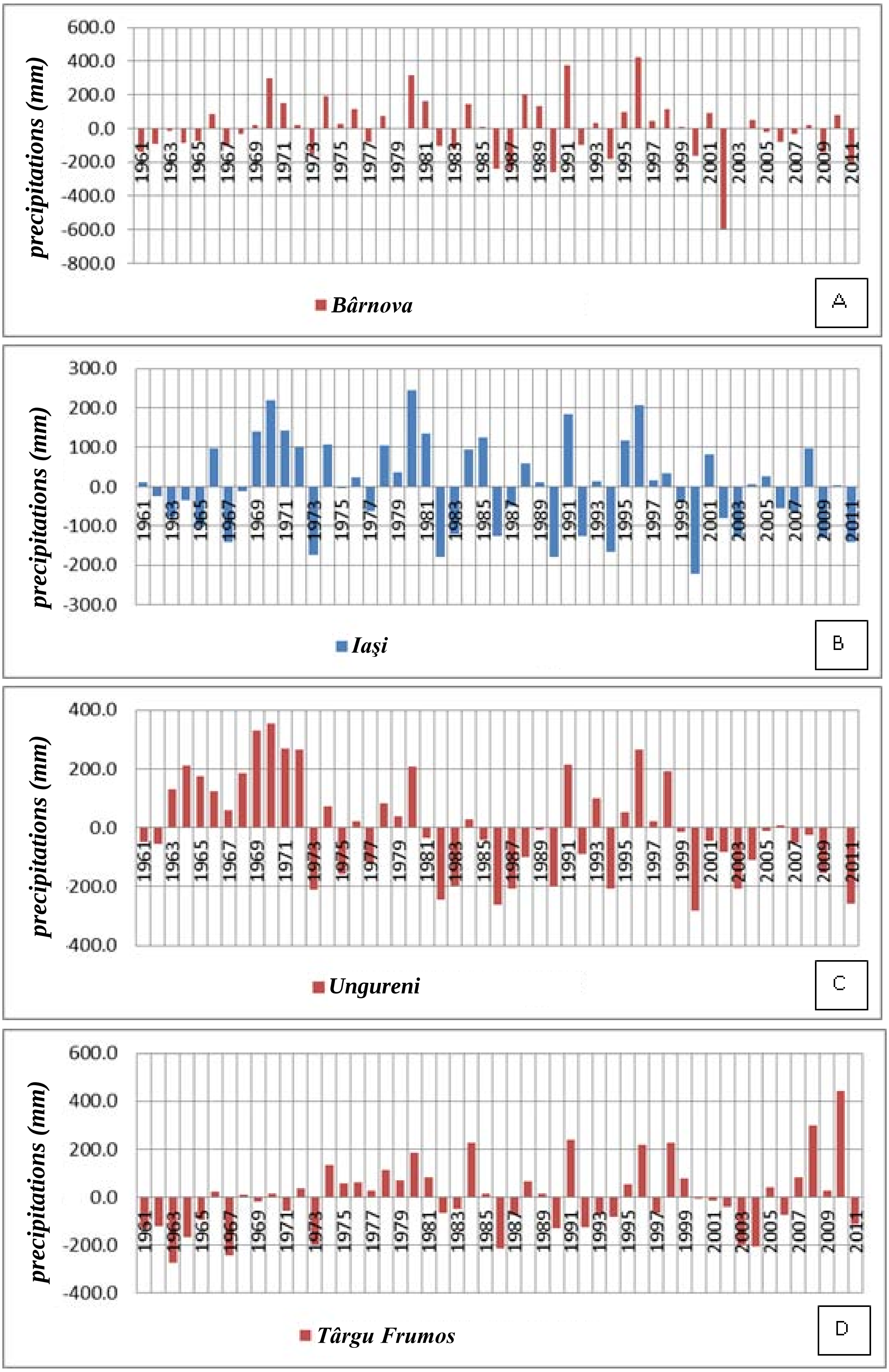
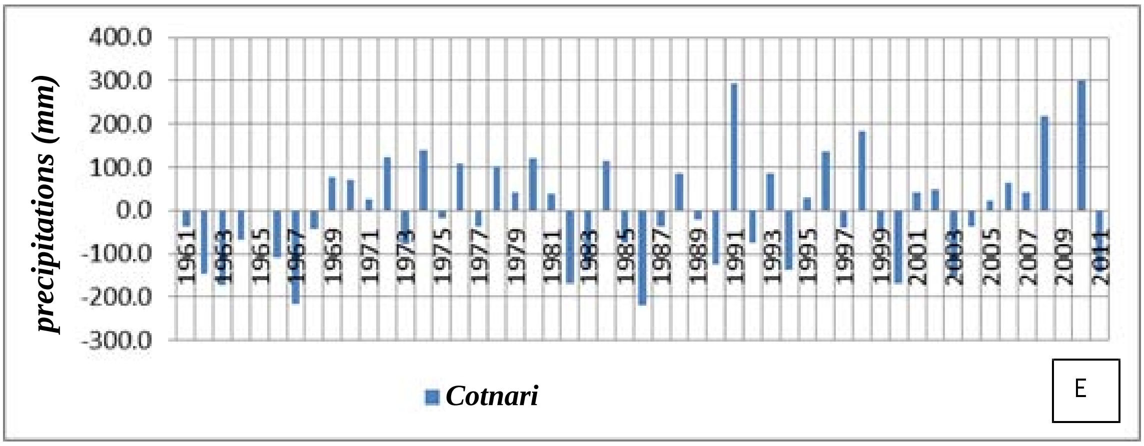
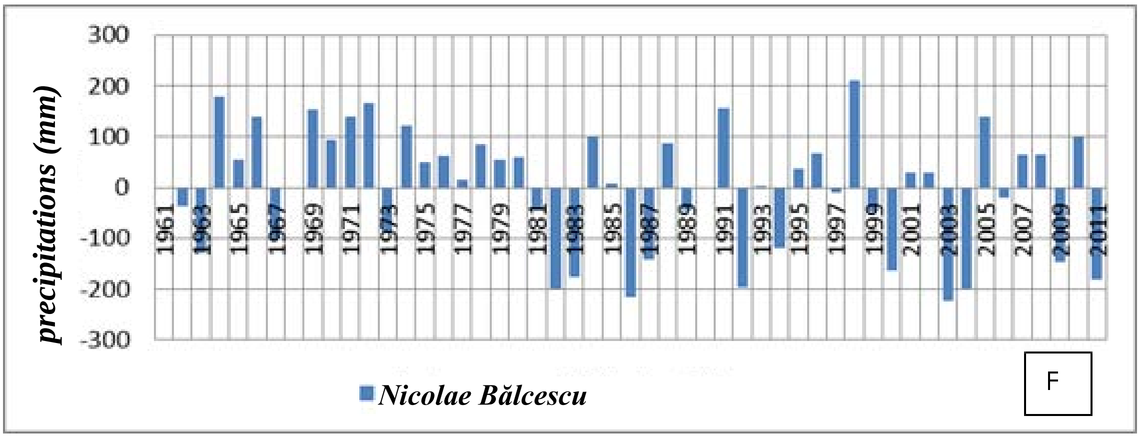


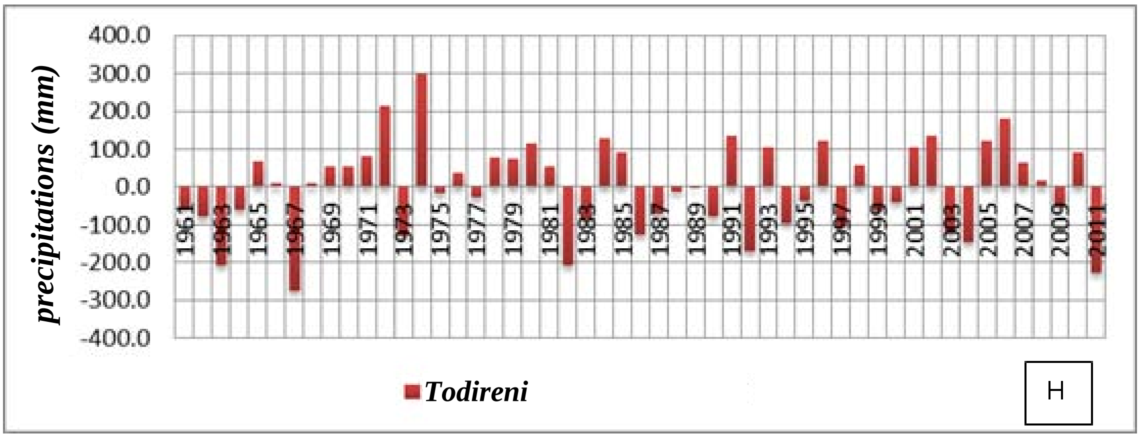
Fig. 5.18 The Moldavian Plain – Variation of the annual precipitations quantities in the 1961-2011 at Iaşi, Cotnari and Botoşani stations

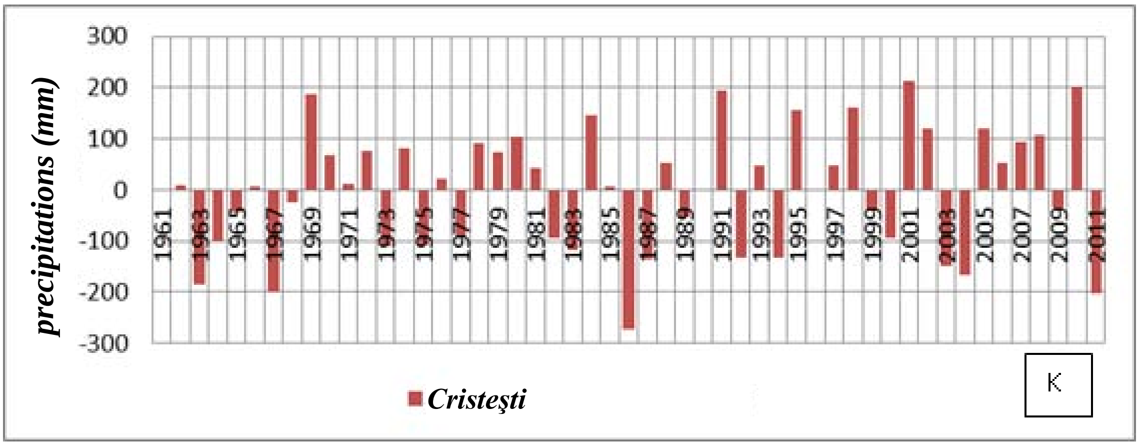
The analysis of the graphic representations on the basis of the observations performed in the last 50 years (with only minor discontinuities), at 11 meteorological stations and pluviometric posts (fig. 5.19) reveals a synonymous evolution of the annual precipitations sums. The precipitations increases or decreases appear, most of the times, in a simultaneous manner in different portions of the Moldavian Plain, at significant distances and in different geographic conditions, in local context, compared to the overall similar (assembly) conditions of the Moldavian Plain. The quantitative and qualitative parameters of the natural environment suffer low amplitutde modifications which do not explain the high amplitude modifications of the quantitative precipitations on wider spaces (Mihailă, 2006).


precipitations (mm)
Bârnova
A
precipitations (mm)
Iaşi
B
precipitations (mm)
Ungureni
C
precipitations (mm)
Târgu Frumos
D


precipitations (mm)
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Cotnari
E


precipitations (mm)
300
200
100
0
-100
-200
-300
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Nicolae Bălcescu
F


precipitations (mm)
400.0
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
-400.0
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Todireni
H


precipitations (mm)
300
200
100
0
-100
-200
-300
1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
Cristeşti
K

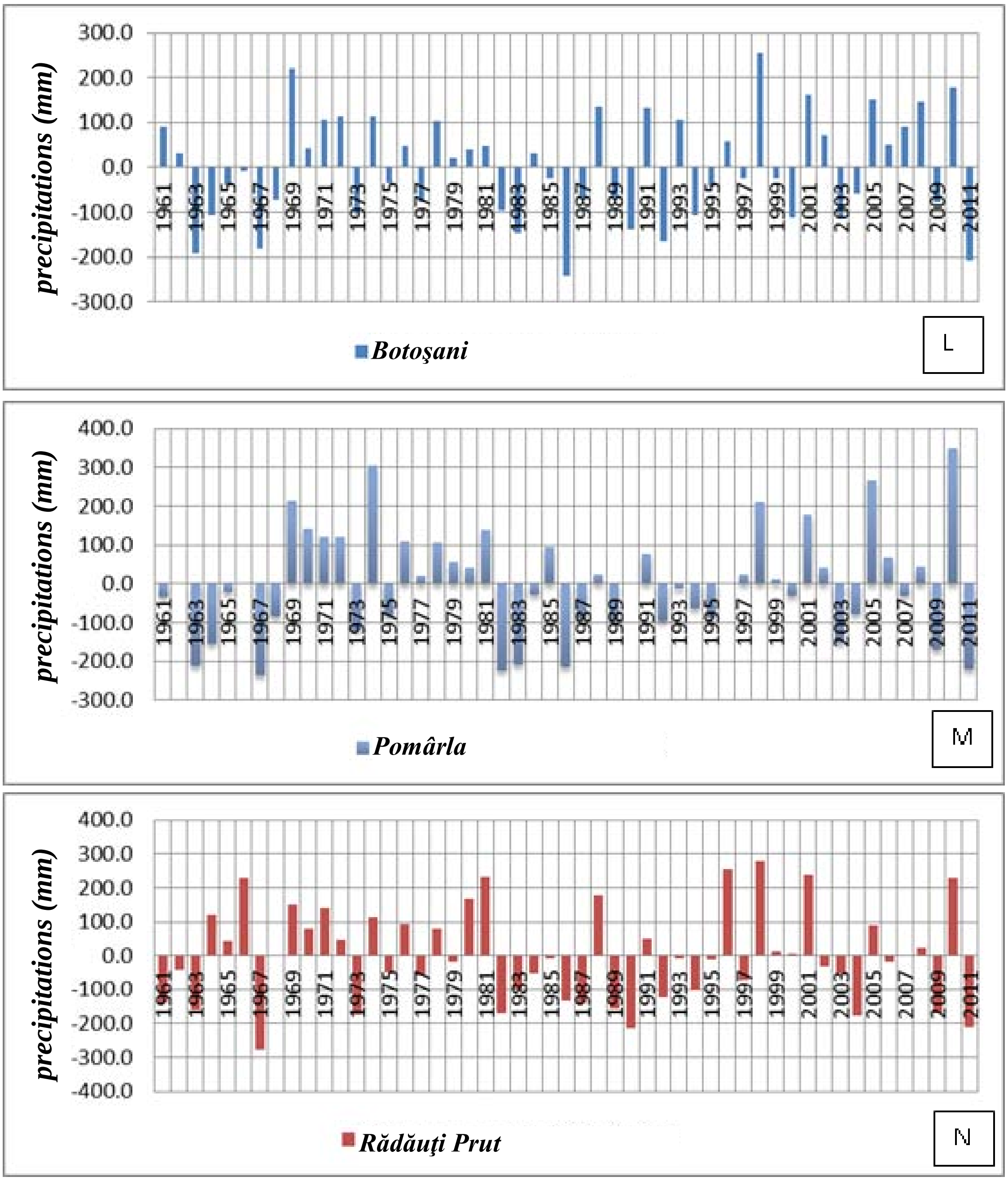


Fig. 5.19 A-N The Moldavian Plain – Deviations from the average multi-annual precipitations quantities in the 1961-2011 interval

The analysis of the graphic representations on the basis of the observations performed in the last 50 years (with only minor discontinuities), at 11 meteorological stations and pluviometric posts (fig. 5.19) reveals a synonymous evolution of the annual precipitations sums. The precipitations increases or decreases appear, most of the times, in a simultaneous manner in different portions of the Moldavian Plain, at significant distances and in different geographic conditions, in local context, compared to the overall similar (assembly) conditions of the Moldavian Plain. The quantitative and qualitative parameters of the natural environment suffer low amplitutde modifications which do not explain the high amplitude modifications of the quantitative precipitations on wider spaces (Mihailă, 2006).

The upward and downward sense of the pluviometric evolution on wide spaces, reported to the multi-annual average, which is considered normal, is imposed by the dynamics of the air masses while the absolute differences for close stations are only explained in the context of local factors influence (relative altitude, aspect, fragmentation and orientation of the relief, the characteristics of the active surface – water surfaces, humid terrain, pastures, arable land, forest, settlement etc.), factors able to amplify or reduce the ascent and thermo-connective processes.

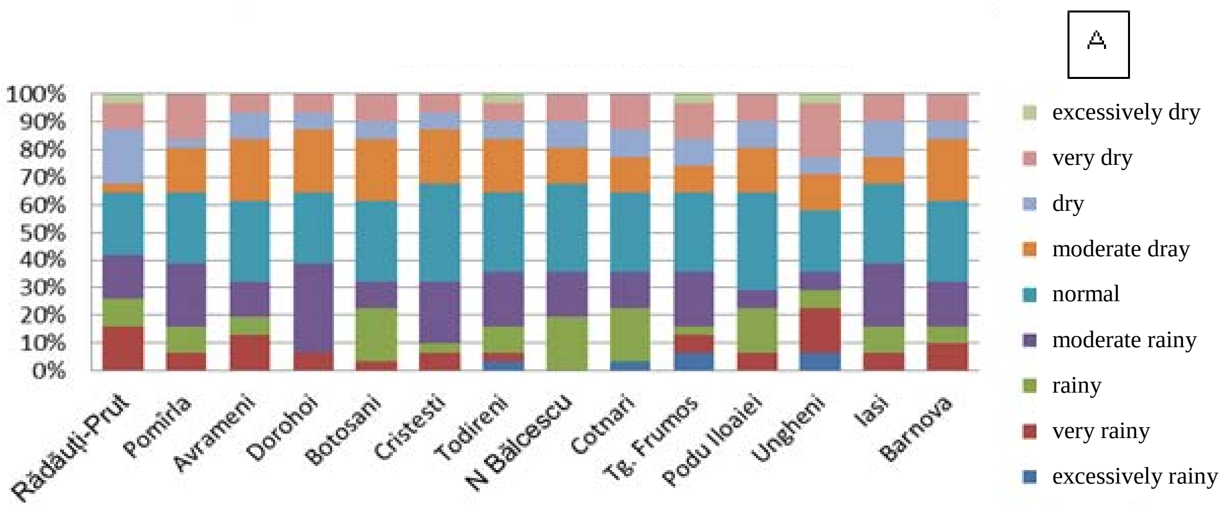
The evolution tendencies on long term, 1961-2011, for atmospheric precipitations show that they are in slight decline for the northern and north-eastern parts of the Moldavian Plain and in a more emphasized increase in the southern and south-eastern parts (Mihăilă, 2006).

5.2.6. The non-periodic variations of the monthly precipitations quantities

In order to emphasize the non-periodic, monthly, seasonal and annual precipitations quantities it is necessary to calculate the deviation of the respective quantities from the multi-annual average, in certain limits and expressed as percentages. As in the case of air temperature, Hellman considers the interval's limits of the deviations as seasonal and annual sums, expressed as halt quantities compared to the monthly sums because their oscillation are lower then the monthly sums (Farcaş, 1988).

A more clear and realistic image on the monthly excesses and shortages for the analyzed period (1961 - 2011) is offered by the Hellman approach which renders the weather types on the basis of percentages monthly deviations from the multi-annual averages; this classifies the months in 9 categories from excessive to deficient concerning rain. In this way the classification of only two categories of months, as excessive and deficient is eliminated on the basis of positive and negative values reported to the average value.

As first instance, for a correct analysis and due to certain posts and stations dismantle since 1990 or setting of new post and stations (with large gap as 1961 reference) we analyzed the data on two common intervals of 30 years: 1961-1991 and 1981-2011 (fig. 5.20).



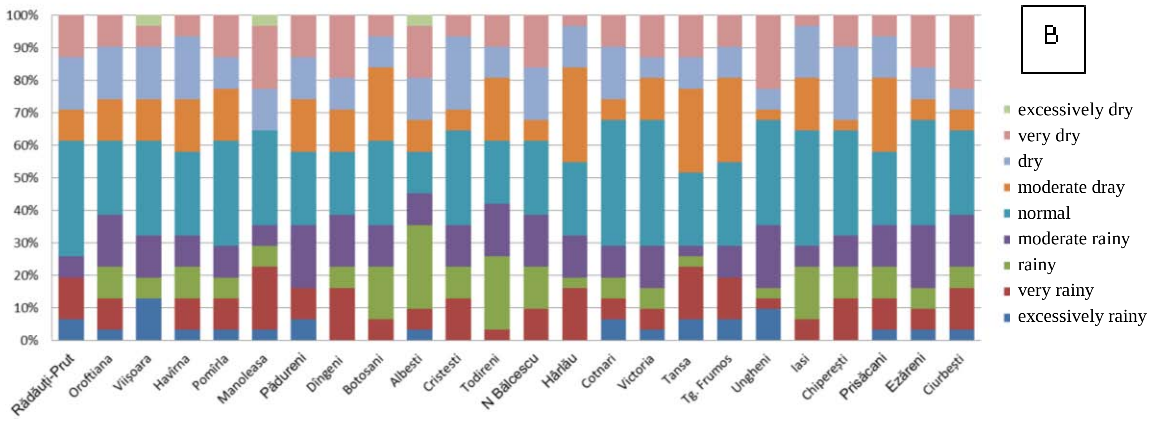


Fig. 5.20 The pluviometric characteristics based on the Hellman criterion in the Moldavian Plain for 1961-1991 (A) and 1981-2011 (B).

For a detailed analysis which also considers the local geographic factors, in the 1981-2011 interval the pluviometric posts were allocated to the subdivisions identified by V. Băcăuanu in the Moldavian Plain:

1. The Upper Jijia and Başeu Plain;
2. The Lower Jijia and Bahlui Plain
3. The Prut Meadow

In the Upper Jijia and Başeu Plain the years considered normal from the pluviometric view point hold the greatest percentage, oscillating between 35% at Rădăuţi-Prut and 24% at Albeşti. The most excessive years as far as rain quantities are concerned reached 6,5% at Rădăuţi-Prut and Pădureni posts and even 12% at Viişoara (fig. 5.21*).*

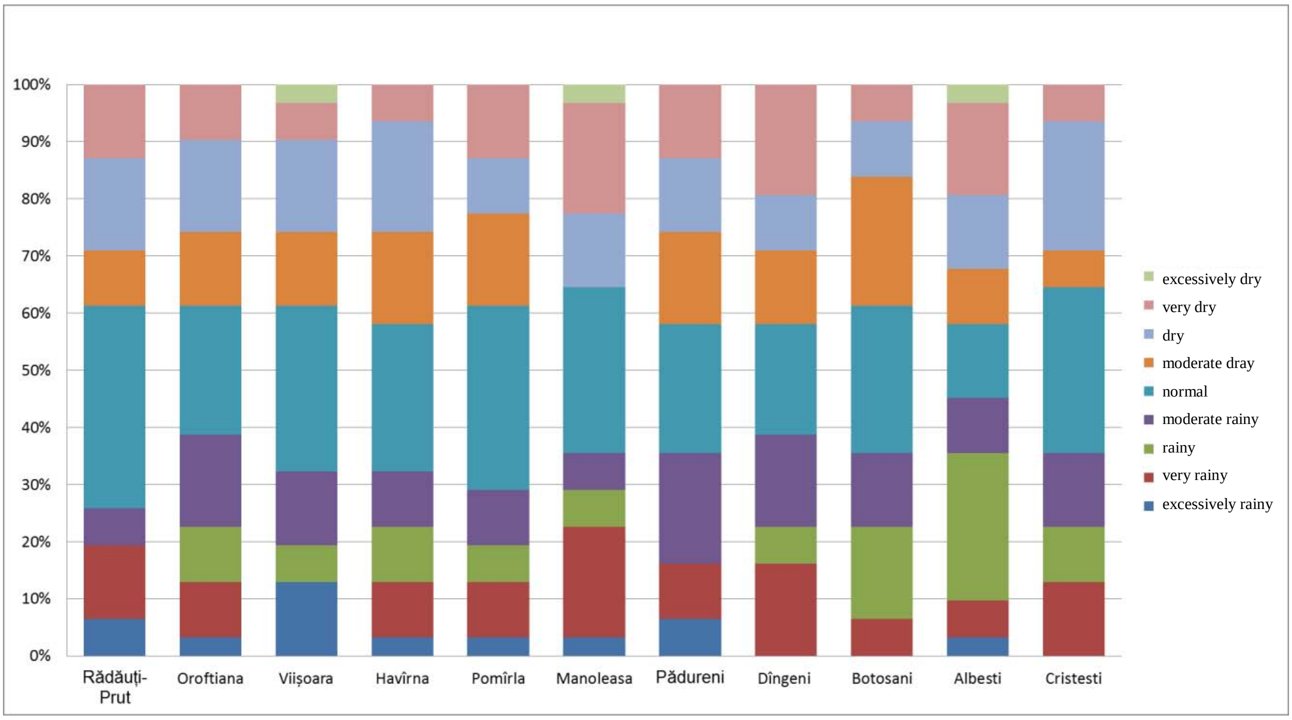
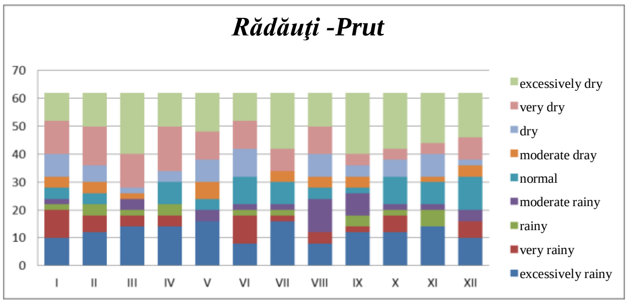
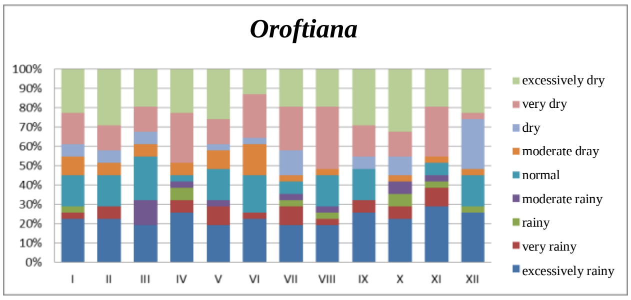
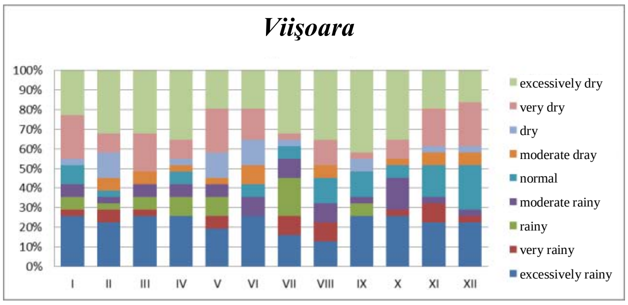


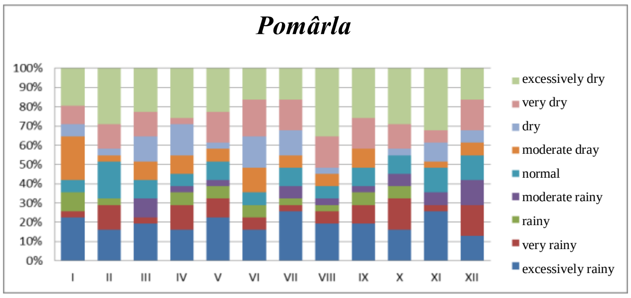
Fig. 5.21 The pluviometric characteristics based on the Hellman criterion for the Upper Jijia and Başeu Plain in the 1981-2011 interval

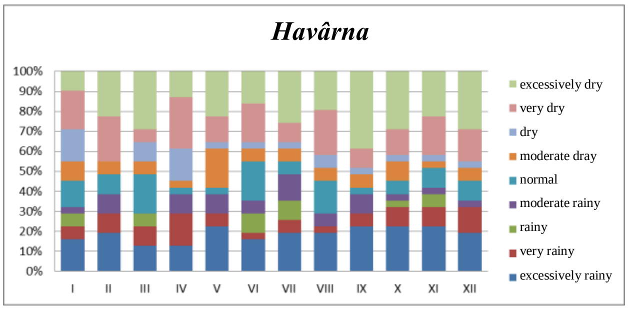
The months considered normal from the pluviometric view point hold an average of 11,6% where the frequence statistics set this months type on the fourth place reported to the other categories. The pluviometric deficitary months are the most representative, with 52,0% from the total and the pluviometric excess months hold 36,3% from the total (fig. 5.22).

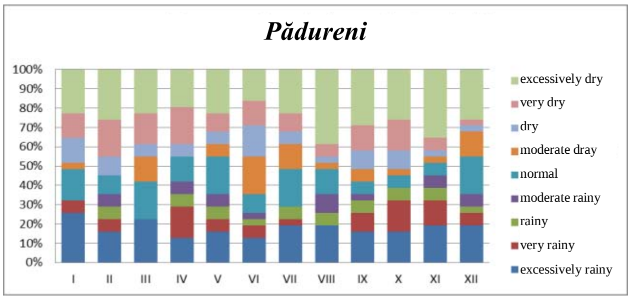


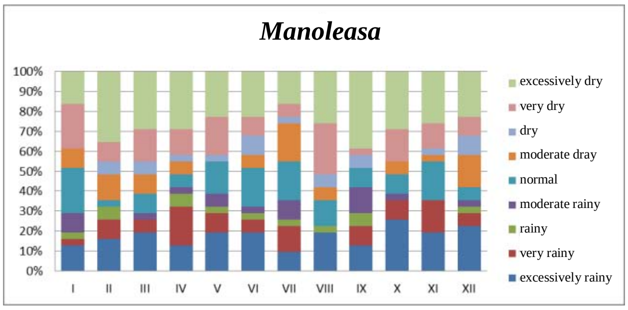


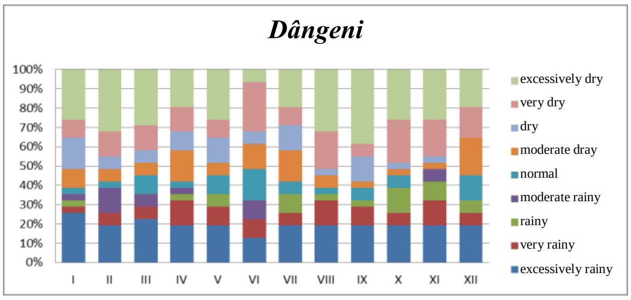


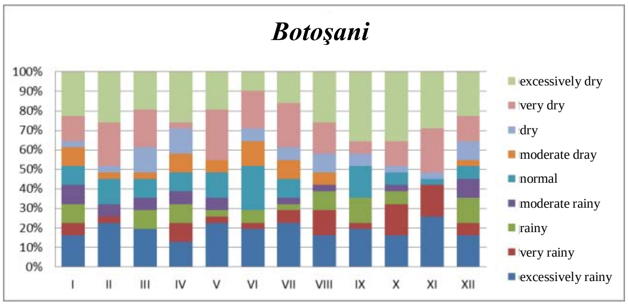


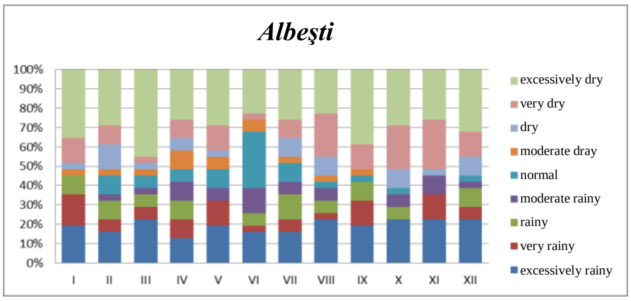












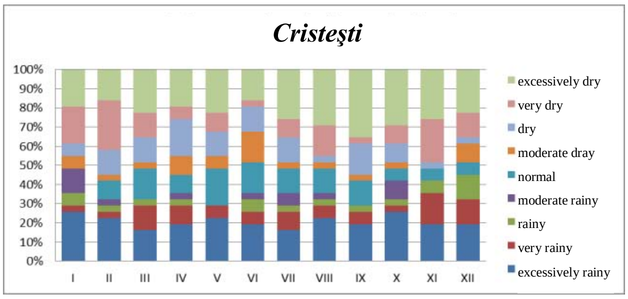


Fig. 5.22 The pluviometric characteristics based on the Hellman criterion for the Upper Jijia and Başeu Plain in the 1981-2011 interval

In the Lower Jijia and Bahlui Plain the eras considered normal have the greatest percentage at Cotnari, 38% (in the 1981-2011 interval) and the lowest percentage at Todireni, 17%. The pluviometric excess years (excessively rainy, very rainy or rainy) hold 22% at the Todireni and Tansa pluviometric posts (fig. 5.23).

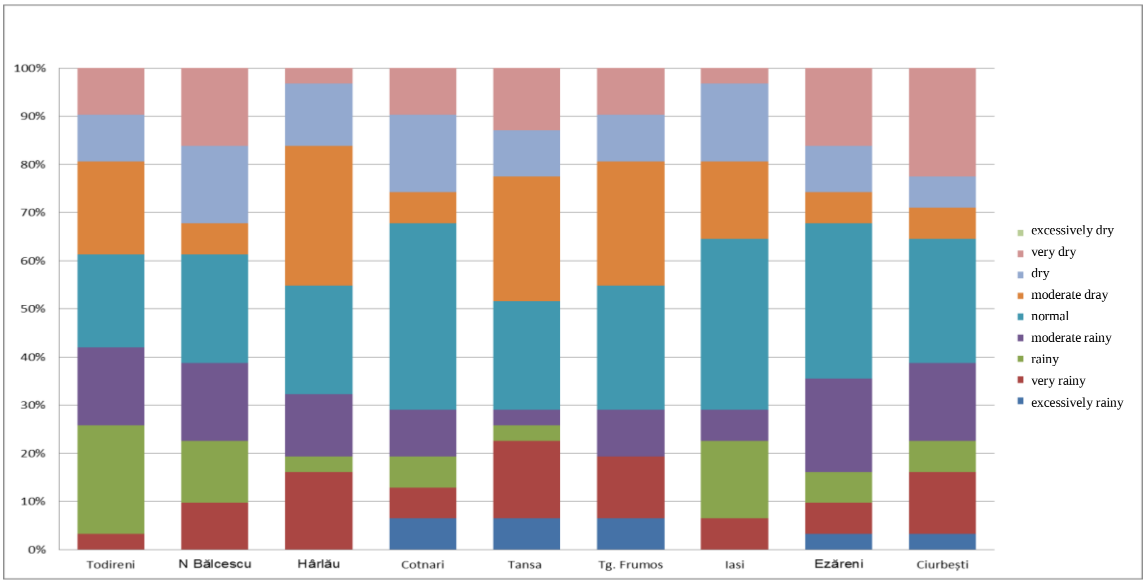
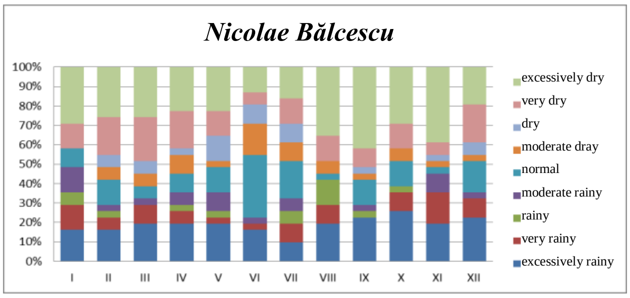


Fig. 5.23 The pluviometric characteristics based on the Hellman criterion for the Lower Jijia and Bahlui for the Moldavian Plain in the 1981-2011 interval

The normal considered months from the pluviometric view point hold 11, 7%. The graphic representation over the stations, posts and months distribution of the 9 weather types is rendered in figure 5.24. The high frequency of the excessive dry and excessive rainy months or the very dry and very rainy months draws the picture upon the typical excessive character in the evolution and the distribution of the overall climatic elements and phenomena.



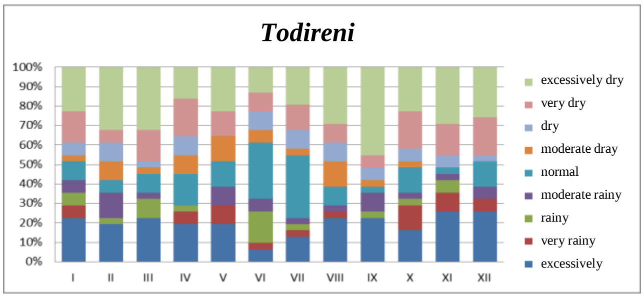


Fig. 5.24 The monthly pluviometric character on Hellman criterion for the Moldavian Plain in the Lower Jijia and Bahlui Plain between 1981 and 2011

In the Prut Meadow, the years considered normal from the pluviometric view point do not exceed 30%. The pluviometric excess years (excessively rainy, very rainy and rainy) oscillate between 35% at Ungheni and 26% at Victoria. The normal months from the pluviometric view point hold an average of 10,9% while the excess month appeared in 27,8% cases (fig. 5.25, 5.26).

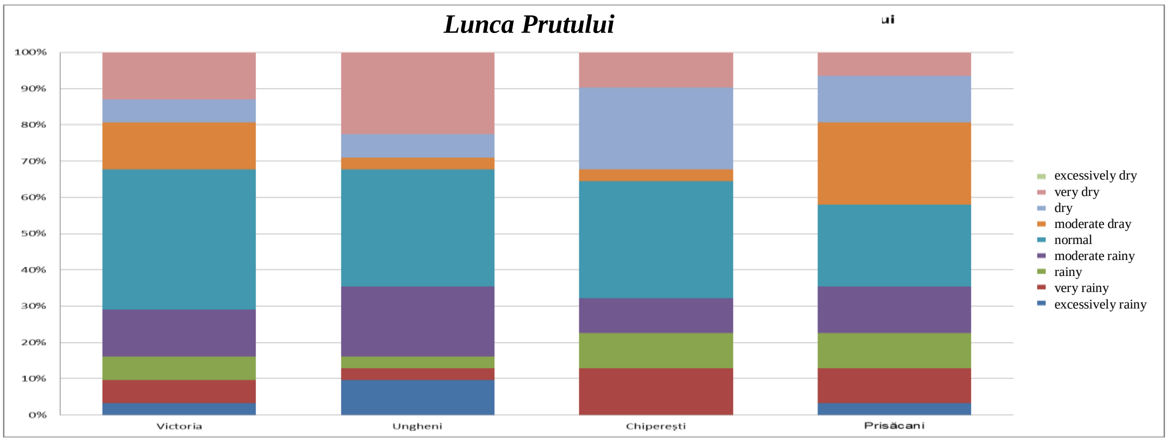


Fig. 5.25 The yearly pluviometric character on Hellman criterion for the Prut Meadow between 1981-2011

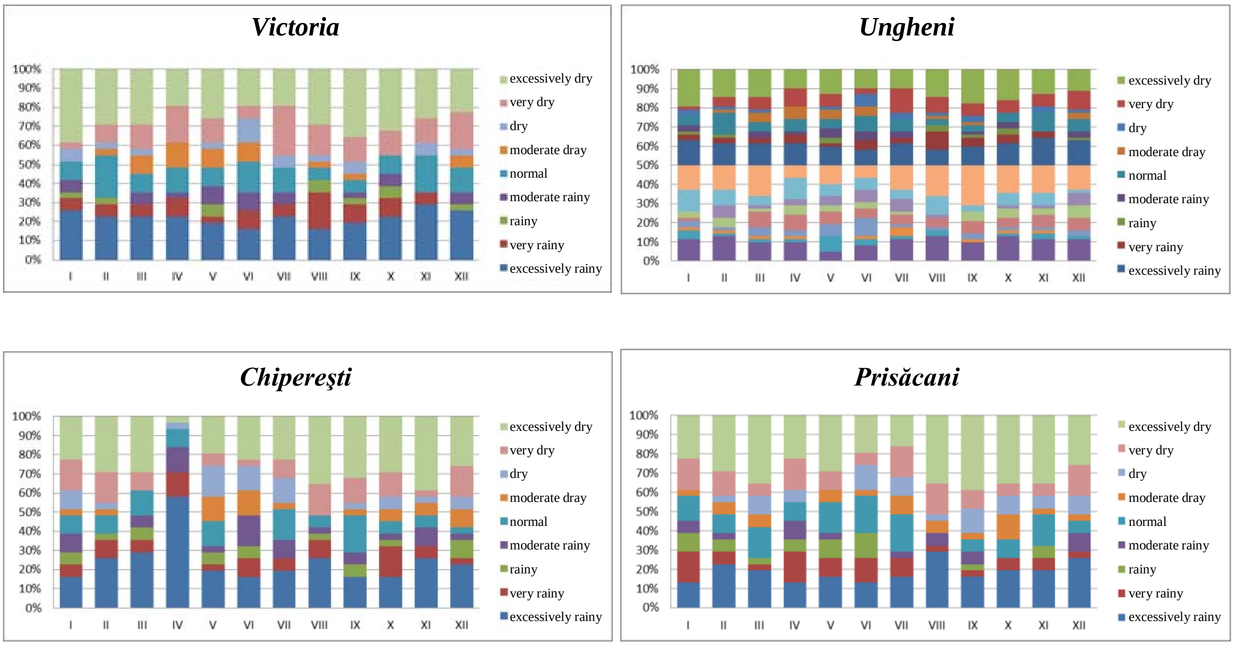


Fig. 5.26 *The monthly pluviometric character on Hellman criterion for the Moldavian Plain in the Meadow between 1981 and 2011*

5.2.7. Precipitations' frequency in the Moldavian Plain

The study of the annual, semestral, seasonal and monthly precipitations' frequencies completes the comprehensive image of the time and space distribution of this element and includes, by synthesis, a multitude of manifestations of the pluviometric factor in the Moldavian Plain; the precipitations are quantified and ordered by the evolution parameters in a concise and suggestive manner which is applied to the whole studied territory. In this way, the variability of precipitations occurrence in time is categorized with each case which finds itself in the evolution tendencies that describe the diverse causality where precipitations are present or not or they display big or small quantities.

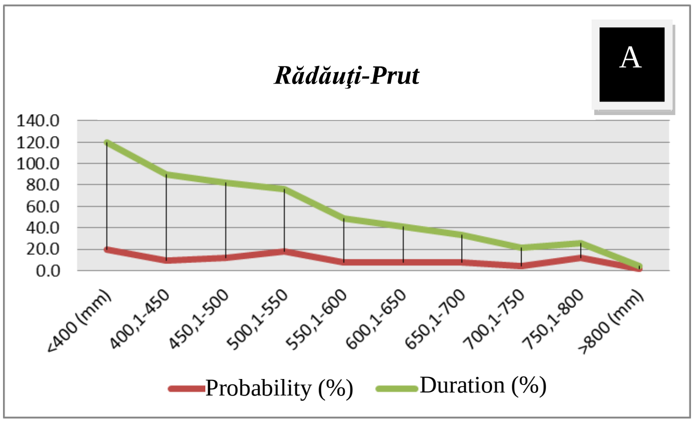
The practical importance of the analysis of different precipitations occurrences is extremely diverse not only for sectors like agriculture, but also for the whole economy and the investments sector as an assembly and for human life in general. The rhythmical recording, even of low precipitations quantities or the irregular recording at big intervals of great rain quantities represent two important types of the pluviometric regime at diurnal, annual and multiannual scales which also apply for NE Romania.

The framing of the Moldavian Plain inside a pluviometric contrasting climate type imposes the calculus of frequencies of precipitations quantities on different temporal samples (years, semesters, seasons and months). This situation conducts to the degree of knowledge regarding the duration curve or the predication of exceptional or poorer quantities of precipitations. In this manner the economic system and the human communities become less vulnerable and more aware in relation with the aggressive manifestations of abundant rains or snows in short intervals or the manifestations of drier periods or prolonged droughts.

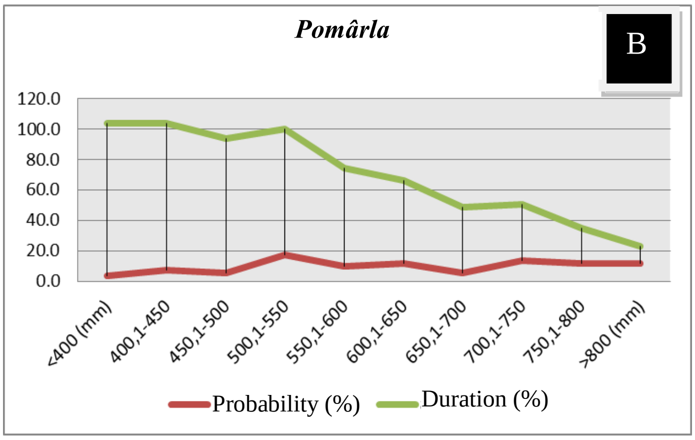
The frequencies values and duration values for the monthly precipitation quantities (fig. 5.27) are expressive and include an increased trustiness and representativeness degrees given by the monthly precipitations analysis on an extended period (1961-2011). Usually, for each month, the greatest frequencies comply with the multiannual average of precipitations for the respective month. From the maximum frequencies these values suddenly drop to lower frequencies and more slowly to the values much higher then the mutiannual monthly averages. As the monthly quantities are lower, in the same sense, increases the precipitation duration for a given small value, while the increase of precipitations quantities progressively lowers the frequencies ordering and the precipitation duration for a given high value.

The maximum percentage values of the monthly sums of precipitations in January and February indicate decreased quantities, usually below the threshold of 30 mm. Toward the warm period of the year the monthly precipitations increase, where in June and July the most frequent values are between 60 and 100 mm. After this point the monthly sums of precipitations decrease progressively until October when the most frequencies are between 20 and 30 mm with a slight increase in November (10-40 mm) followed by the interval of main annually pluviometric minimum.

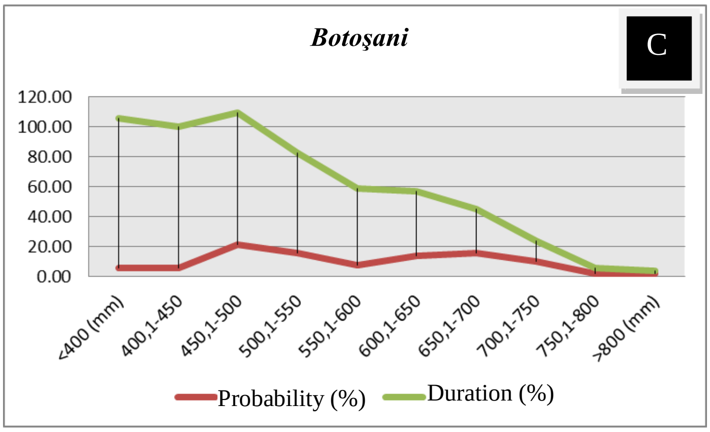
Rădăuţi Prut			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration %
<400 (mm)	10	19.6	100.0
400,1-450	5	9.8	80.4
450,1-500	6	11.8	70.6
500,1-550	9	17.6	58.8
550,1-600	4	7.8	41.2
600,1-650	4	7.8	33.3
650,1-700	4	7.8	25.5
700,1-750	2	3.9	17.6
750,1-800	6	11.8	13.7
>800 (mm)	1	2.0	2.0
Total	51	100,0	100



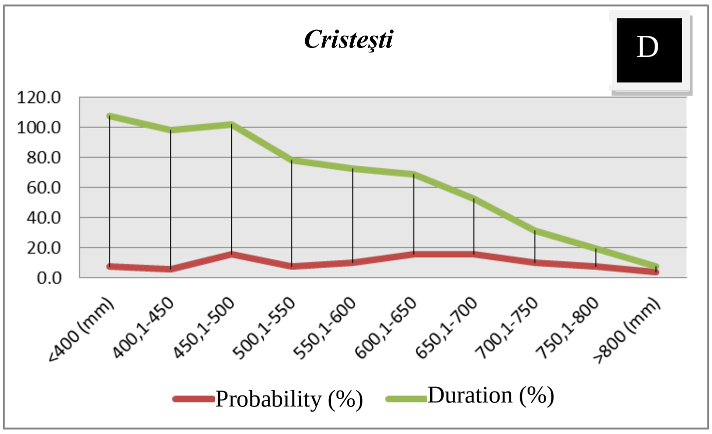
Pomârla			
Precipitations' quantities	Absolute frequency%	Relative frequency%	Duration%
<400 (mm)	2	3.9	99.9
400,1-450	4	7.8	96.0
450,1-500	3	5.9	88.2
500,1-550	9	17.6	82.3
550,1-600	5	9.8	64.6
600,1-650	6	11.8	54.8
650,1-700	3	5.9	43.1
700,1-750	7	13.7	37.2
750,1-800	6	11.8	23.5
>800 (mm)	6	11.8	11.7
Total	51	100,0	100



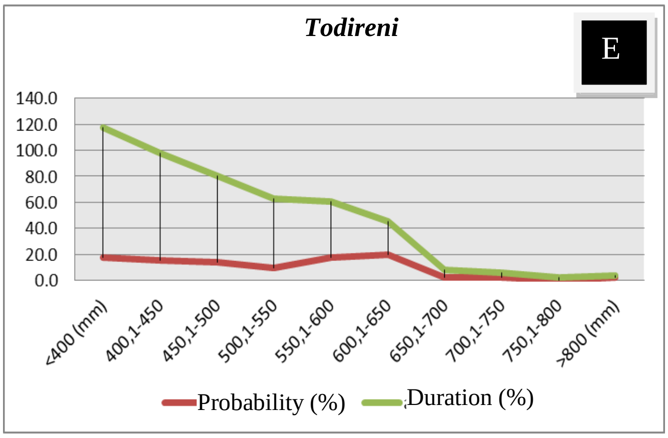
Botosani			
Precipitations' quantities	Absolute frequency%	Relative frequency%	Duration%
<400 (mm)	3	5.88	100.00
400,1-450	3	5.88	94.12
450,1-500	11	21.57	88.23
500,1-550	8	15.69	66.67
550,1-600	4	7.84	50.98
600,1-650	7	13.73	43.14
650,1-700	8	15.69	29.41
700,1-750	5	9.80	13.72
750,1-800	1	1.96	3.92
>800 (mm)	1	1.96	1.96
Total	51	100,0	100



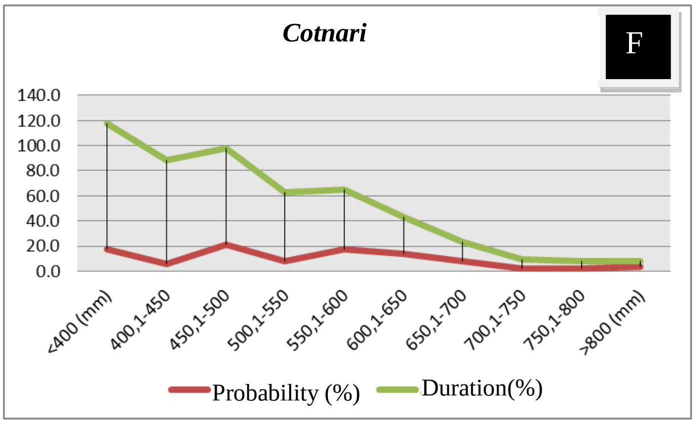
Cristesti			
Precipitations' quantities	Absolute frequency%	Relative frequency%	Duration%
<400 (mm)	4	7.8	100.0
400,1-450	3	5.9	92.1
450,1-500	8	15.7	86.3
500,1-550	4	7.8	70.6
550,1-600	5	9.8	62.7
600,1-650	8	15.7	52.9
650,1-700	8	15.7	37.2
700,1-750	5	9.8	21.5
750,1-800	4	7.8	11.7
>800 (mm)	2	3.9	3.9
Total	51	100,0	100



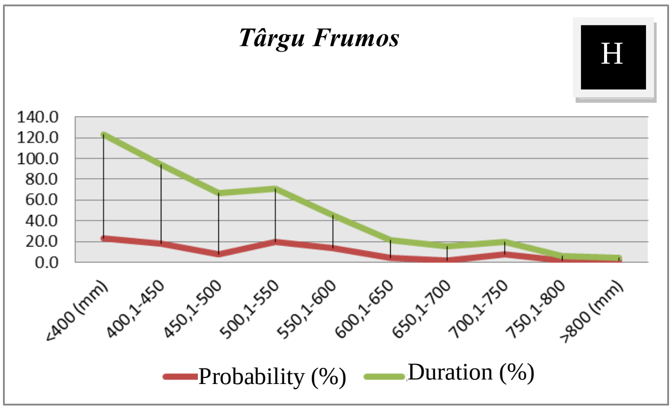
Todireni			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	9	17.6	100.0
400,1-450	8	15.7	82.4
450,1-500	7	13.7	66.7
500,1-550	5	9.8	52.9
550,1-600	9	17.6	43.1
600,1-650	10	19.6	25.5
650,1-700	1	2.0	5.9
700,1-750	1	2.0	3.9
750,1-800	0	0.0	2.0
>800 (mm)	1	2.0	2.0
Total	51	100,0	100



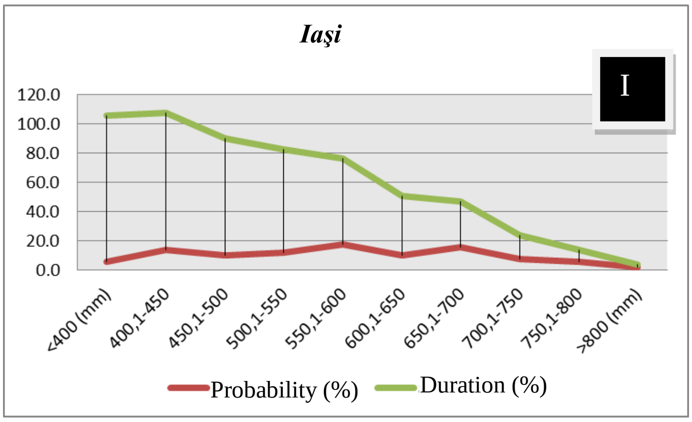
Cotnari			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	9	17.6	100.0
400,1-450	3	5.9	82.3
450,1-500	11	21.6	76.4
500,1-550	4	7.8	54.9
550,1-600	9	17.6	47.0
600,1-650	7	13.7	29.4
650,1-700	4	7.8	15.7
700,1-750	1	2.0	7.8
750,1-800	1	2.0	5.9
>800 (mm)	2	3.9	3.9
Total	51	100,0	



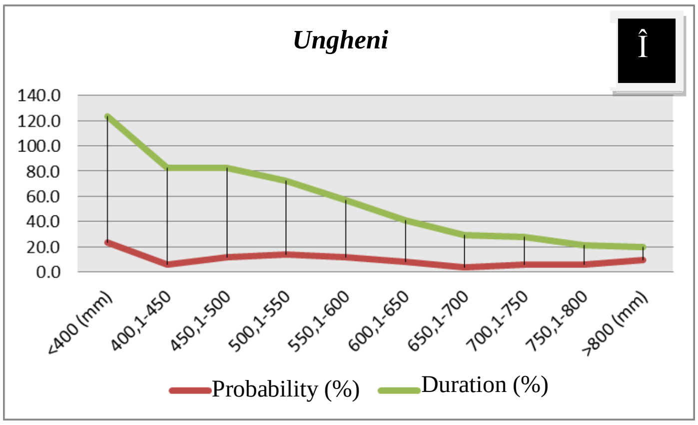
Târgu Frumos			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	12	23.5	100.0
400,1-450	9	17.6	76.5
450,1-500	4	7.8	58.8
500,1-550	10	19.6	51.0
550,1-600	7	13.7	31.4
600,1-650	2	3.9	17.6
650,1-700	1	2.0	13.7
700,1-750	4	7.8	11.8
750,1-800	1	2.0	3.9
>800 (mm)	1	2.0	2.0
Total	51	100,0	100



Iasi			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	3	5.9	100.0
400,1-450	7	13.7	94.1
450,1-500	5	9.8	80.4
500,1-550	6	11.8	70.6
550,1-600	9	17.6	58.8
600,1-650	5	9.8	41.2
650,1-700	8	15.7	31.4
700,1-750	4	7.8	15.7
750,1-800	3	5.9	7.8
>800 (mm)	1	2.0	2.0
Total	51	100,0	



Ungheni			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	12	23.5	100.0
400,1-450	3	5.9	76.5
450,1-500	6	11.8	70.6
500,1-550	7	13.7	58.8
550,1-600	6	11.8	45.1
600,1-650	4	7.8	33.3
650,1-700	2	3.9	25.5
700,1-750	3	5.9	21.6
750,1-800	3	5.9	15.7
>800 (mm)	5	9.8	9.8
Total	51	100,0	



Bârnova			
Precipitations' quantities	Absolute frequency	Relative frequency%	Duration
<400 (mm)	0	0.0	0.0
400,1-450	0	0.0	0.0
450,1-500	0	0.0	0.0
500,1-550	4	8.2	100.0
550,1-600	2	4.1	91.9
600,1-650	4	8.2	87.8
650,1-700	8	16.3	79.6
700,1-750	4	8.2	63.3
750,1-800	8	16.3	55.1
>800 (mm)	19	38.8	38.8
Total	49	100,0	100

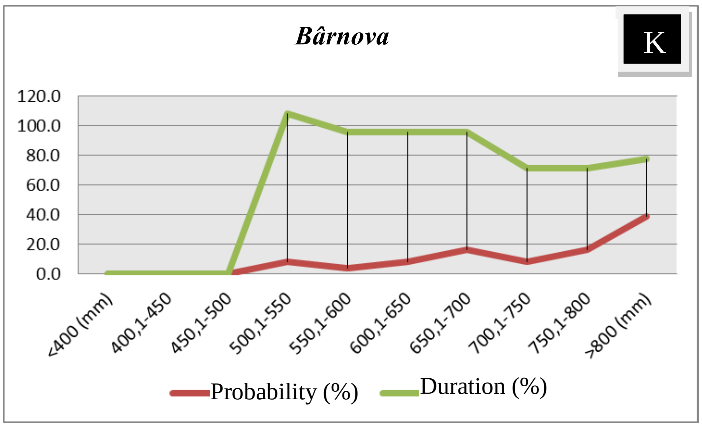


Fig. 5.27 Occurence probability and duration curve degree of different precipitations quantities for the Moldavian Plain pluviometric posts(A-K) between 1961 and 2011

In general, the maximum frequency of the annual precipitations sums in the Moldavian Plain is set between the 450-600 mm quantitative limits. The annual sums increased no more than 750-800 and exceptionally over 800-850 mm, yet the probability of their occurrence maintained very low. Furthermore, a great duration curve degree is given by the 300-350 mm sums interval, yet with a very low frequency.

5.2.8. Diurnal frequency of various precipitations quantities

The evaluation of precipitations frequencies is performed on the basis of occurrence days (rain, snow, drizzle, slush, hail) that equalled or exceeded 0,1 mm. The variation of the days number with different quantities of precipitation depends on the radiative-calorical balance, on the presence of clouds and the atmospheric supra-saturation. By precipitations quantities we have equal or exceeding thresholds days of: 0,1 mm, 0,5 mm, 1,0 mm, 2,0mm, 5,0 mm,10,0 mm, 20,0 mm and 30 mm.

Within the Moldavian Plain, the number of days with precipitations that equal or exceed thresholds do not differ much between its extreme points revealing a direct link between the annual recorded average quantities and the number of days with different values of precipitations; in the more humid parts these are higher and in the more dry parts along an average precipitations year.

In the case of precipitations days of >0,1 mm, in the northern half (Upper Jijia and Başeu) these exceed 130 days per year for the NW side at the contact with the Suceava Plateau and drops fast toward east where it displays only 106 days at Viişoara and just 102 at Albeşti (Tab. 5.1, fig. 5.28).

Table 5.1 Number of days with precipitations > 0,1 mm at the pluviometric posts in Upper Jijia and Başeu river plain

Pluviometric post	***I***	***II***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***IX***	***X***	***XI***	***XII***	***Annual sum***
Rădăuţi Prut	9	9	9	9	10	11	12	8	8	7	8	10	110
Oroftiana	11	10	11	11	13	13	13	10	10	10	10	10	132
Viişoara	8	8	8	10	10	11	11	9	7	7	8	9	106
Ac. Cal Alb	9	9	8	9	10	12	12	9	7	8	8	9	110
Pomîrla	10	10	10	12	14	15	14	10	9	8	9	10	131
Havirna	11	11	12	12	12	13	13	10	10	9	11	11	135
Padureni	10	10	11	12	12	14	13	10	10	10	10	11	133
Manoleasa	11	10	10	10	11	12	12	8	8	9	9	10	120
Dingeni	11	10	11	12	13	13	13	10	9	10	11	11	134
Botoşani	11	11	11	12	14	13	13	10	9	8	10	12	134
Albeşti	9	8	8	9	10	10	10	8	7	7	8	8	102
Cristeşti	11	11	11	12	13	13	12	10	9	10	11	11	134
Media	10	10	10	11	12	12	12	9	9	9	9	10	123

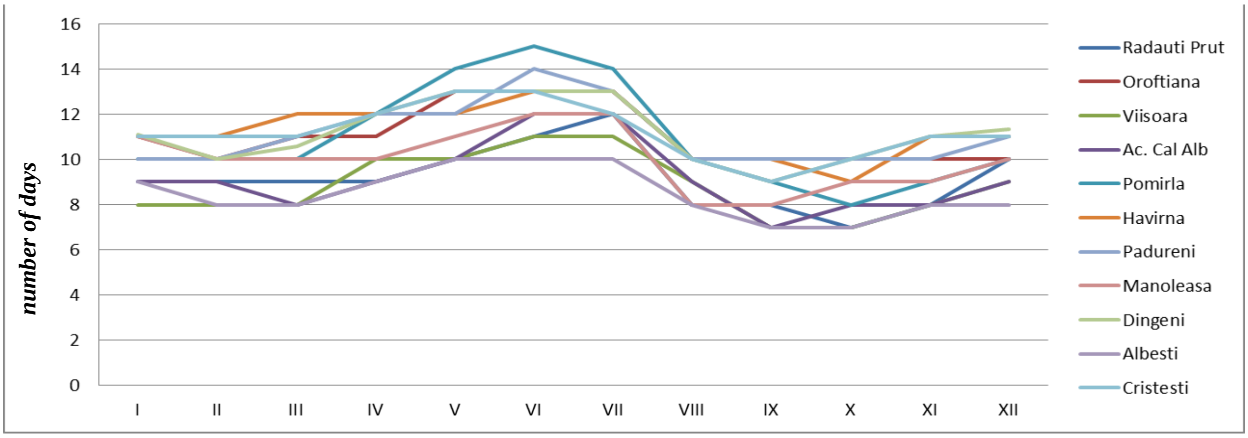


Fig. 5.28 Multiannual variation of >0,1 mm days at the pluviometric posts of the Upper Jijia and Başeu Plain

In the Lower Jijia and Bahlui Plain the average of precipitations days of > 0,1 days is 118, yet it displays a large variation (Tab. 5.2, fig. 5.29). In the north, in the higher altitude zones, at watershed ridges we have posts with an average of 130 (Tudora 139, Pârcovaci 136) while at Tansa the annual number of >0,1 mm precipitations days is only 93. At Iaşi, this parameter has an average of 128 days. The annual regime has a maximum for the month of May (10,5 days), followed by June (9,3 days) and a minimum in October (6,9 days). January and December dispaly a worth mentioning average value of 12 days with over 0,1 mm per year.

Table 5.2 Number of days with precipitations > 0,1 mm at the pluviometric posts in Lower Jijia and Bahlui river plain

Pluviometric post	***I***	***II***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***IX***	***X***	***XI***	***XII***	***Annual sum***
Todireni	*10*	*9*	*9*	*11*	*11*	*12*	*11*	*8*	*8*	*8*	*9*	*9*	*115*
N. Balcesu	*11*	*10*	*11*	*11*	*12*	*13*	*12*	*8*	*8*	*8*	*10*	*10*	*124*
Tudora	*10*	*10*	*11*	*12*	*14*	*15*	*13*	*11*	*11*	*11*	*11*	*10*	*139*
Ac. Parcovaci	*13*	*11*	*11*	*11*	*12*	*13*	*12*	*11*	*10*	*9*	*11*	*12*	*136*
Hîrlau	*11*	*10*	*11*	*12*	*11*	*12*	*11*	*10*	*9*	*8*	*11*	*11*	*127*
Ac. Halceni	*10*	*9*	*10*	*10*	*11*	*11*	*10*	*8*	*9*	*7*	*8*	*9*	*112*
Tansa	*8*	*8*	*8*	*8*	*8*	*10*	*9*	*7*	*6*	*6*	*7*	*8*	*93*
Tg. Frumos	*9*	*9*	*9*	*10*	*11*	*12*	*11*	*8*	*8*	*7*	*9*	*9*	*112*
Iaşi	*12*	*12*	*11*	*11*	*12*	*12*	*11*	*8*	*8*	*8*	*11*	*12*	*128*
Ac Ezareni	*10*	*10*	*10*	*10*	*11*	*12*	*10*	*8*	*8*	*8*	*9*	*10*	*116*
Ac Ciurbeşti	*8*	*8*	*8*	*8*	*9*	*10*	*9*	*7*	*6*	*6*	*7*	*8*	*94*

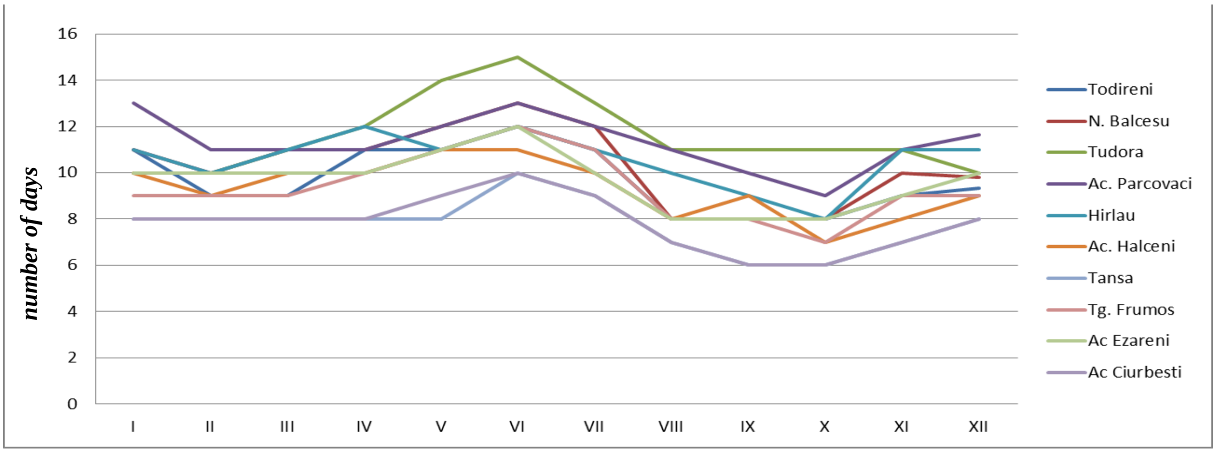


Fig. 5.29 Multiannual variation of >0,1 mm days at the pluviometric posts of the Lower Jijia and Bahlui Plain

In the Prut Meadow the number of days that is equal or exceeding 0,1 mm in one year has a decreased average of only 100 for all the four pluviometric posts. (Tab 5.3, fig. 5.30).

Table 5.3 Number of days with precipitations > 0,1 mm at the pluviometric posts in the Prut River Meadow

Pluviometric post	***I***	***II***	***III***	***IV***	***V***	***VI***	***VII***	***VIII***	***IX***	***X***	***XI***	***XII***	***Annual sum***
Victoria	*9*	*8*	*7*	*10*	*10*	*12*	*10*	*8*	*7*	*7*	*8*	*9*	*82*
Ungheni	*10*	*10*	*9*	*10*	*11*	*12*	*10*	*8*	*8*	*8*	*8*	*10*	*99*
Chipereşti	*10*	*9*	*9*	*10*	*10*	*12*	*10*	*7*	*8*	*7*	*8*	*9*	*96*
Prisăcani	*9*	*9*	*9*	*9*	*11*	*12*	*11*	*7*	*7*	*8*	*8*	*9*	*93*

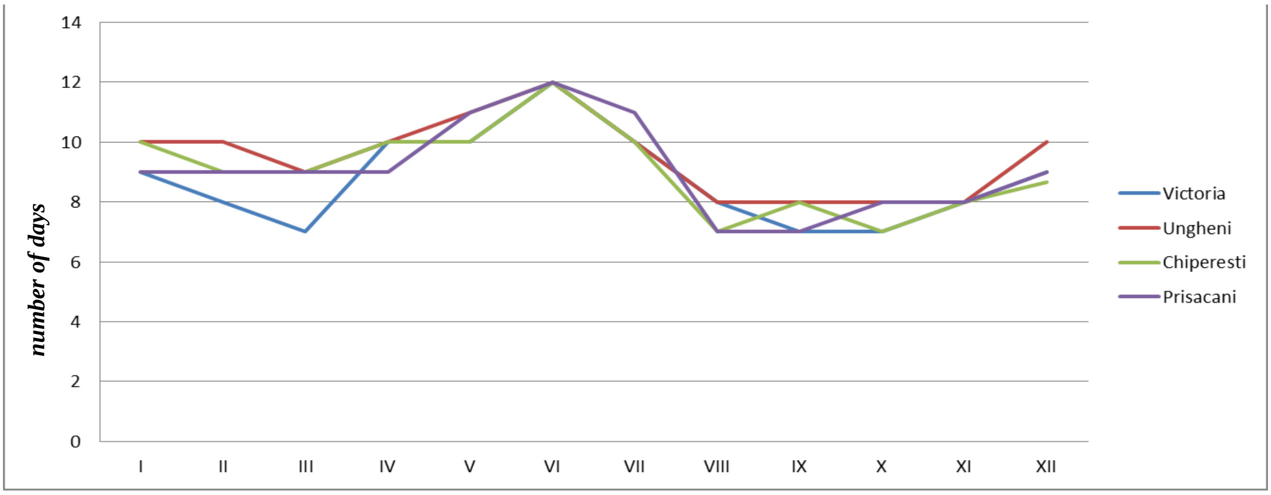


Fig. 5.30 Multiannual variation of >0,1 mm days at the pluviometric posts in the Prut Meadow

In the case of precipitations days of >0,5 mm the highest averages in the Upper Jijia and Başeu Plain we have, for the north and north-east 113 days at Pomârla and 111 at Havîrna (tab. 5.4).

Table 5.4 Number of days with precipitations > 0,5 mm at the pluviometric posts in the Moldavian Plain

Upper Jijia and Bahlui Plain													
Pluviometric post	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Rădăuţi Prut	*8*	*8*	*8*	*9*	*10*	*10*	*11*	*8*	*8*	*6*	*8*	*9*	*103*

Oroftiana	*8*	*8*	*9*	*10*	*11*	*12*	*12*	*9*	*8*	*8*	*8*	*9*	*112*
Viişoara	*8*	*8*	*8*	*10*	*10*	*10*	*10*	*8*	*7*	*7*	*8*	*9*	*103*
Ac. Cal Alb	*8*	*6*	*6*	*8*	*9*	*10*	*10*	*7*	*5*	*7*	*7*	*7*	*90*
Pomîrla	*9*	*9*	*9*	*10*	*11*	*12*	*11*	*9*	*8*	*8*	*8*	*9*	*113*
Havîrna	*8*	*7*	*8*	*10*	*11*	*12*	*12*	*9*	*9*	*8*	*8*	*9*	*111*
Padureni	*9*	*8*	*8*	*9*	*10*	*11*	*11*	*9*	*8*	*8*	*8*	*9*	*108*
Manoleasa	*8*	*7*	*6*	*8*	*9*	*8*	*9*	*7*	*6*	*6*	*6*	*7*	*86*
Dingeni	*9*	*8*	*9*	*10*	*11*	*11*	*11*	*8*	*7*	*7*	*8*	*9*	*108*
Botoşani	*7*	*7*	*8*	*9*	*11*	*11*	*11*	*8*	*7*	*6*	*7*	*7*	*99*
Albeşti	*7*	*6*	*6*	*7*	*8*	*8*	*8*	*7*	*5*	*5*	*6*	*6*	*79*
Cristeşti	*8*	*7*	*8*	*9*	*11*	*11*	*11*	*8*	*7*	*7*	*8*	*8*	*103*
Media													*101*
Lower Jijia and Bahlui Plain													
Pluviometric post	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Todireni	*7*	*7*	*7*	*9*	*10*	*10*	*10*	*7*	*7*	*7*	*7*	*8*	*96*
N. Balcesu	*8*	*7*	*8*	*9*	*10*	*11*	*11*	*8*	*7*	*7*	*8*	*8*	*102*
Tudora	*8*	*7*	*8*	*9*	*10*	*10*	*11*	*9*	*8*	*7*	*7*	*8*	*102*
Ac. Parcovaci	*9*	*8*	*8*	*9*	*9*	*10*	*10*	*9*	*9*	*7*	*8*	*9*	*105*
Hîrlau	*7*	*7*	*8*	*9*	*10*	*10*	*10*	*8*	*7*	*7*	*8*	*8*	*99*
Ac. Halceni	*6*	*5*	*7*	*8*	*8*	*8*	*8*	*6*	*6*	*5*	*5*	*6*	*78*
Tansa	*4*	*5*	*5*	*7*	*7*	*9*	*8*	*5*	*4*	*5*	*5*	*5*	*69*
Tg. Frumos	*6*	*5*	*6*	*8*	*9*	*10*	*9*	*6*	*6*	*5*	*6*	*6*	*82*
Iaşi	*7*	*7*	*7*	*8*	*9*	*10*	*9*	*6*	*6*	*6*	*7*	*8*	*90*
Ac Ezareni	*6*	*6*	*6*	*7*	*9*	*9*	*8*	*6*	*6*	*6*	*6*	*7*	*83*
Ac Ciurbesti	*6*	*5*	*6*	*7*	*7*	*8*	*7*	*5*	*5*	*5*	*5*	*6*	*71*
Prut Meadow													
Post pluvio	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Victoria	*6*	*5*	*5*	*7*	*7*	*8*	*8*	*5*	*5*	*5*	*5*	*6*	*72*
Ungheni	*7*	*6*	*6*	*7*	*9*	*9*	*7*	*6*	*6*	*5*	*6*	*7*	*81*
Chipereşti	*6*	*6*	*7*	*8*	*9*	*9*	*8*	*6*	*6*	*6*	*6*	*7*	*84*
Prisacani	*6*	*6*	*6*	*7*	*8*	*9*	*8*	*6*	*6*	*6*	*6*	*6*	*78*

In the case of the numebr of days with precipitations of > 1,0 mm the values oscillate in a similar manner with the days of 0,1 mm amd 0,5 mm (tab. 5.5).

Table 5.5 Number of days with precipitations > 0,1 mm at the pluviometric posts in the Moldavian Plain

Upper Jijia and Başeu Plain													
Pluviometric post	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Radauti Prut	*6*	*5*	*5*	*7*	*8*	*8*	*9*	*6*	*6*	*5*	*6*	*7*	*77*
Oroftiana	*5*	*5*	*6*	*7*	*9*	*9*	*9*	*7*	*6*	*6*	*6*	*6*	*83*
Viişoara	*5*	*5*	*5*	*7*	*8*	*8*	*7*	*6*	*5*	*5*	*6*	*5*	*71*
Ac. Cal Alb	*5*	*4*	*4*	*6*	*7*	*9*	*8*	*6*	*4*	*5*	*5*	*5*	*68*
Pomirla	*6*	*6*	*6*	*8*	*9*	*9*	*9*	*7*	*6*	*5*	*6*	*7*	*87*
Havirna	*6*	*5*	*6*	*8*	*9*	*10*	*10*	*7*	*7*	*5*	*6*	*7*	*84*
Padureni	*6*	*5*	*6*	*7*	*8*	*9*	*9*	*8*	*6*	*6*	*6*	*6*	*81*
Manoleasa	*6*	*5*	*5*	*6*	*7*	*8*	*8*	*6*	*5*	*5*	*5*	*6*	*72*
Dingeni	*6*	*5*	*6*	*8*	*8*	*9*	*9*	*6*	*5*	*5*	*5*	*6*	*78*
Botoşani	*5*	*5*	*6*	*8*	*9*	*9*	*9*	*7*	*6*	*5*	*6*	*6*	*80*
Albeşti	*6*	*5*	*5*	*6*	*8*	*8*	*7*	*6*	*5*	*5*	*5*	*5*	*71*
Cristeşti	*5*	*5*	*6*	*7*	*9*	*9*	*9*	*6*	*5*	*5*	*5*	*6*	*77*
Lower Jijia and Bahlui Plain													
Pluviometric post	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Todireni	*5*	*4*	*5*	*7*	*8*	*8*	*8*	*6*	*5*	*5*	*5*	*6*	*72*

N. Balcescu	*5*	*5*	*6*	*8*	*8*	*9*	*9*	*6*	*6*	*5*	*5*	*5*	*76*
Tudora	*6*	*5*	*7*	*7*	*8*	*8*	*8*	*7*	*6*	*6*	*5*	*6*	*80*
Ac. Parcovaci	*6*	*5*	*5*	*7*	*7*	*8*	*8*	*7*	*6*	*5*	*5*	*6*	*76*
Hîrlau	*5*	*5*	*5*	*7*	*8*	*8*	*8*	*7*	*5*	*5*	*5*	*5*	*73*
Ac. Halceni	*5*	*5*	*5*	*7*	*7*	*7*	*7*	*5*	*5*	*5*	*4*	*5*	*66*
Tansa	*3*	*3*	*4*	*6*	*7*	*8*	*7*	*5*	*4*	*4*	*4*	*4*	*58*
Tg. Frumos	*4*	*4*	*5*	*7*	*8*	*8*	*8*	*6*	*5*	*4*	*5*	*5*	*69*
Iaşi	*5*	*5*	*5*	*7*	*7*	*8*	*8*	*5*	*5*	*4*	*5*	*5*	*69*
Ac Ezareni	*5*	*5*	*5*	*6*	*8*	*8*	*8*	*6*	*5*	*5*	*5*	*5*	*70*
Ac Ciurbesti	*5*	*4*	*4*	*6*	*6*	*7*	*7*	*5*	*4*	*4*	*4*	*5*	*62*
Prut Meadow													
Pluviometric post	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*Annual sum*
Victoria	*5*	*4*	*5*	*7*	*7*	*8*	*8*	*5*	*5*	*5*	*5*	*5*	*67*
Ungheni	*6*	*5*	*5*	*6*	*8*	*8*	*7*	*5*	*5*	*5*	*5*	*6*	*71*
Chipereşti	*5*	*5*	*5*	*6*	*7*	*8*	*7*	*5*	*5*	*5*	*5*	*6*	*70*
Prisăcani	*5*	*4*	*5*	*6*	*7*	*8*	*7*	*5*	*5*	*5*	*5*	*5*	*67*

The same annual regime is characteristic for the other parameters of the number of days with different precipitations, yet here the annual maximum appears in June and the minimum in the autumn months (October for the >0,5 mm, 1,0 and 2,0 days as a result of the anticyclone regime extension over Romania, especially toward east) or in winter (December for the >5,0 mm and >10,0 mm precipitations and January for the precipitations > 20,0 and >30, 0 mm precipitations).

For the number of days with precipitations of 5,0 mm, 10,0 mm, 20,0 and 30 mm we have a maximum in June and July and, in same cases, even in August and September which accounts for the torrential character of the precipitations in this period of the year.

The number of days with precipitations of > 20,0 mm is higher for two areas: a central-western one (Botoşani and surroundings with over 5 days with precipitations sums of > 20,0 mm) and a south-eastern one (Iaşi - Victoria – Ungheni, with over 5 days with precipitations sums of > 20,0 mm per year). In the rest of the territory (north, central-eastern and south-western parts) the number of >20,0 mm per year drops below 5.

The number of days with precipitations of > 30,0 mm is lower, with over 3 days per year, yet very irregular. As general tendency we can conclude that the number days with very high precipitations values increases from north-west to south-east and from west to east.

At the level of tendencies the situation differs. If for the number of days with precipitations of 0,1 mm, 0,5 mm, 1,0 mm, 2,0 mm, 5,0 mm and 10,0 mm the multiannual tendency is decreasing for the number of days with precipitations of 20,0 mm and 30,0 mm the tendency is constant and even slightly increasing (fig. 5.31). Analyzing each month, especially in the Lower Jijia and Bahlui Plain the tendency is explained by the increase of the days with precipitations of over 20,0 mm and 30,0 mm more frequent in August, September and October which stands for same torrentiality character. This situation is obvious because of the increase of monthly precipitations quantities and the tendency of increase of the monthly sums for these months which are also to be observed in the analysis of the annual precipitations' regime.

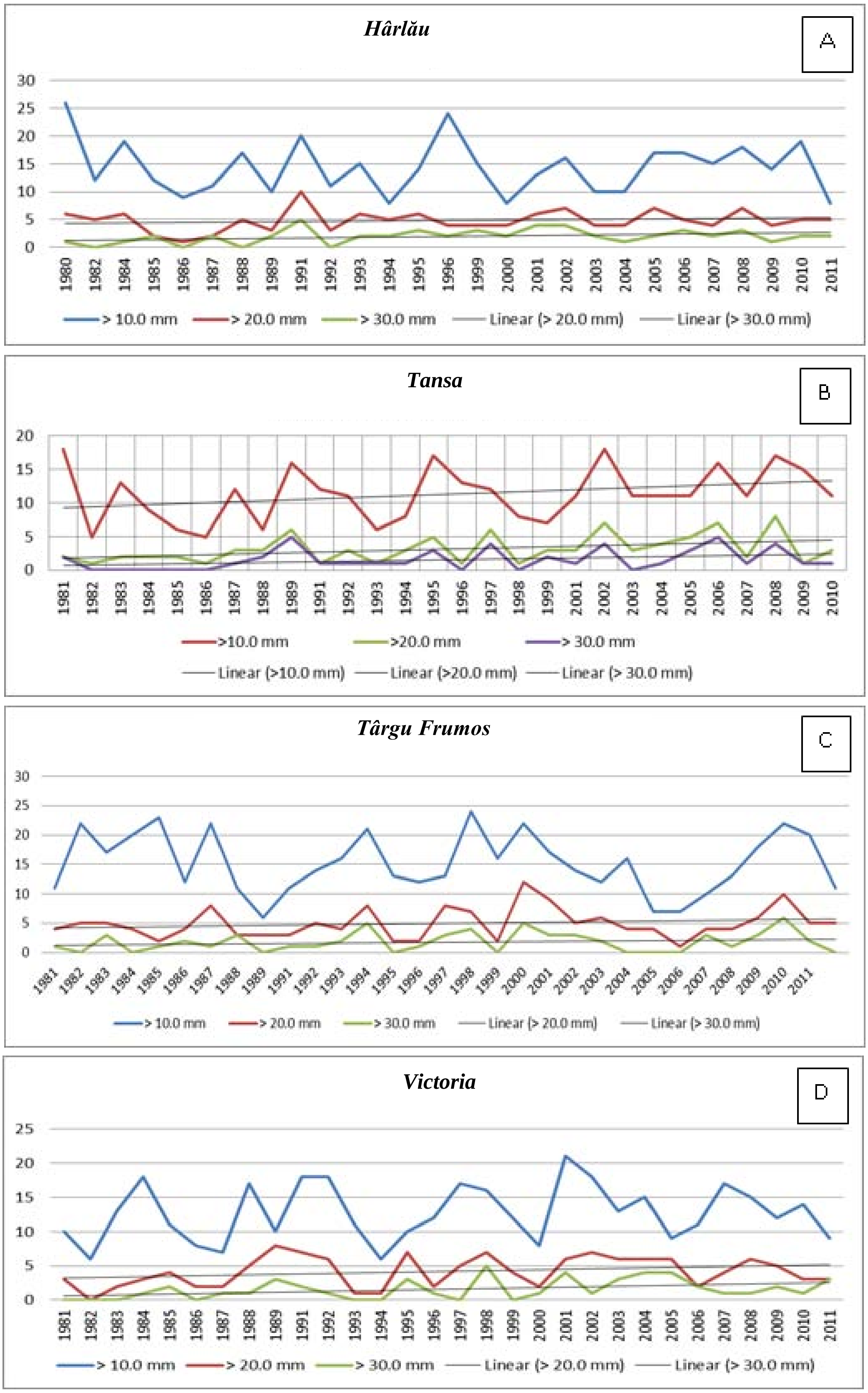


Fig. 5.31 Multiannual variation of the number of days with precipitations of >de 10.0mm, > 20.0mm, >30.0mm at the Hârlău (A), Tansa (B), Tg. Frumos (C) and Victoria (D) pluviometric posts

The monthly maximum days of precipitations that equal or exceed certain limits over a year is recorded in the more humid period, respectivly in May-June-July. The period of annual pluviometric maximum corresponds with the most numerous days of precipitations for the value thresholds. Inside the reminded period the situataion is, to some extent, different, in the sense that for the lowest thersholds (0,1 – 1,0 mm) the monthly maximum number of days with these values and the monthly frequence we have records not only in June, but in May, e.g. at Botoşani for the whole interval between the value thresholds mentioned above.

July is the rainiest month over the year and is distinct for the greatest number of days and the highest frequency for the precipitations quantities. If in the case of May, the inferior thresholds for the daily precipitations are characteristic as an annual maximum, in the case of July the superior thresholds of precipitations quantities (> de 0,5 mm; > de 30,0 mm) are characteristic. It is very rarely when August holds the maximum per year for the number of days with different precipitations quantities (e.g. > 30 mm).

5.2.9. Torrential rains – precipitations' duration, intensity and abundance

Torrential rains are atmospheric phenomena with short duration influence but with great intensity, upon the environment via erosion and flooding. They consist in increased precipitation quantities on short time intervals, sudden change of intensity along with extension of duration.

Torrential rains are relatively rare phenomena, recorded usually at cyclonic activities (Stoenescu et. Al., 1962). Local heating of the active surface may result in strong ascents of air overpassing the high relief or rapid circulation of atmospheric fronts. If these processes take place in humid air masses, usually tropical – maritime, the intense precipitation process, generates, in the warm season the above mentioned torrential rains (Bogdan, Niculescu, 1999).

Torrential rains are very effective and influence the physical geographic processes along with technical works. All the norms used to evidence torrential rains refer to the fall of a high quantity of rain in a short time interval. The increase in quantity may be accompanied by increase in duration which means that for higher quantities intensity can be lower.

The duration of a torrential rain can be extended to the whole rain interval when there are no pluviographic measurements or to the maximum duration for a certain quantity of precipitations (Stoenescu et al, 1965). One first way of evidence for torrential precipitations refers to a reduced number of rains and average or preferably maximum intensities. Torrential rains as analyzed on the entire event have an occurance probability of only 40% per year. The probability of torrential rain occurance according to this criterion oscillates between 5-35% for a single event per year and, for 4-5 torrential rains the probability drops below 3% (Geografia României vol I, 1983).

5.2.9.1. Precipitation's duration

The duration plays and important role in the event since an increased duration of rain fall contributes, usually, to an important pluviometric input at the level of the active surface and to increased possibilities of water infiltration for plants' needs by maintaining humidity values above the fading coefficient.

Cumulatively, the average annual duration of precipitations as rain-falls, torrential showers, snow, snow-showers and drizzle between 1981-2011 was of 810 hours at Botoşani and, at Iaşi the duration exceeded Botoşani with 1200 hours. In this manner the role of urban condensation nuclei at Iaşi is once again evidenced showing the genesis of suplementary precipitations and the increase in their duration (tab. 5.6).

Table 5.6 Average monthly duration in hours and minutes of torrential rains in the Moldavian Plain for the 1991-2011 interval

Luna	**A**		**M**		**I**		**I**		**A**		**S**		**O**	
Statia	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**	**ore**	**min**
Botoşani	12	45	27	09	30	48	31	17	25	23	18	32	7	47
Cotnari	14	43	24	18	26	41	18	20	16	40	23	19	8	46
Iaşi	17	30	27	43	27	30	22	32	18	14	23	21	8	22

The annual regime of precipitationsţ duration shows a main maximum in December and a main minimum in August with a second maximum in Februarz and a second minimum in January. The month with shortest precipitations duration is August, while December is the month with longest precipitations events (duration) and displays an inverse percentage character with torrentiality.

5.2.9.2. Precipitations' intensity

The precipitations' intensity is the parameter that reports the quantity to the time interval (the minute) and plays a very important role in the practical economy (agriculture, transportations, constructions etc.)

Not only in the case of precipitations assembly but also in the case of the characteristic intervals we notice the contraction of torrential rains frequencies and of the characteristic intervals, as low intensity intervals for the spring months (April) and especially the autumn months (October). Inside the warm semester the frequencies of rains or intervals with higher intensity is more evident. If in spring and autumn the rains and intervals display high frequencies, yet with lower intensities, in the rest of the year the frequencies are lower but the intensity intervals are higher.

In the case of torrential rains we detect a relative uniformization of frequencies values, widely displayed on different intervals of intensities with higher values toward the mid-summer. At the begining and the end of the warm semester there is an uniformization of intensity values, associated on groups of lower frequencies. Low intensity rains dominate the begining and the end of the warm semester, while the mid-summer is dominated by more increased intensities; the intensity frequences diplay a harmonic distribution emphisizing the continental character of the precipitations (Dumitru Mihăilă, 2006).

In the case of rains, the maximum intensities do not exceed, at any station in the Moldavian Plain, the 1,01-2,00 value interval where the intensities are closer to the lower side of the interval and, at Cotnari the maximum intensities do not exceed the 1,01 threshold value.

For the characteristic intervals the development on a larger intensity values vertical deviation results in wider and more evident decreasing tendency for the maximum values and a coagulation of these values in the beginning and the end of the warm semester; the intensity intervals limits that include the highest torrential rains sequences are contracting yet they remain larger than the precipitations assembly (Dumitru Mihăilă, 2006).

The stations in the Moldavian Plain recorded distinct torrential rains time sequences, as fallows:

1) at Botoşani the intensity of maximum torrentially are between 8,01 and 9,00 mm/minute. A rain sequence from 11.08.1999 with an intensity of 0,37 and a duration of 37 minutes, between 14.35 and 15.30 with a the water discharge of 13,8 mm had the highest intensity (9,00) where in just one minute (15.12-15.13) there was a 9,0 mm discharge.

2) at Cotnari the intensity went to 3,01-4,00 mm/minute. In 1973 on 24th of September, between 17:18 and 18:15. during 57 minutes there were 71.3 mm for a rain with 1,25 average intensity. During this rain, between 17:49 and 17;52 (3 minutes) there were 10,1 mm which decribes a caharacteristic interval of 3,37 intensity. On 03.07.1991, during a rain of 0,37 intensity that lasted between 00:08 and 1:40 (1 hour and 32 minutes) there were 33,8 mm, where between 0:12 and 0:15 (3 minutes) the characteristic interval had a maximum of 3,37 with 10,1 mm of precipitations.

3) at Iaşi the maximum intensity for a sequence of torrential rain was between 6.01 and 7,00mm/minute. The characteristic interval of maximum intensity (6.30) lasted one minute (12:57-12:58) and had 6.3 mm of water. This interval pertains to a rain of 0,26 average intensity that took place on 11.06.1990 between 12:40 and 13:40 with a total of 15,7 mm.

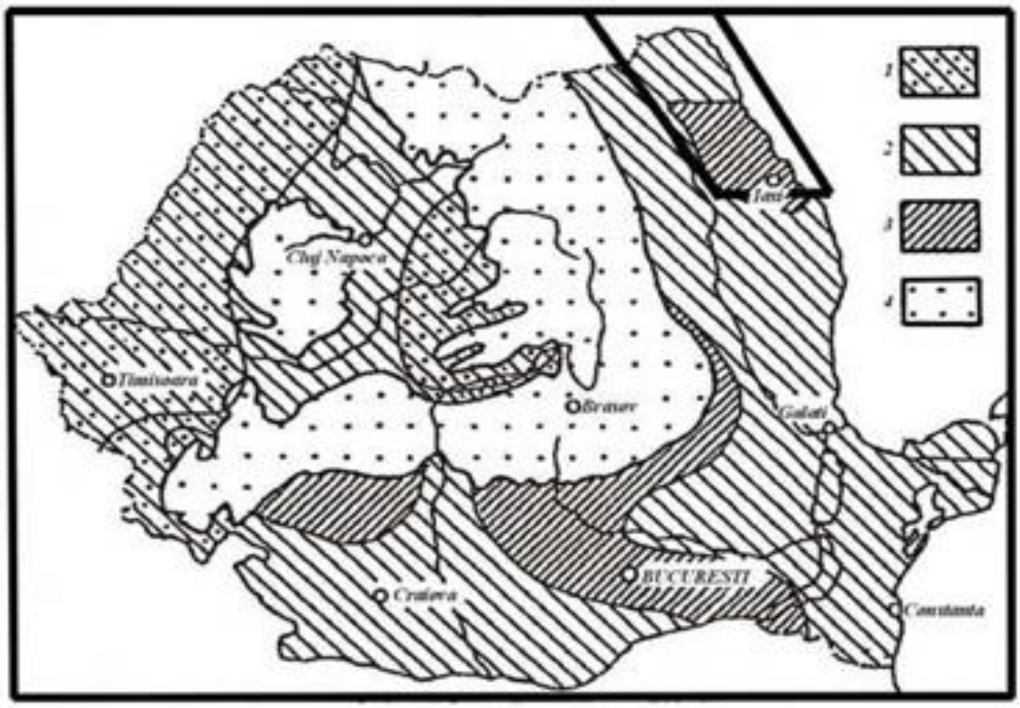


Fig. 5.32 Romanian territory and Moldavian Plain vulnerability at torrential rains (1 - small; 2 - intermediate; 3 - big; 4 - combined) – by Octavia Bogdan et. al., 1999

As far as the vulnerability of the Moldavian Plain to the suumer rains we notice that the northern half displays an intermediate vulnerability while the southern half diplays a higher vulnerability. We also notice that for the whole space east, south-east and south of the Carpathians is vulnerable to an apreciable extent to torrential rains with intermediate and high intensities. In figure 5.32 we also observe that in those areas where oceanic influences predominate, rains have a less violent character and in those areas where continental influence pedominate (as the case of the Moldavian Plain) torrentail rains have a more violent character. In the Moldavian Plain the degree of vulnerability of torrential summer rains increases from WNW to SSE. Torrential rains bring a great pluviometric input that can reach a monthly quantity of 172.1 mm in July at Botoşani and 277.2 mm in June 18â985 at Iaşi. The May-September interval remains the of the greates torrential rains with high and exceptional quantities of rain.

It is worth mentioning that the most rainy years appear as the result of torrential rains input when high frequencies and quantities during the seasons, the warm semester and the whole year result in pluviometric surplus (Dumitru Mihăilă, 2006).

5.2.9.3. Precipitations' abundance

The maximum precipitations quantities in 24 hours are determined by the local dynamic convection, frontal dynamic or orographic dynamic that occur along the year and by the thermic convection that occurs especially in the warm semester. Usually, the greatest precipitations quantities in 24 hours appear in the summer months when the air has a great capacity of water vapours accumulation and when the atmospheric fronts from Atlantic, across Europe (N to W) have a humid and relatively unstable character, frequently affected by the local thermo-dynamics which, in the warm semester, reaches maximum values (Minea, 2009).

The greatest annual value of precipitations quantities in 24 hours for the Moldavian Plain was 145,8 mm at Răuseni, on 06.09.1998 while the lowest maximum value was 75,4 mm at Dorohoi on 22.07.1974. In the same period, at Bârnova pluviometric post, on 7.09.1989 there were 167,9 mm as a result of cold air nucelus that descended from the plateau polar depression and resulted in increased weather instability between 6 and 7th of September 1989 (Sfîcă, 2007) (Fig. 5.33).

The distribution of the 6-7 of September rain isohyets emphasizes the formation of a precipitation nucleus in the south-eastern part of the Moldavian Plain which indicates the role of the convective situations in the production of maximum rain quantities; here we emphasize the altitude differences in this area, of 300 meters between Bahlui Valley and Bârnova Hill.

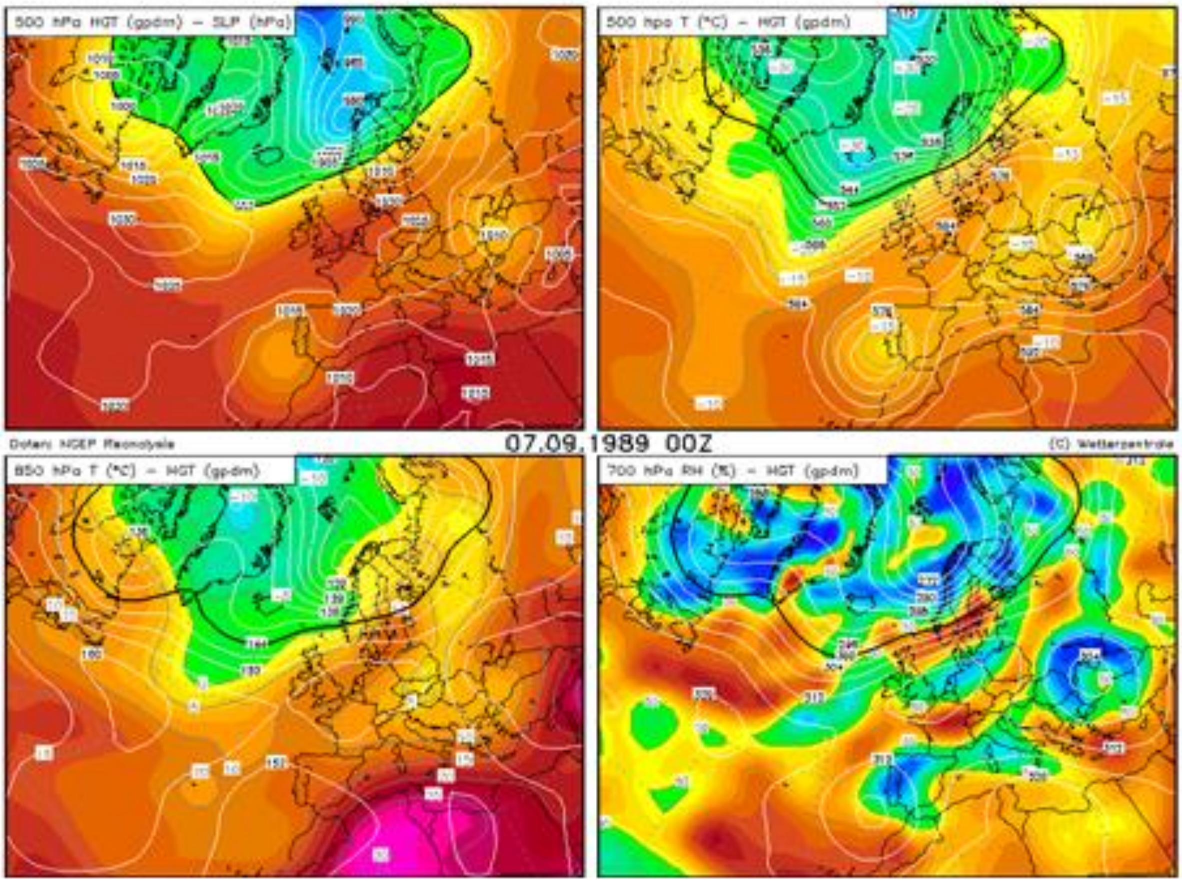
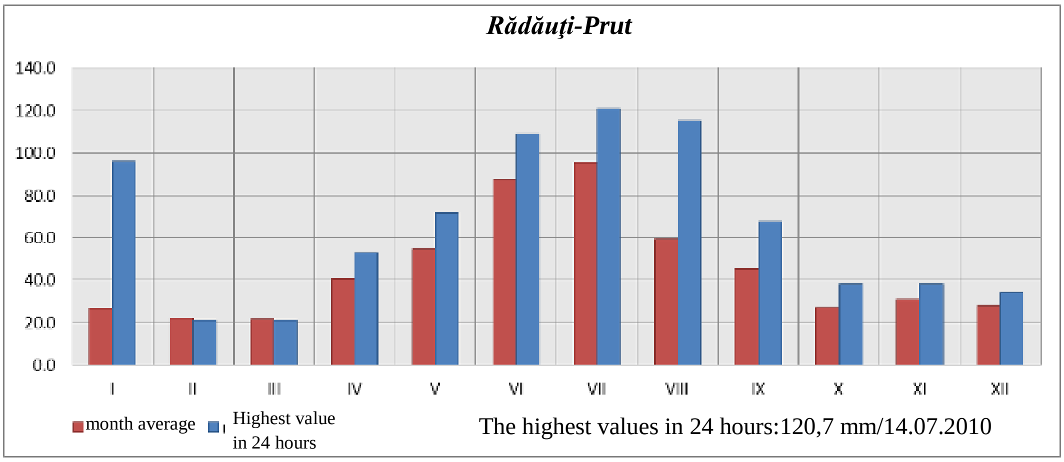


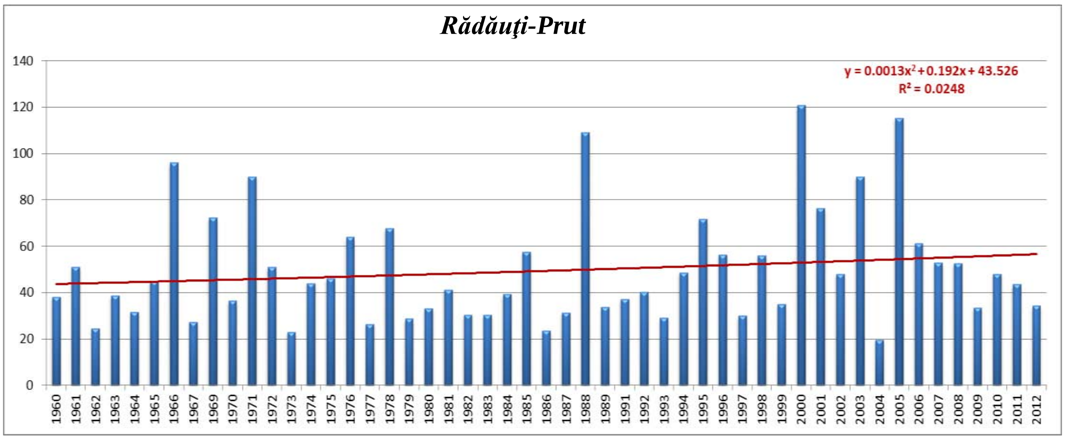
Fig. 5.33 The synoptic situation at 7th of September 1989 (source: http://wetterzentrale.de/topkarten/fsreauer.html)

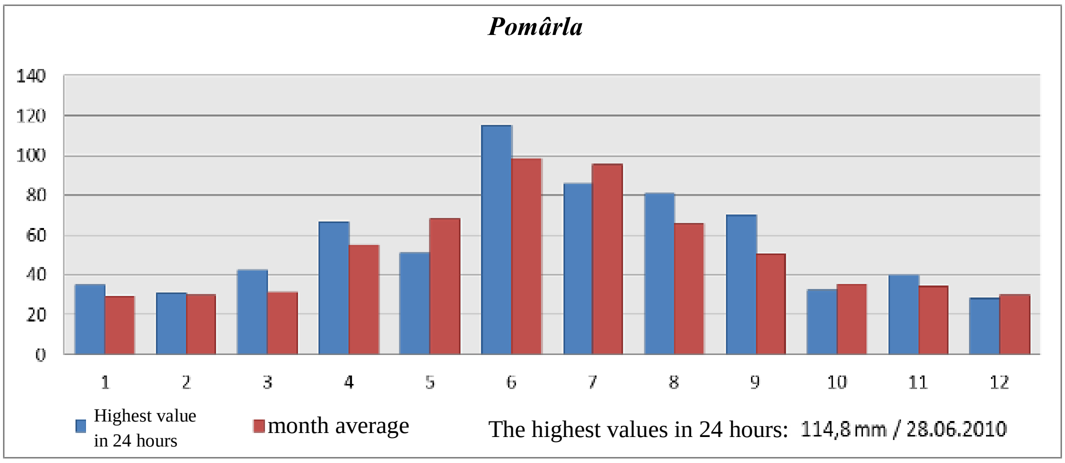
These concentration nuclei are set, usually, in the higher altitude waterhed zones and are conditioned by the local orographic convection (closely related to the local pluviometric gradient). Such a nucleus of precipitations' concentration was evidenced in the Bârnova-Păun Hills perimeter by the analysis of a maximum intensity rains between 1964-1990 (22-24.09.1964, 12-14.07.1969, 25.08.1970, 18-19.06.1985, analyezed by Apetrei, 1992 and 6-7.09.1989, analyezed by Sfîcă, Minea, 2006).

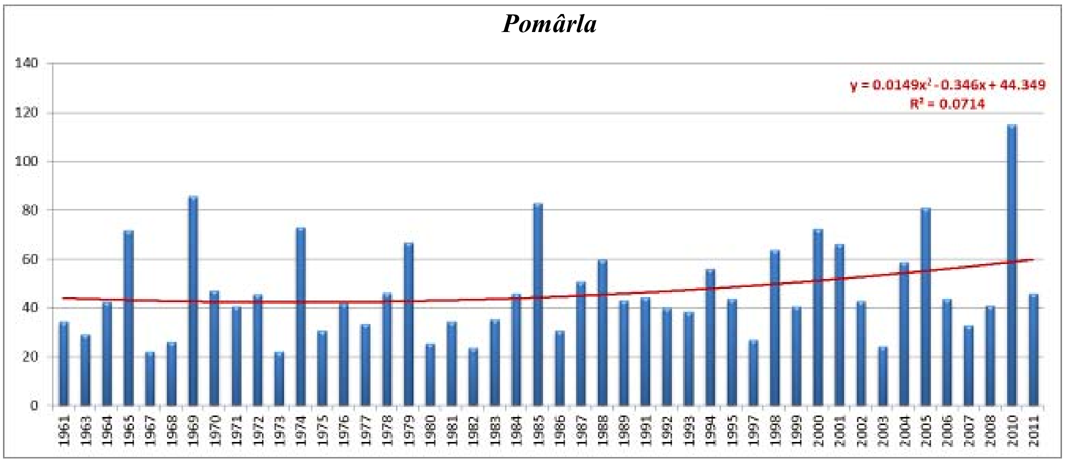
The highest values of precipitations in 24 hours were generally recorded in the summer month and the beginning of autumn. The maximum quantities in 48 hours and 72 hours at Iaşi meteorological station recorded 192,8 mm, respectively, 194,4 mm in the summer month (July) and 30,2 mm and respectively 39,2 mm, in the winter months (February) (Climate of Romania, 2008).

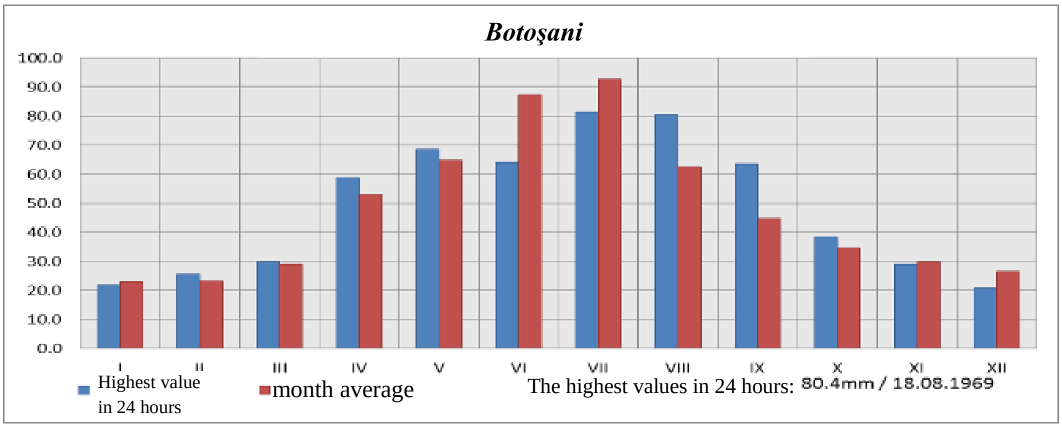
The factors that control the genesis of greatest diurnal precipitations quantities modify their qualitative and quantitative manifestation parameters from one month to another which is why the monthly maximums values variation is widespread across the whole year. In the warm semester, by addition of the favourable dynamics and the thermo-convective processes the diurnal maximums occur while in the cold semester the thermic convection decreases and the dynamics become unfavourable conducting to lower diurnal maximums. The monthly analysis shows that 68,7% of the cases, of maximums in 24 hours, overpass the respective month average while 6,48% of the cases the average of the respective month is overpassed at least two times (e.g. in August, at Beautiful Mart, Ungheni and Iaşi) (fig. 5.34).

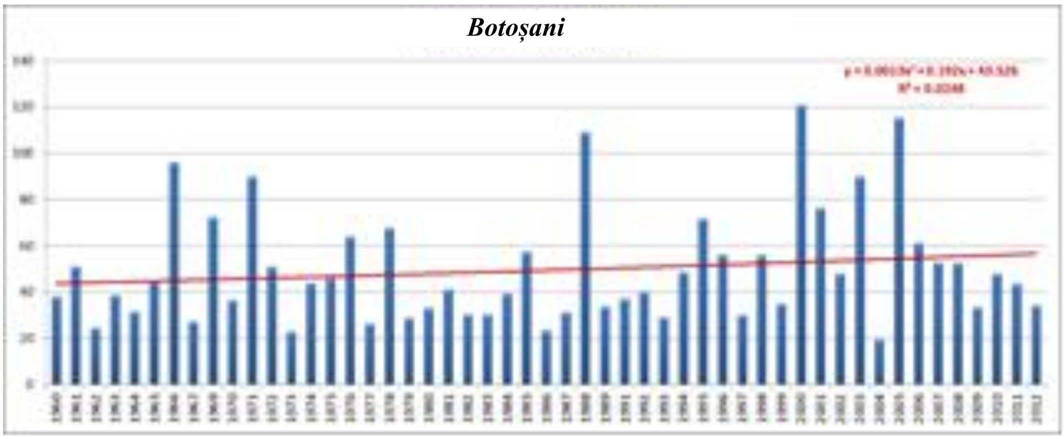

Rădăuţi-Prut
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
I II III IV V VI VII VIII IX X XI XII
month average
Highest value in 24 hours
The highest values in 24 hours:120,7 mm/14.07.2010

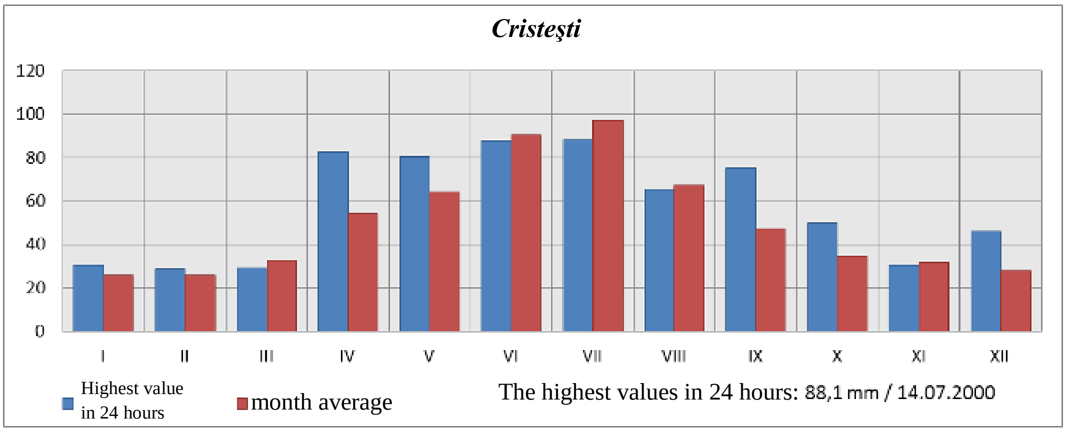

Rădăuţi-Prut
y = 0.0013x²+0.192x+43.526
R² = 0.0248
140
120
100
80
60
40
20
0

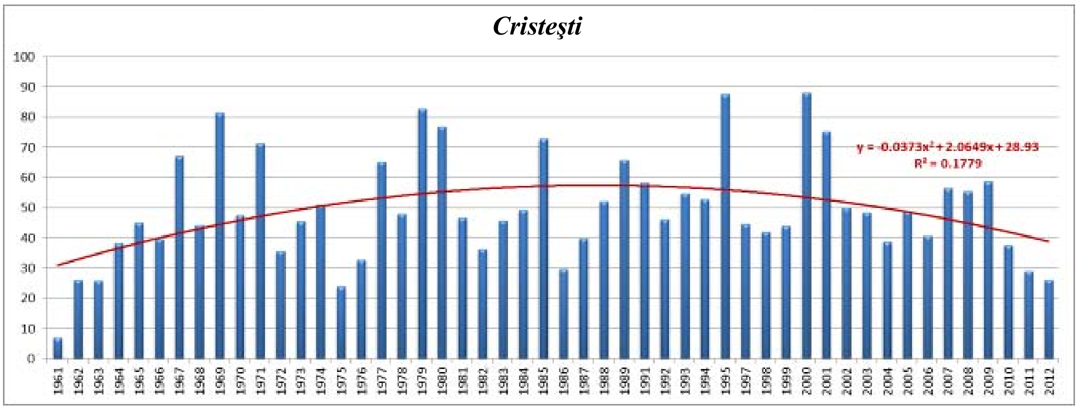

Pomârla
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12
Highest value in 24 hours
month average
The highest values in 24 hours: 114,8 mm / 28.06.2010

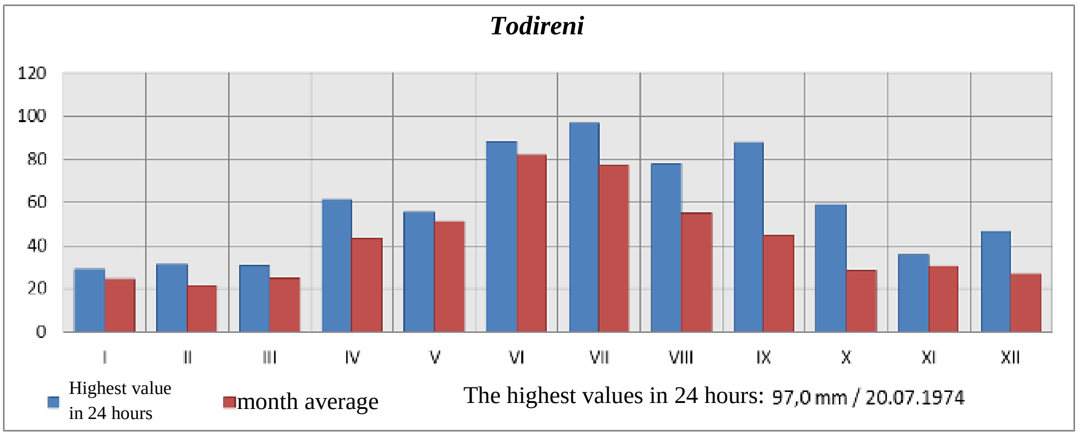

Pomârla
y = 0.0149x² - 0.346x + 44.349
R² = 0.0714
140
120
100
80
60
40
20
0

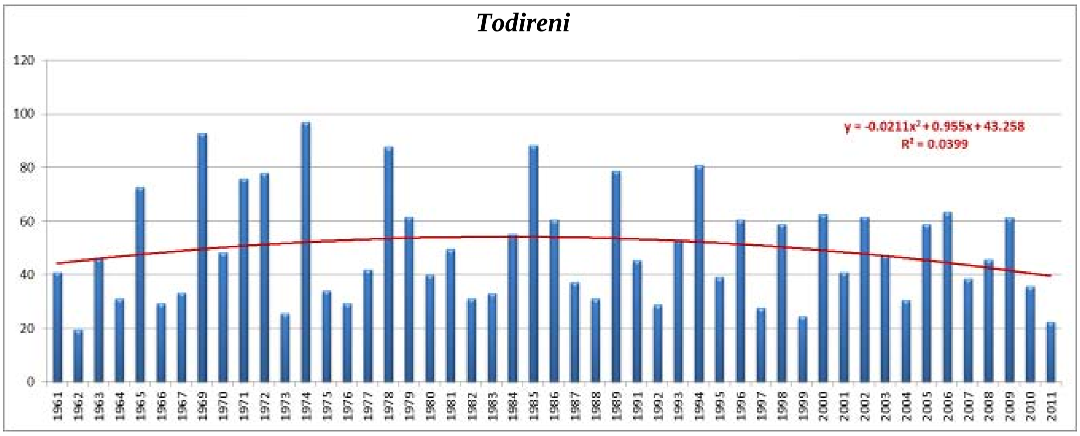

Botoşani
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Highest value in 24 hours
month average
The highest values in 24 hours: 80.4mm / 18.08.1969

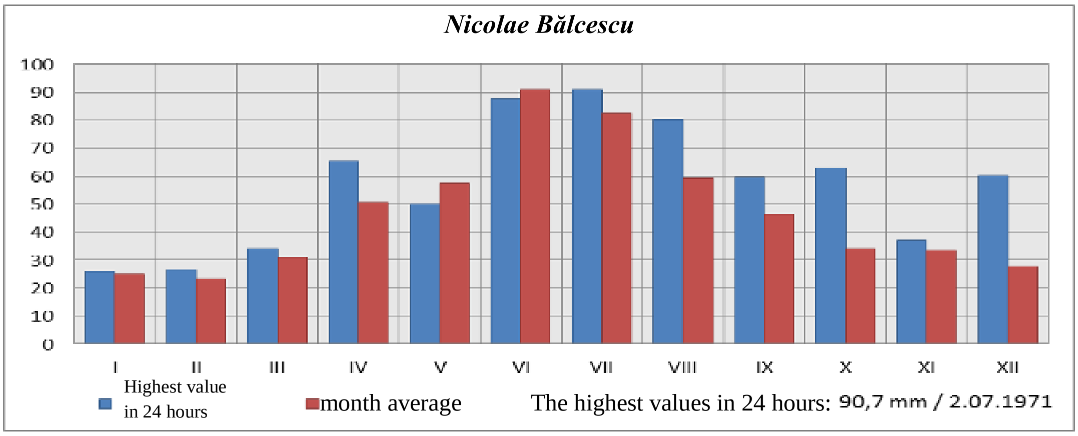

Botoșani

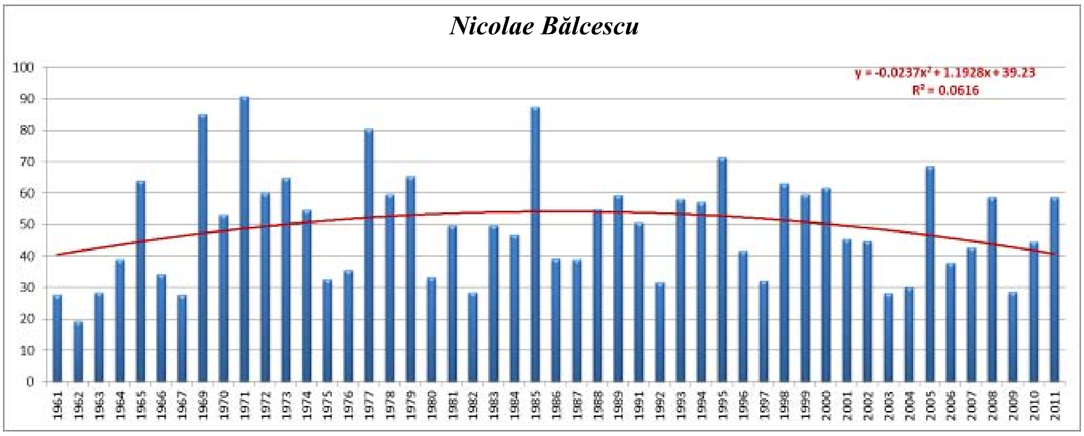

Cristeşti
120
100
80
60
40
20
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Highest value in 24 hours
month average
The highest values in 24 hours: 88,1 mm / 14.07.2000

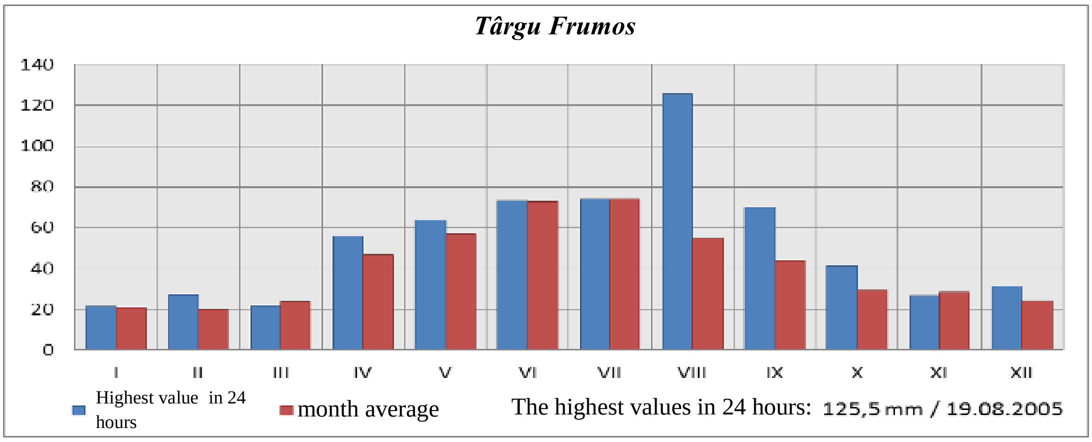

Cristeşti
100
90
80
70
60
50
40
30
20
10
0
y = -0.0373x²+2.0649x+28.93
R² = 0.1779

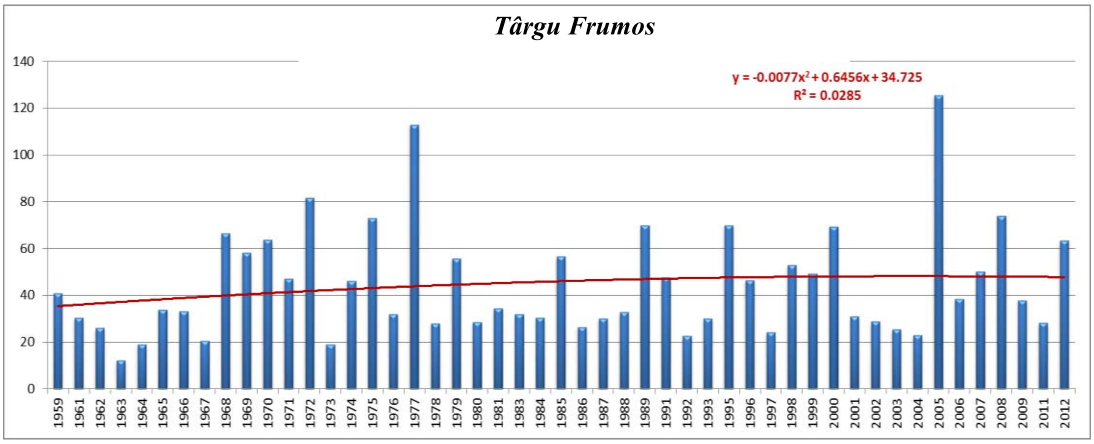

Todireni
120
100
80
60
40
20
0
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Highest value in 24 hours
month average
The highest values in 24 hours: 97,0 mm / 20.07.1974

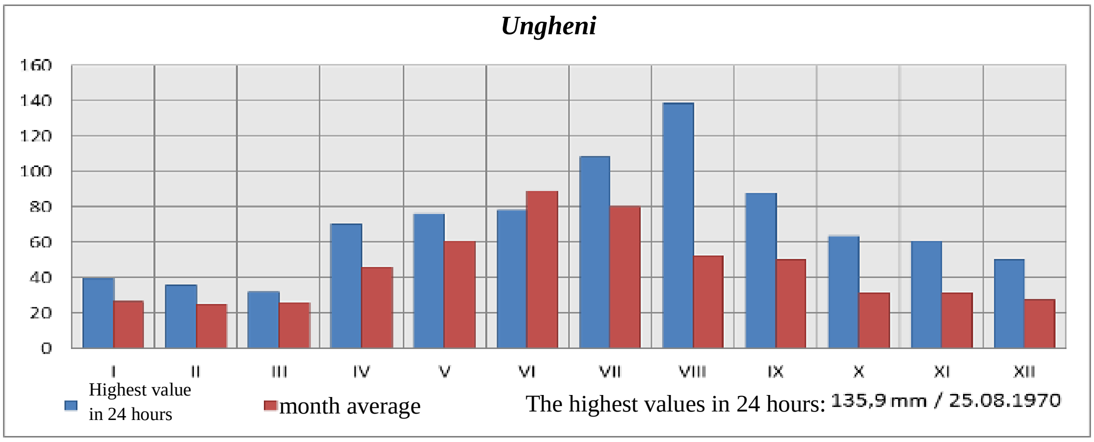

Todireni
y = -0.0211x² + 0.955x + 43.258
R² = 0.0399

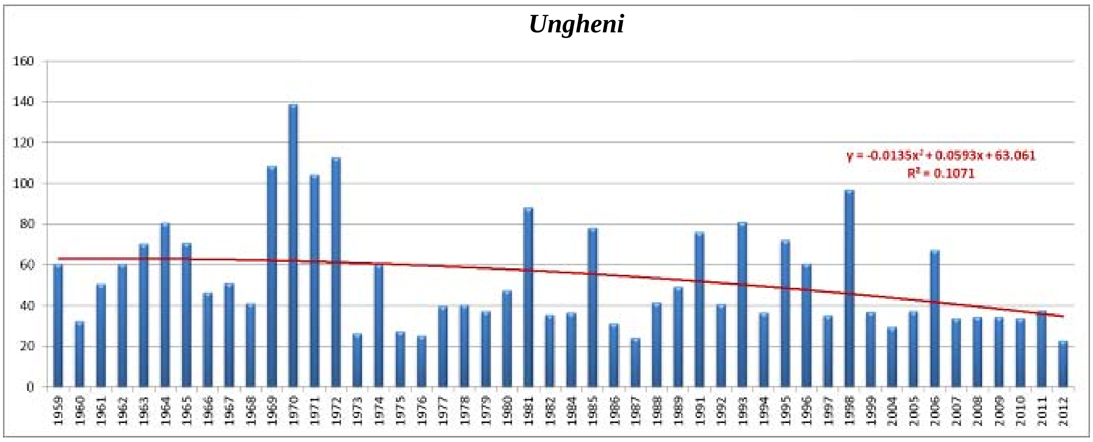

Nicolae Bălcescu
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
Highest value in 24 hours
month average
The highest values in 24 hours: 90,7 mm / 2.07.1971


Nicolae Bălcescu
y = -0.0237x² + 1.1928x + 39.23
R² = 0.0616


Târgu Frumos
Highest value in 24 hours
month average
The highest values in 24 hours: 125,5 mm / 19.08.2005


Târgu Frumos
y = -0.0077x² + 0.6456x + 34.725
R² = 0.0285


Ungheni
Highest value in 24 hours
month average
The highest values in 24 hours: 135,9 mm / 25.08.1970


Ungheni
y = -0.0135x² + 0.0593x + 63.061
R² = 0.1071

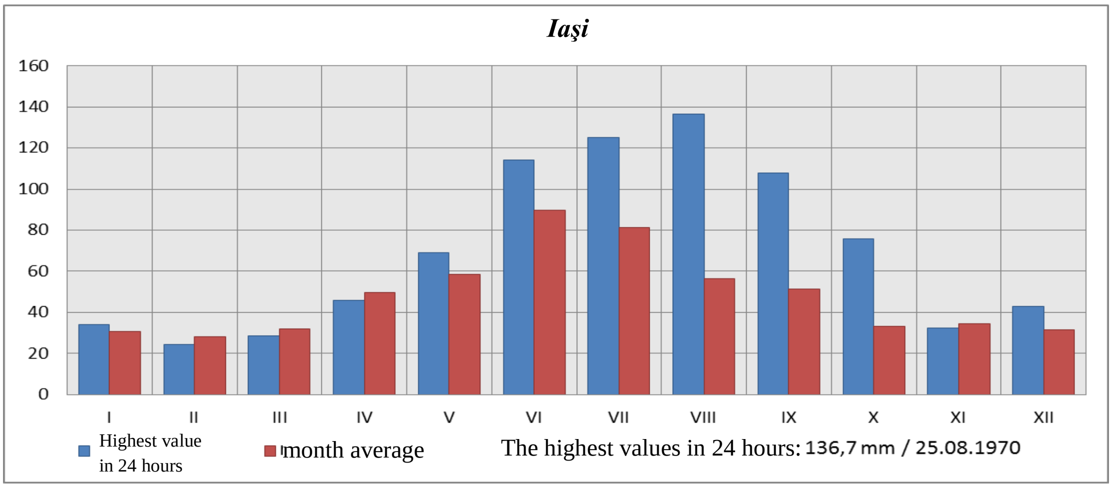


Fig. 5.34 Maximum precipitations quantities in 24 hours at the Moldavian Plain pluviometric posts between 1961-2011

Yearly statistics show that, in the Moldavian Plain, the greatest monthly precipitations quantities in 24 hours, as absolute values, were recorded in August (50% of the cases), June (25% of the cases), May and September (12,5% of the cases each) while the lowest precipitation quantities per month, in 24 hours, were recorded in January (50% of the cases), February (25% of the cases), December and March (12,5% each).

The fact that August-September-October have the highest percentage deviations for the maximum precipitations in 24 hours compared to the monthly sums is explained by the favourable dynamics and thermic situations in the end of summer and beginning of autumn (2/3 of autumn) compared to winter when the thermic convection is insignificant and the atmospheric dynamics of the dry and cold air masses do not favour considerable precipitation quantities.

The analysis of maximums precipitations in 24 hours has a very important role as far as the associated hydrologic processes are concerned. In this way, each rain on a certain interval displays a spatial variation with the individualization of higher precipitations areas compared to the rest of the territory.

The spatial variations of these rains determine, in a direct manner, the discharge mode, in general and the floods behaviour, in particular. The areas of discharge concentration as a result of rain have a bigger water input compared to the rest of the watershed and the hydrograph of the flood that corresponds to a certain rain shows a more accentuated maximum compared to the more uniform theoretical spatialization at the level of the entire watershed. Another characteristic of rain-falls of maximum intensity is given by their movement along with the generating atmospheric fronts, on certain directions with various speeds. For the same rain quantity, with a uniform temporal distribution, the maximum discharges resulted from the atmospheric fronts movement, on the same spring to runoff direction are higher than the ones where fronts move in opposite direction. This fact is to be observed in the case of Bahlui watershed which displays an elongated form on the NW-SE direction which is synchronous with the general direction of atmospheric movements at local level resulting in an increase of discharge for the rivers during abundant rains and increasing the risk of short time floods (flash floods) and inundations with negative effects on certain social and economic objectives and goods.

5.2.10. The snow and the snow cover

The hydrologic regime in the Moldavian Plain is also influenced, in a great extent, by the types of precipitation in different seasons (rains or snows). The precipitations quantity to fall in the cold season, as snow, and their duration is a very important hydrologic parameter. Thus, for the cold season when these characteristics are favourable, then, in spring a prolonged leakage on the intermittent rivers and an abundant leakage on the main streams are assured.

In the studied zone, the snow precipitations fall early (as average) on the north-western high ridge (13-XI) and later in the south-eastern side (Moldavian Plain) (23-XI). The snow cover melt takes place, in average until 21 of March in the lowlands and until 28 of March in the highlands. In this respect the duration of snow fall as probability grows from 118 days to 135 day depending on altitude and latitude (MP).

In the Moldavian Plain, depending on the weather states, the snow cover is expected to reach different thicknesses starting with the first decade of October and until the last decade of April. The snow cover thickness is determined, in the first place, by the air and soil temperatures followed by the snow type (mild or blizzard) and the snow density (*Mihăilă*, 2002).

The average thickness of the snow-cover is relatively small. It grows starting with the beginning of November (0,1 cm) until mid-February when the thickness becomes maximum (13 cm) and lowers until the beginning of April (0,5 cm).

Very thick snow-cover were recorded in January 1936 with 134 cm for the north-western part of the Moldavian Plain and 111 cm for the south-eastern margin on the basis of increased north-western and north ern wind frequencies which bring humid air masses of polar origin. Increased snow quantities fell in the winters of 1953 – 1954, 1961 and 1963.

In average, at the watershed level, the records are between 58 days with snow-cover (Iloaia's Bridge) and 82 days of snow-cover (Strunga) and the average thickness per year reaches 5 cm at Iloaia's Bridge, 6 cm at Iaşi, 7 cm at Cotnari, 8 cm at Strunga and 14 cm at Bârnova.

The highest thickness values of snow-cover were recorded in January 1959 at Iaşi (where the average was 49 cm), January 2002, at Bârnova (average 73 cm), January 1963, at Iloaia's Bridge (average 32 cm), January 1985, at Strunga (average 30 cm). During the year the thickest snow-covers are recorded in the first decade of February (Minea, 2009).

In the specific conditions of the Moldavian Plain there can be important differences in snow-cover thickness as measured at posts located at various altitudes and in distinct physical-geographic conditions. Such an example is the winter of 1999-2000 when at two pluviometric posts with different conditions (Ungheni in the Prut Valley, at 40 meters altitude close enough from the Bahlui and Jijia rivers confluence with similar conditions as the lower Bahlui and Bârnova Valleys, the pluviometric post at the highest altitude) yet the snow thickness being higher at the Bârnova post (395 meters altitude). The differences in snow thickness are considerable. At Bârnova the average for the analyzed period was 23.8 cm while at Ungheni, only 5.61 cm, which demonstrates the role of the altitude in this respect by the different conditions induced to the physical water forms and, implicitly, to its leakage regime (Fig. 5.35).

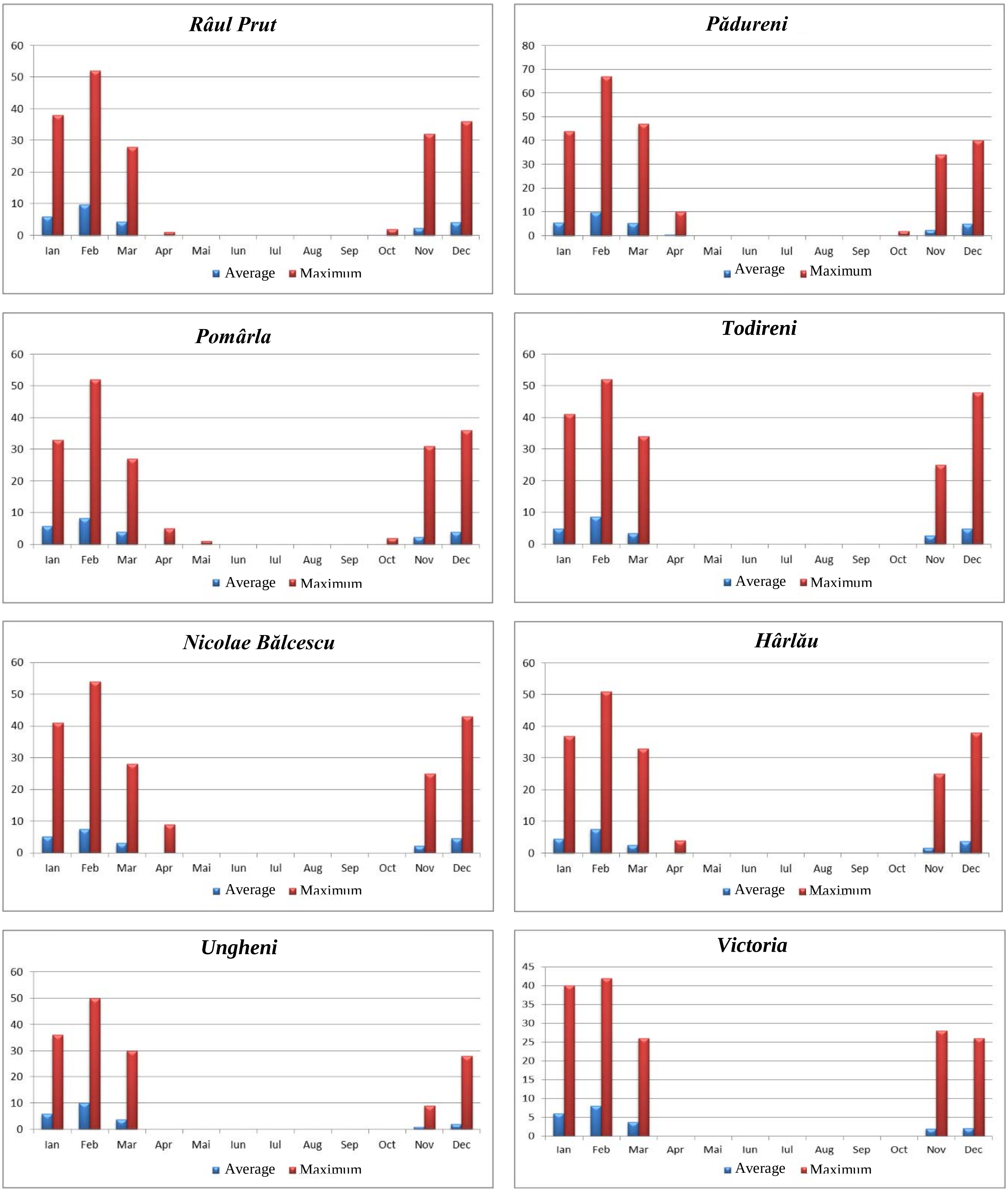


Fig. 5.35 Monthly average and amximum snow-cover at the pluviometric posts of the Moldavian Plain between 1981 and 2011

As a rule, the snow-cover, melts in average with 1 to 11 days earlier then the average date for the last snow; the later snow falls indicate the fact that their consistence does not allow another snow-cover formation that can last, moreover they only have a sequential short duration (*Mihăilă,* 2002).

The latest snows appear in the third decade of April and only in extreme situations there can be events like the one in 14.05.1980 at Dorohoi and Botoşani as a result of a high pressure air mass of Scandinavian-Baltic origin with cold humid character to interfere with a warmer, air depression centred on the Black Sea and the Caspian Sea. At this air masses contact (fig. 5.36) the solid precipitations generated a snow-cover which lasted until the second day, 15.05.1980.

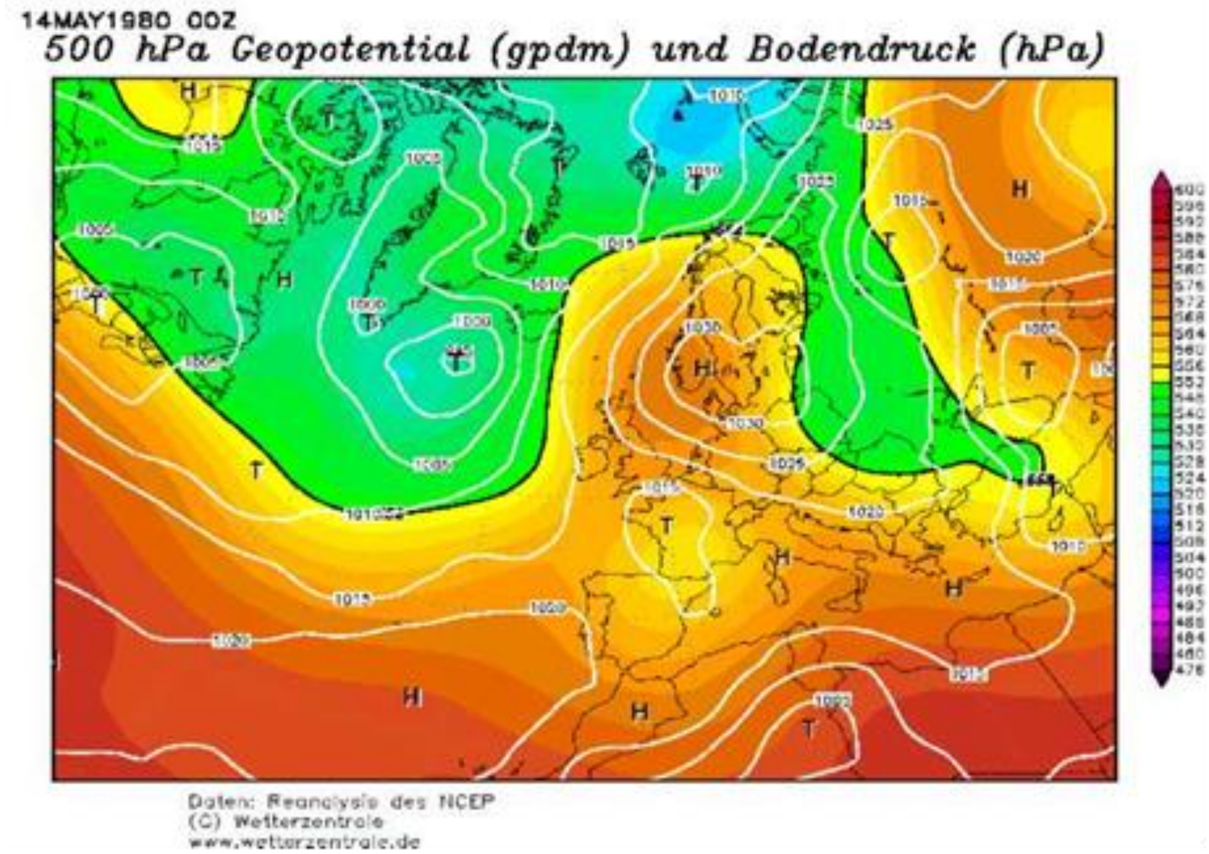


Fig. 5.36 Air pressure distribution reported to ground surface and to the 500hPa isobaric surface level over Europe on 14th of May 1980 - www.wetterzentrale.de

The extreme dates for snow occurrence and snow-cover that are very early or very late in the season are, therefore, a consequence of polar air invasion or polar and subtropical air masses' contact; thus the air masses' contact zones become proper for solid precipitations genesis in favourable thermic conditions that result in consistent snow-cover.

The snow-cover is to melt on an appreciable time interval with a compass, according to calculus, between 69 days at Avrămeni and 102 days at Botoşani while the last snows may occur in large intervals of time, between 55 days at Avrămeni and 89 days at Dorohoi (*Mihăilă*, 2002).

The annual maximum number day with snow probability (as a result of the sum of the earliest and the latest snow), according to records oscillates between 180 days at Iloaia's Bridge and 221 days at Botoşani while the probable snow-cover (calculated in the same way) is between 166 days at Iloaia's Bridge and 210 days at Dorohoi. This values are theoretical, yet based on records of extreme situations, and they show that in favourable weather conditions the snow-cover can last more than a half year, during the cold semester, while the snow falls may last almost half a year resulting in long lasting snow-covers (as in Dorohoi 210 days) (Mihăilă, 2002).

5.2.11. Hydrological modeling – watershed hydrologic modelling behaviour related to rain-fall per surface

5.2.11.1. Precipitations recorded on the hydrographic basin surface

Located in the north-eastern part of Romania, the Moldavian Plain is drained, mainly, by five hydrographic systems: Ghireni, Volovăţ, Başeu, Corogea and Jijia. The Corogea, Volovăţ and Ghireni rivers display their watersheds entirely inside the Moldavian Plain while Başeu river displays its upper watershed, up to 10%, in the Suceava Plateau. The Jijia river receives 80% of the input from the central, western and southern Moldavian Plain and 20% from the eastern heights of the Suceava Plateau and northern Central Moldavian Plateau.

One of the important hydrology approaches refers to the correct evaluation of the meteoric afflux inside a watershed, respectively the precipitations quantity that is received on a certain surface in a certain time interval.

Într-un bazin hidrografic pot exista un număr insuficient de posturi pluviometrice sau acestea pot fi situate doar în zonele accesibile ale acestuia. În plus distribuţia precipitaţiilor pe suprafaţa unui bazin este foarte diferită de la o zonă la alta.Precipitaţiile înregistrate pe un bazin hidrografic reprezintă valori de calcul obţinute, admiţând anumite ipoteze privitor la distribuţia spaţială a precipitaţiilor. Cantităţile de precipitaţii căzute în unitatea de timp sunt maxime în zona nucleului ploii şi descresc neliniar spre periferia ariei cu precipitaţii.

Rain – discharge process scheme

Because the surface of a hydrographic basin receives atmospheric precipitations which turn into liquid discharge this assembly can be viewed as a specific structure system (Pârvulescu, 1978).

The system inputs (watershed) are given by the climatic factors: solar radiation, temperature, atmospheric pressure, humidity, wind and precipitations. The hydrological models take into consideration only the temperatures and the precipitations either in liquid or solid form.

The system's structure. Atmospehric precipitations to fall on a watershed surface, hit, at first instance, the vegetal cover which retains a small quantity of the precipitation and constitutes the interception and, additionally, the depressions with no discharge on those terrains that favour retention. The interception and retention in terrain's depressions, together, form the superficial retention (Giurma, 1987).

The outputs of the hydrographic system consist of: the hydrographic network discharge in the control section (or closing section) of the watershed, the evapo-transpiration at the watershed level inside the all above mentioned sub-systems (vegetation, soil, ground-water and hydrographic network) and the source inputs of some deep ground-waters which do not pertain to the above established system (Giurma, 2000).

The transformation of precipitations in leakage components is rendered in figure 5.37 (Vladimirescu I. 1978). We notice three distinct zones: A the input for the hydrologic system zone; B the proper system zone with subsystems; C the output zone.

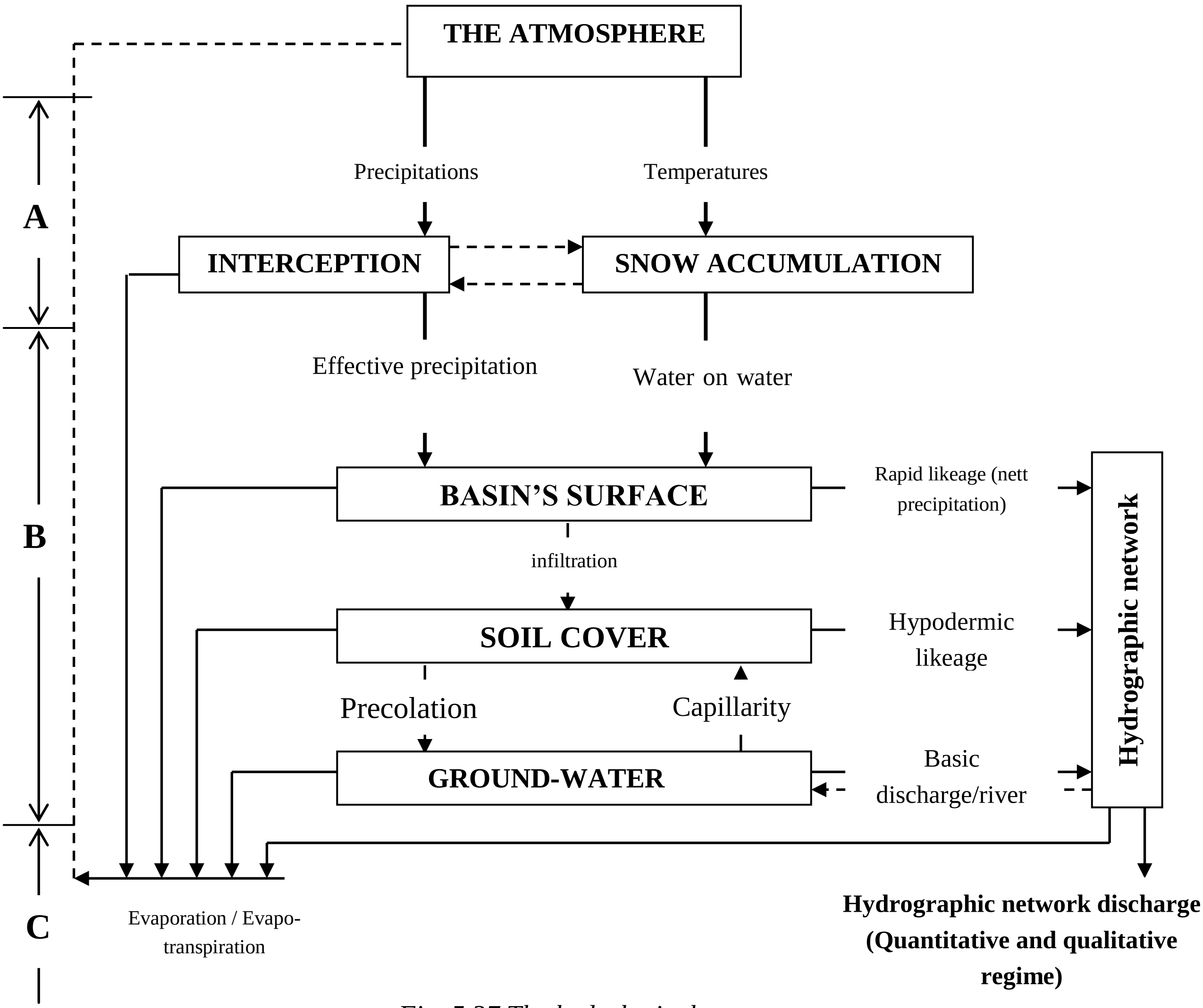


Fig. 5.37 The hydrological system

The hydrologic system can also be represented as in figure 5.38 where the internal processes are not described. Practical reasons of hydrology only consider the hydrological outputs as discharges of th hydrological network and discharge of ground-waters, that is why only the outputs of the hydrographic systems as surface or underground discharge are considered.

Fig. 5.38 The simplified hydrologic system

5.2.11.2. The composite rain – precipitations to generate the events used to calibrate the hydrological parameters

All the above mentioned elements are included in the calculus to model the rain-leakage phenomenon. Depending on the calculus model in use, the level of parameters detailing when calculated might be lowered or leveraged. At present, the experts use different models of calculus. MIKE 11 RR – UHM is one of them and has the advantage of rendering hazard maps as consequence of floods propagation with certain overload probabilities from scattered data. The MIKE 11 RR – UHM model is based on the unitary hydrograph method. The unitary hydrograph method represents the response of the watershed behaviour at a unitary net rain on the watershed surface at one singular event.

The result of the hydrological modelling is a discharge hydrograph calculated in the control section when simulating the behaviour of the hydrographic basin at a certain rain on the basins surface. The hydrological modelling scope is to use the discharge hydrograph as input in the hydraulic model of the main river.

The hydrological modelling activity is realized in three main steps:

- gathering of the input data for topography and geomorphology;
- calibration and validation of the hydrological models with recroded precipitations
- using the precipitations (p%) to run the rain-leakeage models for the watersheds or group of watersheds with S<100 kmp surface to obtain the hydrograph (p%) necessary for the closing/control section.

As input data that are necessary for the modelling activity refreing to rain-leakeage, the following are used (fig. 5.39):

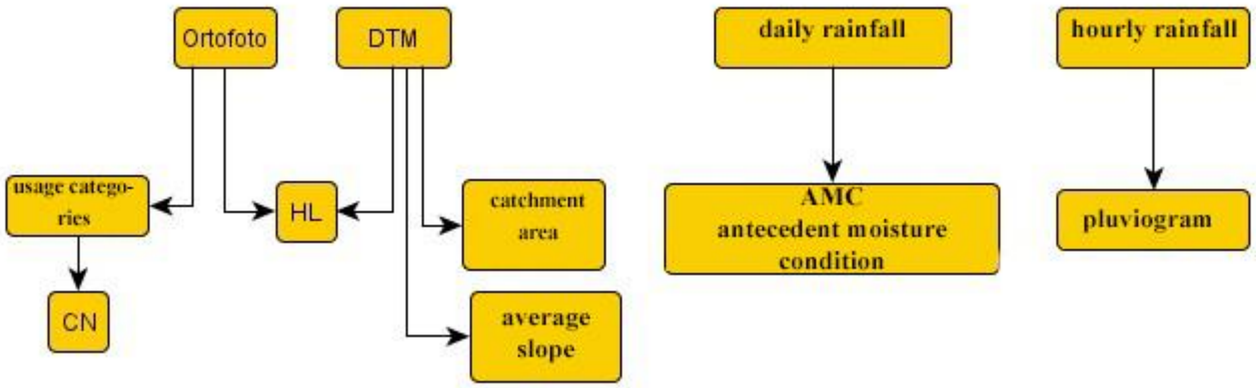


Fig. 5.39 Input data preparation

- the precipitations that generate significant floods with hourly pace at the ANM stations;
- the initial state of the watershed – analysis of diurnal precipitations averages from the ABA archive
- DTM – the terrain digital model used to substract the morphological details for each watershed in order to be hydrologically modelled (surface, average slope, streams' length);
- The land use map used to determine the CN index (Curve Number).

In the Romanian meteorological network the measurement of atmospheric precipitations quantities for the four climatological terms (1,7,13 and 19) are performed with the IMC pluviometric device.

Beside precipitations measurement with the aid of pluviometer, there is a continuous record for the water quantity from liquid precipitations, in the warm interval of the year, with the pluviograph. Usually at the stations in the flat and plateau areas the functioning interval is April to October. The hourly precipitations data are extracted from pluviogrammes.

Pluviogrammes are used to substract and select the greatest information referring to precipitations quantities as part of the annual precipitations' total, on previous established intervals (between 5 and 1440 minutes); the condition is to equal or to exceed the limits imposed by the Berg criterion (e.g.: at least 2.5 mm in 5 minutes, 3.8 mm in 10 minutes or 5.0 mm in 15 minutes). The intensities that correspond to these quantities are obtained applying the following formula:

$i = h / t$

where *h* is the precipitation quantity measured as mm and *t* is the durationof rain measured in minutes

The time intervals for which the pluviogrammes are desciphered are (in minutes)

5	10	15	20	25	30	35	40	45	50	55	60
65	70	75	80	85	90	95	100	105	110	115	120
140	160	180	240	300	360	720	1440				

From the daily total only the records with values that are equal or exceeding, in the given interval times, as former established criteria on quantities are chosen (Berg index).It is worth mentioning that not all the quantities that correspond to time intervals (5 to 1440 minutes) have the same, common, origin. This origin does not coincide, in a compulsory manner with the beginning of the rain and the maximum quantities can be chosen from different rain events and become the so called calculus rains.

The value of maximum annual precipitations with P% overpassing probability depends on the watershed surface and the precipitation duration (considered equal with concentration time).

For small watersheds (< 100 km^2) one may consider that P% results in a flood event with a peak discharge P%. In this instance the first step is to determine the precipitation accumulation that corresponds to an overpass/overload probability (P%) for a time interval that is equal with the concentration time in these watersheds. The overall accumulated precipitation stratum is obtained via statistical processing on the basis of the maximum hourly precipitation at annual level.

For each analyzed watershed one must determine the concentration time and the rain duration which is equal with this value. The composite rain is cantered to the nucleus spot where if the concentration time is 1 hour one must choose line 13 from the composite rain table. If the concentration time is 5 hours one must choose lines 11-15 from the same table (fig. 5.40 - 5.45).

Iasi pluviogramme							
hour	0.10%	0.50%	1%	2%	5%	10%	20%
1	**100.9**	**69.9**	**59.6**	**51.5**	**42.0**	**35.3**	**28.9**
2	118.1	81.8	69.8	60.3	49.2	41.3	33.8
3	132.6	91.9	78.3	67.7	55.2	46.4	38.0
4	146.1	101.2	86.3	74.5	60.8	51.1	41.8
5	158.5	109.8	93.6	80.9	66.0	55.5	45.4
6	170.0	117.8	100.4	86.8	70.8	59.5	48.7
7	180.6	125.1	106.7	92.2	75.2	63.2	51.7
8	190.3	131.9	112.4	97.2	79.2	66.6	54.5
9	199.2	138.0	117.7	101.7	82.9	69.7	57.1
10	207.4	143.7	122.5	105.8	86.3	72.5	59.4
11	214.7	148.8	126.8	109.6	89.4	75.1	61.5
12	221.4	153.4	130.8	113.0	92.2	77.5	63.4
13	227.4	157.5	134.3	116.1	94.7	79.6	65.1
14	232.8	161.3	137.5	118.8	96.9	81.5	66.7
15	237.7	164.6	140.4	121.3	98.9	83.1	68.1
16	242.0	167.6	142.9	123.5	100.7	84.6	69.3
17	245.8	170.3	145.2	125.4	102.3	86.0	70.4
18	249.1	172.6	147.2	127.2	103.7	87.2	71.4
19	252.1	174.6	148.9	128.7	104.9	88.2	72.2
20	254.7	176.4	150.4	130.0	106.0	89.1	73.0
21	257.0	178.0	151.8	131.2	107.0	89.9	73.6
22	259.0	179.4	153.0	132.2	107.8	90.6	74.2
23	260.8	180.7	154.0	133.1	108.6	91.2	74.7

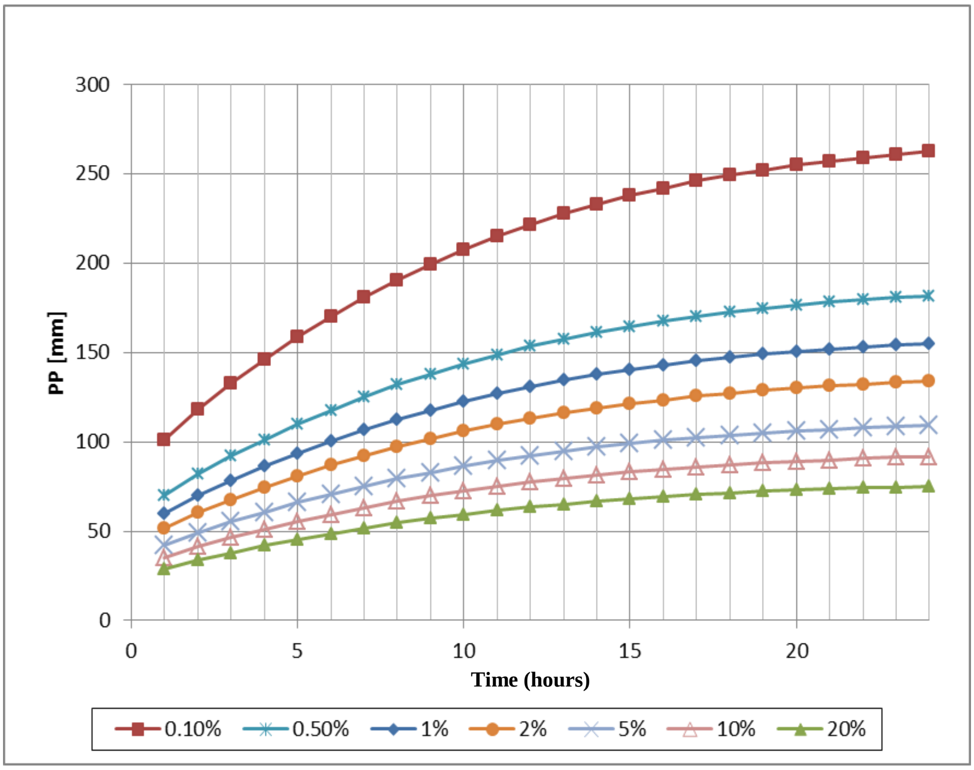


Fig. 5.40 The tabelar and graphical pluviogramme calculated for Iaşi meteorological satation at different occurance probabilities

Iasi composite rain							
hour	0.10%	0.50%	1%	2%	5%	10%	20%
1	1.59	1.10	0.94	0.81	0.66	0.56	0.46
2	2.01	1.40	1.19	1.03	0.84	0.70	0.58
3	2.61	1.81	1.54	1.33	1.08	0.91	0.75
4	3.37	2.33	1.99	1.72	1.40	1.18	0.96
5	4.30	2.98	2.54	2.19	1.79	1.50	1.23
6	5.40	3.74	3.19	2.76	2.25	1.89	1.55
7	6.67	4.62	3.94	3.41	2.78	2.33	1.91
8	8.11	5.62	4.79	4.14	3.38	2.84	2.32
9	9.73	6.74	5.74	4.96	4.05	3.40	2.79
10	11.51	7.97	6.80	5.87	4.79	4.03	3.30
11	13.46	9.32	7.95	6.87	5.60	4.71	3.85
12	17.20	11.92	10.16	8.78	7.16	6.02	4.93
13	100.90	69.90	59.60	51.50	42.00	35.30	28.90
14	14.50	10.04	8.56	7.40	6.03	5.07	4.15
15	12.46	8.63	7.36	6.36	5.19	4.36	3.57
16	10.60	7.34	6.26	5.41	4.41	3.71	3.03
17	8.90	6.16	5.26	4.54	3.70	3.11	2.55
18	7.37	5.11	4.35	3.76	3.07	2.58	2.11
19	6.02	4.17	3.55	3.07	2.50	2.10	1.72
20	4.83	3.35	2.85	2.46	2.01	1.69	1.38
21	3.81	2.64	2.25	1.95	1.59	1.33	1.09
22	2.97	2.05	1.75	1.51	1.23	1.04	0.85
23	2.29	1.59	1.35	1.17	0.95	0.80	0.66
24	1.78	1.23	1.05	0.91	0.74	0.62	0.51

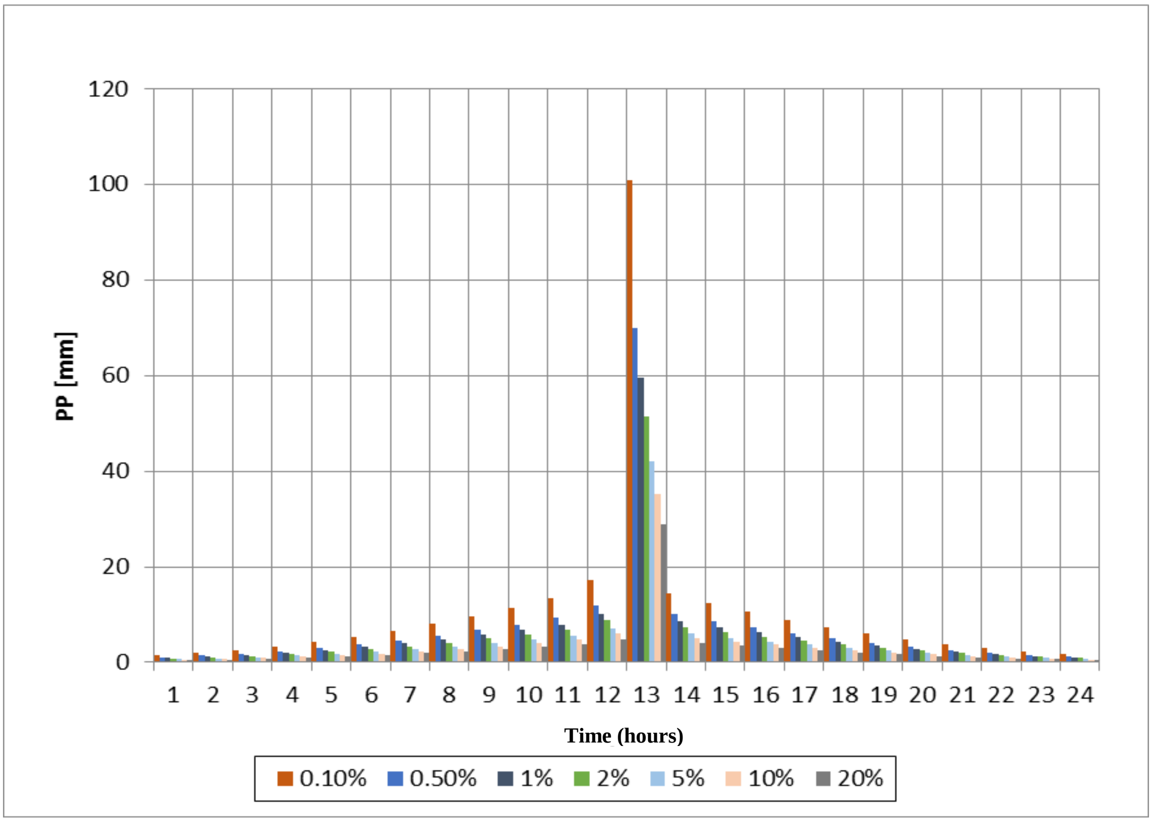


Fig. 5.41 The tabelar and graphical composite rain calculated for Iaşi meteorological satation at different occurance probabilities

Cotnari pluviogramme							
hour	**0.10%**	**0.50%**	**1%**	**2%**	**5%**	**10%**	**20%**
1	148.3	93.8	76.6	63.6	48.6	38.7	29.9
2	169.3	107.1	87.5	72.6	55.5	44.2	34.1
3	187.1	118.3	96.6	80.2	61.3	48.8	37.7
4	203.5	128.7	105.1	87.3	66.7	53.1	41.0
5	218.8	138.4	113.0	93.8	71.7	57.1	44.1
6	232.8	147.3	120.3	99.8	76.3	60.8	46.9
7	245.8	155.4	126.9	105.4	80.5	64.1	49.5
8	257.6	163.0	133.1	110.5	84.4	67.2	51.9
9	268.5	169.9	138.7	115.2	88.0	70.1	54.1
10	278.5	176.2	143.9	119.4	91.3	72.7	56.2
11	287.6	181.9	148.6	123.3	94.3	75.1	58.0
12	295.9	187.2	152.9	126.9	97.0	77.2	59.7
13	303.5	192.0	156.8	130.2	99.5	79.2	61.2
14	310.4	196.3	160.3	133.1	101.7	81.0	62.6
15	316.7	200.3	163.6	135.8	103.8	82.6	63.8
16	322.4	203.9	166.5	138.3	105.7	84.1	65.0
17	327.7	207.2	169.2	140.5	107.4	85.5	66.1
18	332.5	210.3	171.7	142.6	109.0	86.8	67.0
19	336.9	213.1	174.0	144.5	110.4	87.9	67.9
20	341.1	215.7	176.2	146.3	111.8	89.0	68.8
21	345.0	218.2	178.2	148.0	113.1	90.0	69.6
22	348.8	220.6	180.1	149.6	114.3	91.0	70.3
23	352.4	222.9	182.0	151.1	115.5	92.0	71.0
24	356.0	225.1	183.9	152.7	116.7	92.9	71.8

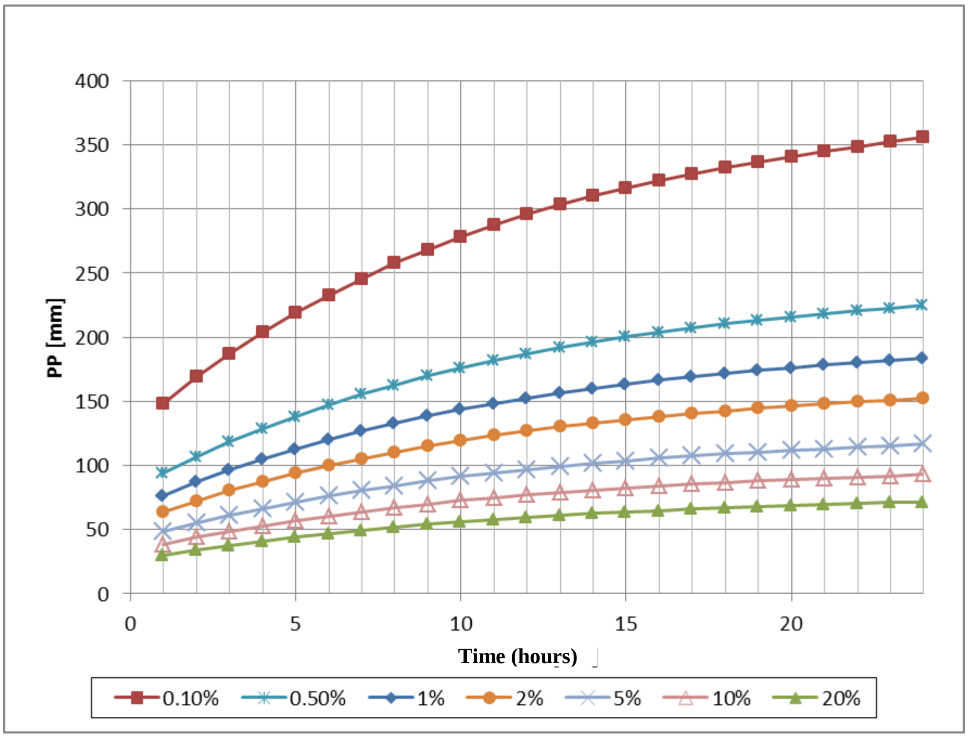


Fig. 5.42 The tabelar and graphical pluviogramme calculated for Cotnari meteorological satation at different occurance probabilities

Cotnari composite rain							
hour	0.10%	0.50%	1%	2%	5%	10%	20%
1	3.58	2.27	1.85	1.54	1.17	0.93	0.72
2	3.74	2.37	1.93	1.61	1.23	0.98	0.76
3	4.16	2.63	2.15	1.78	1.36	1.08	0.84
4	4.82	3.05	2.49	2.07	1.58	1.26	0.97
5	5.73	3.63	2.96	2.46	1.88	1.50	1.16
6	6.90	4.36	3.56	2.96	2.26	1.80	1.39
7	8.31	5.26	4.29	3.56	2.72	2.17	1.68
8	9.97	6.31	5.15	4.28	3.27	2.60	2.01
9	11.89	7.52	6.14	5.10	3.89	3.10	2.40
10	14.05	8.89	7.26	6.03	4.60	3.67	2.83
11	16.46	10.41	8.50	7.06	5.40	4.30	3.32
12	21.02	13.30	10.86	9.01	6.89	5.49	4.24
13	148.30	93.80	76.60	63.60	48.60	38.70	29.90
14	17.76	11.24	9.18	7.62	5.82	4.64	3.58
15	15.22	9.63	7.86	6.53	4.99	3.97	3.07
16	12.94	8.18	6.68	5.55	4.24	3.38	2.61
17	10.90	6.89	5.63	4.67	3.57	2.84	2.20
18	9.11	5.76	4.70	3.91	2.99	2.38	1.84
19	7.57	4.79	3.91	3.25	2.48	1.98	1.53
20	6.28	3.97	3.25	2.69	2.06	1.64	1.27
21	5.24	3.32	2.71	2.25	1.72	1.37	1.06
22	4.46	2.82	2.30	1.91	1.46	1.16	0.90
23	3.92	2.48	2.02	1.68	1.28	1.02	0.79
24	3.63	2.30	1.88	1.56	1.19	0.95	0.73

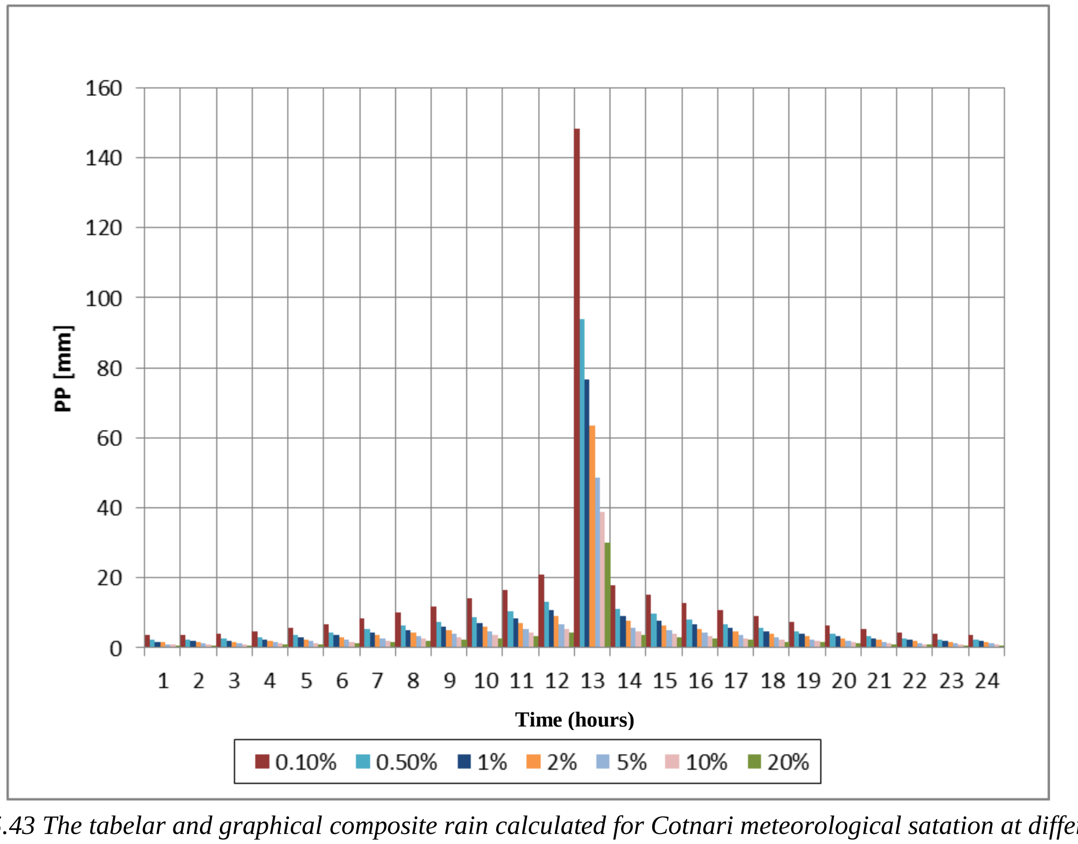


Fig. 5.43 The tabelar and graphical composite rain calculated for Cotnari meteorological satation at different occurance probabilities

Botoşani pluviogramme							
hour	**0.10%**	**0.50%**	**1%**	**2%**	**5%**	**10%**	**20%**
1	122.2	85.2	73.0	61.9	48.7	39.6	31.3
2	139.5	97.3	83.3	70.7	55.6	45.2	35.7
3	154.2	107.5	92.1	78.1	61.4	50.0	39.5
4	167.7	116.9	100.2	85.0	66.8	54.4	43.0
5	180.3	125.7	107.7	91.3	71.8	58.4	46.2
6	191.8	133.8	114.6	97.2	76.5	62.2	49.1
7	202.5	141.2	121.0	102.6	80.7	65.6	51.9
8	212.3	148.0	126.8	107.5	84.6	68.8	54.4
9	221.3	154.3	132.2	112.1	88.2	71.7	56.7
10	229.5	160.0	137.1	116.2	91.5	74.4	58.8
11	237.0	165.2	141.6	120.1	94.5	76.8	60.7
12	243.8	170.0	145.7	123.5	97.2	79.0	62.5
13	250.1	174.4	149.4	126.7	99.7	81.0	64.1
14	255.8	178.3	152.8	129.6	101.9	82.9	65.5
15	260.9	181.9	155.9	132.2	104.0	84.6	66.8
16	265.7	185.2	158.7	134.6	105.9	86.1	68.0
17	270.0	188.2	161.3	136.8	107.6	87.5	69.2
18	274.0	191.0	163.7	138.8	109.2	88.8	70.2
19	277.6	193.6	165.9	140.6	110.6	90.0	71.1
20	281.1	196.0	167.9	142.4	112.0	91.1	72.0
21	284.3	198.2	169.8	144.0	113.3	92.1	72.8
22	287.4	200.4	171.7	145.6	114.5	93.1	73.6
23	290.4	202.4	173.5	147.1	115.7	94.1	74.4
24	293.3	204.5	175.2	148.6	116.9	95.1	75.1

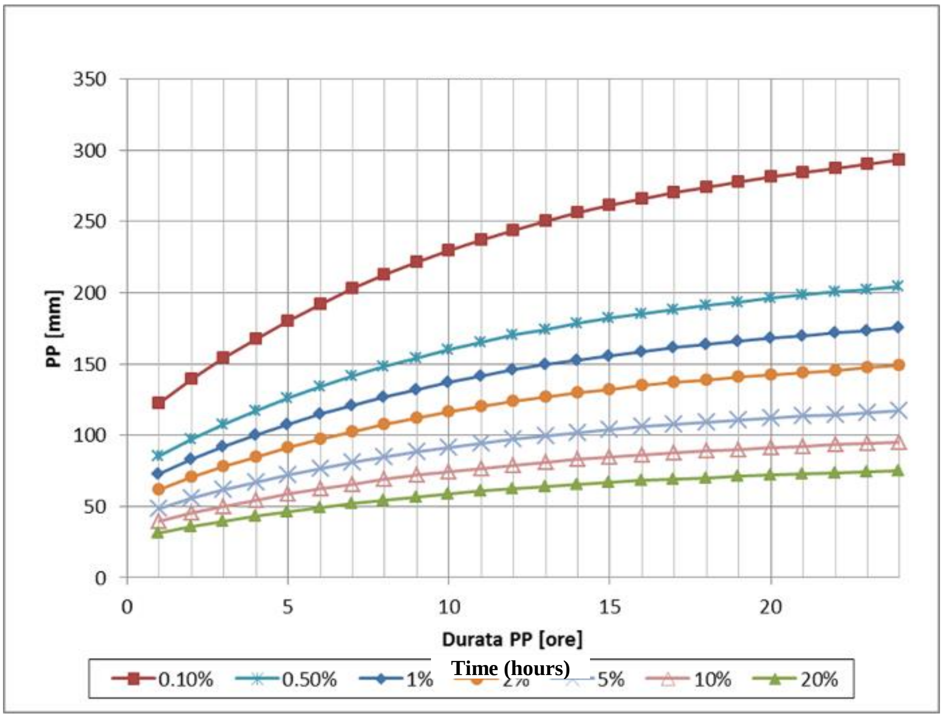


Fig. 5.44 The tabelar and graphical pluviogramme calculated for Botoşani meteorological satation at different occurance probabilities

Botoşani composite rain							
hour	0.10%	0.50%	1%	2%	5%	10%	20%
1	2.95	2.06	1.76	1.50	1.18	0.96	0.76
2	3.09	2.15	1.84	1.56	1.23	1.00	0.79
3	3.43	2.39	2.05	1.74	1.37	1.11	0.88
4	3.97	2.77	2.37	2.01	1.58	1.29	1.02
5	4.72	3.29	2.82	2.39	1.88	1.53	1.21
6	5.68	3.96	3.39	2.88	2.26	1.84	1.46
7	6.85	4.77	4.09	3.47	2.73	2.22	1.75
8	8.22	5.73	4.91	4.16	3.27	2.66	2.10
9	9.79	6.83	5.85	4.96	3.90	3.17	2.51
10	11.58	8.07	6.92	5.86	4.61	3.75	2.97
11	13.57	9.46	8.10	6.87	5.41	4.40	3.47
12	17.32	12.08	10.35	8.77	6.90	5.61	4.44
13	122.20	85.20	73.00	61.90	48.70	39.60	31.30
14	14.64	10.21	8.74	7.41	5.83	4.74	3.75
15	12.55	8.75	7.49	6.35	5.00	4.07	3.21
16	10.66	7.43	6.37	5.40	4.25	3.45	2.73
17	8.98	6.26	5.36	4.55	3.58	2.91	2.30
18	7.51	5.23	4.48	3.80	2.99	2.43	1.92
19	6.24	4.35	3.73	3.16	2.49	2.02	1.60
20	5.18	3.61	3.09	2.62	2.06	1.68	1.33
21	4.32	3.01	2.58	2.19	1.72	1.40	1.11
22	3.67	2.56	2.19	1.86	1.46	1.19	0.94
23	3.23	2.25	1.93	1.64	1.29	1.05	0.83
24	2.99	2.09	1.79	1.52	1.19	0.97	0.77

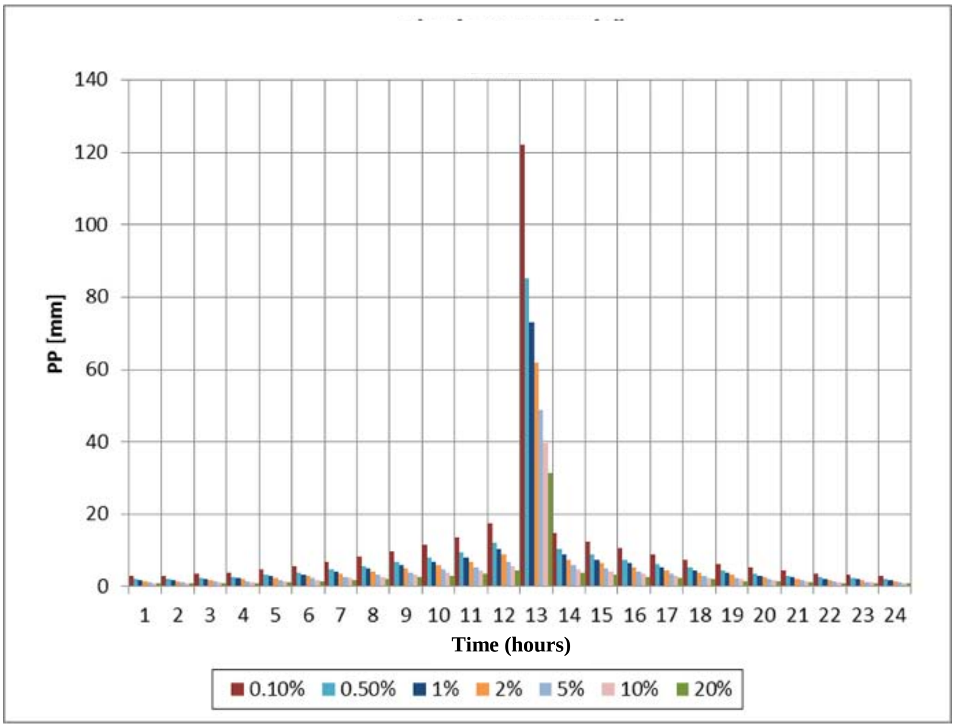


Fig. 5.45 The tabelar and graphical composite rain calculated for Botoşani meteorological satation at different occurance probabilities

6. The hydrographic features of the Moldavian Plain

6.1. Subterannean waters characterization

The subterranean waters represent all the type of waters under the surface of the terrain either in the saturation zone or in direct contact with the soil and sub-soil. These are aquifer accumulations within one or more geological strata with adequate porosity and permeability that enables a significant leakage of the subterranean waters or their capture as representative quantities.

In certain Romanian aquifers where the recorded data were sufficient the water bodies were delimitated as distinct bodies of subterranean water units or distinct aquifers as parts of units.

On the moldavian Plain territory 3 subterannean water bodies were delineated and described (Bretotean et al. 2006):

ROPR01 / the Upper Prut Meadow

ROPR02 / the Meadow and the terraces of mid-lower Prut and the tributaries

ROPR07 / the Moldavian Plain

All the three water bodies that were identified pertain to the porous type and are accumulated in Quaternary and Sarmatian-Pontian deposits. They were delimitated in meadow areas and terraces and developed in alluvial and fluvial deposits, of porous-permeable type of Quaternary age. The subterannean water are close to the surface level which is why they are of free movement type.

6.1.1. The Upper Prut Meadow subterannean water body

The Upper Prut Meadow body water is of porous-permeable type and pertains to Holocene and develops in the Prut alluvial plain on the northern side of Romania (the Oroftiana – Rădăuţi Prut zone).

The deposits of the phreatic aquifer in the Upper Prut alluvial plain consist in fine and medium sands, along with gravels of 2-5 meters thick. The cover stratum consists in caly and siltitic sands or clay-sands with discontinuous distribution and with thicknesses of 5 to 7 meters. The freatic waters are free movement waters and the source of alimentation resides in precipitations and, to a smaller extent, in river water infiltrations. The efficent infiltration value is between 15 and 32 mm/year.

The Piper and Scholler diagrams (figure 6.1) resulted from the geological drills chemical analysis in the National Hydrological Network show that the waters are loaded with calcium bicarbonated and sulphate – magnesite.

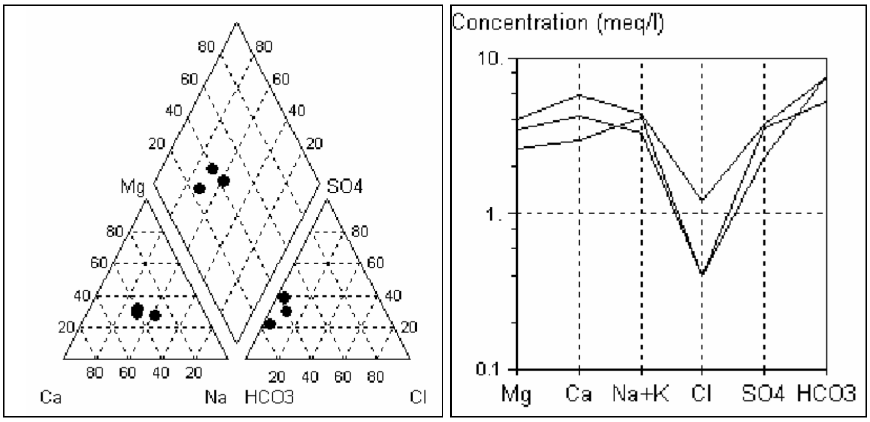


Fig. 6.1 Piper and Scholler diagrams resulted from the geological drills chemical analysis in the National Hydrological Network

The Upper Prut Meadow water body (ROPR01) is covered by 55% cultivated terrains and 24% forested terrains as it results from the land-use map (fig. 6.2)

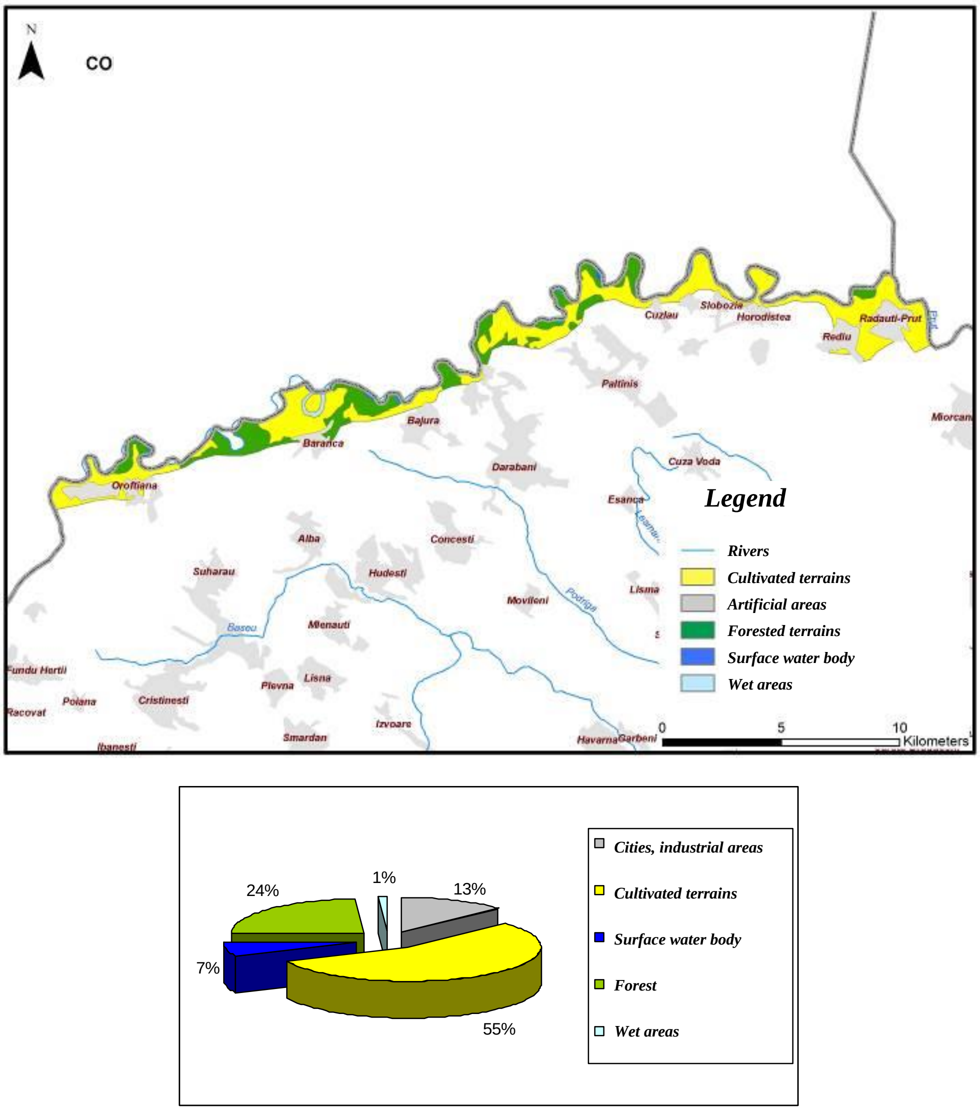


Fig. 6.2 Land-use for ROPR01- Upper Prut Meadow subterannean water body (data of ABA Prut-Bârlad – the Prut-Bârlad Watersheds Administration)

6.1.2. Middle and Lower Prut meadow and terraces subterannean water-body

The subterranean water-body locations is in the meadow and the terraces of the Prut river and its; tributaries and represents porous-permeable quaternary deposits. In the Jijia river meadow and the tributaries the phreatic aquifer consists in fine sands and clay sands with gravel intercalations. The discharges oscillate in wide limits depending on the aquifer's lithology. Increased discharge appears in the Truşeşti zone where the alluvial deposits at 3 to meters below ground sustain a 2 litre per second discharge (in fine and medium and deposits and gravels and 5 meters oscillations of the deposits profile). The filtration coefficients of Upper Jijia oscillate between 2 and 14 meters per day.

In the Middle Jijia sector the aquifer consists in fine sandy-clay and medium to coarse sized sands between 2 and 8 meters depth.

In the Volovăţ alluvial plain the aquifer consists in fine sands between 5 and 6 meters. The phreatic waters of the Başeu alluvial plain lie at a reduced depth (only 2 meters). At the level of certain caly and fine sand deposits in the Başeu meadow and its tributaries the aquifer rests at 1+3 meters depth while those below the alluvial clay deposits at approximately 5 meters.

The Sitna river alluvial plain generates discharges of 2 litres per second where the oscillation of the profile is 2.5 meters. The alluvial deposits consist in sand, at 10-12 meters in the Bodeşti area where the phreatic aquifer is under pressure.

At Săveni, in the Podriga's alluvial plain the fine sands appear at 8-12 meters depth with discharges of 1 litre per second and a 3 meters profile oscillation. The phreatic aquifer here is fed exclusively from precipitations and is a weak source of water.

In the Prut meadow the phreatic aquifer resides in fine silt sands with rare gravel intercalations. The deposits have 2-10 meters thickness and the thickest deposits are located at the hydro-geological stations in Cârniceni I and Costuleni.

The granulometric composition of the deposits displays vertical and horizontal oscillations from fine sands to medium and coarse sands with scattered gravel intercalations.

The phreatic aquifer horizon is covered (to a great extent) by impermeable or semi-permeable clay, clay-silts and siltitic clays with 5 to 10 meters average thickness and maximums of 20 meters. Due to the low permeability of cover deposits the water level becomes ascensional with rare artesian character at maximum levels.

The depth of the aquifer horizon is between 3-4 meters (at Măstăcani) and lowers, progresively where at Fălciu-Vetrişoaia reaches 7-16 meters (fig. 6.3).

The hydrostatic level in the Prut alluvial plain oscillates between 0 and 2 meters. On the terraces and the high fields the depth grows markedly and reaches 10-20 meters.

The nature of the deposits and the discharges are fluctuant from one sector to another. In the alluvial plain that pertains to Iaşi region the alluvial deposits are at 1.5 meters to 15 meters depth and consist in fine, medium and coarse sands with gavels base.

The inferior Prut terrace consists in sands, gravel and boulders. The hydro-geological parameters display the following values: filtration coefficients between 0.5-10 meters per day, trasmissivity between 1-50 m^2/day and specific discharges under 1 litre/s/m.

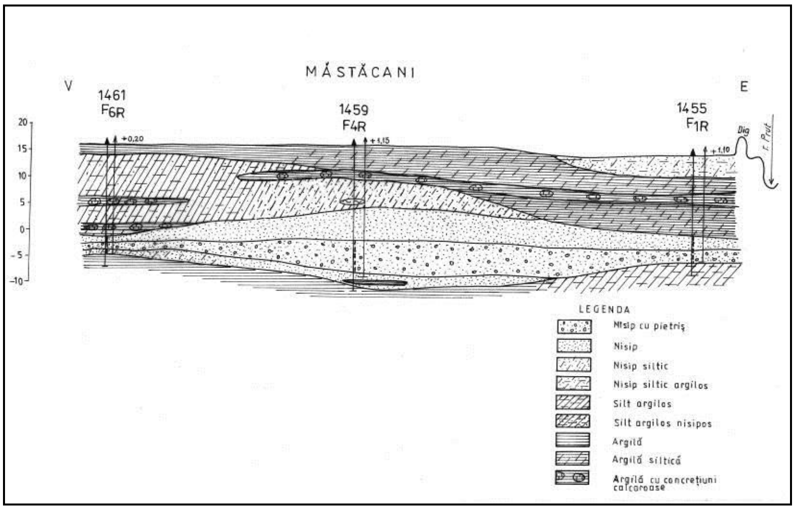


Fig. 6.3 Hydro-geological profile (W-E) through the drills in the Middle and Lowwer Prut meadow and terraces

6.1.3. The Moldavian Plain subterannean water-body

The subterranean water-body is of porous and permeable type and resides in the Upper Volhinian and Lower Bessarabian deposits. The Upper Volhinian and Lower Bessarabian deposits consist of clays and marl-clays with sand, sand-gravel and sandstone (rarely oolitic) intercalations.

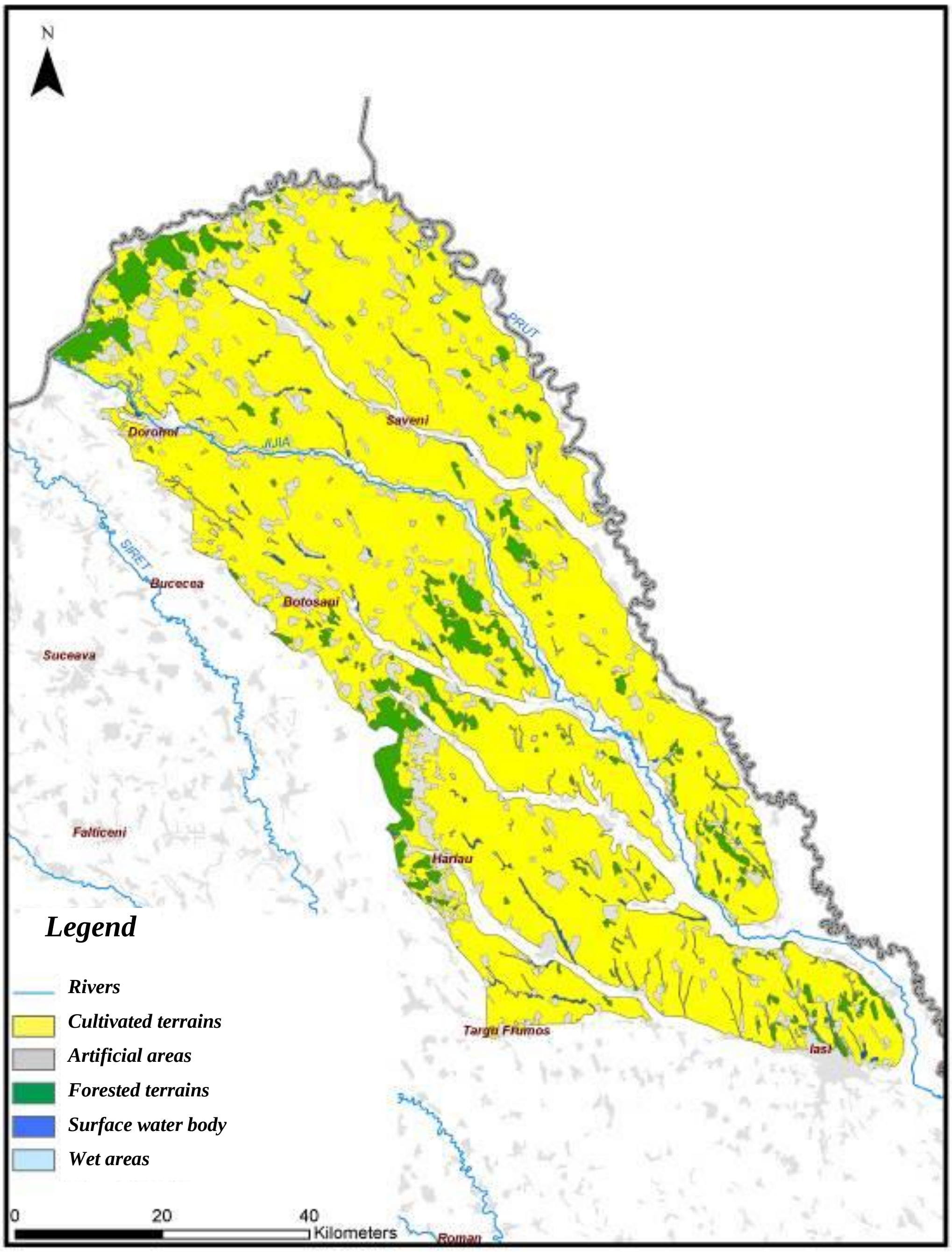
Even if the predominant lithology consists in clay material there are distinct zonal characteristics. Thus, the presence of sands intercalations is more frequent east from Jijia. Here we have sand intercalation with tuphous aspect. In the Jijia-Sitna interfluve the intercalations appear very rarely and thin profiles.

This aquifer presents important variations concerning the discharge capacities and consists in a porous-permeable horizon with sands, gravel-sands, usually at 15 meters depth where it can only be intercepted in wells and drills of lower depth in close relation with the surface waters and prone to pollution. The hydrostatic level is between 2 and 5.4 meters.

The phreatic aquifer was intercepted in 5 drills across Botoşani area. Their depth is 8.5 meters to 11.9 metres with discharges that oscillate between 3.3 and 13.6 litres per second and profile variations of 0.7 to 3 meters.

In the Coşuleni-Băluşeni area the phreatic aquifer in villagers wells of 7 to 15 metres depth display a 1 to 12 meters hydrostatic level.

For the ROPR07-Moldavian Plain subterranean water-body residing in the Sarmatian deposits, the land-use map (figure 6.4) indicates that 82% of this subterranean water surface is covered by agricultural terrains.



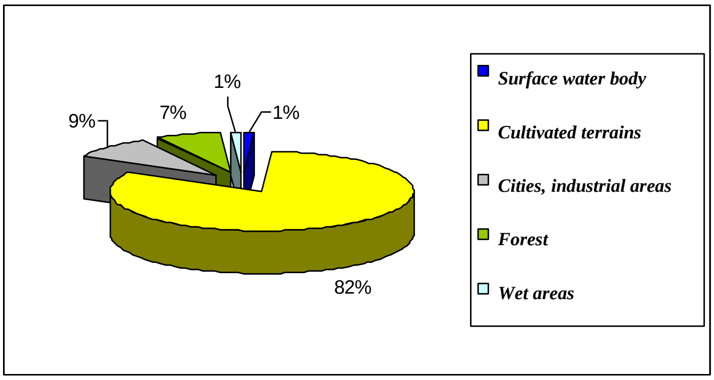


Fig. 6.4 Land-use for the ROPR07-Moldavian Plain subterannean water-body

6.2. The hydrographic network

The hydrological regime depends to a great extent on the hydrological network which constitutes an important assembly that limits the influence of the geographical factors. The dimensional characteristics of the rivers and of the source watersheds influence the volume of the received precipitations and the necessary time for main streams catchment and watershed output. These characteristics impose, finally, the volume of the liquid discharge.

6.2.1. The hydrographic network scheme

As compared to the Carpathian range the river in the present study pertain to the eastern group of the Prut hydrographic basin. On the basis of the hydrographic systems classifications that refer to tributaries' association model, for Romania, T. Morariu et. al. (1962) we conclude that the above mentioned rivers are organized in a dendritic geometry. In most of the cases the river junctions are in narrow angles and oriented to the main stream effluence direction.

Apart from of the discharge character the water courses length is 11,000 km, where 3000 km are permanent streams, approximately 6000 km are semi-permanent and almost 2000 km are intermittent streams. Amongst the Moldavian Plain rivers there is Jijia with 282.6 km, Bahlui 110.6 km, Başeu 106 km, Sitna 69.3 km, Volovăţ 52 km, Bahlueţ 50.1 km while other streams do not exceed 50 kilometres (fig. 6.5).

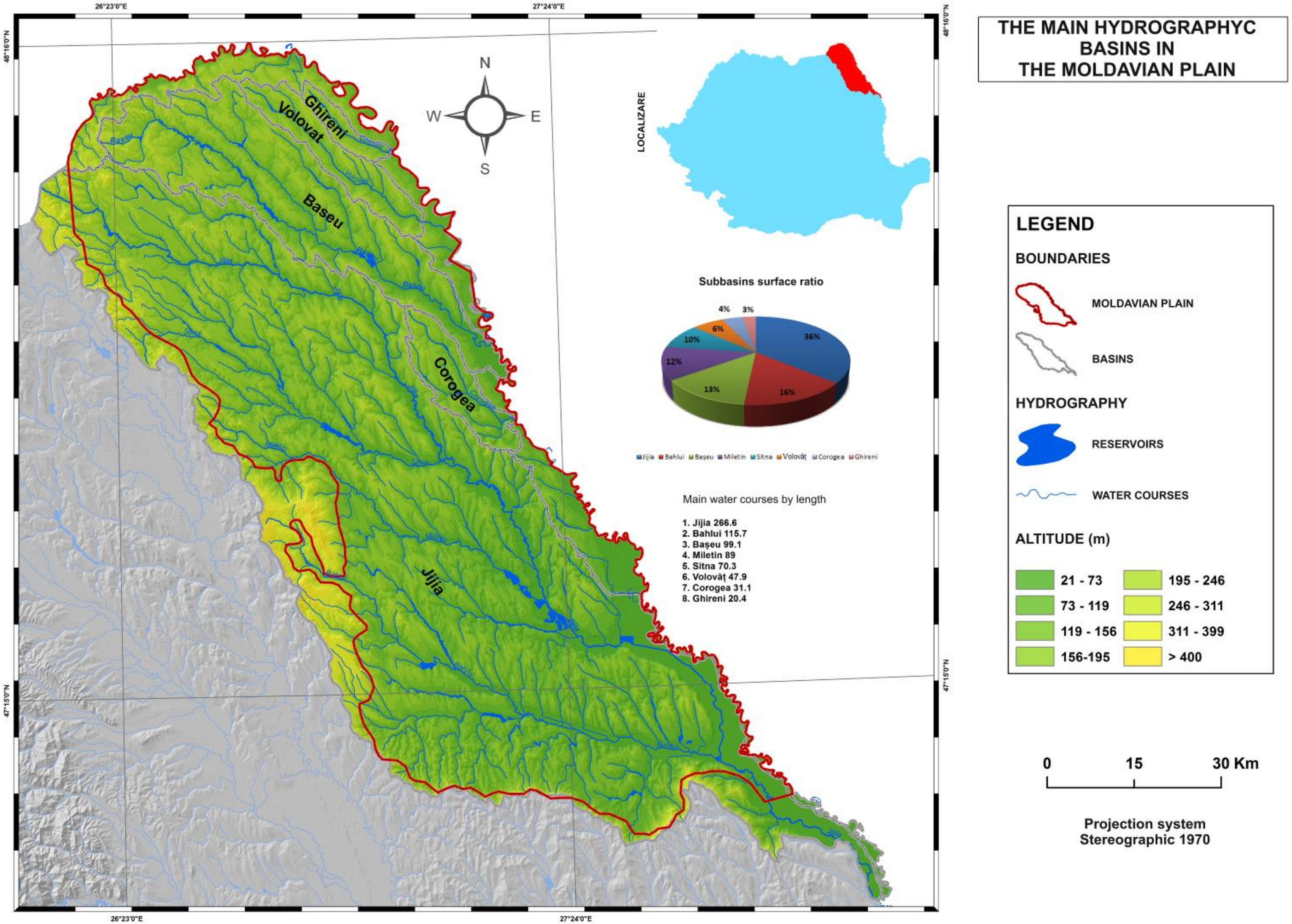


Fig. 6.5 The main hydrographic basisns in the Moldavian Plain

6.2.2. The morphometric and morphographic characterization of the hydrographic basins

6.2.2.1. Watershed ridges

The Moldavian Plain is limited to the south and west by the Siret hydrographic basin by ridges that pertain to the eastern extremity of the Upper Moldavian Plateau. The basin's water ridge, in this area consists in a succession of imposing heights (over 200 meters in the south and over 300 meters in the west) with insular prominent peaks of over 400 meters in the south (Păun Hill, 404 meters) and over 500 meters in the west (590 meters in Great Hill and Tudora heights).

Between the Prut river tributaries the ridge/watershed is well represented with 1-2 km interfluves in certain situations and marked by prominent peaks of over 200 meters altitude as in the northern half of the Moldavian Plain, fig. 6.6.

The main Prut tributaries effuse under narrow angles (lower than 45°) after a parallel trajectory with double bed streams on tens of kilometres (70 km for Jijia in the Prut alluvial plain). In these lower sectors, the main collectors are separated from Prut River by a 5 meters longitudinal grid of heights (M. Pantazică, 1974).

The watershed (ridge) has few sectors of low resistence where it loses it's prominant character and may be overpassed (overspill) at maximum discharges. Thus, in the western region, to the Suceava Plateau the separation line between Siret and Prut in highly unstable. This situation results mainly from a reduced relative altitude of 130 meters which separates the two main alluvial fields at the same latitude (V. Băcăuanu, 1968).

The base-level lowering for the rivers in the right Mid-Prut basin suffers from regressive erosion and advance to the left Siret basin. This process, where Prut river increases its basin narrowing the Siret basin, was causally analyzed by numerous geographers (V. Mihăilescu, 1930; V. Tufescu, 1932, 1937; C. Martiniuc and V. Băcăuanu, 1962).

This type of sectors where the watershed (ridge) presents an high degree of instability is to be observed in the Lozna Saddle (between Bahlui and Bahnei tributaries) and was described by V. Tufescu in 1983. Between the two afluents there is a portion of surface waters of unstable discharge direction.

To the south, in the Bucecea Saddle sector, the streams of Upper Sitna basin advanced in the Siret alluvial plain (V. Mihăilescu, 1930). This sector stands for future catchment area. On the basis of this assumption C. Mateescu proposed a project for a hydro-power station construction in the catchment spot. Furthermore, even at present there is the idea of to deviate some waters from Siret basin to Jijia basin via Sitna Valley in order to increase the irrigated surfaces.

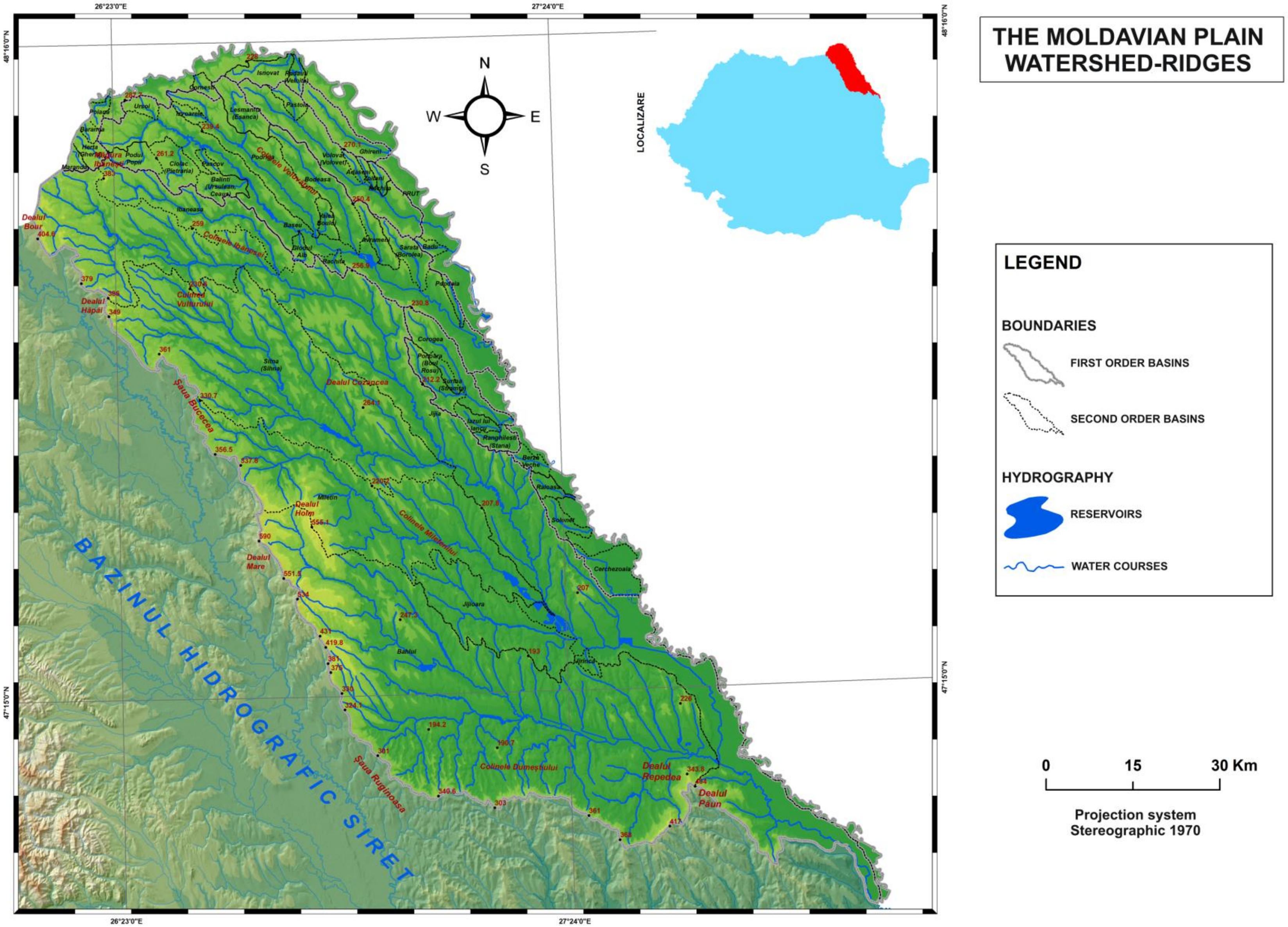


Fig. 6.6 The Moldavian Plain watershed-ridges

V. Tufescu, in 1932 observed the unstable character of the water ridge in the Strunga-Ruginoasa Saddle. In this sector the Siret basin is raced by the Bahlueţ hzdrological network..

To the south, toward the Bârlad basin, the interfluve and the ridge dispaly certain narrow sectors between Mogoşeşti and Horleşti where in some situation the ridge is no wider than a road and intensively modelled by the Bahlui advancement.

The general tendency in the studied region is of Prut river watershed enlargement and the increase in water input for the respective hydrological network.

Even the Prut afluents suffered modification as far as the water-ridge is concerned (V. Băcăuanu, 1968), yet with lesser hydrological consequenes.

In the maximum discharge interval for Prut River the water-ridge and the affluent in the common alluvial plain lose their clear delineation. In such cases the overspills from Prut pass over the some saddles (where the deposits are no more than 1 meter in height) to the affluent increasing the discharge in these small basins.

Before the construction of the Stânca-Costeşti dam when even the affluents of the Prut had increased discharges the effect of floods was catastrophical (e.g. in 1932, 1955 and 1969). In such situations the Prut-Jijia alluvial plain at the confluence with Bahlui became a huge lake of 8 kilometers extension that lasted 15 days. The areas were compared by V. Tufescu with the Danube Fen (everglades).

At Prut overspills events, the first and the second order affluents in its lower course display the afflux/backwater phenemenon where the waters cover the secondary alluvial fields increasind the flood phenomenon. Such events appeared in June 1932, August 1955 and April 1968.

6.2.2.2. The hydrographic basins surface

The surface of the hydrographic basins increases in dimension along with the river advance to the lower sectors when affluents become more numerous and new surfaces are dreained. The bigger the watershed the bigger the water discharge volumes. For example, the Bahlui river has a discharge of 0.421 sq. meers/second at Hârlău (S=139 sq. km) 1.06 421 sq. meers/second at Iloaia’s Bridge (S = 587 sq. km) and 3.03 421 sq. meers/second at Iaşi (S=1436 sq. km) (tab. 6.1).

The input basins of different orders display an elongated shape and are oriented, in great majority, from NW to SE (fig. 6.7) which gives a peculiar importance to the production and evolution of hydrological processes. The basins orientation in the Moldavian Plain facilitates, in the spring, the snow melting from the lower to the upper basins as conditioned by the temperature variation in latitude and sustains the gradual output of the respective waters. In March and April, the temperature difference, between the south and the north of the region is, in average, 1,5°-2°C. For example, it is possible that the entire region be covered in the same air mass for short time and have, in consequence, the same characteristics. Such a situation can favour the melting of snow in the same time for the most parts and result in river floods as in 1940 (M. Pantazică, 1974)

Table 6.1 Dimensional elements of the surface increase chart on right bank of Middle Prut River (M. Pantazică, 1974)

No.	Surface denomination	Surface in square kilometers				River lenght km	Prut length km
		Right basin	Left basin	Total	Sum		
1	Inter-basin	-	-	44,8	44,8	-	24,0
2	Teioasa basin	8,0	4,8	12,8	57,6	6,0	24,0
3	Inter-basin	-	-	38,0	95,6	-	54,0
4	Ianovăţ basin	24,0	10,8	34,8	129,4	23,0	54,0
5	Inter-basin	-	-	1,0	130,4	-	57,0
6	Rădăuţi basin	4,8	8,0	12,8	143,2	49,0	57,0
7	Inter-basin	-	-	56,8	200,0	-	108,0
8	Chireni basin	38,0	25,2	63,2	263,2	22,0	108,0
9	Inter-basin	-	-	41,2	304,4	-	136,0
10	Volovăţ basin	98,0	122,0	220,0	524,4	52,0	136,0
11	Inter-basin	-	-	8,8	533,2	-	142,0
12	Radului basin	6,4	4,8	11,2	544,4	8,0	142,0
13	Inter-basin	-	-	47,6	592,0	-	184,0
14	Başeu basin	302,0	659,0	961,0	1553,0	106,0	184,0
15	Inter-basin	-	-	23,2	1576,2	-	196,0
16	Corogea basin	142,0	48,0	190,0	1766,2	28,0	196,0
17	Inter-basin	-	-	8,0	1774,2	-	216,0
18	Berza Veche basin	8,0	10,0	18,0	1792,2	8,0	216,0
19	Inter-basin	-	-	12,4	1804,6	-	229,0
20	Râioasa basin	8,0	9,2	17,2	1821,8	9,0	229,0
21	Inter-basin	-	-	15,2	1837,0	-	240,0
22	Soloneţ basin	15,2	12,	27,2	1864,2	11,0	240,0
23	Inter-basin	-	-	106,0	1970,2	-	416,5
24	Jijia basin	4566,6	1155,4	5722,0	7692,2	282,0	416,5

As a consequence of the high degree of elongation of the watersheds as reported to their height, with 12 to 1 for Başeu and 14 to 1 for Jijia, the necessary time for waters to move from the side sub-basins to the streams thalweg (on an inclined slope) may be between 24 and 28 times smaller than the time necessary for water movement from the upper watershed to the lower one. Hence, on these alluvial plains (as in the summer of 1965 on Bahlui Valley at the confluence with Cocoara) the predominant floods are the side-floods on tributaries. In comparison with these, in the Corogea basin, the reported between length and width is only 4 to 1. In this respect the probability that the upper basin flood wave and the side basins flood wave become superimposed.

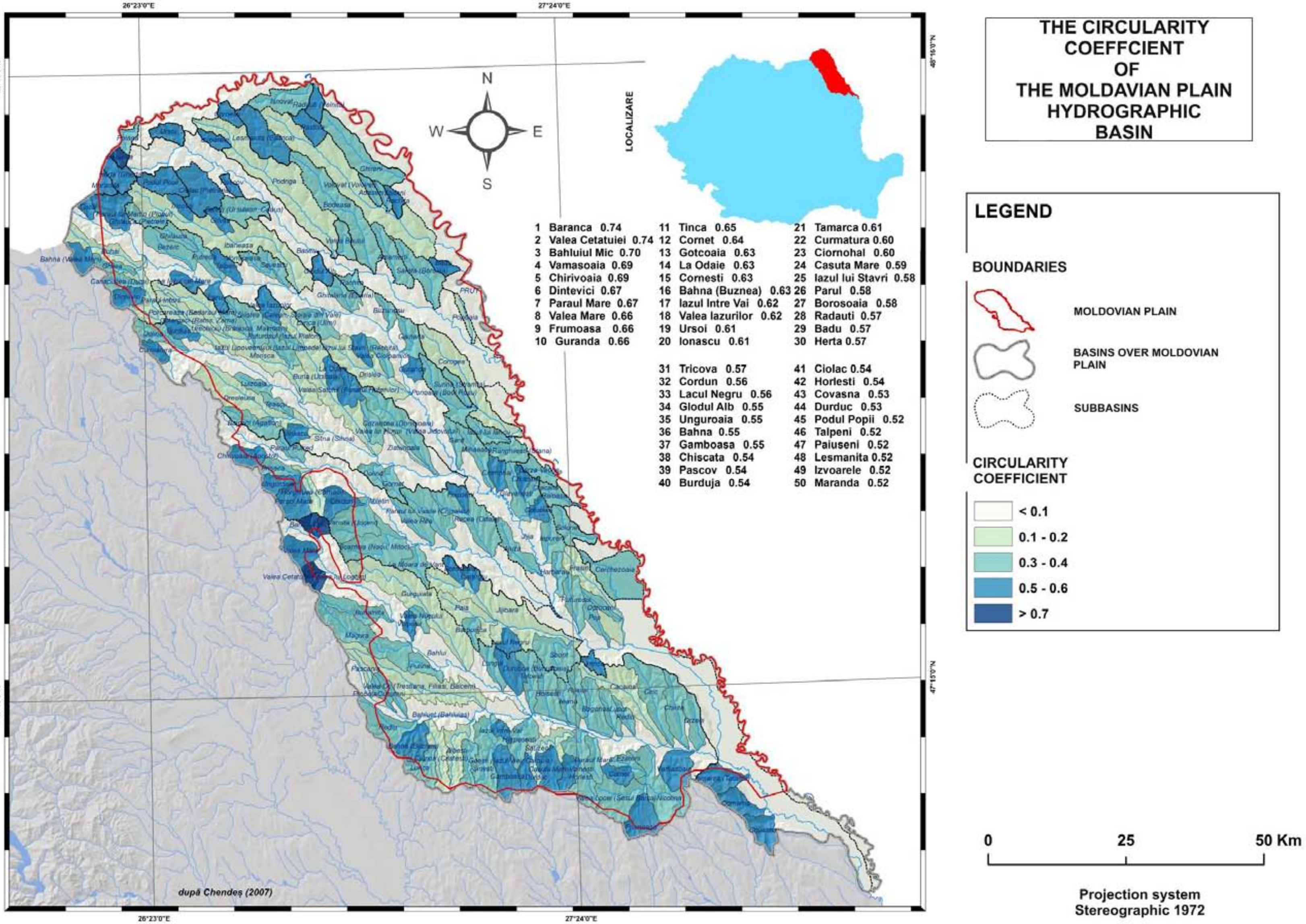


Fig. 6.7 The circularity coefficient of the Moldavian Plain hydrographic basins

The elongation coefficient of the watershed denotes the same situation. Its value oscillates between 1.5 for the Corogea basin and 2 for the Miletin basin. Thus, water transportation outside the watershed is more rapid in the Corogea basin. The Jijioara River is in the same situation and this explains the increase in humidity for the Larga area on Jijia, at the confluence with Jijia. Inside the hydrographical basins the majority of rivers hold a lateral position which results in an asymmetrical input.

The wider part of the basins influences the leakage value per year while the narrow part influences the maximum leakage value. One example is the Jijia River, down from Truşeşti. This river has a very narrow left sub-basin which results in very frequent floods in the left alluvial plain at torrential rains (M. Pantazică, 1974).

6.2.2.3. Average watershed hillsides in the Moldavian Plain

The necessary time for the water from precipitations to be collected in the hydrographical network depends also on the versants inclination inside the basin. The higher inclinations are on the versants of the Upper Jijia and the tributaries, on the right side basin, developed, as seen before, in a much higher relief with harder rocks. At Hârlău, the Bahlui for example, displays versants of 80‰ in average while at Nicolae Bălcescu the Miletin has versants of 79‰ in average. The average value of the slopes in the above mentioned basins lowers when more surfaces from the Moldavian Plain add in. For example, the average slope of the Bahlui basin is 62‰ until Iloaia's Bridge, 41‰ until Iași or as in the Jijia basin, 74‰ until Dorohoi, 61‰ until Todireni, 50‰ until Victoria and 44‰ until Chipereşti (fig. 6.8).

6.2.2.4. Average altitudes

The average altitude (H med) is another dimensional characteristic of great importance which helps in the quantification of the predominant relief unit in which a hydrographic basin develops. As reported to H med the natural environment components combine and result in different types of landscapes that have different hydrological regimes. As a consequence, the hydrologic regime of a river is the result of average geographic conditions reported to a certain altitude as the value of the most representative hypsometry at the basins' level (fig. 6.9).

If we analyze the repartition of altitudinal zones as reported to the surface of the region we can understand why at the majority of hydrometric posts the average basins input altitude is around 150 meters. The average altitude, actually explains the average geographic conditions assembly where the respective hydrologic regime is described for a river at at hydrometric post and its value decreases along the river toward the lower sector.

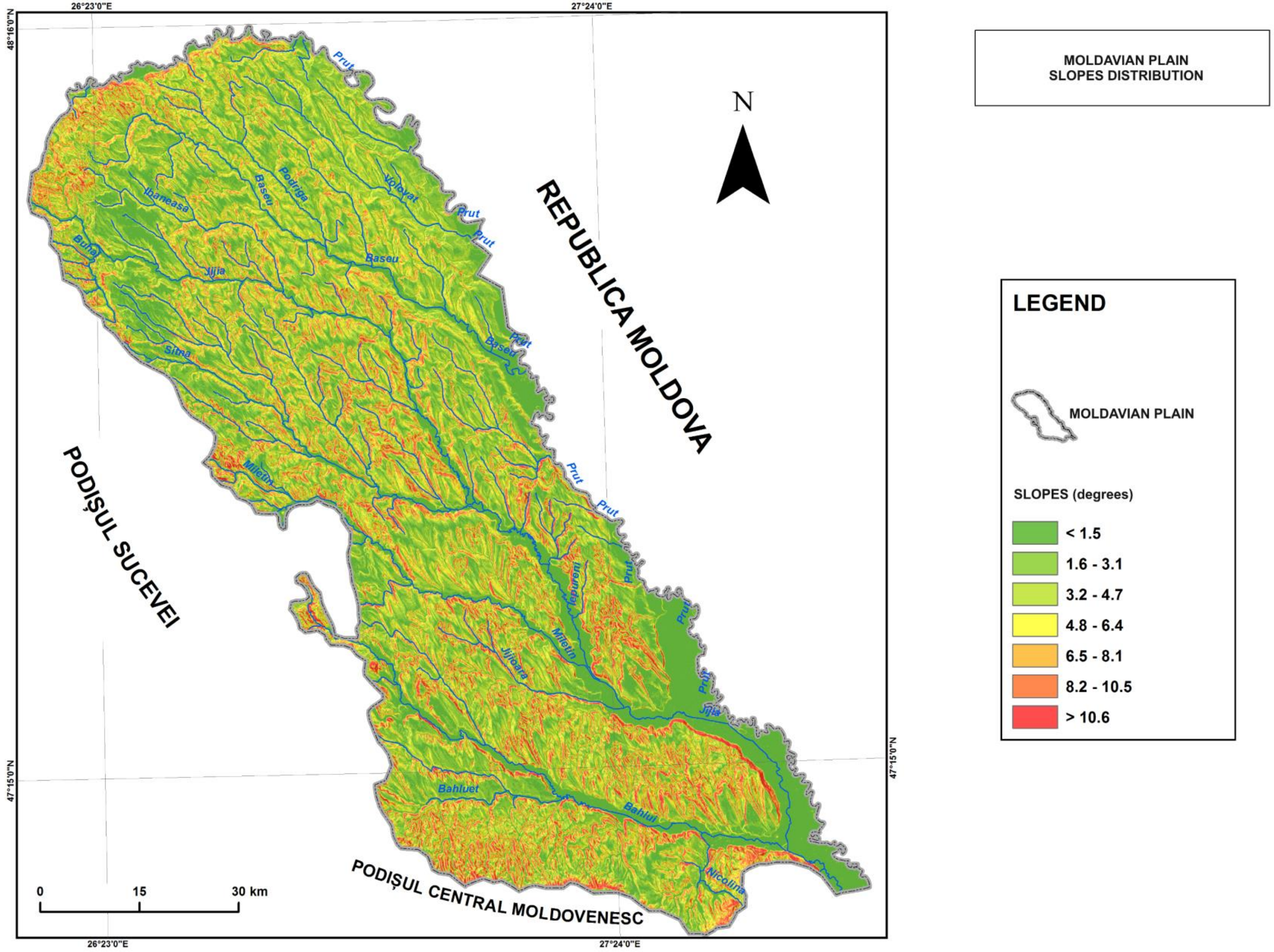


Fig. 6.8 Moldavian Plains' slopes distribution

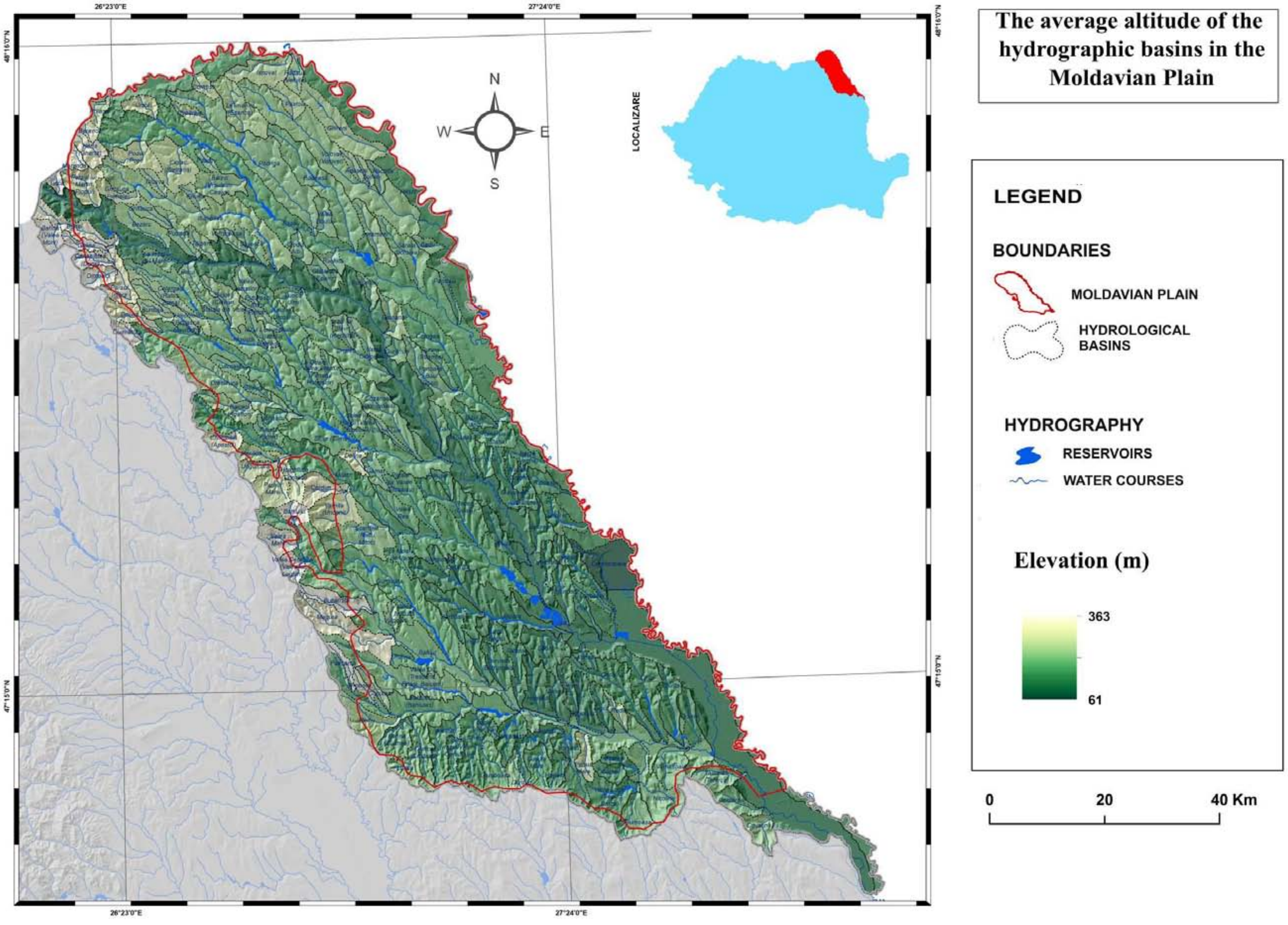


Fig. 6.9 The average altitude of the hydrographic basins in the Moldavian Plain

The link between the average altitude and the value of different aspects of the hydrologic regime is more evident when inside the watershed there is a pronounced vertical superposing of the relief as in the case of the Suceava Plateau.

In the Moldavian Plain, the law of vertical zones superposing of the hydrologic processes manifests in a reduced manner and is more prominent in the west and north. The values of the hydrologic characteristics recorded at Dorohoi, on Jijia, at Botoşani, on Sitna, at Nicolae Bălcescu, on Miletin, at Hârlău, on Bahlui and at Tg. Frumos, on Bahlueţ represent the consequences of average altitudes for the input basins, developed, in the upper streams of the Suceava Plateau.

6.2.2.5. Hydrographic network density

The hydrographic network density represents an important dimensional characteristic for the leakage formation. Thus, the surface waters drainage and subterranean waters possibilities are higher where the network is denser. In the Moldavian Plain the most frequent floods appeared at lower Todireni, on Jijia, at lower Plugari, on Miletin (Mid-upper Jijioara basin), on the Bahlui river between Belceşti and Iloaia's Bridge (in the Sheep Valley basin), mostly where the total density of the hydrographic network is more then 1,25 km/km^2.

When analyzing the hydrographic network density map (fig 6.10) we notice values between 0,1 and 0,7 km/km^2 for the permanent rivers in the NE of the Moldavian Plain. The highest values (over 0,50) are encompassed on the right Jijia basin and the lowest values (predominantly below 0,40) describe some small basins that are tributary to Prut River directly.

For the study zone the average density of the permanent network is 0,45 km/km^2 which is very close to the national average (0,49 km/km^2).

Due to the fact that in the study region the aquifer, subterranean strata are weak during the draught periods, they tend to strongly reduce the input for rivers and the wet leakage is interrupted. The permanent leakage on rivers is maintained only where the subterranean waters are more abundant as in the eastern side of the Suceava Plateau, on the well-developed terraces sectors or where they intersect alluvial aquifers.

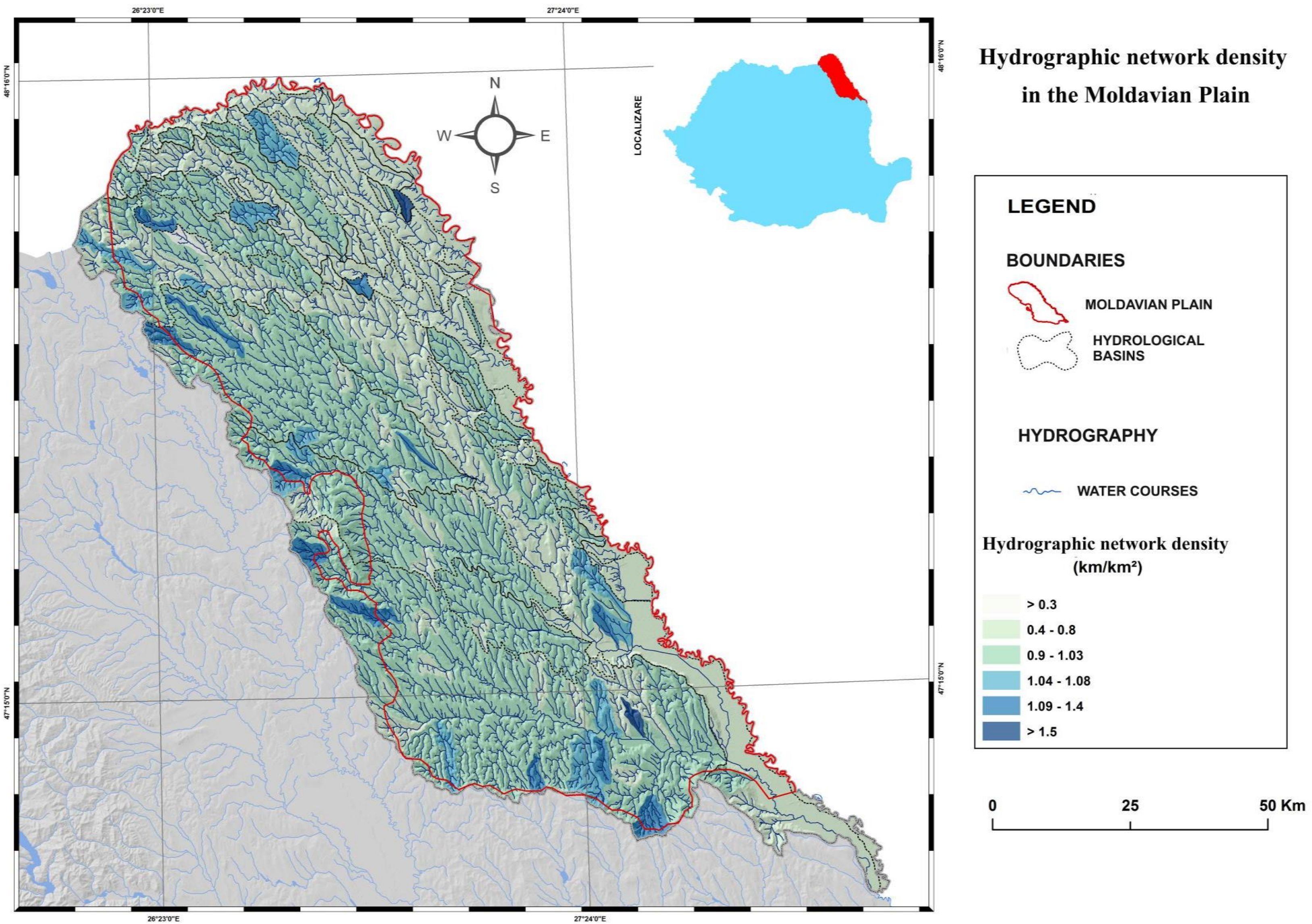


Fig. 6.10 Hydrographic network density in the Moldavian Plain

6.2.3. The main hydrographic systems of the Moldavian Plain

The main hydrographic systems that drain north-eastern Romania and especially the Moldavian Plain spring, in great majority, from the high hills in the eastern Suceava Plateau and the Central Moldavian Plateau and are collected by the Prut River. From north to south we have the rivers of Ghireni, Volovăţ, Başeu, Corogea and Jijia (fig. 6.5).

From the entrance in Romania, in the Oroftiana point and until Mitoc settlement, on 94 kilometres, the Prut River receives short tributaries on its right side, with lengths under 5 kilometres and temporary leakage. This is due to scarce springs in this basins and their weak source located in the deluvial cover aquifer on versants that strongly influenced by the climatic regime.

At Mitoc, the Prut River receives a more important affluent, the Ghireni River which springs from the Hill of Miorcani at 200 absolute altitudes, fig. 6.11. The input watershed of this river has a length of 20 kilometres and a width of 4 kilometres and the versants are very degraded and affected by strong landslides that hold lakes which are more numerous on the right side. The stream has a temporary character, with small depth and a humid alluvial plain which sustains reed vegetation. Down from Miorcani there is an increased slope where water is stagnant and forms an alluvial plain lake called the Great Fen. The river is 22 kilometres long, a slope of 4,5 ‰ and a 500 meters wide alluvial plain. In very few spots (approximately 3) the river is blocked by small earth dams in order to hold water for cattle.

The Volovăţ is the second most important affluent of Prut which enters the main river at Bold settlement, upstream Ripiceni. This river springs from the Mălăiţă Hill at 200 meters absolute altitude and runs across 52 kilometres on a 2‰ slope with a 105 meters vertical deviation. The river has a permanent leakage and the alluvial plain is 700 meters wide; the river is exposed to floods and has some reed vegetation sectors. The versants are degraded with landslides and gullies. The affluents of Volovăţ spring from 150 altitude and have a permanent course in the main alluvial plain fig. 6.12.

After 184 kilometres, at the entrance in Romania, the Prut river increases its right basin with 961 km^2 receiving the Başeu river. This river is 106 kilometres in length and springs the Cristineşti Forest Hill at 260 meters absolute altitude and effuses at 58 meters next to Româneşti settlement describing an average slope of 2,3 ‰.

The river receives the name of Başeu when crossing the Başeu settlement and cumulates here the Suharău and Cristineşti-Lişna rivulets. This rivulets have permanent courses from 150-200 meters altitude where the spring drain the subterranean waters inside the strata or the deluvial deposits of Suceava Plateau fig. 6.13.

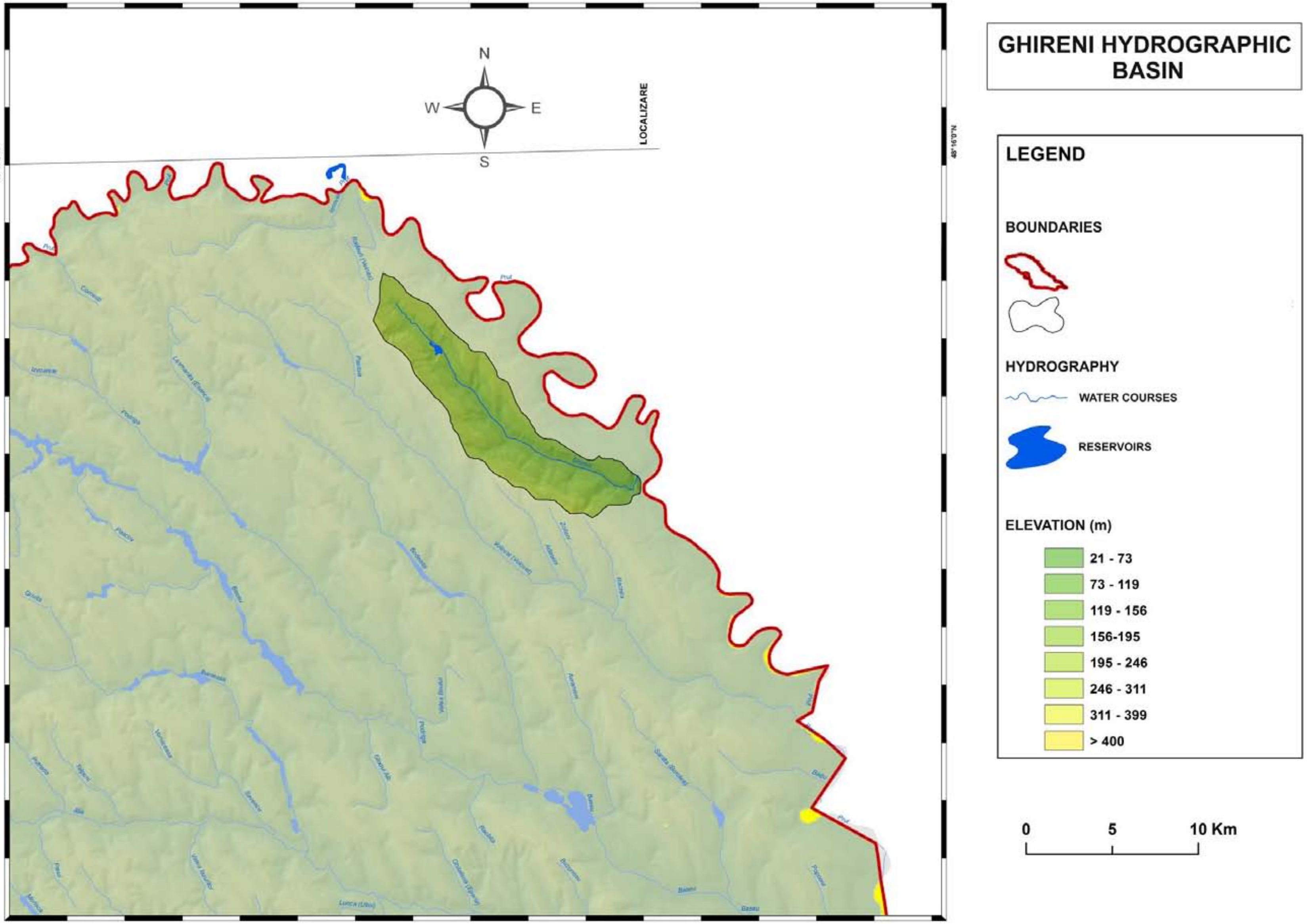


Fig. 6.11 Ghireni hydrographic basin

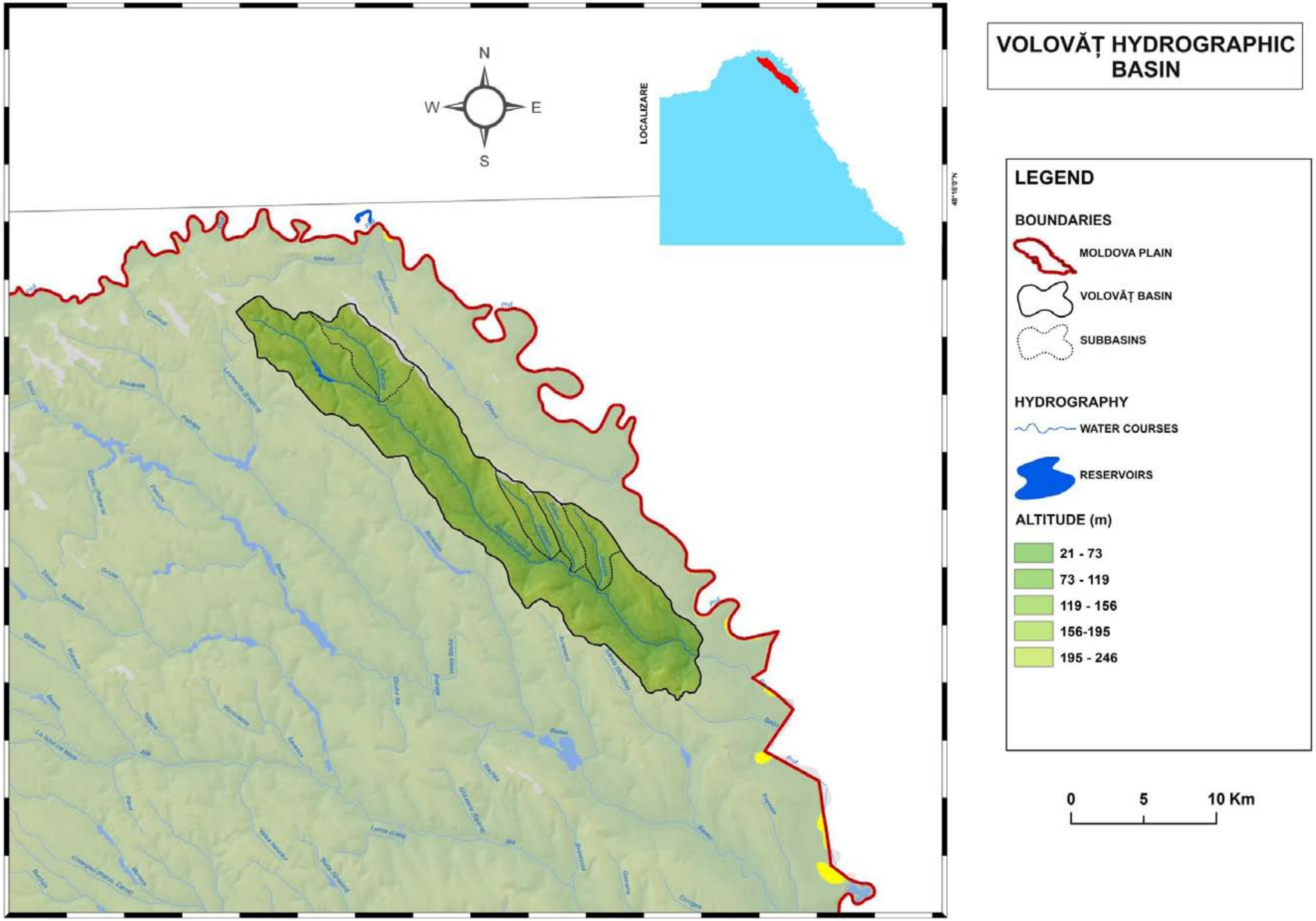


Fig. 6.12 Volovăț hydrographic basin

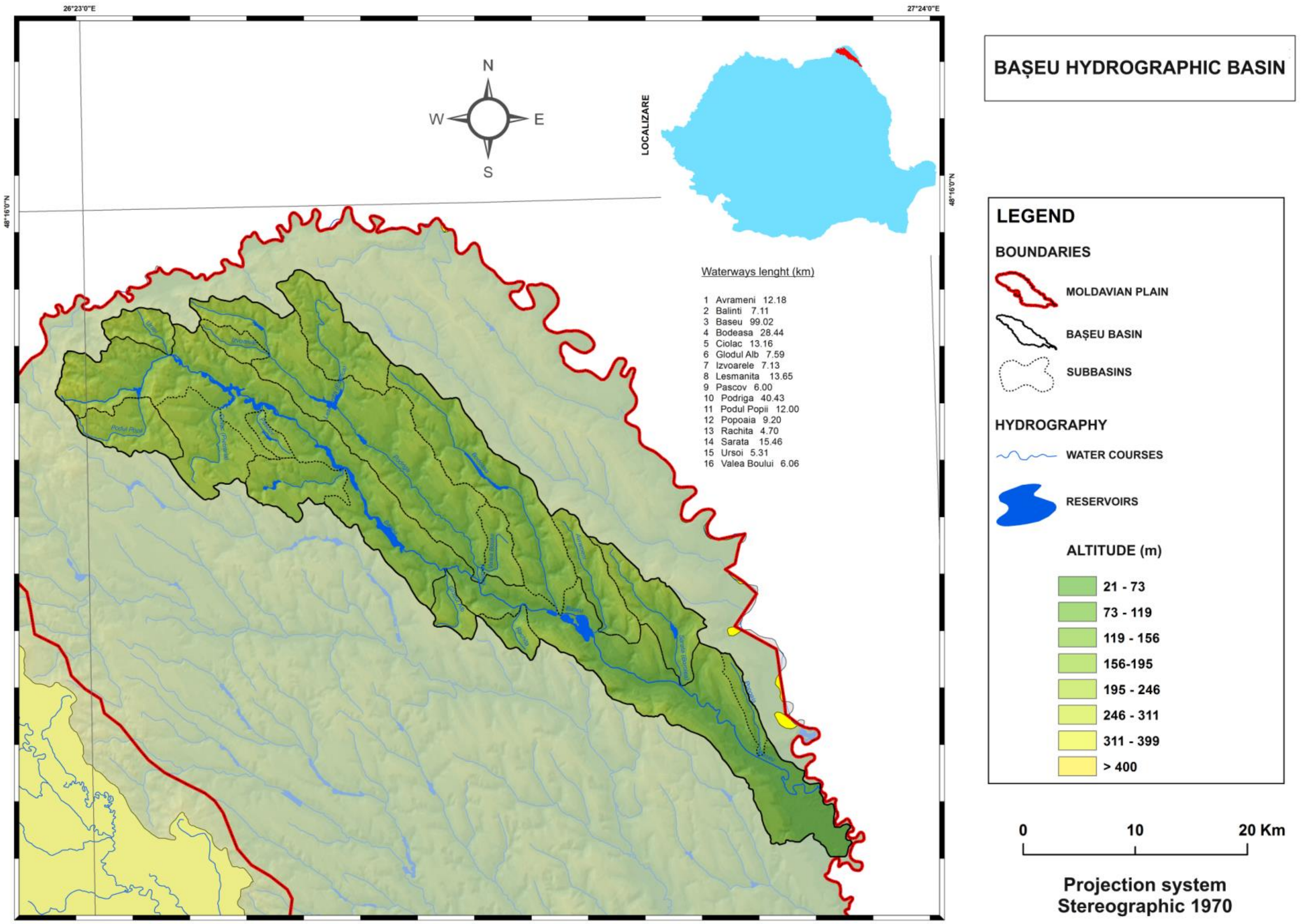


Fig. 6.13 Başeu hydrographic basin

As a consequence of the general morpho-structural conditions of Başeu basin and of the friable deposits, predominantly clay, the general form is elongated with a sub-unitary report (RF = 0,27) (Secu C., 2003). The evolution of the hydrographic network and the aggresivity of some Jijia affluents to the south-west resulted in an unequal development of the two main versants (63% the left versant and 39.9% the right versant). River collects the main affluents on the left versant while the right versant is more developed only in the upstream sector, in the sub-sequent valleys sector and becomes narrower in the mid sector.

The affluents are short and insignificant. The valley's versants are more degraded down-stream. On the left of the main valley, upstream Havârna, there is a line of springs at 140 meters altitude next to the Tătărăşeni, Negreni, Ştiubeni villages where the valley is blocked in transversal profile. Here, between ponds, the minor bed is locally deepened while the major alluvial bed is used for agriculture since it is mostly drained. The majority of Başeu basin represent temporary water course. The same aspects are characteristic for Podriga and Ciumaşu, Avrămeni and down-stream Bodeasa. Even the main stream, Başeu does not have water all the year; in summer the river gets dry down-stream Ştiubeni becoming an alternative dry and wet sectors where water holds fens. The permanent sectors are: upstream Ştiubieni, Lişna, Pîşcov and Podriga, in the Scutari village sector. The water is present all the year in those sectors where the aquifer subterranean waters are placed at the bases of the accumulative terrace deposits and alluvial plains which sustains the hydrographic network.

A characteristic of the Başeu Basin Rivers, as with other rivers in the Moldavian Plain, is the presence of numerous ponds with diverse utility: water for cattle, irrigations, fishing. The ponds of Başeu become genuine pond-systems sometimes (as in Başeu, Podriga, Avrămeni, Pâşcov ponds). Most of them are drained which is why the older pond-systems became only systems of washbasins in different silting stages. The most extended functional ponds are: Hudeşti, Tătărăşeni, Chişcăreni on Başeu River; Mileanca on Podriga; Pâşcov, Murgu, Sălişte, Podul Gruilor on Pâşcov River and Borolea, Great Pond, Small Pond on Borolea River.

Upstream Ştefăneşti, on 10 kilometres onto Păun village the stream is branched with lateral wet brooks and dry books. In this sector, 4 kilometres are channelled in order to favour water rapid discharge at floods. Downstream Ştefăneşti, the Başeu River enters the Prut valley under a very sinuous course with an average coefficient of 2.6 and avoiding on right the alluvial cone constructed here. When Prut also brings high waters the link with Başeu is made on right side of Bădiuţi village via the Doloca brook.

The biggest Başeu affluents are on the left side: Podriga 40 kilometers, Bodeasa 30 kilometers, Avrămeni 14 kilometers and Borolea 16 kilometers. On the right the most important affluents are Lişna 11 kilometers, Ciumaşu 14 kilometers and Pâşcov 13 kilometers.

The most important affluent is Podriga with the Eşanca affluent which bring together half of the Başeu's annual discharge at the Săveni post (downstream this confluence). Podriga runs parallel with Başeu on its entire course and displays similar characters.

Downstream Başeu, at approximately 3 kilometres there is the Corogea effluent (that runs in Prut) with 30 kilometres length, on a small depth bed, slightly sinuous and with permanent course. The versants are degraded and the major alluvial beds are exposed to floods at high waters, fig. 6.14.

Next, until the confluence with Jijia, the Moldavian Plain is also drained, in the eastern side, by short rivers, many under 5 kilometres long, with small watersheds, under 10 km^2. The respective rivers, although with a reduced discharge, have a permanent discharge being fed by the phreatic aquifers on the basis of the Prut terraces. The minor beds are shallow and slightly sinuous while the major beds are narrow and totally exposed to floods. The above presented rivers are characteristic for the eastern Moldavian Plain.

After 283 kilometres from entering Romania the Prut River receives the most important right side Jijia fig. 6.15.

Jijia springs west from Pomârla settlement an the eastern versant of Bour (Urus) Massif. In the springs zone it displays two branches, each of 10 kilometetrs long with permanent discharge from 340 meters altitude. In this area the versants' slope exceeds 10° while the longitudinal slope is over 13‰; these elements control the surface discharge. The streams are almost straight with deepened sectors as a consequence of rivers' erosion befor entering the main alluvial plain which is 140 meters lower then the plain of Moliniţa (an affluent of Siret that goes on the western Bour Massif).

After the confluence of the two branches, downstream Corjăuţi, the river is called Jijia and displays a slightly sinuous course, shallow in some sectors, with two distinct branches and a dry plain but exposed to floods until Crişan where it receives, on the left side the Pomârla brook with the same characteristics. Next, toward Dorohoi the plain character changes and becomes very humid with reeds and marshes in some sectors forming the marshy sink of Dorohoi (Dorohoi Tarn).

Between Dorohoi and Dângeni, Jijia displays, in general a west-east direction. The river is well imposed and sinuous and the sinuosity coefficient is 1.4 in average. The common character of this sector is the deepened minor bed. At Dorohoi the depth is more pronounced (10 meters; also as a result of plain superimposing with materials brought by the Buhai River). Downstream the depth decreases in-between 5 and 3 meters. In general, the deepened sectors appear in high alluvial plains where the deposits are superimposed by affluents' activity. In this part the plain is flooded only by the affluents or downslope discharge. The lateral erosion and the vertical erosion are also sustained by the lithology where the major bed displays clay-sands. In some sectors the erosions entered the clay-marl deposits creating a batter inside the minor bed. This batter is visible at low waters and is the support of the phreatic aquifer of the alluvial plain that feeds Jijia in the dry seasons. These kinds of springs appear frequently also downstream.

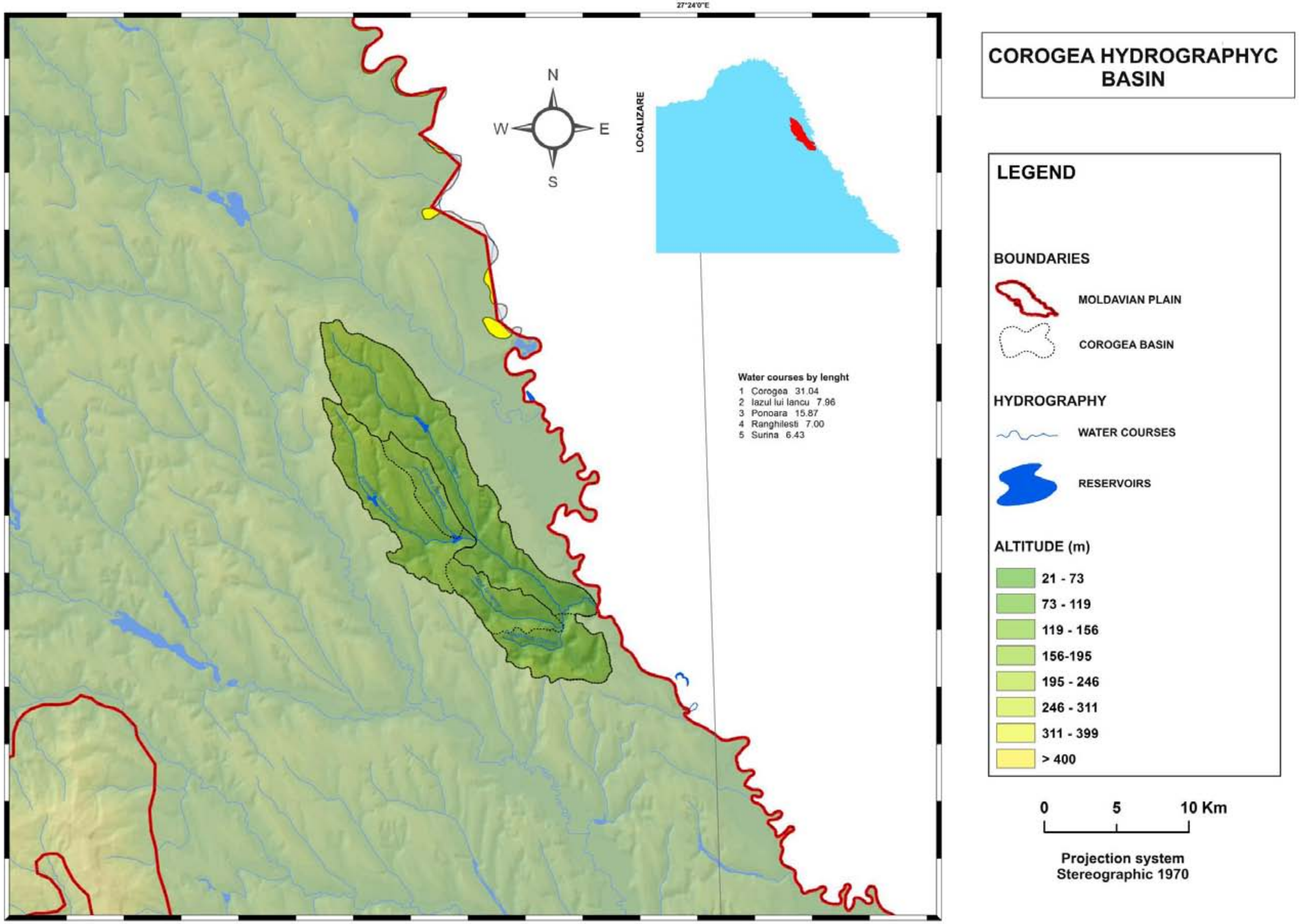


Fig. 6.14 Corogea hydrographic basin

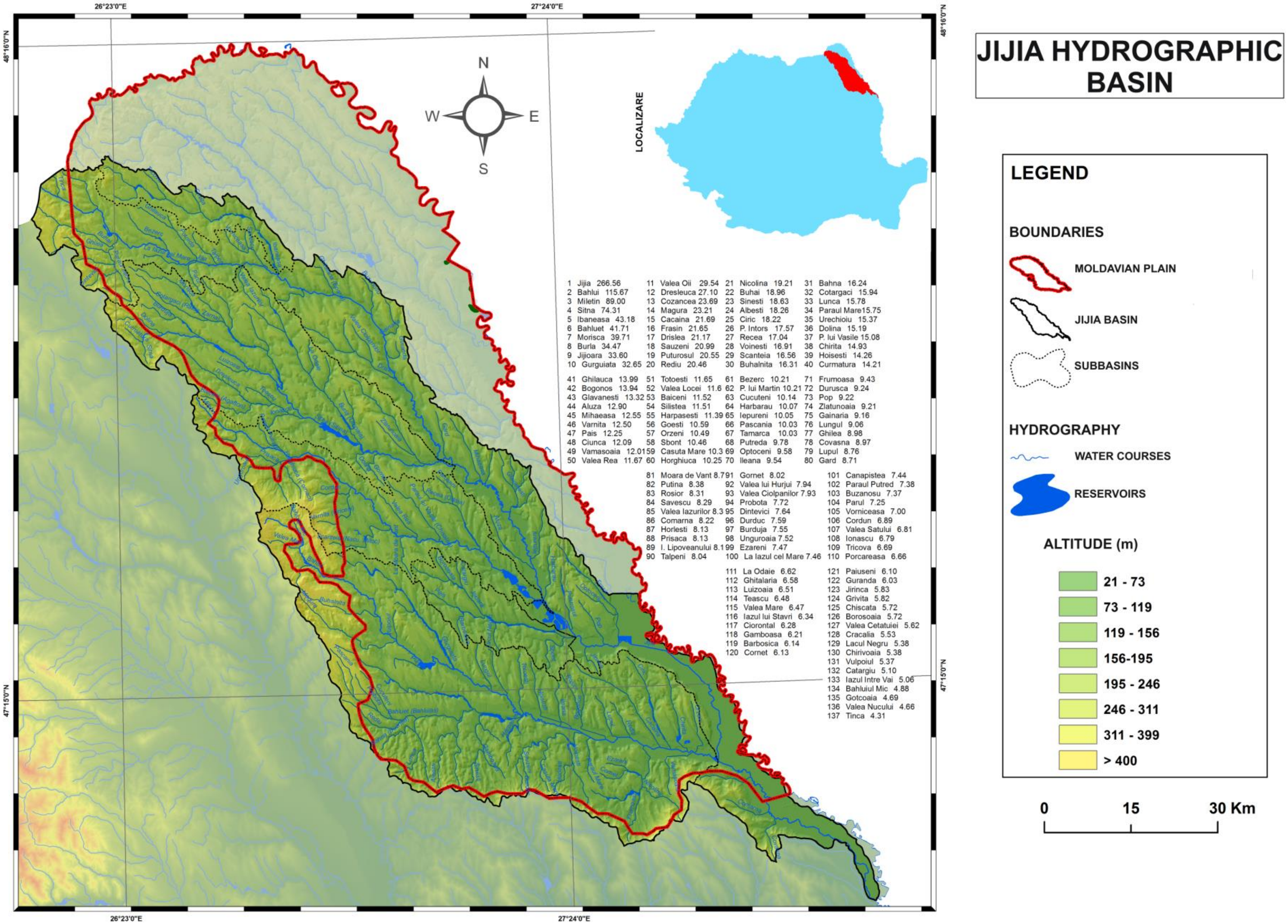


Fig. 6.15 Jijia hydrographic basin

Between Călugăreni and Borzești the depth of the minor river-bed is 3 to 4 meters while the alluvial plain is narrow and records frequent versant inundations that result in lake accumulations due to the knobs at the slope base.

From Borzești to Iacobeni the alluvial plain is larger (1 km), well drained and the depth of the minor river-bed reach 4 meters in the river's dead branches where human intervention resulted in lakes formation as the one downstream Plopeni. Between Iacobeni and Dângeni the water course is channelled on 4 kilometres.

Downstream Dângeni the river's general direction becomes south-east. Until Trușești the course is linear and also channelled on 4 kilometres. To the side, on the right part of the alluvial plain the old, empty course is to be observed. Downstream Trușești the river and the alluvial plain aspects change completely with alternative branched sectors, meanders and temporary along with permanent courses.

Between Trușești and Todireni the minor river-bed is 2-3 meters deep. On the right and on the left sides of the river there are secondary, shallow courses which disappear across the alluvial plain and are used by the floods on Jijia. The alluvial plain is exposed to inundations, especially via the discharges from versants which present gutters. The wetlands are covered by reeds are narrow and appear downstream Trușești.

Between Todireni and Andrieșeni the course of the river is characterized by a high sinuosity degree, with over 2m/sq. km in certain sectors. On the alluvial plain, especially on the right, there are meanders and fossil meadows with no water. In this sector the river has a rich lateral supply via an array of springs at the versants' bases.

Between Andrieșeni and Vlădeni the river is deepened and is frequently flooded and less sinuous. Downstream Vlădeni, until Larga, the Jijia river losses its individual character and the water course is hardly observed across the humid alluvial plain where the vegetation cover is given by herbs and reeds. In this sector, from place to place, there various ponds and dryland islands. The Miletin River, one of the important affluent, which effluences in this sector does not have a distinct river-bed all the yearlong until the confluence with Jijia. Only in the dry season, when the alluvial waters evaporate, one can observe, more clearly, the effluence of Miletin into Jijia at approximately 3 kilometres after entering the alluvial plain, near Vlădeni, right in front of the Țugui Knob. The appearance of this area, known as the Marsh of Vlădeni, in the specialized literature was analysed in various paper works (Al. Obreja 1958; V. Băcăuanu, 1968).

Along the Prut alluvial plain, Jijia runs on 70 kilometers until the confluence point which is near the Gura Bohotin (Bohotin Mouth) locality at 28 meteres altitude.

Between Jijia and Prut, the common alluvial plain, there is longitudinal bar of 3-4 meters, non-floodable which constitute the watershed. In this part Jijia is very sinuous with numerous branches and empty meanders that only receive water at high discharges.

In order to reduce the effects of inundations and to extend the agricultural surfaces, numerous water control works were performed on Jijia. Thus, downstream Chiperești, there is a split (hydrotechnical node) of the main stream and some of the debits (the Old Jijia) go to Gorban and other debits (the New Jijia) go to Moreni, along the new river-bed.

Starting with Chiperești the river course is diverted via a man-made channel with the role of conducting Jijia and Bahlui straight to Prut, upstream Moreni. Here, a new river-bed was established between to embankments.

The old course of Jijia, highly meandered from Chiperești-downstream has 56 kilometres and is the natural course of this river. The inferior course is modified with certain cuts resulted from river control works; the most important works are at Costuleni. The inferior part of the course is exclusively meant to collect the discharges of four smaller affluents and to conduct them to the Prut River, at Gorban.

Inside the basin which has an elongated form, the Jijia has a lateral position. From the total surface of 5722 km^2 more than ¾ is developed on the right side from where it receives the most important affluents: Bahlui, Jijioara, Miletin and Sitna rivers.

The Bahlui River, the main affluent on the right for Jijia, drains approximately 2023 km^2 and descents on a 395 meters altitude level difference. The main course is 119 km and the average slope is 3.3‰. The river springs from the Hărlău-Great Hill, in the east of Suceava Plateau, at 510 meters altitude, yet, the permanent course is distinct at 430 meters altitude. In the upper course the river is sparsely meandered, the average slope is 16 ‰ with a narrow major river-bed. It is only after Hărlău where the major river-bed becomes wider with 0.2 and 0.3 kilometres transversal sectors.

Among the most important affluents of Bahlui, on the right upper course, there are Buhalnița and Măgura while on the left there is Gurguita.

The Bahlueț, the main affluent springs from Stroești Hill (east of Todirești) at 395 meters altitude. The permanent course occurs at 355 meters and the length of the river is 50 kilometres.

Downstream the confluence with Bahlueț, the Bahlui River receives an array of affluents, on the left side where the most important streams are: Totoești (11 km and 25 sq. km), Bogonos (14 km and 52 sq. km.), Cacaina (21 km length and 63 sq. km. surface), Ciric (17 km and 58 sq. km.), Chirița (15 km. and 39 sq. km.). On the other side, on right, only three affluents are more important: Voinești (17 km. and 138 sq. km) with the Săuzeni affluent (30 km and 75 sq. km.), and Nicolina (20 km and 177 sq. km) with the affluents, Locva Valley (12 km and 85 sq. km.), Ezăreni or Izăreni, on the topographic maps (8 km and 34 sq. km) and Vămeșoaia (12 km and 35 sq. km drainage surface).

Jijioara, the next affluent, effluences in Jijia in the Larga locality. This river is 32 kilometers long and spring out from the Petroșica Hill at 140 meteres altitude and runs into Jijia at 47 meters altitude with 93 level difference and a 249 sq. km. basin.

Miletin, the third affluent of Jijia, from south to north, on the right side springs from south-western Botoșani city between Bârda, Baisa and Crivăț hills in the eastern Suceava Plateau at approximately 32 meters altitude and is formed by the Cărpinişu, Buda, Poiana Costişei and Căprăria creeks. Through their confluence the Burned Marsh takes shape which, downstream the confluence with the Black Marsh receives the name of Miletin until it runs into Jijia at Vlădeni (47 meters absolute altitude). Between the springs and the effluence the average sinuosity coefficient is 1.2 and the average slope is 3.2‰.

The depth of the Miletin's river-bed oscillates between 0.5 m, upstream Cristești and 3 m at Hălceni and the width is between 2 and 5 meters. From Hălceni, downstream the river is rectified.

The affluents of Miletin are small, in general, with only 4-5 kilometres courses except Uriceni, Lătăi, Modrusu on the right and the Bad Valley, Vasilache's Creek and La Odăi (at the Huts) with 10 to 15 kilometres courses. The short courses of these affluents allow rapid evacuation of the surface waters supplying the Miletin River in short time. The majority of the affluents have a temporary course except some short sectors that spring from the Suceava high Plateau (rich in subterranean waters) and receive inputs from the Miletin's terraces or from alluvial plains like: Unguroaia, Uriceni, Movila Părului and Budu.

Sitna is another important affluent of Jijia. This springs from the east of Suceava Plateau, in the Brăești Hill, at 261 meters altitude and runs into Jijia near Hlipiceni village (at 60 m absolute altitude). Between the springs and the confluence Sitna has a north-western to south-eastern direction on 95 kilometres and is strongly meandered downstream the Sulița Pond, where the sinuosity coefficient is 2.1 compared to the 1.6 average. This also explains the low value of the slope in this sector (0.3‰) as reported to the general average slope of 2.08‰.

The Sitna hydrographic basin displays on large surface a temporary discharge is as in the case of Cozancea and Burla rivers and their upper and middle parts, Cotârgaci in some sectors and, generally speaking, for all the secondary affluents of the main stream.

Sitna and most of its affluents inside the Moldavian Plain present overspills when they completely flood the alluvial plains in the high surface supply period. Upstream the Dracșani-Sulița Lake, the Sitna River and its main affluents give the impression of a developed drainage network with a sediment rich river-beds and marshy meadows, frequently covered by swamp vegetation. This situation is mainly induced by the large number of ponds (approximately 120).

Buhai River, after the confluence with Horlăceni creek is the last affluents of Jijia on the right side. This hydrographic system develops almost entirely in the Suceava Plateau where it receives an important supply of surface and subterranean waters. This determines the permanent character of the river with steady courses all along the year until Dorohoi. Downstream this confluence Jijia consolidates its course.

Ibăneasa River is the only affluent of Jijia on the left. It springs from the Ibănești Hill at 240 meters altitude and is supplied permanently from strata type subterranean waters. The river crosses the Dumbrăvița contact depression where, the Dragulea Pond was established while, at Dumeni, the river enters the Moldavian Plain. In this last sector, until the confluence with Jijia (at Borzești) the alluvial plain is floodable, with some marshy sectors and reeds vegetation, as in the south of Grivițele at Slobozia. The Ibăneasa small stream has a permanent course and also a rich supply from underground waters of the Moldavian Plain in the upper and middle sectors. The entire course of 44 km is slightly sinuous and the minor river-bed is shallow except the confluence sector. The confluence altitude is 100 meters giving an altitude difference, between spring and effluence, of 140 meters; as reported to the total length the average slope is 3.2 ‰.

The rest of the Jijia's affluents, on the left are short and temporary, except those courses which traverse Jijia's terraces, as in the case of Victoria, Dragalina, Călăraşi, Cracalia, Iacobeni and Găureni creeks, all of them upstream Trușești. On all these affluents, the inundations are mixed (versant-river) due to the small width of the basins (1.5 km) and the increased slopes (5 degrees in average), strongly fragmented by trenches.

6.2.4. Types of water discharge in the Moldavian Plain

Depending on the type of discharge in the hydrographic network of the Moldavian Plain, there three aspects to be considered:

- *the permanent discharge* is specific to the rivers that develop at the limits of the Suceava Plateau, the Nicolina river in the Central Moldavian Plateau and also Volovăț, Corogea, Bahlui, Ibăneasa and the rest of first order affluents of Prut, on the right and of Jijia, on the left, in certain sectors. The permanent flow of these rivers is insured by the underground strata waters in the hills of the Moldavian Plateau and the terraces and alluvial plains of the Moldavian Plain.
- *the intermittent discharge* is characteristic for all the rivers with south-north direction on the cuesta type versants. In the frame of the excessive continental climate of the Moldavian Plain, for the NE Romania, these highly inclined versants have poor subterranean waters. On these rivers the discharge occurs only in abundant surface supply (snow melt and torrential rains).
- *the semi-permanent discharge* is representative for the rest of the hydrographic network, in fact, for almost all of the study region and is determined by the semi-permanent character of the aquifer strata. Depending on the value of the climatic elements (temperatures, precipitation and humidity) and on their repartition in different years, the underground waters of the Moldavian Plain, in the narrow interfluves and on the Sun exposed versants, become very poor, reaching the 0 value which results in discharge interruption.

On the majority of rivers in the Moldavian Plain the character of the discharge is determined by the human activities. In this category we also include the rivers that were transformed in pond chains.

In the summer, this rivers, affected by average climatic conditions can remain dry. This happens when the water is retained in ponds for the safe of fisheries in the optimal fish period. Moreover, in the excessive dry autumns, during fish production, the first pond which is usually the largest is entirely discharged inducing an extra supply that exceeds the normal supply conditions in the respective basin at normal climatic conditions.

If we analyse the possibilities of supply for rivers during the year and, especially the rains supply as reported to the discharge we notice an important influence of human intervention. Thus, in the autumn, during November, the modular coefficient proves a two times higher discharge as in October and this mainly as a result of the ponds controlled discharge during fish exploitation periods.

6.2.5. The hydrometric know-how status

The first information on the spatial distribution of the hydrometric and meteorological stations, at the level of the Moldavian Plateau are to be found in the study-work of Gugiuman, published in 1945 (1920 for Bahlui at Iași, 1923 for Jijia at Victoria). The detailed analysis of the meteorological and hydrometric stations determine the author to consider that there is an obvious necessity of establishing new stations and posts on the majority of the Moldavian rivers in order to induce a better management of the water resources and for "enlarging the data for water levels behaviour, especially in the most scientifically and practically important spots".

At national level there are a series of scientific works that analyse the hydrometric network and the specific problematic: Diaconescu, Diaconu (1954), Dediu (1963), Motea, Panait, Stănescu (1965), Dumitrescu (1966) and Diaconu (1969).

In the hydrographic scientific work upon the Moldavian Plain, Maria Pantazică (1974) observes various stages of the hydrologic knowledge development in relation with the density of posts and stations and their objectives, as follows:

I – the stage of the first, unique observations (1920-1944);

II – the stage of the hydrologic observations organisation (1945-1958);

III – the systematic and complex hydrologic observations stage (since 1958);

Amăriucăi, in 1975, brings a series of information on the hydrometric network in Eastern Romania considering that there are two periods of the network development in the Prut basin; one until 1945 and the other one from 1945 onward. The first period is considered as being the one in which the data on rivers have a pure informative character when the first stations and observations occur. At the level of the Bahlui hydrographic basin, the first station is established at Iași in 1920, on the Bahlui River. The second period, after 1945 is characterized by the projection and realization of an "efficient hydrometric network with complex observations and measures for a precise parameter behaviour for the hydrological regime"

In this respect a series of stations are established on Bahlui, at Hârlău-Bădeni (1946) and Iloaia's Bridge (1947). Hence, a series of hydrometric posts occur on the affluents, at Târgu Frumos (1948) and Iloaia's Bridge (1952), on Bahlueț and at Iași (1964) on Vămășoia and at Ciurea (1964), on Tinosa creek.

In 1980, Pasoi performs some considerations on the hydrometric network projection in the frame of the intensive transformation of the water course while Sorocinski brings observations on the required measurements (1978) to improve observations for the surface discharge.

Even if the rivers in the Jijia-Başeu-Volovăţ basins had a very irregular regime, being poorly supplied in the dry season and very strong supplied at the snow melting and torrential rains they did not catch administrative attention because of the local character of the economy. Being hill region rivers with small basins they did not offer slopes and water volumes proper for hydro power or transportation. Additionally to the low profits these rivers affected only small owners.

This first stage in the hydrological knowledge in the region is characterized by a reduced number of observations on just two rivers in the target area. At the respective hydrometric posts only water level measurements were performed, with certain gaps. Additionally they were installed in improper river-beds sectors and insufficiently endowed.

Between 1945 and 1958 the measurements on the hydrologic regime started to grow for the sake of national integration. The first step was the increasing of the observation points. Thus, in this interval, in the Jijia and Bașeu, 17 hydrometric posts were installed for the main purpose of level variation observations.

The high speed of these posts installation resulted in improper positioning that is why, between 1953 and 1958 they were reorganized. Certain gauges were replaced or the observation point was changed in the more stable river-bed parts, on a linear direction and outside vegetation. Changes were made on Jijia at Trușești and Răuseni, on Miletin at Nicolae Bălcescu, on Bahlui at Hârlău and Iloaia's Bridge and Iași. In this period, beside water levels observations, additional observations are performed on the frost regime.

On the bases of the simultaneous observations (level and discharge) limno-metrical keys were obtained for the indirect determination of the discharges for a larger period of time. The respective data were necessary for the specialists in order to elaborate assembly water-control works on the rivers (D.G.A.S.P. 1960, 1962).

After 1958 the posts' position and their work programme are entirely established and a systematic observation period follows on approximately 10 to 14 years. Thus, an important variety and high quality array of data is accumulated.

In this period 17 base posts function simultaneously each having a surface of 441 sq. km. to cover. Analysing the situation on hydrographic basins we observe that the most endowed basin is the Bahlui with 7 posts, 280 sq. kilometres for each post.

Referring to the posts repartition we notice that basins larger than 550 sq. km. were taken into observation and the smaller basins are completely ignored, where inundations frequencies and their amplitudes give instant important discharges. This is the case of Volovăț and the affluents on the left side of Jijia which are narrow valleys rivers that have the entire basin inside the Moldavian Plain.

At present, the fund of hydrological data accumulated in the last years and its quality allow a better knowledge of the rivers' regime in the studied region. Table 6.2.

Table 6.2 Present situation of the hydrometric posts in the Moldavian Plain

No.	RIVER	STATION	Distance from confluence (km)	Reception basin		The altitude of the) plane, gauge (m)	Date of establishment	The rendered discharge elements
				Surface (km²)	Altitude (m)			
1	Prut	Oroftiana	714	8020	579	123.47	1.I.1976	-
2	Prut	Radauti-Prut	652	9074	529	101.87	1.I.1976	-
3	Prut	Stanca downstream	554	12000	480	62.00	5.XII.1978	Q monthly averages
4	Prut	Ungheni	387	15620	361	31.41	1.I.1914	Q monthly averages
5	Baseu	Stefanesti	6.3	917	168	61.94	3.VI.1980	Q monthly averages
6	JIJIA	Dorohoi	267	238	262	142.02	1.IV.1946	Q monthly averages

No.	RIVER	STATION	Distance from confluence (km)	Reception basin		The altitude of the) plane, gauge (m)	Date of establishment	The rendered discharge elements
				Surface (km²)	Altitude (m)			
7	Jijia	Dangeni	214	840	196	75.19	13.IV.1966	Q monthly averages
8	Jijia	Todireni	181	1070	186	58.14	1.VIII.1952	Q monthly averages
9	Jijia	Andrieseni	164	2183	176	47.41	1.VIII.2000	Q monthly averages
10	Jijia	Vladeni	140	2275	160	42.10	3.III.1982	Q monthly averages
11	Jijia	Victoria	112	3463	159	35.58	28.III.1923	Q monthly averages
12	Jijia	Chiperesti	3.5	5535	155	29.95	22.III.1978	Q monthly averages
13	Buhai	Padureni	8.0	54.2	165	183.91	5.V.1980	Q monthly averages
14	Drislea	Drislea	5.8	80.0	159	86.92	1.IV.1986	Q monthly averages
15	Sitna	Catamarasti	46.5	173	202	104.16	1.I.2000	Q monthly averages
16	Sitna	Dracsani	18.0	771	175	69.76	1.I.1977	Q monthly averages
17	Sitna	Todireni	3.2	940	167	57.43	1.IV.1945	Q monthly averages
18	Miletin	N.Balcescu	46.0	220	202	87.35	1.I.1946	Q monthly averages
19	Miletin	Sipote	14.0	608	155	54.24	14.IV.1978	Q monthly averages
20	Miletin	Halceni	1.2	664	166	46.45	1.VI.1990	Q monthly averages
21	Bahlui	Parcovaci	87.0	101	323	150.94	1.I.1990	Q monthly averages
22	Bahlui	Harlau	82.0	137	317	129.67	20.XI.1957	Q monthly averages
23	Bahlui	Belcesti	59.2	344	254	76.61	1.I.1977	Q monthly averages
24	Bahlui	Pd. Iloaiei	39.0	588	202	52.55	1.I.1947	Q monthly averages
25	Bahlui	Iasi	12.0	1717	150	37.60	1.I.1978	Q monthly averages
26	Bahlui	Holboca	5.0	1922	155	33.17	1.I.1983	Q monthly averages
27	Magura	Carjoaia	11.0	39	315	162.51	10.VII.1979	Q monthly averages
28	Bahluet	Tg. Frumos	23.5	68	252	89.96	14.I.1948	Q monthly averages
29	Bahluet	Pd. Iloaiei	1.5	523	159	52.42	1.I.1978	Q monthly averages
30	Voinesti	Cucuteni	1.8	130	199	49.83	1.I.1978	Q monthly averages
31	Nicolina	Iasi	4.37	173	139	37.60	1.I.1978	Q monthly averages

Along with the knowledge on the geographic conditions of the supply basins and their morphometric and morphologic features one can analyse the hydrologic regime for the respective rivers.

6.2.6. Rivers liquid discharge in the Moldavian Plain

The liquid discharge represents the most important characteristic because it actually expresses the water reserves transported on rivers. The projects on practical water requirements should be based on these observations.

The leakage regime of the rivers is influenced by the state of the weather at air masses movement, weather state which takes a certain form and intensity at a given moment (precipitations, evapotranspiration, humidity and air temperatures). The analysis of the general, regional and local influences are necessary for the interpretation of the elements' regime and the climatic phenomena and for the climatic potential interpretation in the study area.

The natural waters' regime at the surface of the Moldavian Plain is controlled, mainly by the physical-geographic conditions and the geological conditions. Among the physical-geographic the main role is played by the climatic conditions with a share of 80 to 90%.

The most important aspect in the understanding of the hydrologic regime is the analysis of the liquid discharge and its spatial distribution. The liquid discharge, in assembly, evidences the entire water quantity that transported on rivers. The liquid discharge and its spatial and temporal manifestation is conditioned by a series of physical-geographic factors among which the climatic factors (mainly precipitations) are the most important. Beside these, in the present period, the anthropic influence becomes more and more important.

The rivers' supply is influenced, mainly, by the climatic conditions that exist inside the hydrographic basin. In the cases where evapotranspiration does not exceed the precipitations quantities the surface liquid discharge is present.

6.2.7. Rivers intake

The particularities of the liquid discharge regime of the rivers in the Moldavian plain are determined by the supply source and by the variations characteristics during the year.

The water supply sources for the river in Romania were studied by I. Ujvari (1954, 1957, and 1960), D. Lăzărescu and I. Panait (1958) and, especially for the north-eastern region by Pantazică (1978). From the study of the above mentioned authors we subtract that the north-eastern region is supplied by surface water sources and subterranean water surface.

a) The surface sources are given by the precipitation waters and contribute in a decisive percentage to the leakage formation for the majority of rivers in the Moldavian Plain. Their supply, as reported to the total volume of transported water on rivers, oscillates between 85% in the southern part of the study region (85 % highest frequency) and 96.4% (highest frequency) in the uplands from the western part of the study region.

Analysing the discharge genesis in the close to normal distribution years we notice a slight increase of the values (approximately 4%) at altitudes increase in the higher hilly region. The increase is not appreciable because of the existence of sand intercalations in this part and because of the presence of increased forest covers which allow the partial subtraction of precipitations from the surface leakage. In the same time, there is a slight increase of surface supply for the southern Moldavian Plain as compared to the northern part. Here, the lithological constitution (loamy clay) and the relief's fragmentation, expressed through a high density hydrographic network, allow a more rapid drainage of the precipitations via a more organized discharge toward the main streams.

In the case of surface supply the precipitations contribute to the formation of immediate discharge when we speak about rains and with a slight delay when we speak about the snow. The report under which these two precipitation forms contribute is expressed by the value of the Zs index. Table 6.3

Table 6.3 Water input sources for the rivers in the Moldavian Plain (Pantazică, 1974)

No.	River	Post	% from total			% from superficial sources	
			Uo	Pl	Zs	Zs	Pl
1	Bahlui	Iaşi	14,6	50,5	34,9	40,1	59,9
2	Bahlui	Pd. Iloaei	14,5	51,3	34,2	40	60
3	Bahlui	Hârlău	5,0	60,8	34,2	36	64
4	Miletin	Vlădeni	14,3	49,7	36,0	42	58
5	Miletin	N.	5,1	57,0	37,9	40	60
6	Sitna	Todireni	14,5	49,3	36,2	42,5	57,5
7	Sitna	Botoşani	5,2	56,9	37,9	40	60
8	Jijia	Chipereşti	14,0	48,9	37,1	43	57
9	Jijia	Victoria	14,3	49,4	36,3	42,5	57,5
10	Jijia	Todireni	14,2	50,6	35,2	41	59
11	Jijia	Dorohoi	3,6	60,8	35,6	37	63
12	Başeu	Ştefăneşti	14,0	49,4	36,6	42,5	57,5
13	Başeu	Săveni	13,6	49,3	37,1	43	57
14	Volovăţ	Coţuşca	13,7	49,5	36,8	42,5	57,5

As an average, the value of the Zs index supplied by snows as compared to the general situation in Romania varies in short limits, due to a relatively uniform degree of the influencing factors in the Moldavian Plain. This oscillates between 36% (on Bahlui at Hârlău h.s.) and 43% (on Jijia at Chipereşti h.s.; on Başeu at Ştefăneşti h.s.).

Following the classification norms proposed by M. I. Lvovici and L Ujvari (1957) for the surface sources the supply is considered of *moderate pluvial type* (Pz) when the Zs index oscillates between 20% and 40% and of *snow-pluvial type* (pz) when Zs is between 40% and 50%. In this respect we can affirm that the rivers in the Moldavian Plain display two characteristic types as far as the surface supply is concerned:

- *the moderate pluvial type* (Pz) is characteristic to the high hills (I. Ujvari, 1959), including the extreme western part and the southern part of the Moldavian Plain, in the contact piedmonts zones (M. Pantazică 1978). There are decreased winter waters and increased spring waters from March to April. As compared to the rest of the region this part does not have high water level oscillations. For this type the summer floods are characteristic which frequently exceed the transport capacities in the minor river-beds in short intervals of time (1 – 2 hours). The existence of this type is induced by the reduced precipitations quantities in winter, below 10%, and by the assembly geographic conditions which allow a more rapid water infiltration of the waters from snow melt which takes longer time here.

- *the snow-pluvial type* (pz) is characteristic to the rest of the Moldavian Plain; due to this type of supply the high waters appear in February-March and is better represented in the discharge regime because of more abundant snow precipitations in this part (above 15% of the total) and the snow melt is more rapid and on wider surfaces. Additionally, the low permeability of this part contributes to a slight increase of the discharge in this season as compared to the previous season.

b. The subterranean sources represent the second important element of supply for the rivers, mainly from the descendent subterranean waters, as more profound waters which do not deplete in the droughts periods. These supply sources are important, not because of their volume (20% contribution) but because of their continuous character which insures the permanent river flow of some important streams in the Moldavian Plain (Jijia, Bahlui Buhai, Ibăneasa etc.), in those periods when surface water is missing.

In average, this subterranean supply source contributes to the discharge formation with 3.6% on Jijia at Dorohoi and with 14.6% on Bahlui la Iaşi. Even if in the high hills (the values at Hârlău, Botoşani and Dorohoi) the percentage of this kind of supply seems to be lower (below 10%) the subterranean supply is more stable with a small quantitative variation, in time. In the Moldavian Plain the subterranean supply oscillates wider, between 3% and 20%. In this part there are also frequent cases when, during autumn, the supply power of the descendent aquifers is severely reduced resulting in the interruption of water supply in the springs.

According to the Lvovici classification the subterranean water supply is weak if the percentage is below 10% for the rivers discharge and moderated if the contribution is between 10% and 35%.

Considering the uniform character of the supply in the hills region which compensate for the variable one in the Plain, Maria Pantazică considers all the north-eastern Moldavia as having a moderate subterranean supply.

In conclusion, for the NE of Moldavia there were established two types of water supply for the rivers I. Ujvari, 1959):

1) *the pluvial moderate and subterranean moderate type* characteristic to the high hills in the Plateau also identified by us as present in the western and southern Moldavian Plain, in the contact depressions zone;

2) *the pluvial-snow and subterranean moderate type* which is characteristic for the central and eastern Moldavian Plain.

6.3. The hydrologic balance

The hydrologic balance represents a method to determine the quantitative report in which the source possibilities for the water input behave according to the water output in a precisely delineated region. The hydrologic balance analysis reflects the aquatic quantitative reserves of a certain region. The spatial differentiation of the hydrologic balance is manly determined by the general decrease of air humidity from NW to SE in the study region.

For the determination of the hydrologic balance, Maria Pantazică, in the Moldavian Plain Hydrography uses the Lvovici's equation where the superficial leakage (So) added to the soil's total humidity (Wo) is considered equal to the water input from precipitations (Xo) calculated as averages of an extended period (over 20 years) (tab. 6.4):

$X0 = Y0+Z0 = S0+U0+Z0$

X0 –the average of annual precipitations' sums;

Y0 – the global average leakage;

Z0 – evapotranspiration;

U0 – subterranean leakage;

S0 – superficial leakage.

The total soil's humidity represents the sum of water quantity which, via infiltration, contributes to the formation of the subterranean sources leakage (Uo) and the quantity of water lost through evapotranspiration (Zo).

Table 6.4 Elements of hydrologic balance of the rivers (A.B.A. Prut-Bârlad supported data)

No.	River	Post	Hmed m.	Xo mm	Yo mm	Zo0 mm	So mm	Uo mm	Wo mm
1.	Bahlui	Iaşi	150	603	55.5	547.9	41.3	7.1	554.6
2.	Bahlui	Pd. Iloaiei	202	498	56.9	441.2	45.1	8.2	444.7
3.	Bahlui	Hârlău	317	526	96.7	429.7	79.8	6.1	440.1
4.	Miletin	N. Bălcescu	202	560	67.4	492.8	47.8	5.2	507
5.	Sitna	Todireni	167	506	78.9	427.3	44.2	7.2	454.6
6.	Sitna	Botosani	202	566	90.1	476.3	51.5	4.9	509.6
7.	Jijia	Chiperesti	155	521	69.5	447.3	37.9	6.5	476.6
8.	Jijia	Victoria	159	514	62.1	407.4	38.4	5.8	469.8
9.	Jijia	Todireni	186	503	66.0	440.1	43.8	7.6	451.6
10.	Jijia	Dorohoi	262	548	87.5	461.0	71.2	4.8	472.0
11.	Baseu	Stefanesti	168	499	56.8	441.8	37.1	6.8	455.1
12.	Volovăţ	Manoleasa	178	501	61.6	439.4	40.1	6.0	455.1

The precipitations (Xo) constitute the most important element of the equation because they represent the comparing unit for the sum of the other hydrological balance components. From the analysis of the annual precipitations distribution in the Moldavian Plain we observe that the atmospheric precipitations decrease slightly from west to east as a consequence of relief's lowering on this direction and due to an increased frequency of air masses from west, which are Atlantic origin air masses that partially discharge toward east. The presence of the foehn in the west results lower west to east differences as a function of the vertical pluviometric gradients for the northern Moldavian Plateau.

From the analysis we observe the decrease of the precipitations to the east and in the same time with the altitudes lowering.

The general precipitations' decrease from the north and west to the south and central-eastern zone is a consequence of relief's lowering in the same direction but also a consequence of distance increase from the high morphometric border that delineates the Moldavian Plain, border which is mainly covered by forests. This fact allows the continentalization of the air masses from west and, as a result, the humidity is decreasing as compared to the saturation point.

The average leakage (Y0) represents the second important element of the hydrologic balance and is calculated based on the liquid discharges in the same period over the precipitations.

From the average leakage repartition we observe the same decrease of the values from west to east as conditioned by the altitudes lowering and by the modification, as a consequence, of the physical-geographic assembly.

From the precipitations' total the leakage represents 9% for the eastern part and 16% for the western part in the study region. The decrease of the leakage coefficient (Y0) from west to east is conditioned by the decrease, in the same direction, of the precipitations and average leakage, by the slopes decrease and, in general, by the plane or slightly undulated surfaces increase.

*The average surface le*akage (S0) oscillates in the same direction with the global average leakage and has big values in the high altitude hydrographic basins and smaller values in the lower altitude hydrographic basins.

The *evapotranspiration* (Z0) is the third main component in the balance equation and is calculated through the difference between the average fallen precipitations and the average leakage recorded at the hydrometric stations. It takes lower values in the higher lands from west and north and higher values in the lower lands to the east where the average values are over 440 mm per year.

Taking into consideration the oscillation limits of the hydrological balance components' values, as established by *Ujvari* (1972) for different zones of humidity in Romania, the Moldavian Plain pertains to the *deficient humidity*, this due to the alternation of high humidity and deficient humidity years where the deficient humidity years prevail.

6.4. Average discharge

The average discharge of the rivers is determined by the average arithmetic value of the daily average discharges, monthly average discharges and annual average discharges on a multi-annual period, where the average gets as stable as possible for the given physical-geographic conditions as a result of more data accumulation. The average discharge can be expressed for comparable necessities, in specific discharges (l/s/km^2) or water strata (mm).

Considering the anthropic influences, the natural average monthly and annual discharges are reconstructed on the bases of monthly and annually averages at the hydrometric stations, according to the following balance relation: measure

Qnat.=Qmeas+$\sum Qc - \sum Qr + \sum Wa/Wd + \sum Q_P - \sum Q_E + \sum Q_{GH}$

where:

Qnat. – the reconstructed discharge at a certain hydrometric station (m^3/s);

Qmeas. – the effective measured discharge at the hydrometric station;

$\sum Qc$ - the sum of discharges taken from up-stream hydrometric data;

$\sum Qr$ - the sum of the rendered discharges for up-stream data as compared to the hydrometric station (including the supply from water derivations from other basins or of water infiltrations);

$\sum Wa/Wd$ - the sum of the accumulated/discharged from lakes up-stream the hydrometric station;

$\sum Q_p$ - the sum of the discharges from atmospheric precipitations fallen on the lakes' surfaces , up-stream the hydrometric station;

$\sum Q_E$ - the sum of the discharges from evapotranspiration in the water accumulations up-stream the hydrometric station;

$\sum Q_{GH}$ - the sum of the discharges from ices on the water accumulations up-stream the hydrometric station;

In general, for discharges' rendering, the three types of data (precipitations, evapotranspiration and ice cover) are calculated only if the percentage of Q_P-Q_E,, respectively Q_{GH} exceeds 10-15% of *Qnat* value.

If up-stream the hydrometric station there are only consumption situations we should only use the following relation:

Qnat. = Qmeas + $\sum Qc - \sum Qr$

For each case it is necessary to detail the correction discharge on the bases of data regarding the modifying factors for the river-bed discharge and considering the stored and the released discharges for different uses. The calculus is made for each hydrometric station with the sums for the consumption uses.

6.4.1. Average multi-annual discharge

The annual average discharge of the rivers is the one of the main leakage regime characteristics. It represents the index of aquatic capacity to be considered in various hydro-economic estimations. Its value and its variation mode reflect the complex interaction of the physical-geographic factors inside the study region and, especially the influence of the climatic factors.

In order to be as constant as possible, this characteristic must be observed on a long period. In the research area, the discharges are regularly measured since 1950 that is why, for the majority of the hydrometric posts, we calculated the discharge of last year. For the sake of analysis we took the average annual discharges and monthly average discharges for 3\23 characteristic points in the region, of which, 7 posts are in the northern half and 11 in the southern half.

From the resulted data analysis and from the ones, graphically represented (fig. 6.16), we notice the increase of the annual average discharges from springs to effluences, as directly reported to the increase of the affluences number and, respectively to the increase of the supply basins' surfaces. For example, on Jijia, the main stream of the study region the discharges are 0.67 m^3/s at Dorohoi, 2.25 m^3/s at Todireni, 6.38 m^3/s at Victoria and 12.3 at Chipereşti. The increase gradient has an average of 1.75 m^3/s at 1000 km^2.

Due to the physical-geographic conditions of the supply hydrological basins, the discharge's increase as reported to their unequal surfaces suffer from a high asymmetry as evidenced by the analysis of the specific discharges. Thus, when reporting the discharge to the corresponding surface we notice a decrease of values when basins become larger (fig. 6.17). This situation indicates the fact that, in reality, the input strength for the rivers in larger basins becomes lower because the more extended basins suffer from the excessive character of the continental climate that is less favourable for water discharge.

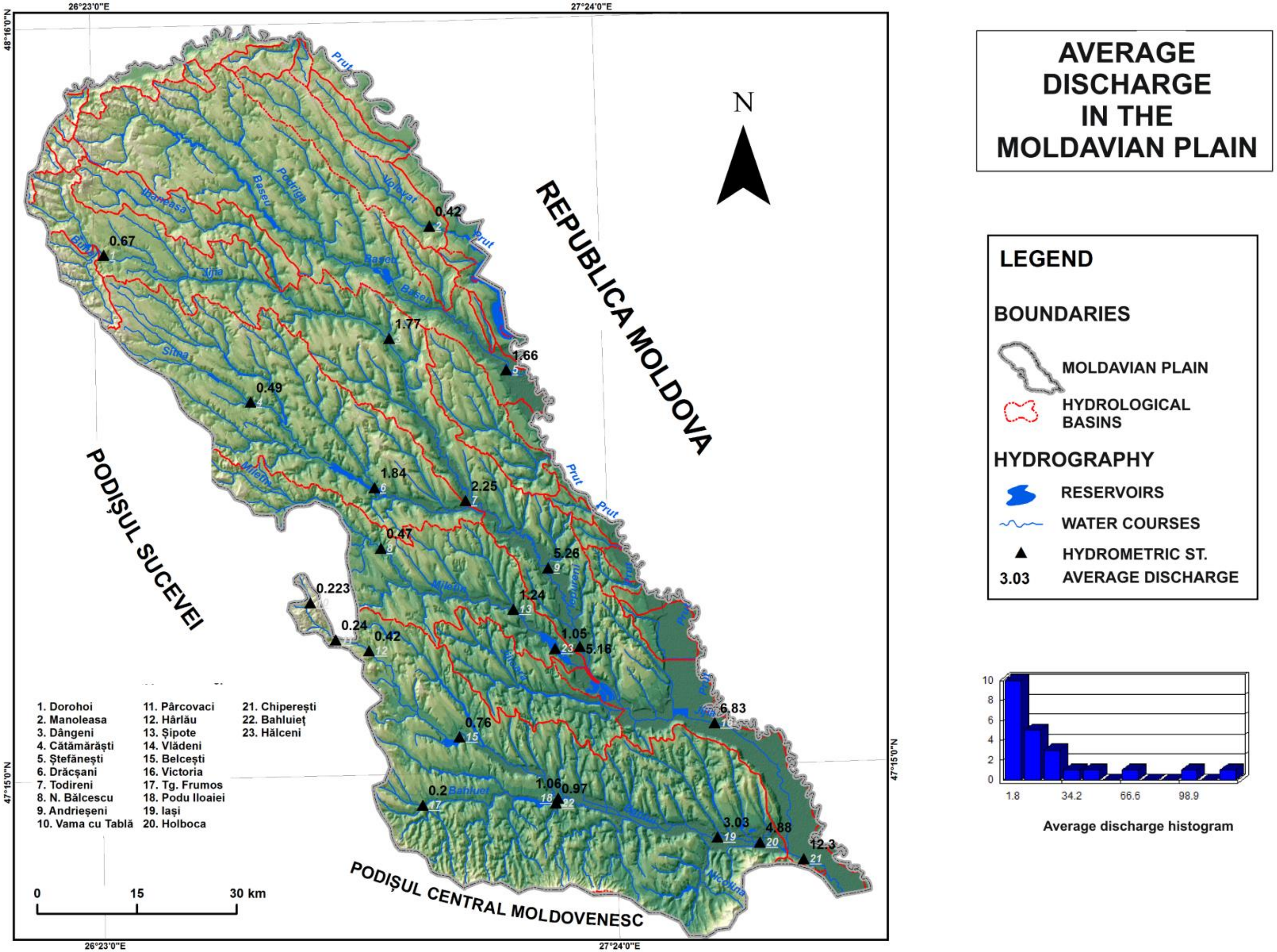


Fig. 6.16 The average rivers' discharges in the Moldavian (1950-2011)

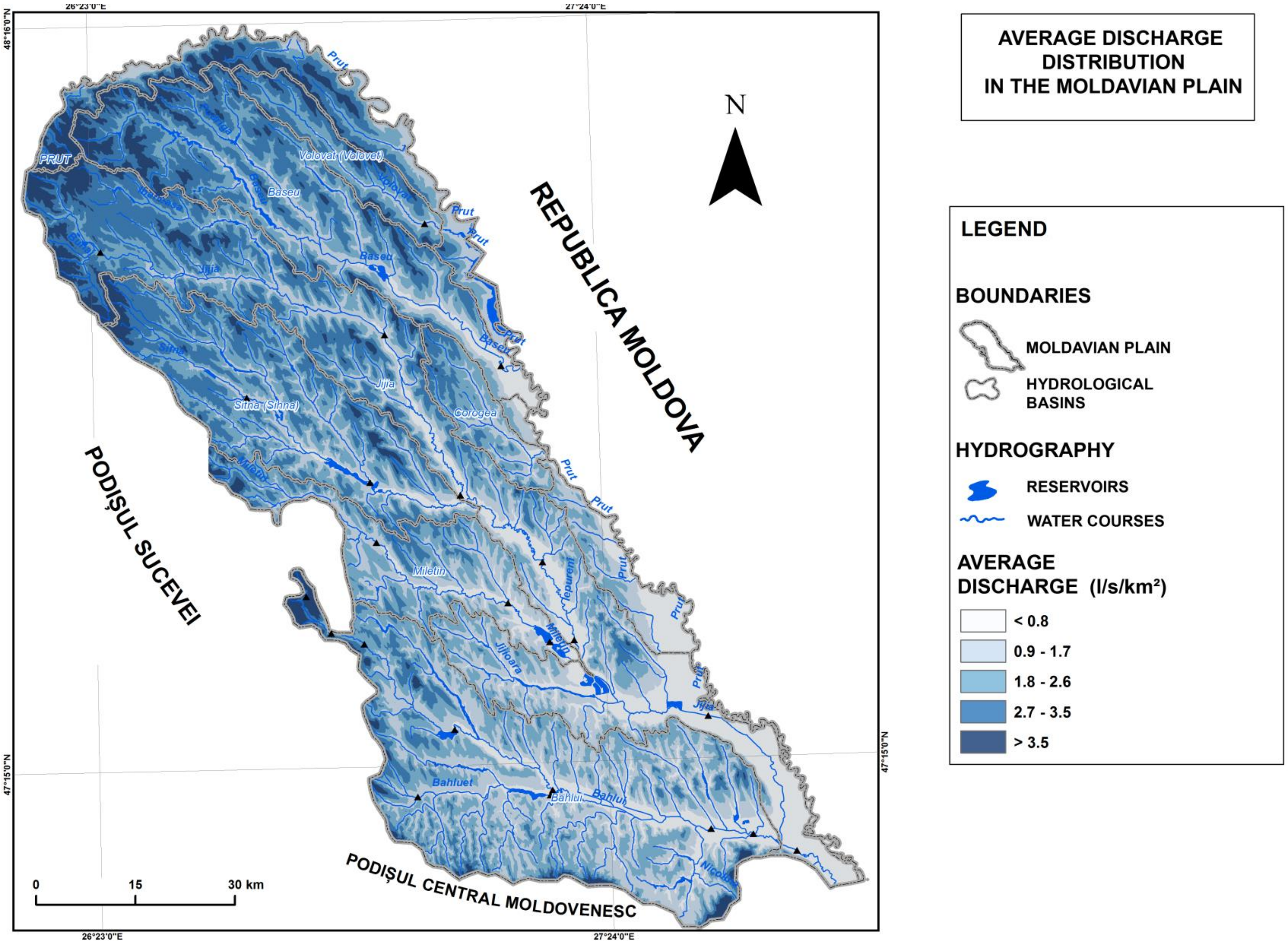
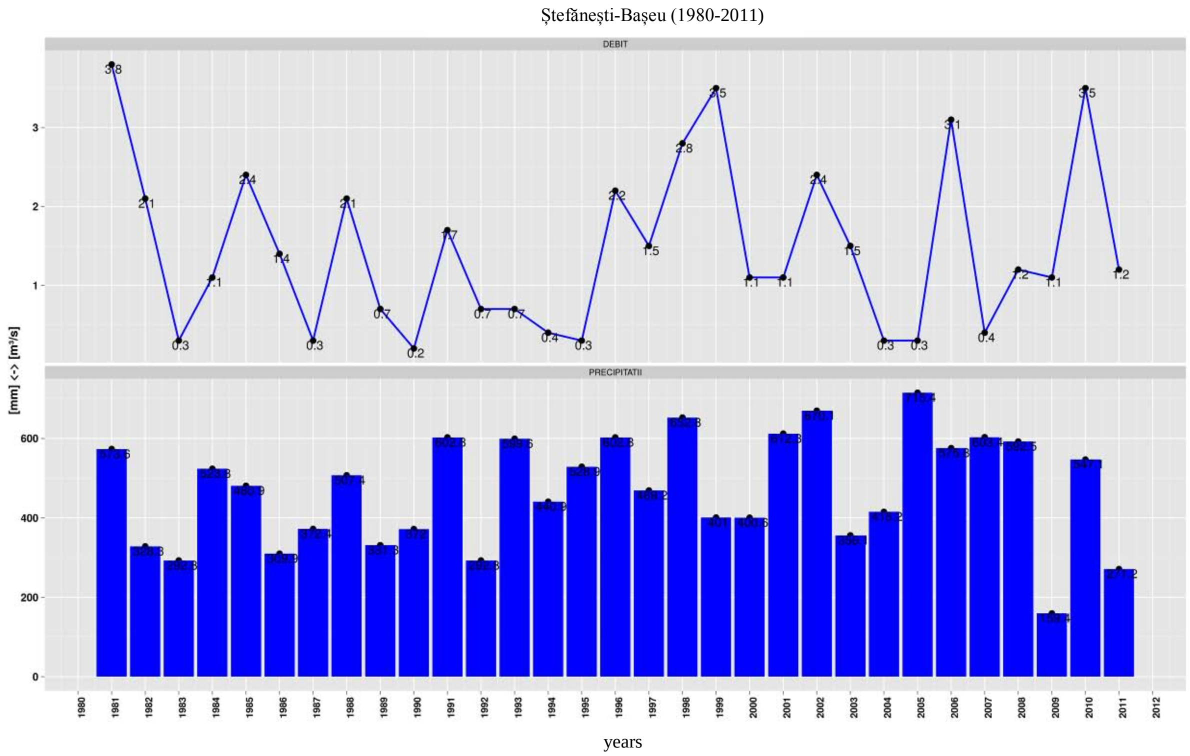


Fig. 6.17 Average discharge distribution in the Moldavian

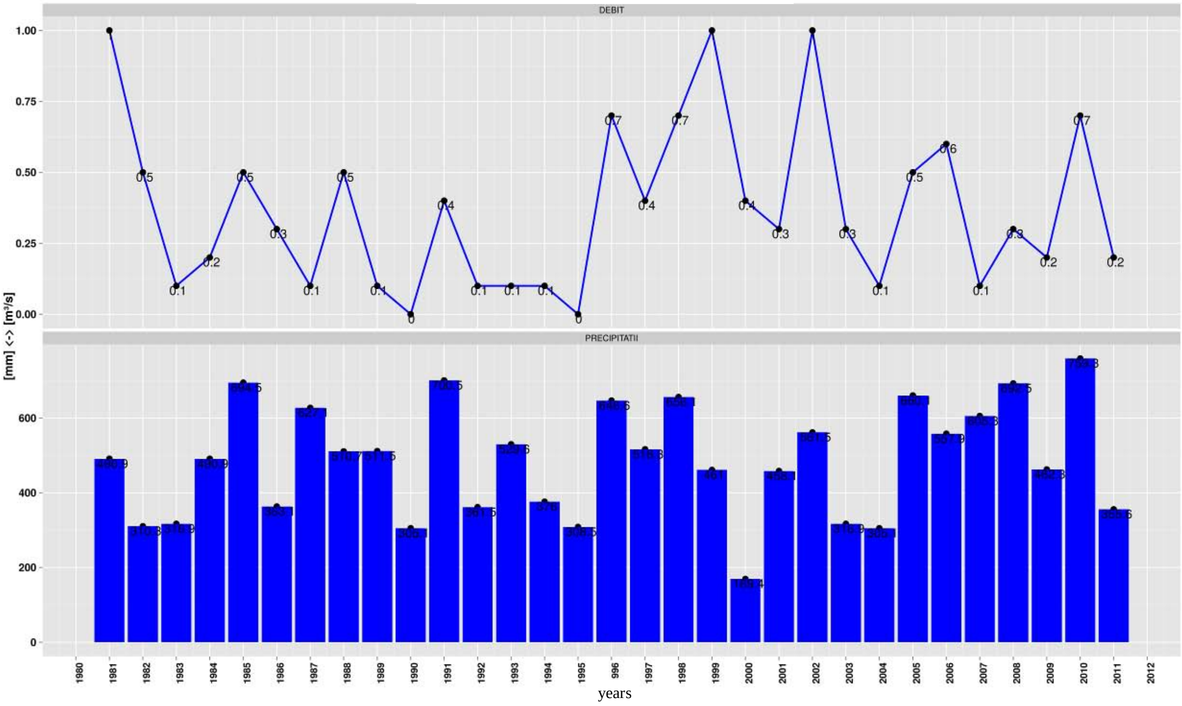
From the analysis of the general map of the territorial distribution of the specific liquid discharge we notice values between 2.6 and 3.5 litres s/km^2 in the upper basins, as a results of abundant precipitations, steep slopes and high relief's fragmentation while, in the rest of the region the specific discharge oscillates between 1.8 litres/s/km^2 where the water supply is reduced and the stream network less organized. The vertical gradient of the discharge oscillates between 0.4 litres/s/km^2 at 100 meters in the Moldavian Plain and approximately 1 litre/ s/km^2 at 100 meters at the contact with the high Plateau in the west and in the south of the study region.

From the analysis of the specific discharge map we can deduce that, annually, in average the biggest water quantity is brought to Jijia by the right-side affluents. Among this, the Bahlui, Miletin and Sitna which drain 50% of the entire surface of the basin contribute with 70% of the total discharge.

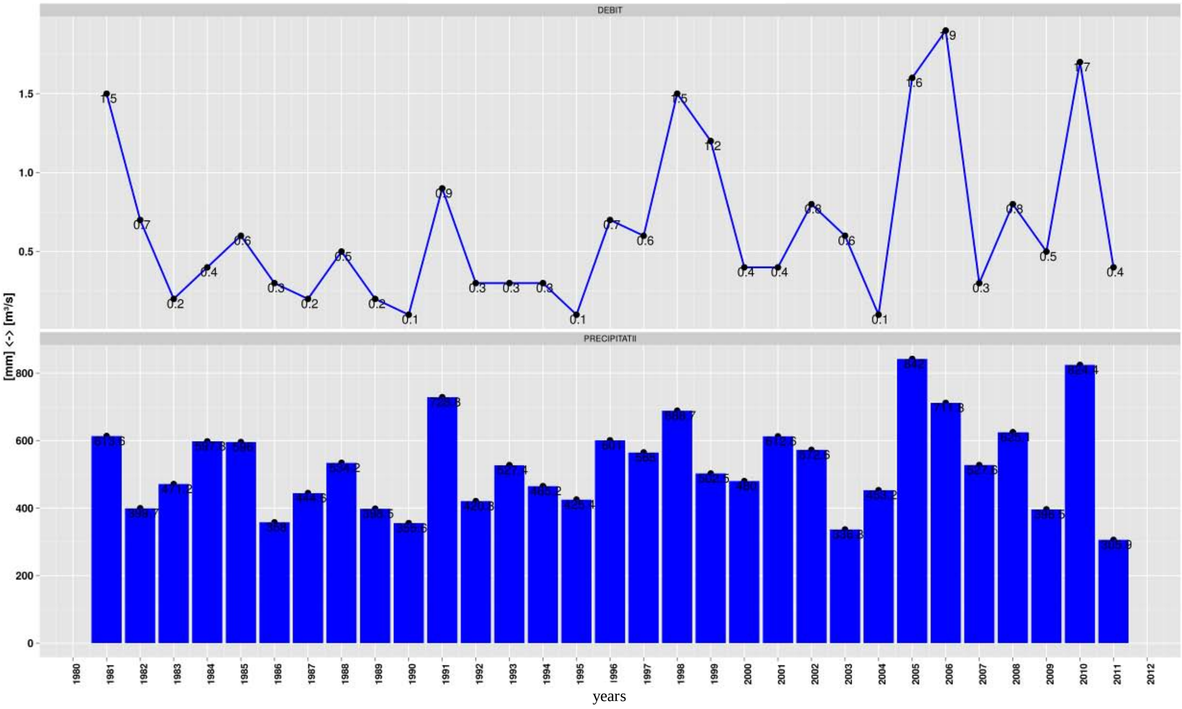
From year to year the average discharges oscillate over a long period, especially as a function of the climatic elements variation. Thus, the variations of precipitations, which are the main source of supply for rivers and the temperatures, along with humidity variations determine the value of the discharge for each year (fig. 6.18).



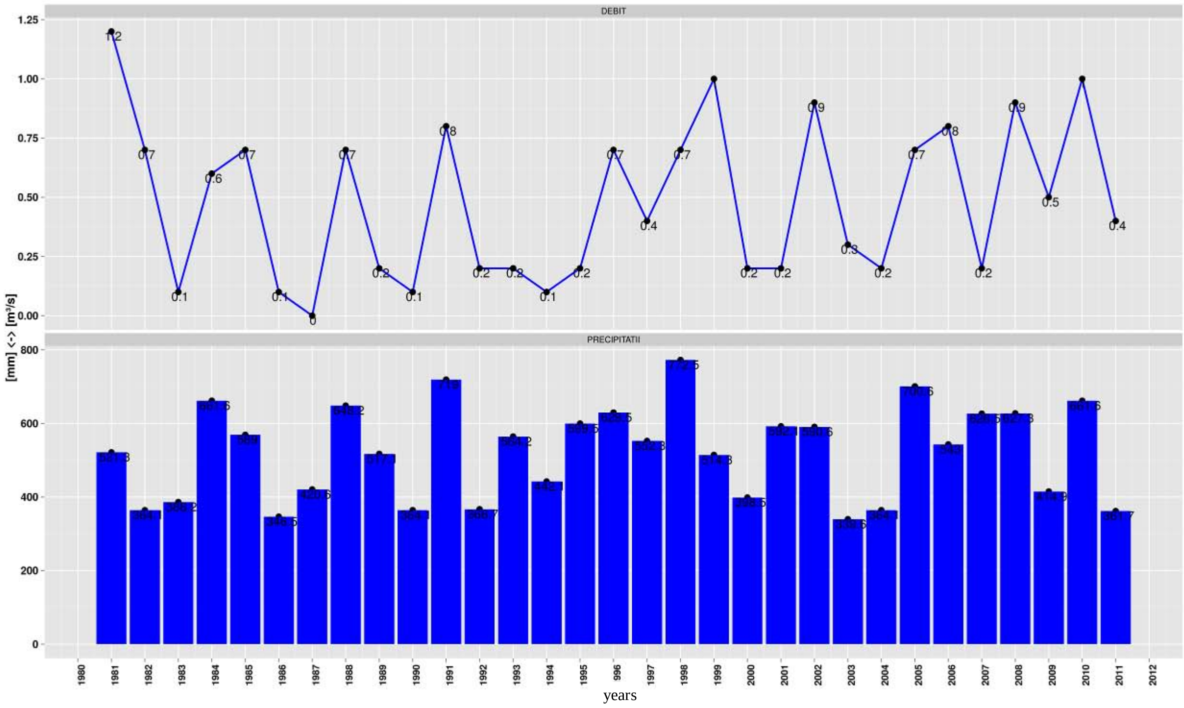
Manoleasa - Volovăț (1980-2011)



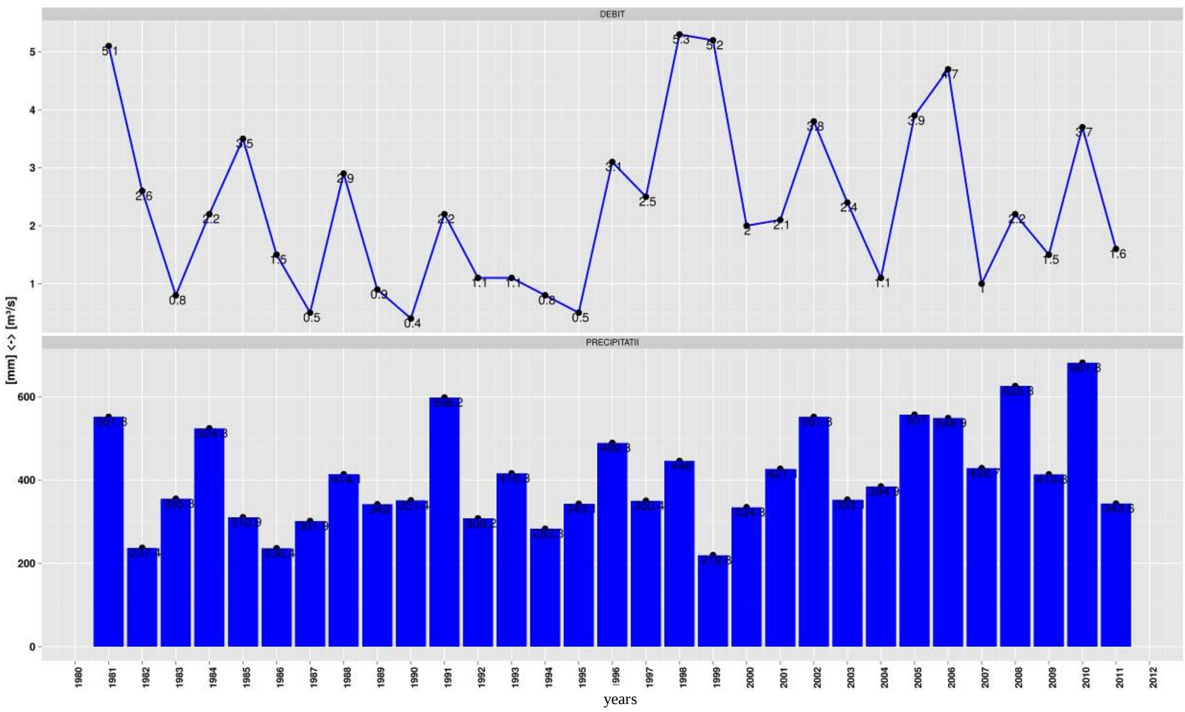
Dorohoi - Jijia (1980-2011)



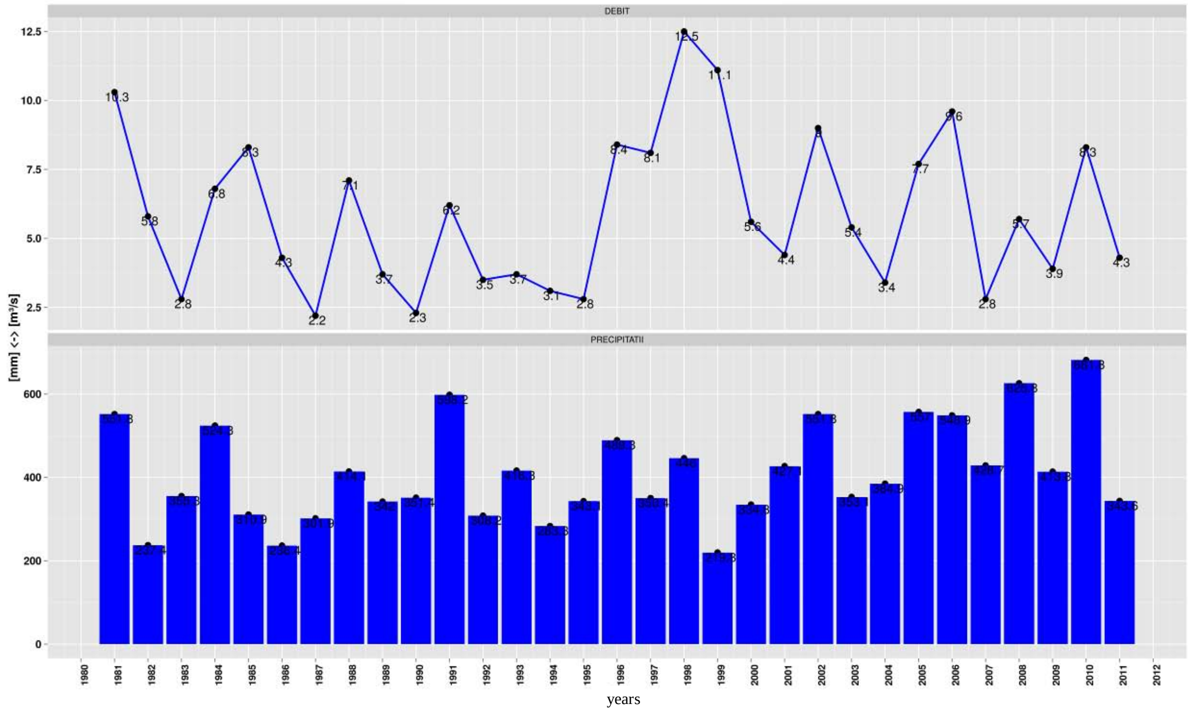
N.Bălcescu - Miletin (1980-2011)



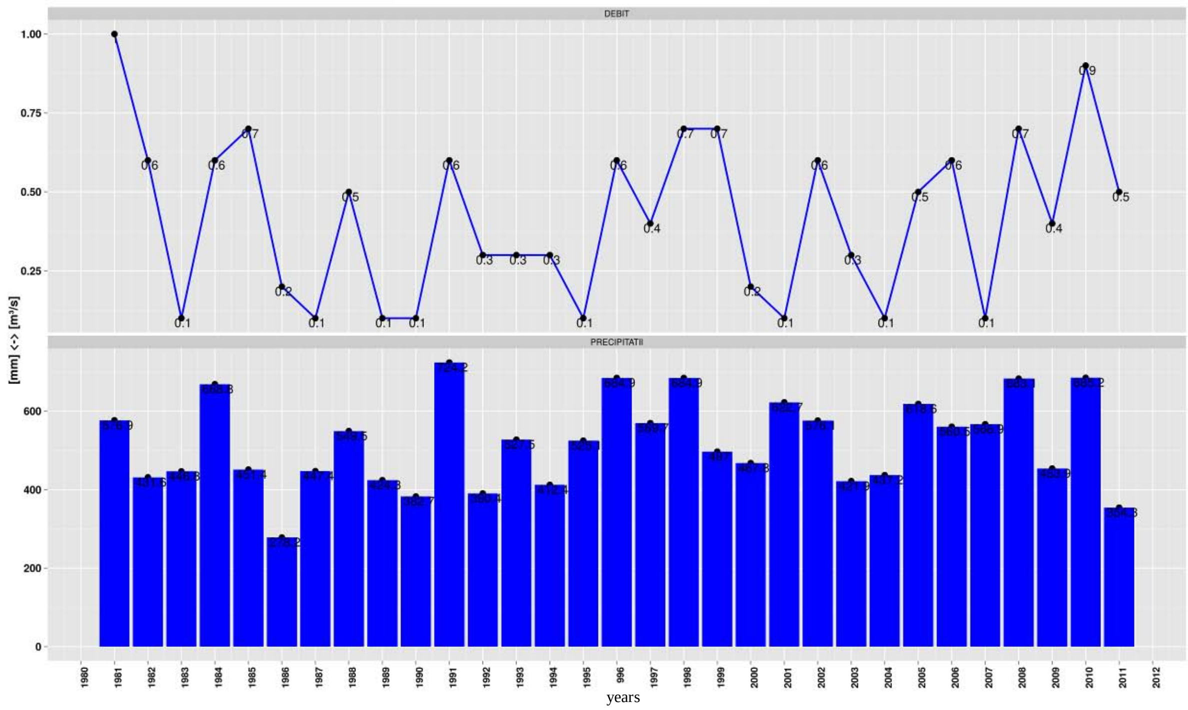
Sipote - Miletin (1980-2011)



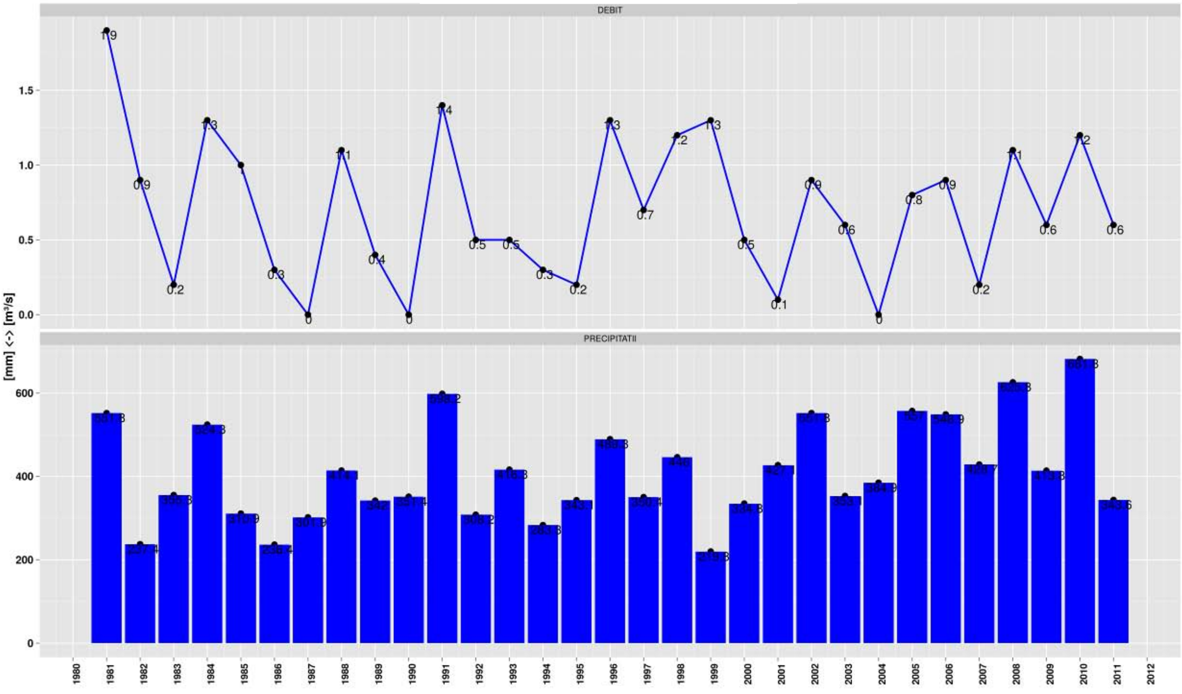
Vlădeni - Jijia (1980-2011)



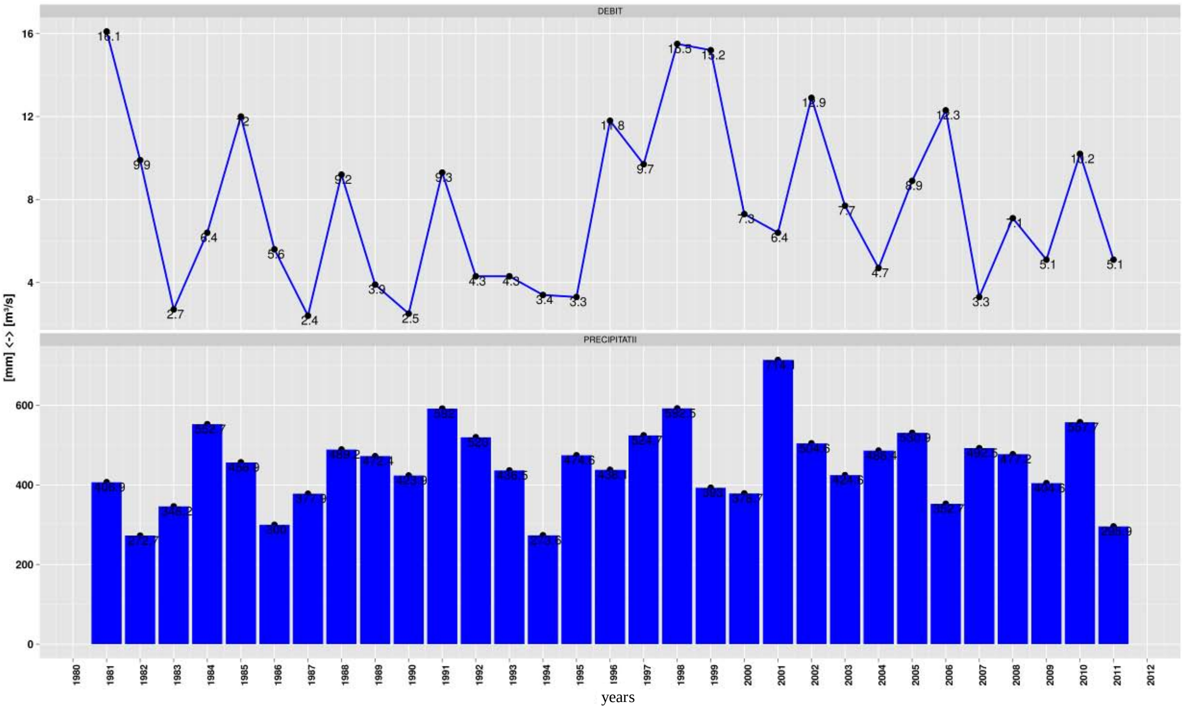
Hârlău - Bahlui (1980-2011)



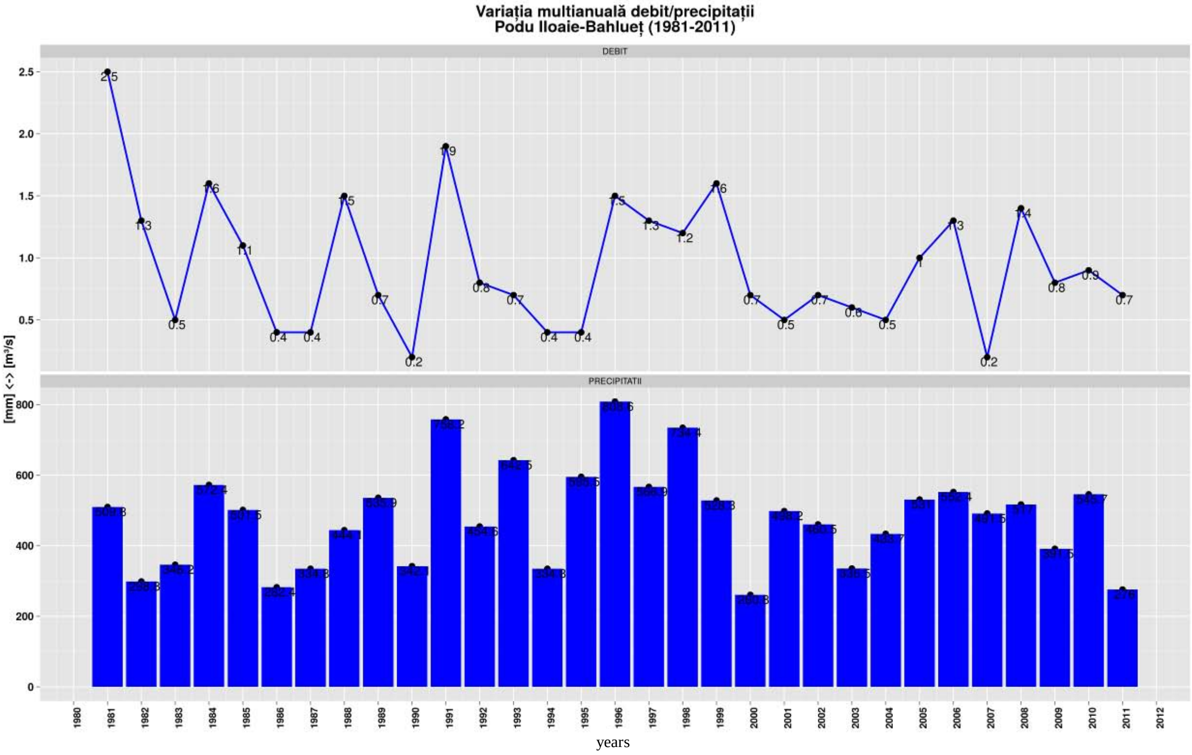
Belcești - Bahlui (1980-2011)



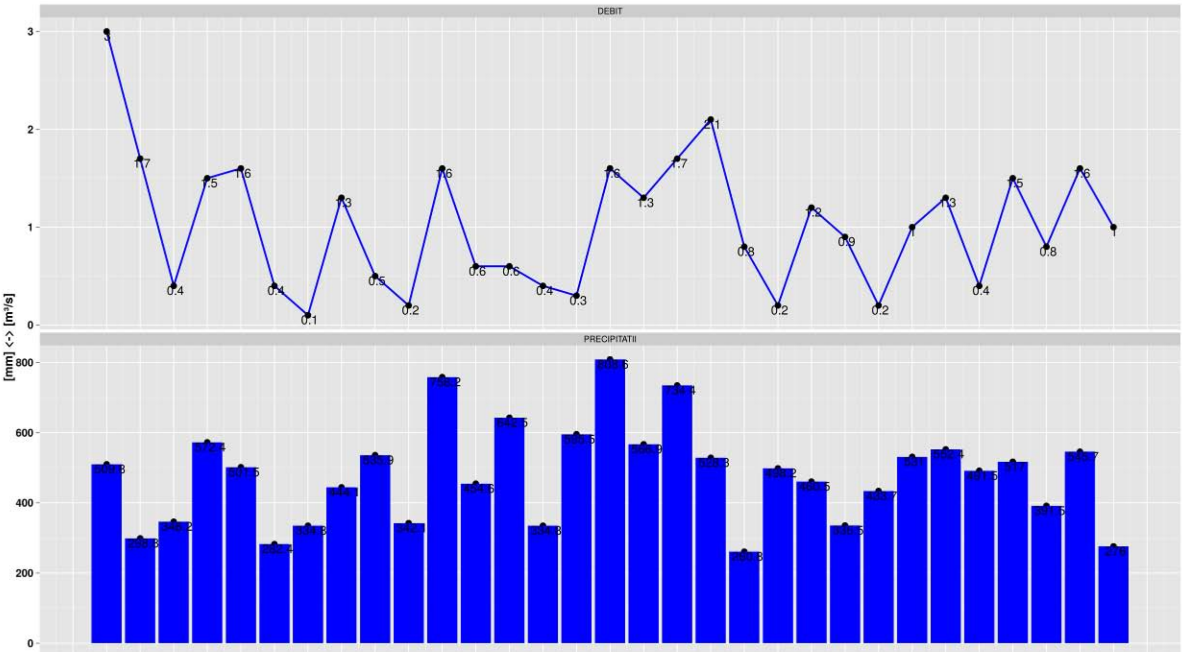
Victoria - Jijia (1980-2011)



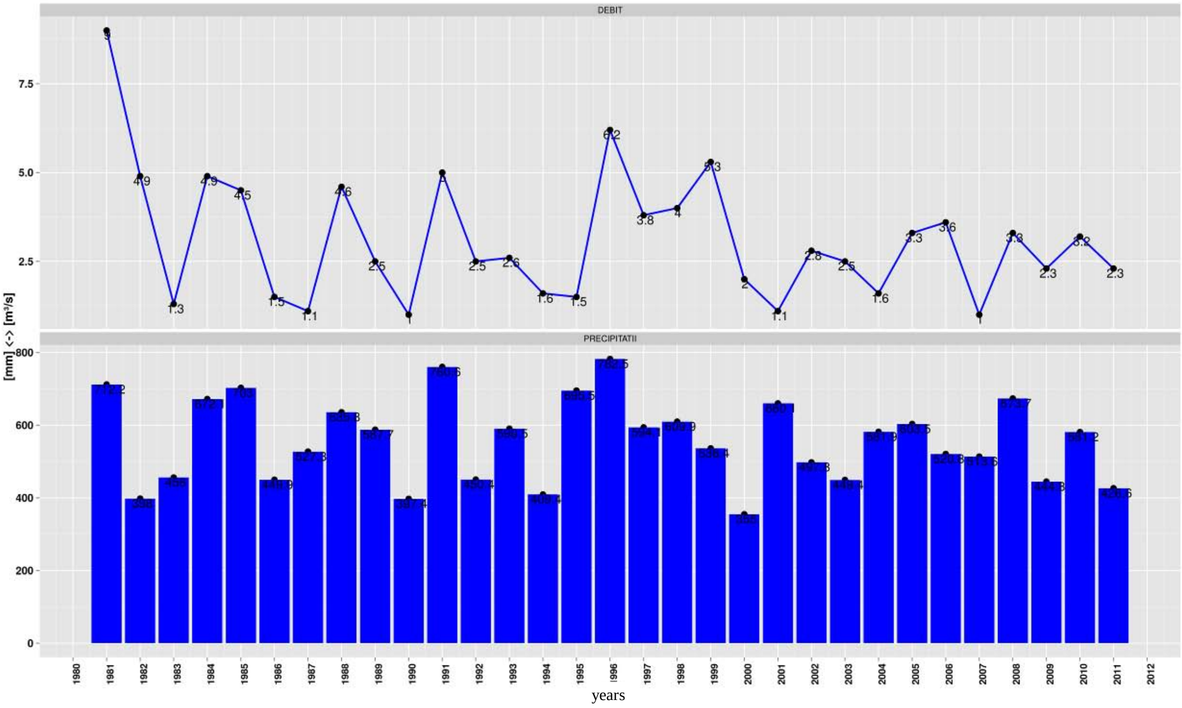
P. Iloaie - Bahlueț (1980-2011)



P. Iloaie - Bahlui (1980-2011)



Iaşi - Bahlui (1980-2011)



Chipereşti-Jijia (1981-2011)

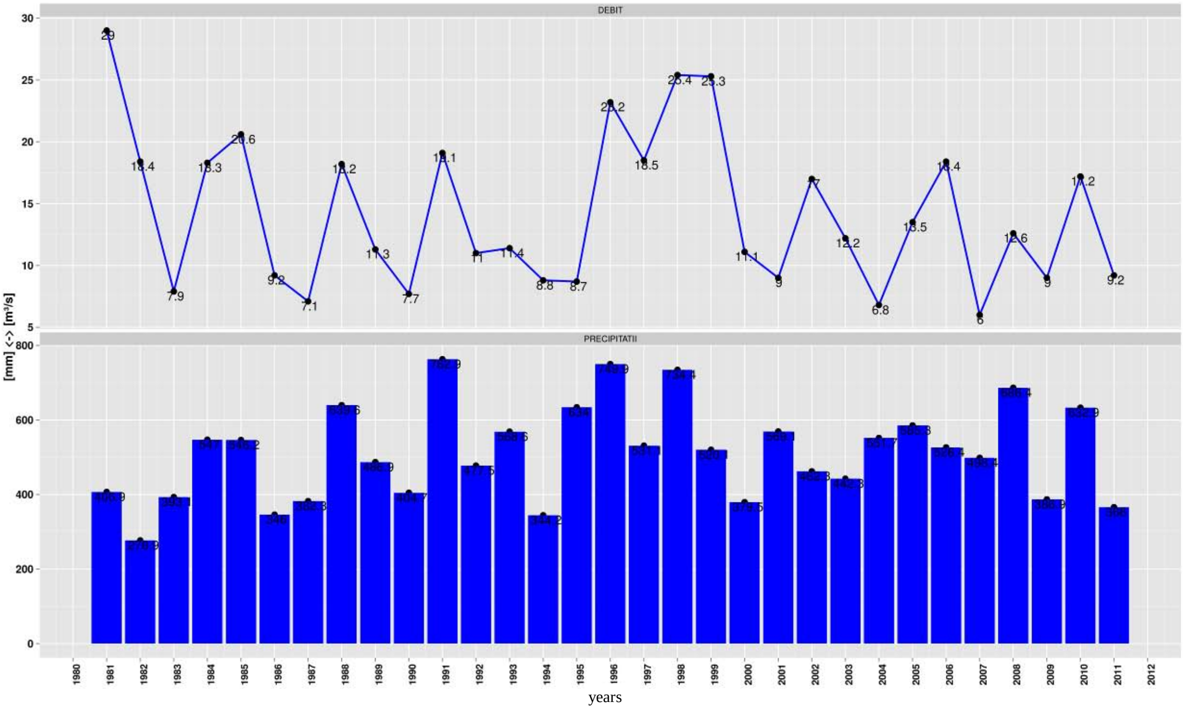
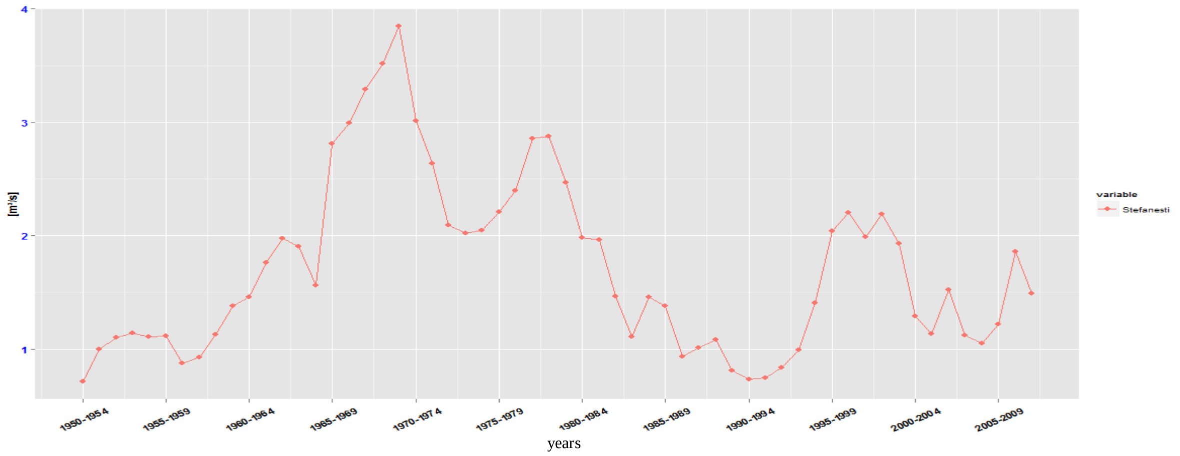


Fig. 6.18 The multi-annul variation of the average discharges and precipitations in the Moldavian Plain

6.4.2. Cyclic variation of the average discharge

In order to determine the cyclic character of the discharge for the hydrometric stations in the Moldavian Plain we calculated the moving averages on 5 years for the average values of the annual discharges. By graphically transpose the results (fig. 6.19) we observe that all the hydrometric stations present two periods of increase on rivers; the first period between 1965 and 1984 and the second period between 1995 and 2010, determined by the precipitations' increase. Inside the first period we notice two important peaks in the rivers discharge corresponding to 1969 and 1982. In the same time, analysing the moving averages on 5 years we can identify, very easily, the decrease between 1985 and 1989.

water catchment Bașeu (1950-2012)



water catchment Volovăț (1950-2012)

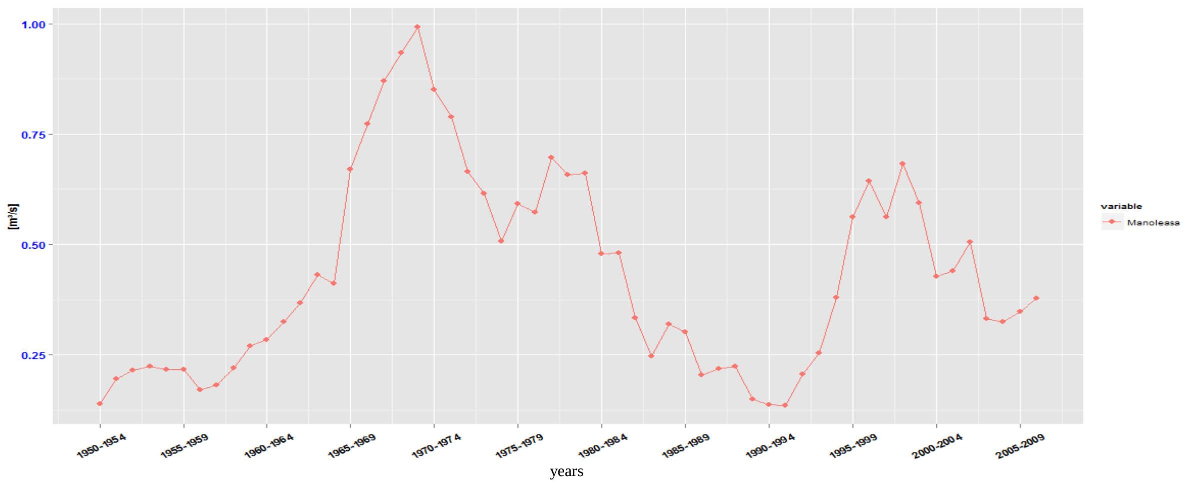
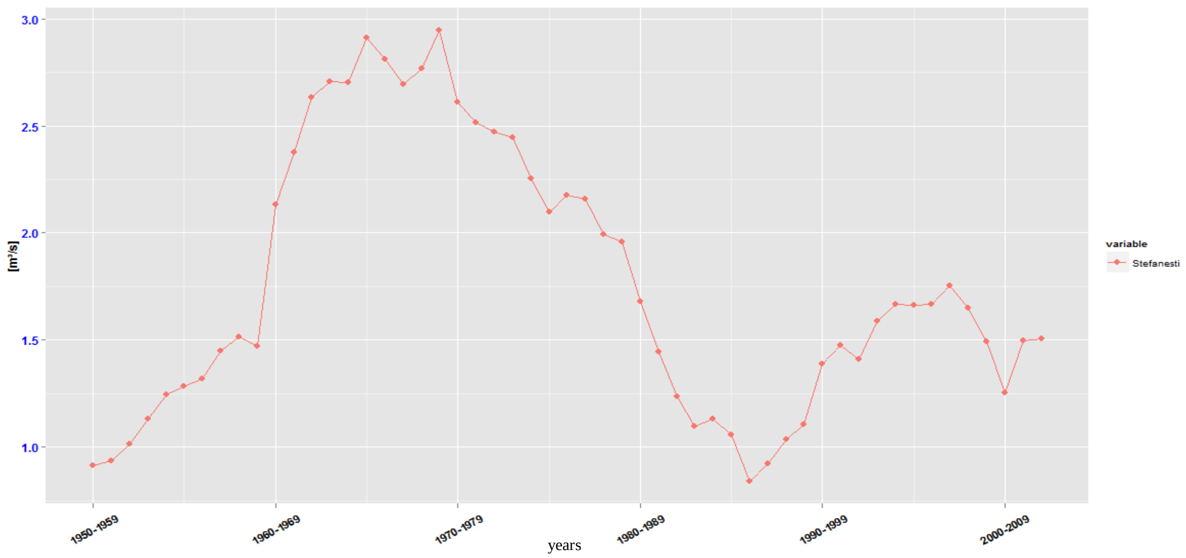


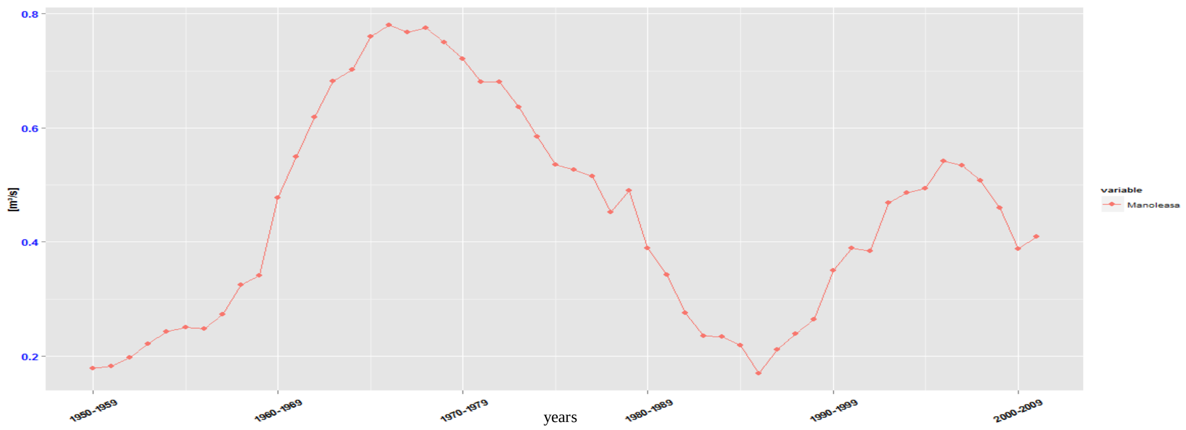
Fig. 6.19 The variation of the average discharges on five years moving averages for the main rivers in the Moldavian Palin

The same evolution periods, with certain drawbacks are evident if we analyse the cyclicity of the average discharge regime on 10 years moving averages (fig. 6.20).

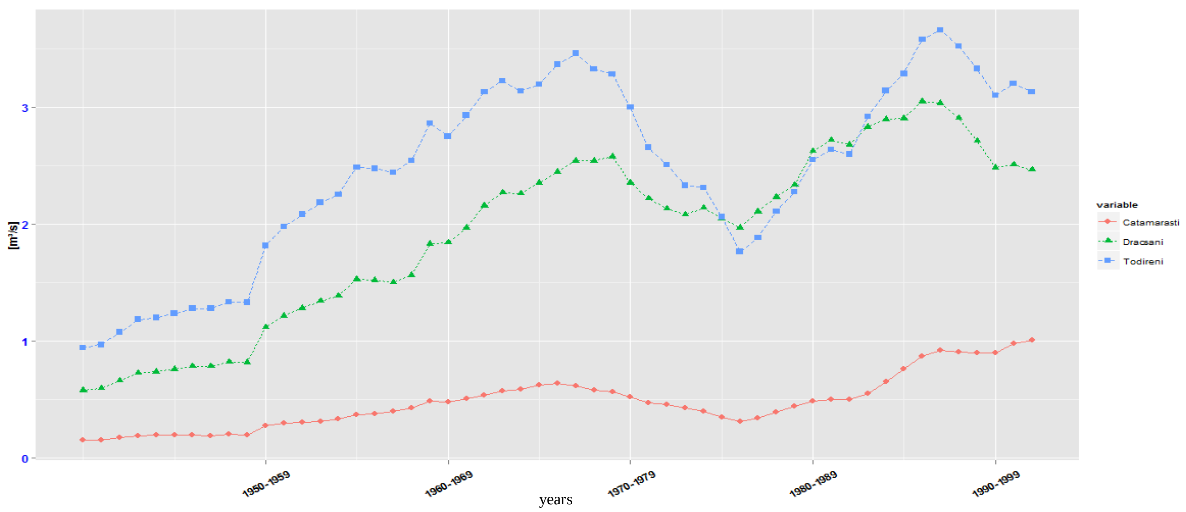
water catchment Bașeu (1950-2012)



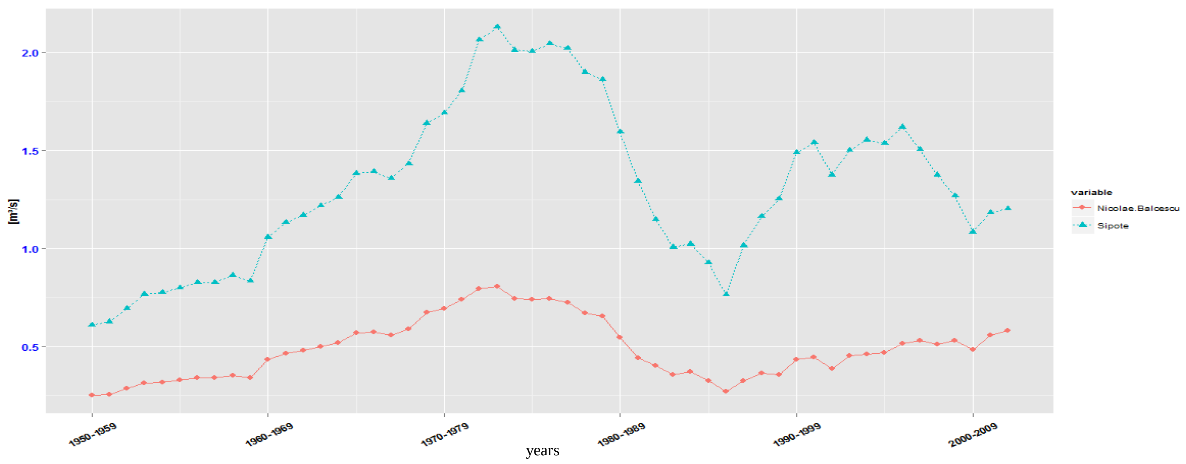
water catchment Volovăț (1950-2012)



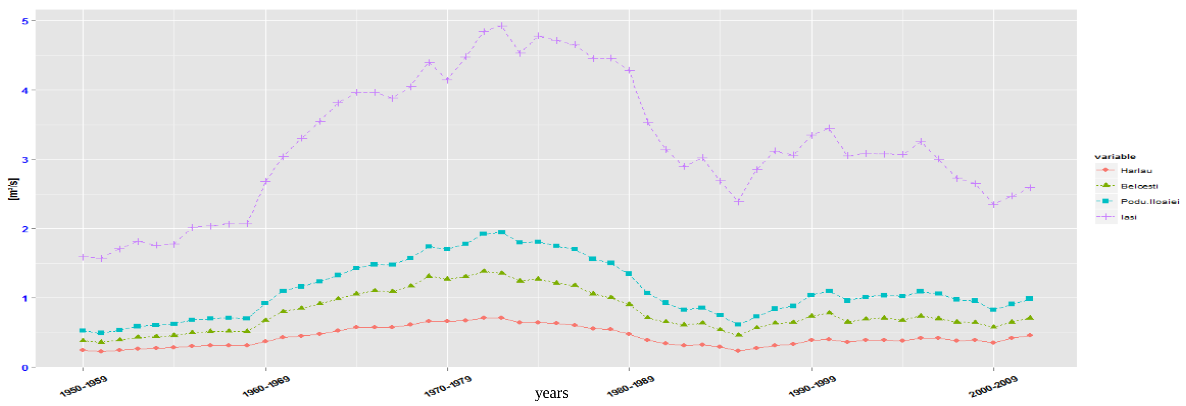
water catchment Sitna (1950-2012)



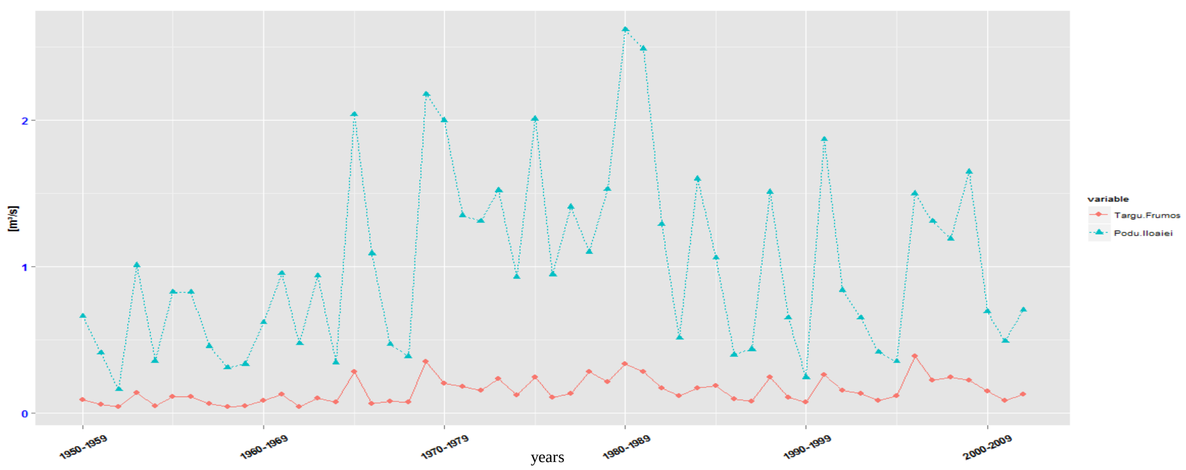
water catchment Miletin (1950-2012)



water catchment Bahlui (1950-2012)



water catchment Bahlueț (1950-2012)



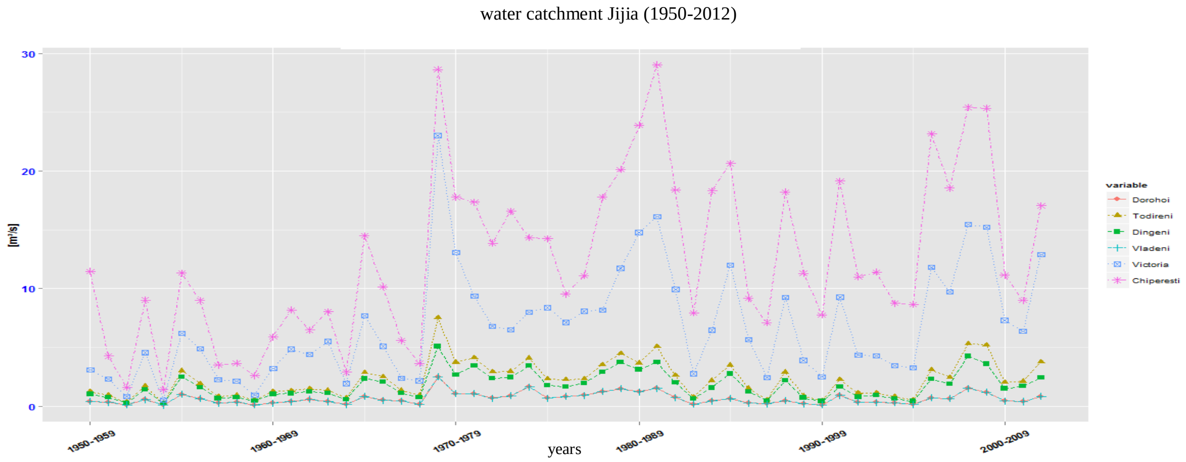


Fig. 6.20 The variation of the average discharges on 5 years moving averages for the main rivers in the Moldavian Plain

The characterization of the variability of annual discharges for a certain period, as reported to the multi-annual discharge is suggestively expressed via the variation coefficient (Cv).

For the rivers in NE Moldavia the values of Cv for the annual average discharges oscillates between 0.07 on Bahlui, at Hârlău and 0.78 on Jijia, at Victoria. Comparing these results with the ones calculated by S. Dumitrescu (1964) for 38 characteristic points in Romania we infer that, in the main basins of the Moldavian Plain, the annual average discharges are very unstable, mainly as a consequence of the excessive continental climate.

The variation coefficient in the study region can take low values at lower average altitudes, depending on the river-bed local conditions. We notice here the Jijia River, at Todireni and Larga or the Bahlui River, in the Erbiceni sector where the existence of a wide alluvial plain with dead river branches, swamps and shallow minor river-beds allow important water quantities storage in case of floods; as a consequence, the annual discharge amplitudes are lower. Differences from the above mentioned rule are observable for the variation coefficient, also in the case of upper values interval of the average high altitudes. As an example, in the NE (upper Jijia), the Baltic influences are more pronounced and expressed by stronger summer convections with abundant torrential rains. In this part, the existence of deep minor river-beds (over 10 m) insure 100% percent discharge, without losses, even at high inputs and creating conditions for large amplitudes occurrence (Jijia at Dorohoi Cv=0.77), table 6.5, figure 6.21.

Table 6.5 Variation and asymmetry coefficient values at the hydrometric stations in the Moldavian Plain

Nr. crt	River	Hydrometric station	Maximum discharges			Variation coefficient	Asymmetry coefficient	Cs/Cv report
			0.01%	0.05%	0.1%			
1	Prut	Radauti	3900	1400	1200	0.342	0.667	1.949
2	Prut	Stanca	700	637	577	0.321	0.523	1.630
3	Prut	Ungheni	700	637	577	0.332	0.468	1.410
4	Volovat	Manoleasa	210	113	77,7	0.761	0.953	1.252
5	Baseu	Stefanesti	320	173	118	0.743	1.414	1.902
6	Jijia	Dorohoi	255	138	94,4	0.777	1.261	1.623
7	Jijia	Dangeni	380	205	140	0.643	0.751	1.168
8	Jijia	Todireni	400	216	148	0.665	0.987	1.485
9	Jijia	Vladeni	550	297	204	0.580	0.738	1.272
10	Jijia	Victoria	355	192	131	0.648	1.087	1.677
11	Jijia	Chiperesti	300	162	111	0.547	0.550	1.005

Nr. crt	River	Hydrometric station	Maximum discharges			Variation coefficient	Asymmetry coefficient	Cs/Cv report
			0.01%	0.05%	0.1%			
12	Buhai	Padureni	120	64,8	44,4	0.657	0.720	1.097
13	Sitna	Catamarasti	180	92,7	66,6	0.674	0.818	1.213
14	Sitna	Dracsani	320	173	118	0.574	0.368	0.642
15	Sitna	Todireni	380	205	140	0.569	0.414	0.728
16	Miletin	N. Balcescu	270	145	100	0.671	0.514	0.765
17	Miletin	Sipote	383	207	142	0.707	0.953	1.349
18	Bahlui	Vama cu Tabla	290	157	107	0.790	1.286	1.628
19	Bahlui	Harlau	280	151	104	0.611	0.310	0.507
20	Bahlui	Belcesti	278	150	103	0.670	0.506	0.756
21	Bahlui	Podu Iloaiei	303	164	112	0.661	0.769	1.163
22	Bahlui	Iasi	480	259	178	0.619	0.996	1.608
23	Bahlui	Holboca	480	259	178	0.547	0.374	0.684
24	Magura	Carjoaia	85,0	45,9	31,4	0.565	0.426	0.754
25	Bahluet	Tg Frumos	115	62,1	42,5	0.553	0.829	1.499
26	Bahluet	Podu Iloaiei	290	157	107	0.604	0.852	1.411
27	Voinesti	Cucuteni	140	75,0	50,0	0.814	1.000	1.229
28	Nicolina	Iasi	190	103	70,3	0.656	0.611	0.931

Disposing of an array of hydrological data, in the present case, apart from the annual discharge averages and the degree of terms vulnerability as reported to the multi-annual average one can determine their frequencies inside certain limits and intervals and obtain the distribution curve. Such a model allows the deduction of the values that pertain to the analysed period. The integral of the frequencies curve forms the duration curve which takes the form of the frequencies curve and is numerically expressed by the asymmetry coefficient (Cs). The increased values of this coefficient indicate a strongly asymmetric curve where the corresponding frequencies that pertain to the discharges' arithmetical mean and the maximum frequencies record high differences.

Taking into consideration that the variation coefficient and the asymmetry coefficient are closely related (inter-dependent) the value of the second coefficient is directly determined by considering its value, inside the average discharges, as equal with 2xCv. The average multi-annual discharge (Qa), the variation coefficient (Cv) and the asymmetry coefficient (Cs) represent function parameters that allow the calculation of duration curve discharges when certain assured discharges are known.

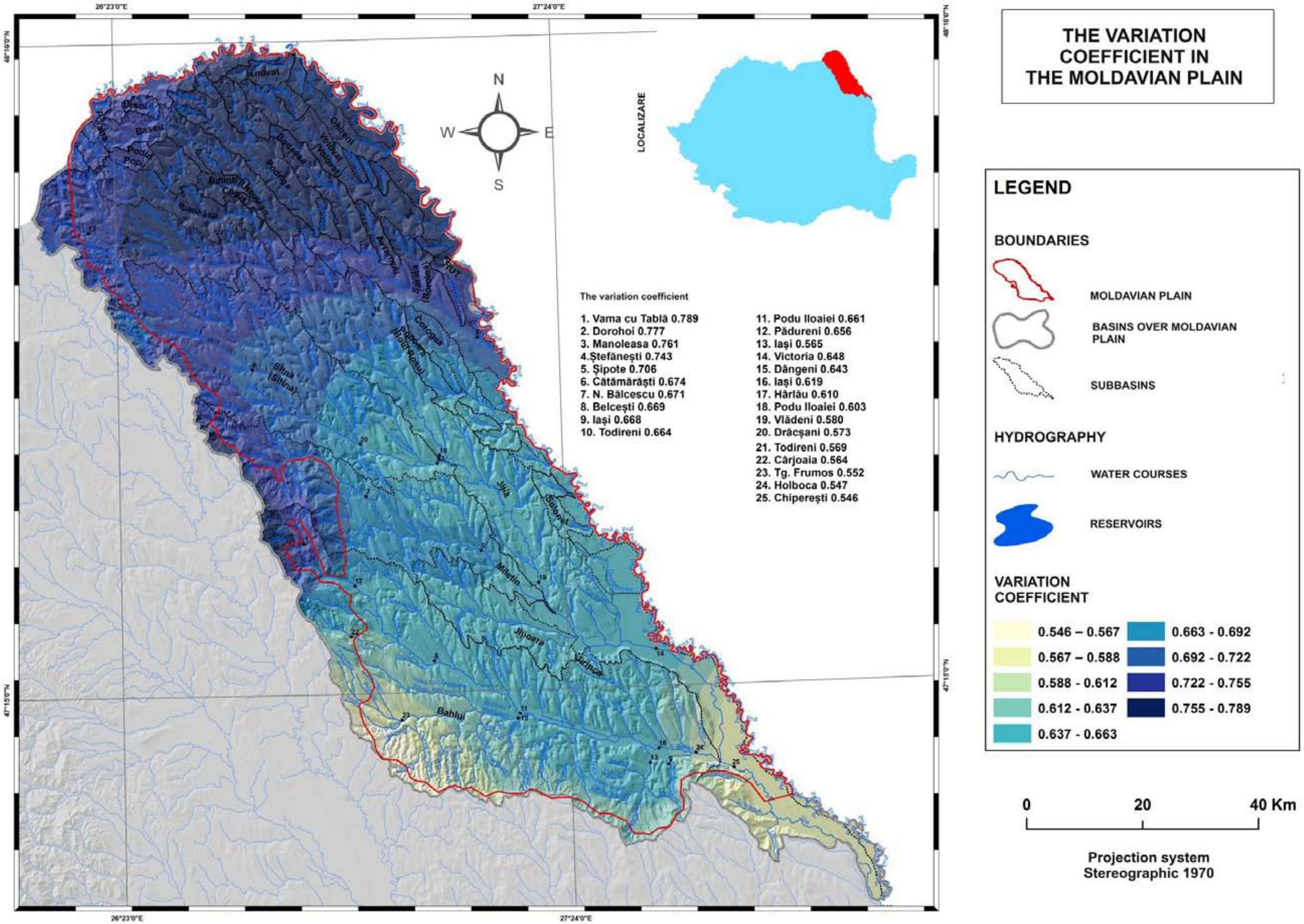


Fig. 6.21 The variation coefficient in the Moldavian Plain

6.4.3. Average seasonal discharge

The seasonal repartition of the liquid discharge is determined by the way in which, the main sources of input combine during the year which are, in turn, influenced by the physical-geographic characteristics of the Moldavian Plain and, especially, the main climatic elements (precipitations, evapotranspiration and temperature). When analysing the leakage variation we notice, for all the seasons, the tight link between water discharge and the average basins' altitude with reduced variations inside each season for the study area.

In winter there are reduced values for the average leakage as a result of low subterranean input and the storage of atmospheric precipitations as snow cover and ice. In this season there are low value discharges, sometimes at only halt of the average.

In spring, the Moldavian Plain's rivers transport between 34% (Jijia River at Chipereşti h.s.) and 50% (Miletin River at Şipote h.s) of the average water volume. The high values are recorded especially at the hydrometric post at high altitude. Table 6.6

Table 6.6 Average and percentage values for the seasonal mean discharge in the Moldavian Plain

Nr. Crt	River	Station	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
			Average discharge (mc/s)				%			
1	Bahlui	Harlau	0.26	0.83	0.45	0.17	15.04	48.66	26.47	9.82
2	Bahlui	Belcesti	0.44	1.36	0.83	0.44	14.31	44.46	27.01	14.23
3	Bahlui	Holboca	3.73	6.98	5.00	3.63	19.30	36.09	25.84	18.76
4	Bahlui	Iasi	2.17	4.35	3.05	2.11	18.57	37.29	26.08	18.06
5	Bahlui	Podul Iloaiei	0.70	1.81	1.07	0.67	16.37	42.54	25.24	15.85
6	Bahluet	Podul Iloaiei	0.65	1.56	0.97	0.72	16.76	40.08	24.73	18.44
7	Bahluet	Targu Frumos	0.13	0.23	0.16	0.09	20.43	38.16	26.15	15.26
8	Jijia	Chiperesti	9.58	15.72	12.1	8.79	20.74	34.02	26.21	19.03
9	Jijia	Dingeni	1.39	3.02	1.84	0.88	19.48	42.34	25.83	12.35
10	Jijia	Dorohoi	0.42	1.17	0.80	0.29	15.51	43.70	30.03	10.76
11	Jijia	Todireni	1.80	3.93	2.23	1.10	19.85	43.32	24.64	12.18
12	Jijia	Victoria	5.26	10.86	7.00	4.46	19.08	39.39	25.37	16.16
13	Jijia	Vladeni	4.16	8.27	5.09	3.31	19.99	39.70	24.44	15.87
14	Miletin	N. Balcescu	0.33	0.90	0.51	0.18	17.09	47.09	26.57	9.25
15	Miletin	Sipote	0.94	2.33	0.81	0.53	20.43	50.49	17.62	11.46
16	Sitna	Catamarasti	0.44	0.68	0.47	0.38	22.43	34.38	23.91	19.28
17	Sitna	Dracsani	1.46	2.67	1.93	1.50	19.35	35.32	25.55	19.79
18	Sitna	Todireni	1.90	3.67	2.26	1.66	20.00	38.72	23.80	17.48
19	Baseu	Stefanesti	1.20	2.56	1.78	1.16	17.95	38.20	26.52	17.33
20	Volovat	Manoleasa	0.40	0.65	0.42	0.22	23.75	38.28	24.65	13.33

In summer the water volume to be transported by the rivers in the Moldavian Plain oscillates between 17% and 30% from the annual discharge. In this season the rivers' supply consists from precipitation, in general, which are more abundant in June and July and decrease in August. In summer 63% of the average discharges cases decrease progressively from June to August.

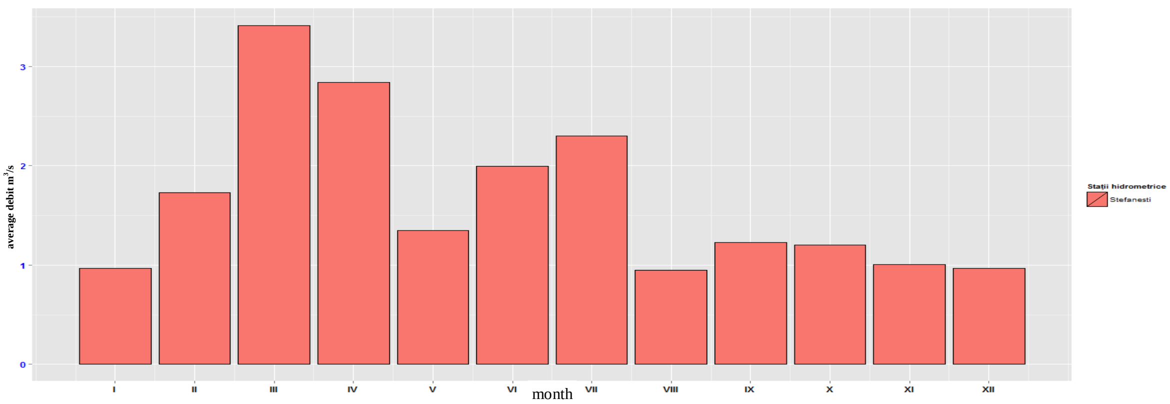
In autumn, under the effects of weather characteristic states with relatively low precipitations, the volume of water that is transported by the rivers inside the Moldavian Plain is between 9% and 19% form the annual discharge. The values are higher for the main downstream basins' parts as a function of altitude decreasing and supply surface increasing. This situation is sustained by the torrential rains, more frequent in this season in the lower Jijia Plain as compared to the high hills and by the decrease of average evapotranspiration as a result of air temperatures' lowering and of the controlled discharge from the accumulation lakes for the autumn fish production (I. Minea, 2009).

At the level of the Moldavian Plain, the average seasonal discharge is higher in the spring (41%), lowers in summer (25%) and is lowest in winter (19%) and in autumn (15%) and pertains to the SSWA regime (spring-summer-winter-autumn), as defined by *Ujvari*, *1972*, *Lăzărescu, Luca 1979, Geography of Romania*, *vol.I*, *1983*). *I*

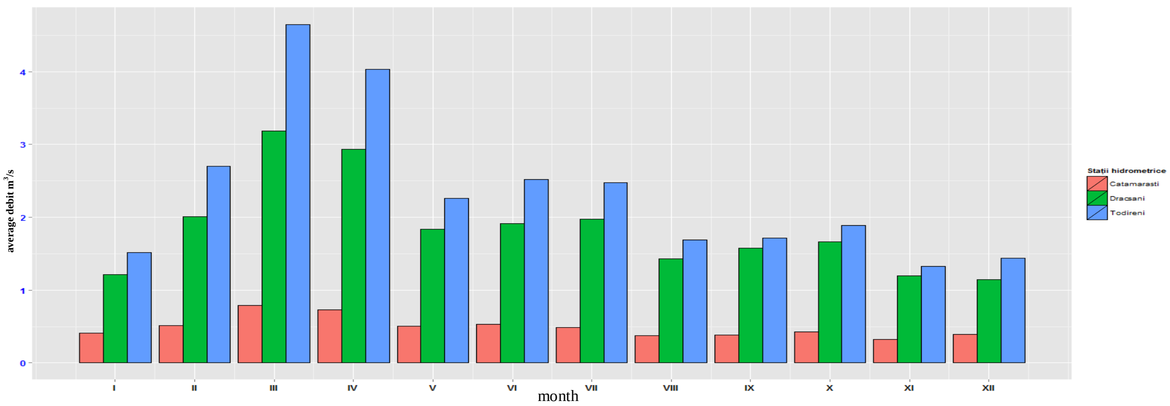
6.4.4. Average monthly discharge

If we analyse the average monthly discharge over the year (fig. 6.22) we notice the existence of a uniform regime for all the rivers in the Moldavian Plain.

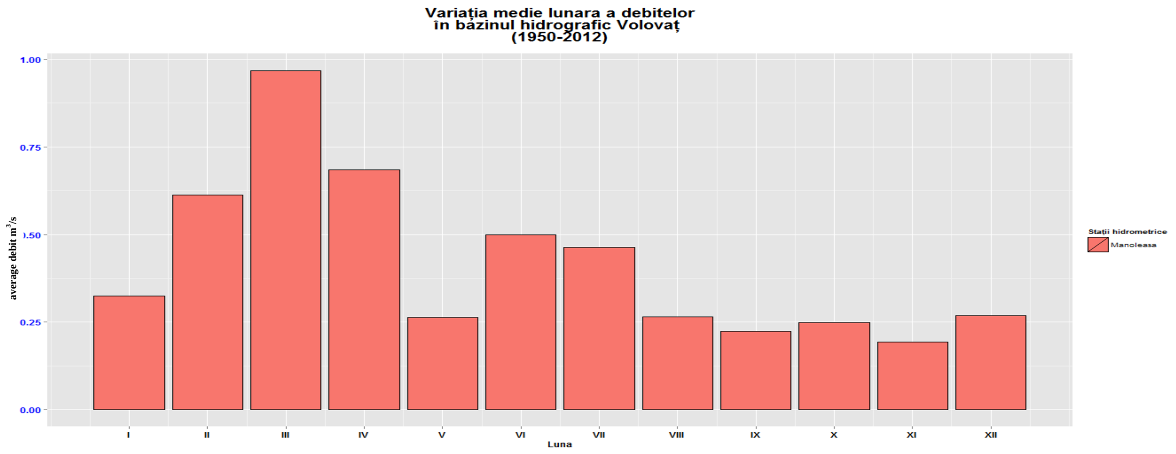
water catchment Başeu (1950-2012)



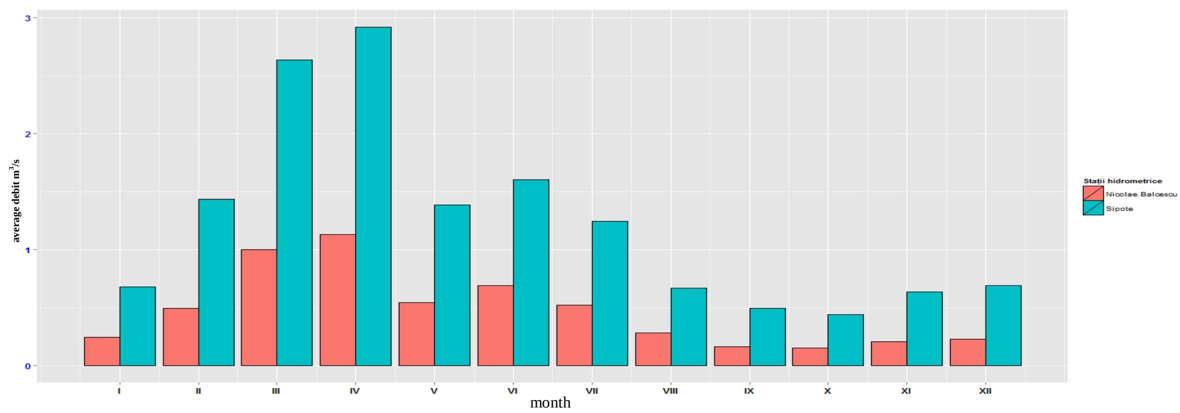
water catchment Sitna (1950-2012)



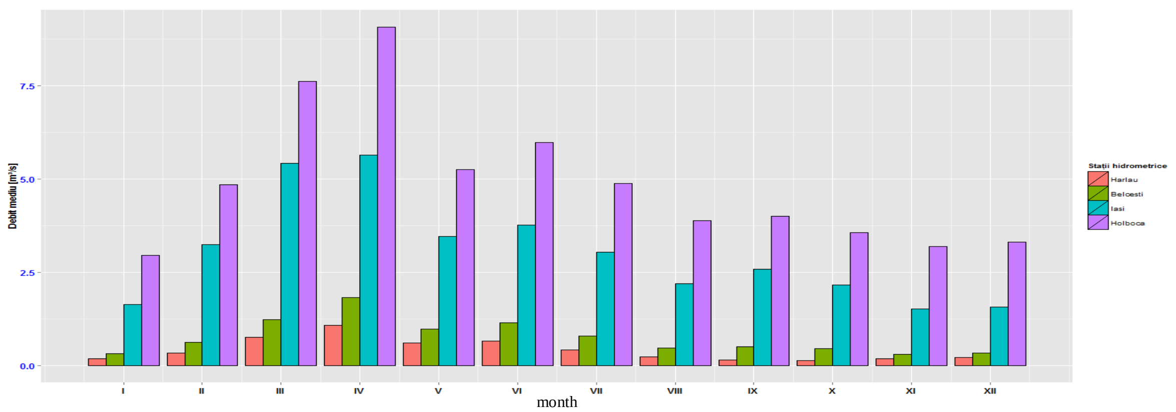
water catchment Volovăț (1950-2012)



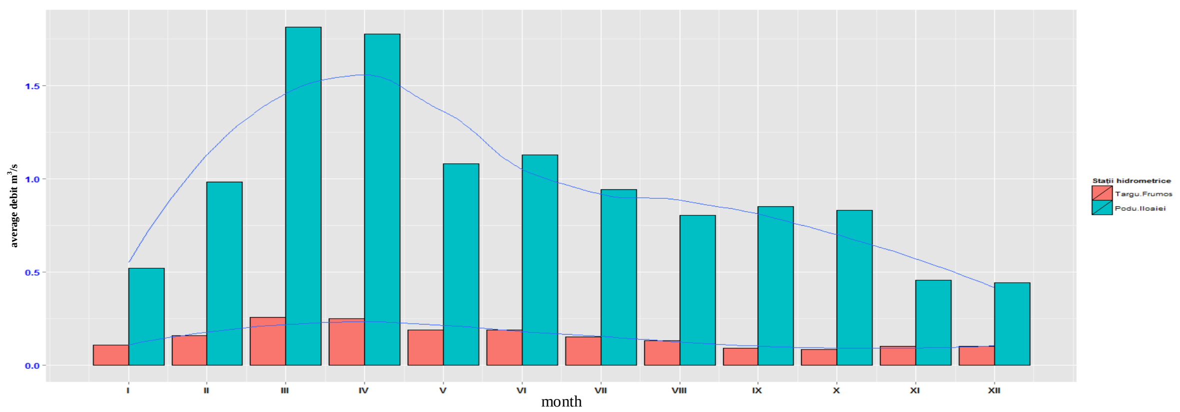
water catchment Miletin (1950-2012)



water catchment Bahlui (1950-2012)



water catchment Bahlueț (1950-2012)



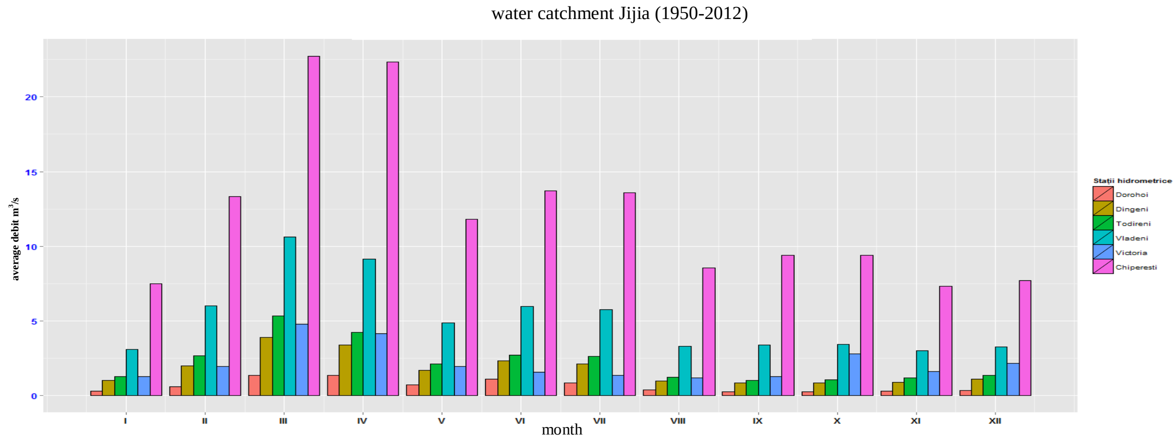


Fig. 6.22 The monthly average variation of the discharges in the Moldavian Plain

In January the average discharge values are very low, under 0.5 m^3/s and the volume of water transported by rivers is between 2.5 and 5% from annual volume. The values of average leakage in this month are determined by the meteorological conditions that unfavourable to liquid discharge: solid atmospheric precipitations, average temperatures below minus 5 ºC in the south and minus 7ºC in the north of the Moldavian Plain. Analysing this month's discharge at all the hydrometric stations we notice the decrease of the average specific monthly discharge as the altitude increases as a consequence of more negative temperatures days and the better keeping of the snow and ice cover.

In February, the monthly average discharges increase and the transported water volumes may become double compared to January with 9% of the annual leakage volume. The average discharges are between 0.6 and 13.0 m^3/s.

In March there is significant increase of the leakage, favoured by the meteorological conditions. In this period the transported water volume is 15% to 22% from the annual average total. For the most hydrometric stations, in this month, there are the highest values of average leakage as reported to the annual average.

In April the records are high, as in March, and there is significant increase of the average leakage on Miletin and Bahlui rivers and also in the upper basins, in general, as a result of snow melt. The water volume for these months is between 13 % and 21%.

In May there are significant decreases for the average monthly leakage, up to 12% from the annual volume as compared to April and only 8% to 11% of the average total annual volume is transported in this month.

In June we notice a slight increase of the water volume in the rivers of the Moldavian Plain with a maximum of 3% over the previous month as a result of the pluviometric maximum at the end of spring and beginning of summer.

In July the average discharges continue to decrease and the average leakage values are between 5.5% and 9.5% from the annual average volume. The average discharges are lower than June with few exceptions (on Başeu at the Ştefăneşti station and on Sitna as Dracşani).

In August the average discharges decrease more as a result of the highest leakage instability. The water volume in the rivers is between 5% and 7% from the annual average.

In September we have low values of the average discharges and of the water volume, between 4% and 8% from the annual average.

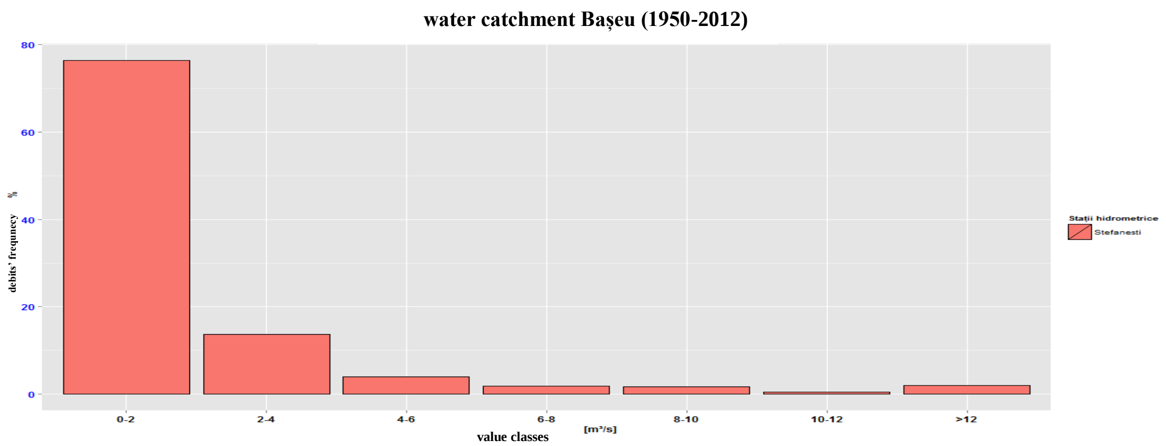
In October the monthly average leakage values are smaller the previous month and the volume is below 5% from the annual average volume.

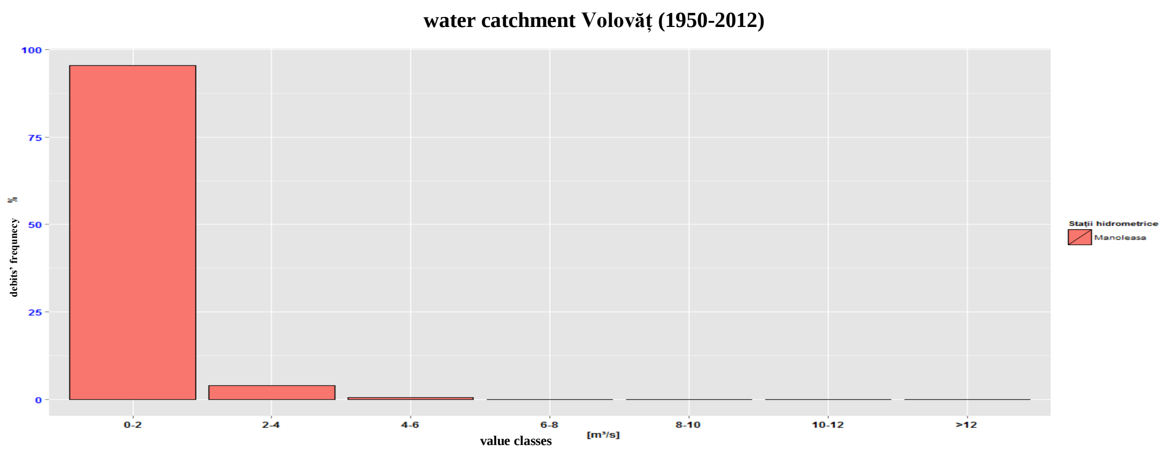
In November the average leakage slowly increases and is a bit higher at the hydrometric stations from high altitudes.

The increase of the average discharges is determined by the air temperature decrease and implicitly, by the evapotranspiration decrease. The average volume for this month, on the rivers, is between 4% and 6% from the annual volume.

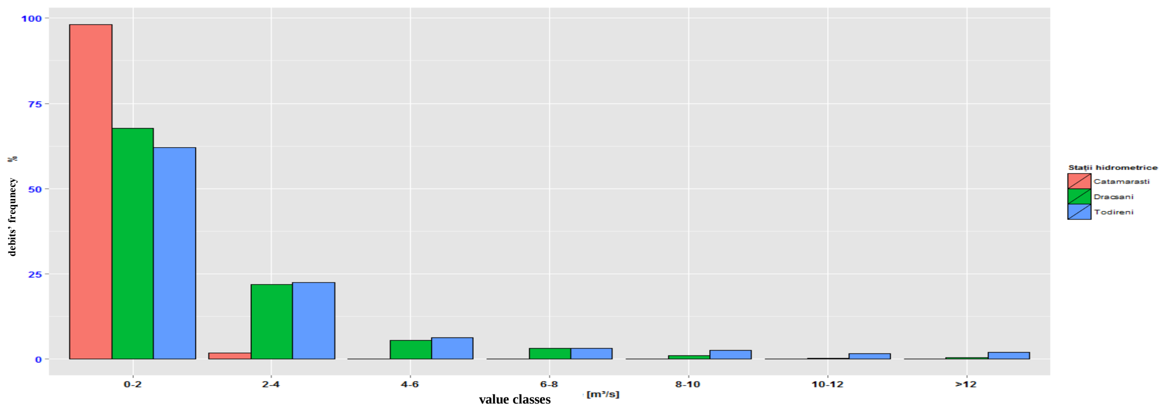
In December there is a slight increase for the average leakage except some stations on Başeu, Sitna, and Bahlueţ where it decreases. The average volume of transported water in the December, in the Moldavian Plain oscillates between 2.5% and 5% from the annual average volume.

If we analyse the frequency of the monthly discharges for an array of years (1950-2011) (Fig. 6.23), we notice the highest frequency in the study zone is given by the 0 to 2 m^3/s discharges' class (78% for Başeu at the Ştefăneşti hydrometric station, over 90% on Volovăţ, at Manoleasa, on Sitna at Cătămărăşti, on Miletin at Nicolae Bălcescu, on Bahlui at Hârlău and on Jijia at Dorohoi).

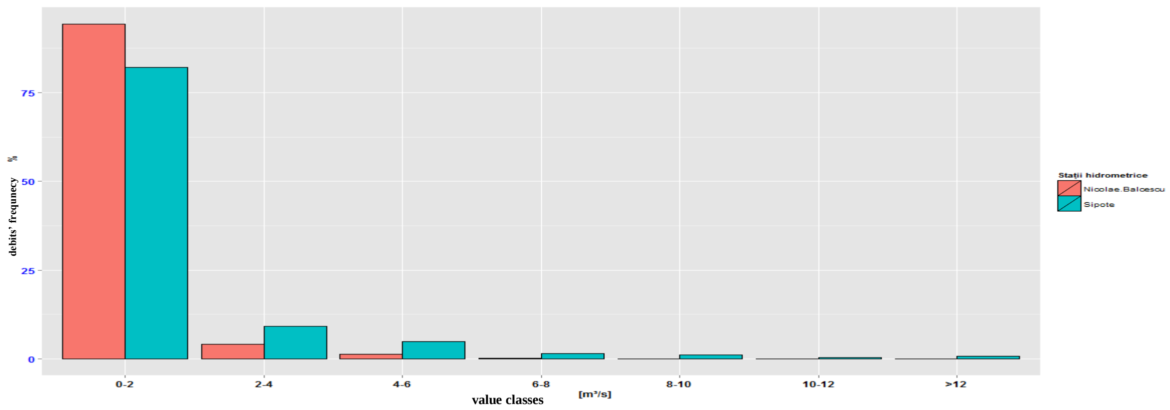




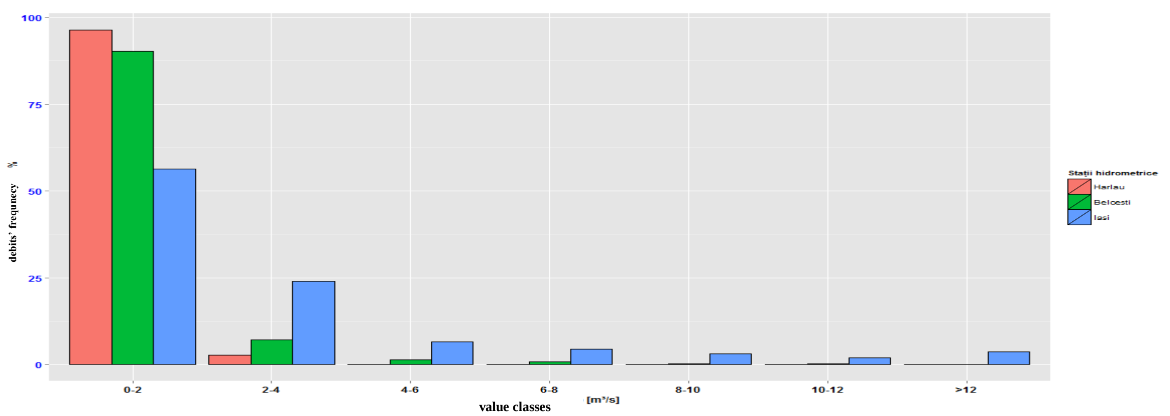
water catchment Sitna (1950-2012)



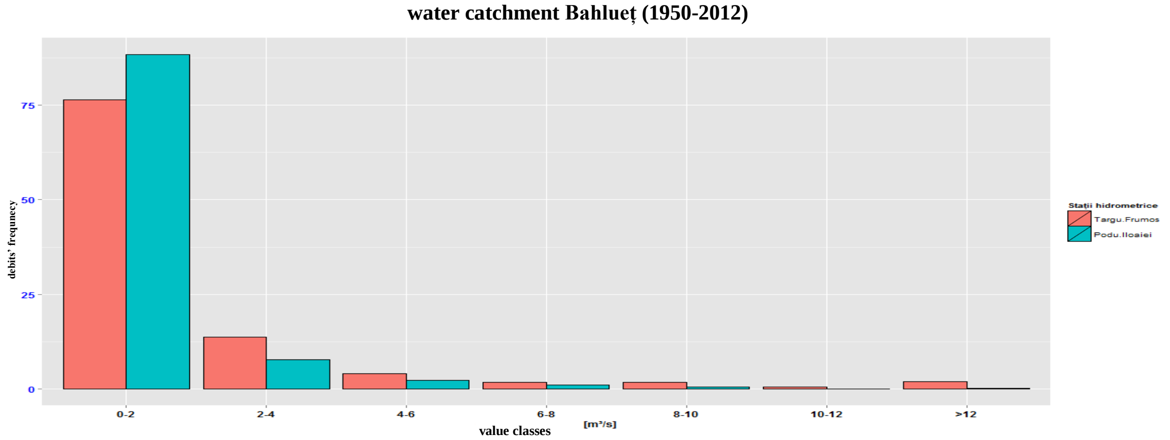
water catchment Miletin (1950-2012)



water catchment Bahlui (1950-2012)



water catchment Bahlueț (1950-2012)



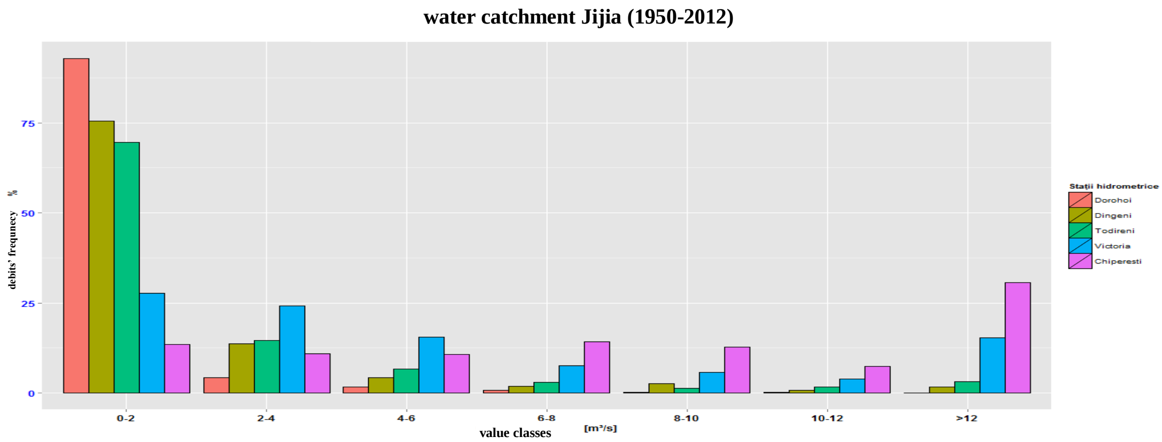


Fig. 6.23 The monthly discharges' frequency at the Moldavian Plains' hydrometric stations.

The 2-4 m^3/s discharge class is second as importance (25% on Bahlui at Iaşi and on Jijia at Victoria hydrometric station).

The lowest frequencies for the monthly average discharges are those of 12 m^3/s which have a maximum value of 30% on Jijia at Chiepereşti but these discharges are occasional. Even if these kind of values have, in a usual regime, have increased frequencies at the downstream stations, due to anthropic intervention (water accumulations) the situation is changed. For example, on Bahlueţ at Târgu Frumos there are average discharges of over 12 m^3/s more frequent than at Iloaia's Bridge.

The analysis of each month for the discharges' frequencies, on classes of values, for the important hydrometric stations in the Moldavian Plain, shows the following:

- on Bahlui the monthly discharges' frequencies are dominated by the 0-2 m^3/s class, except March and April when the dominant class is 2-4 m^3/s;

- on Başeu, at the Stefăneşti h.s., the monthly frequency is dominated by the 0-2 m^3/s class and the 12 m^3/s class is present in March, July, April, June and September.

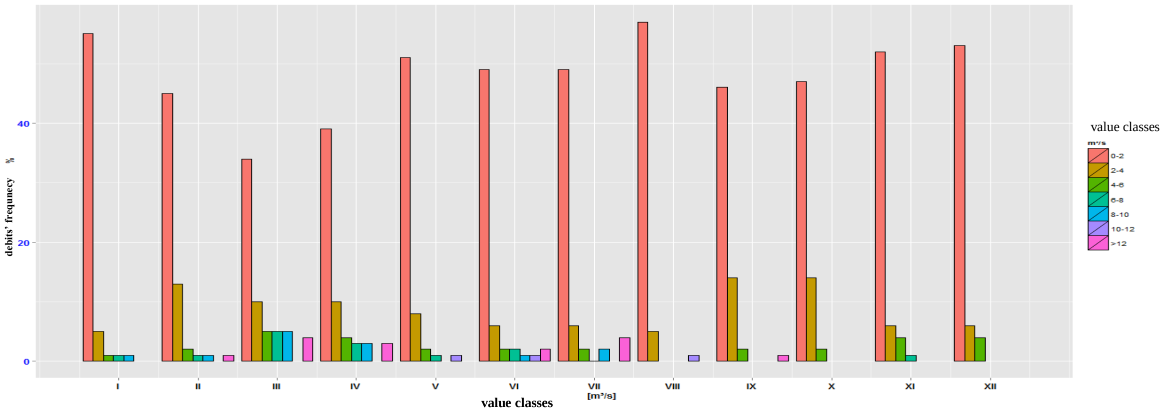
- on Volovăţ, at Manolease h.s. the 0-2 m^3/s class is the most representative, followed by the 2-4 m^3/s and 4-6 m^3/s classes. The higher classes are not present here.

- on the Jijia affluents, Sitna and Miletin the most frequent class is 0-2 m^3/s. The maximum of 12 m^3/s are more frequent in March, April and June on Sitna and April, July and June on Miletin.

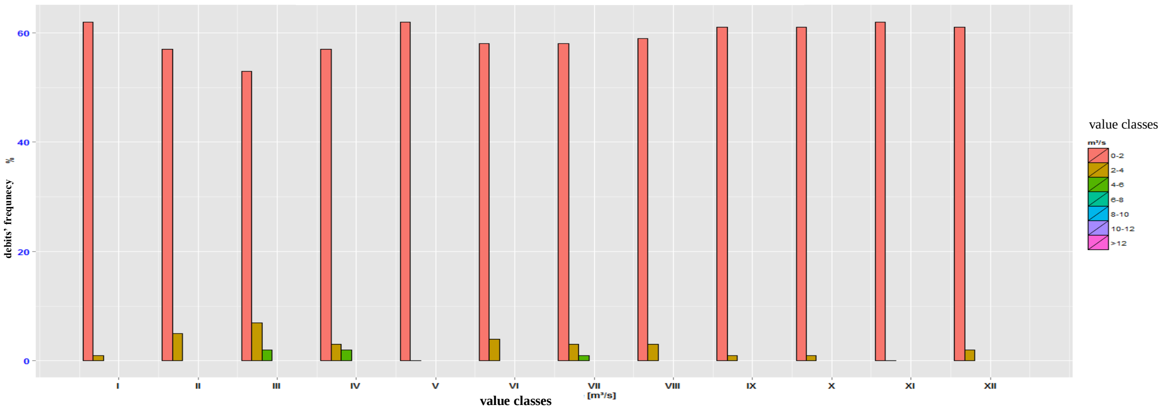
- on Bahlui river, at Iaşi h.s., the dominant monthly discharges' frequency is 0-2 m^3/s, except March (with 2-4 m^3/s) and April when 0-2 m^3/s and 2-4 m^3/s have similar frequencies; the high discharges frequency (12 m^3/s) is much higher in March, April and June.

- on Jijia, at the majority of the hydrometric stations, the monthly discharges frequency is dominated by the 0-2 m^3/s class, except Chipereşti h.s. where the discharges' class of 12 m^3/s is the most frequent (Fig. 6.24).

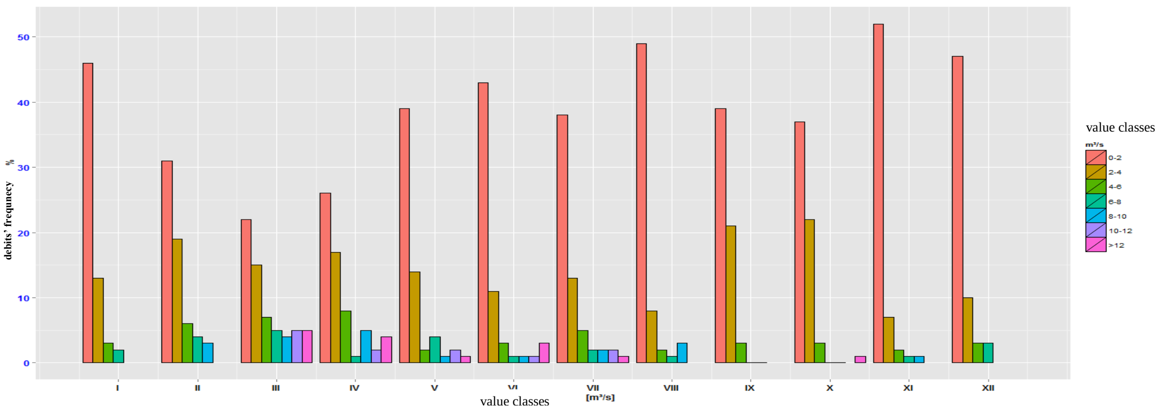
h.s.Ştefăneşti - Başeu (1950-2012)



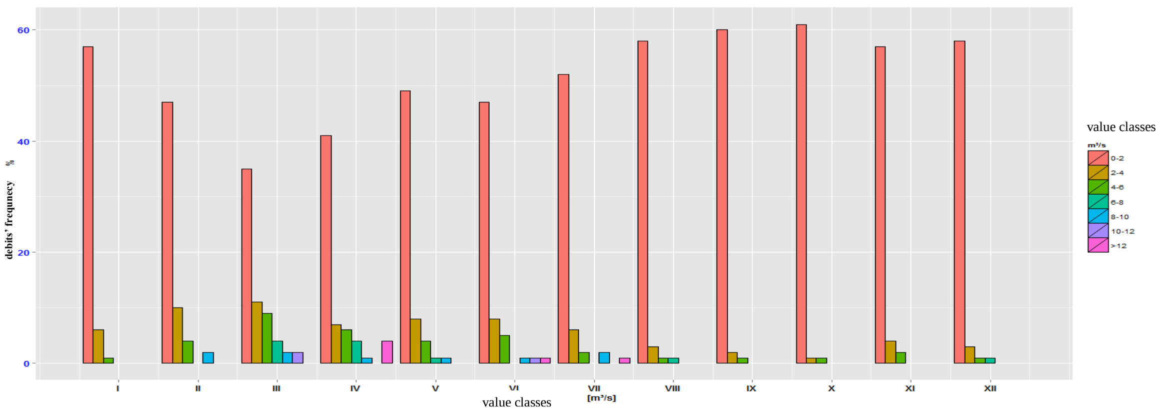
h.s. Manoleasa - Volovăţ (1950-2012)



h.s. Todireni -Volovăţ (1950-2012)



h.s. Şipote -Miletin (1950-2012)



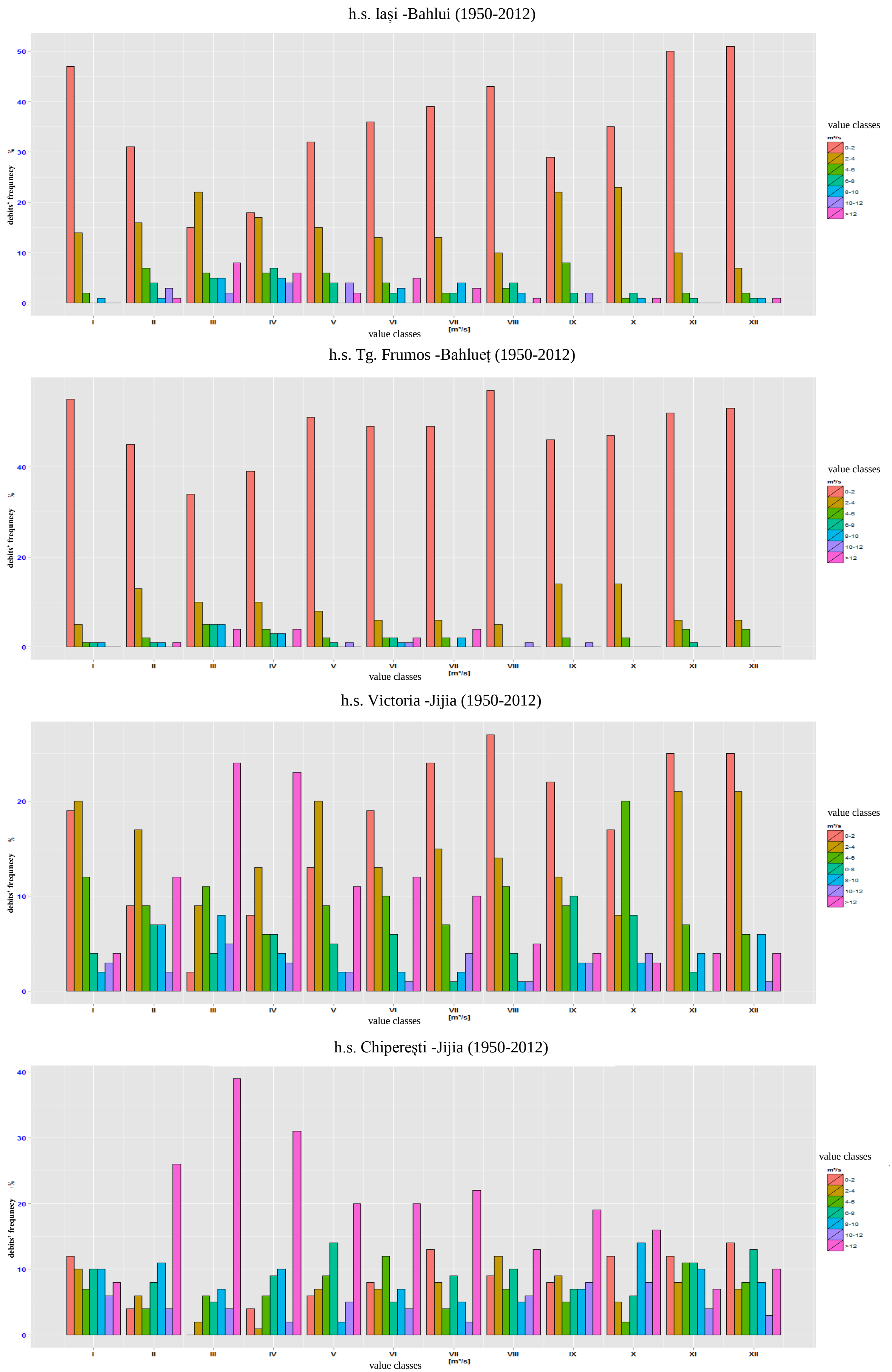


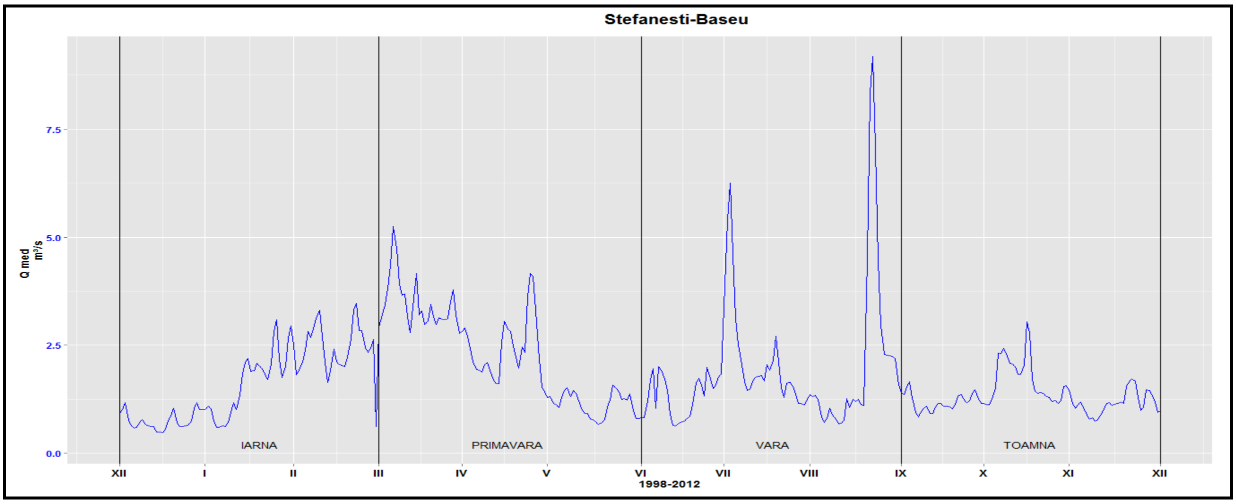
Fig. 6.24 The monthly discharges' frequency on value classes at the main hydrometric stations in the Moldavian Plain

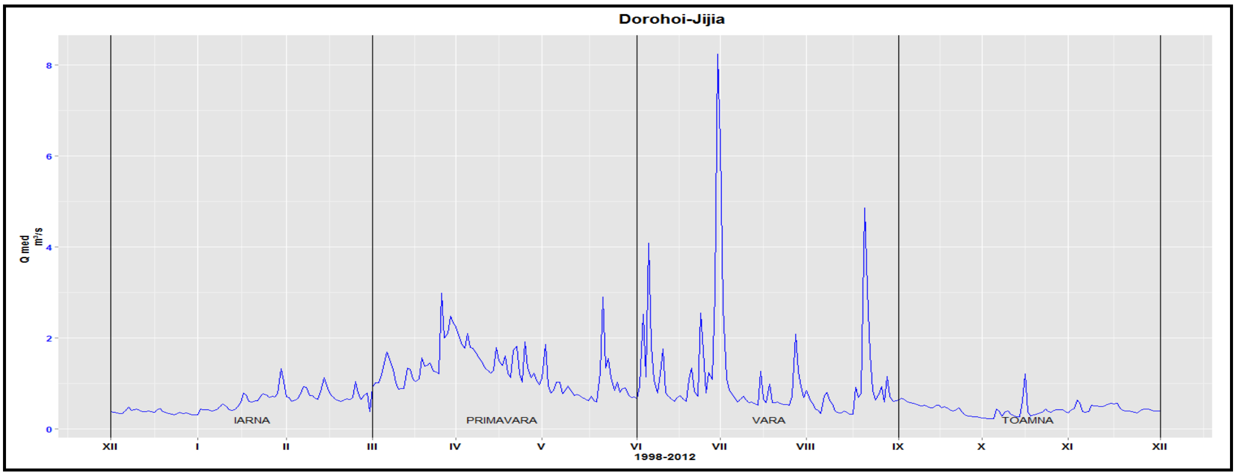
6.5. The maximum discharge and the associated risks

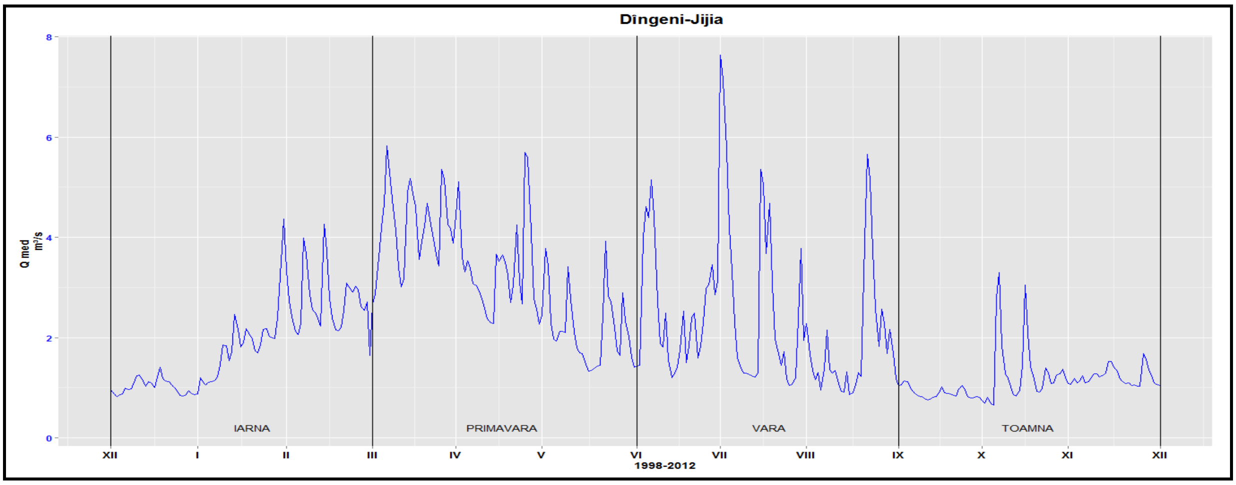
An important characteristic of the Romanian rivers discharge regime is the presence, all along the year, of high discharges periods that are induced either by the very abundant atmospheric precipitations or by snow melt or by these two phenomena combined. The intensity and duration of these high discharge periods are strictly influenced by the physical-geographic characteristics of a certain hydrographic basin. Among these characteristics the climatic element is dominant and represented mainly by the precipitations (either liquid or solid or mixed). The other factors or elements control the formation of high discharges: drainage basins' morphometry, relief characteristics, the type and degree of soil humidity, the geological structure and the vegetation cover. An important role, especially in the hydrotechnical modified basins, is played by the human factor via construction of water accumulations or evacuations and embankment works.

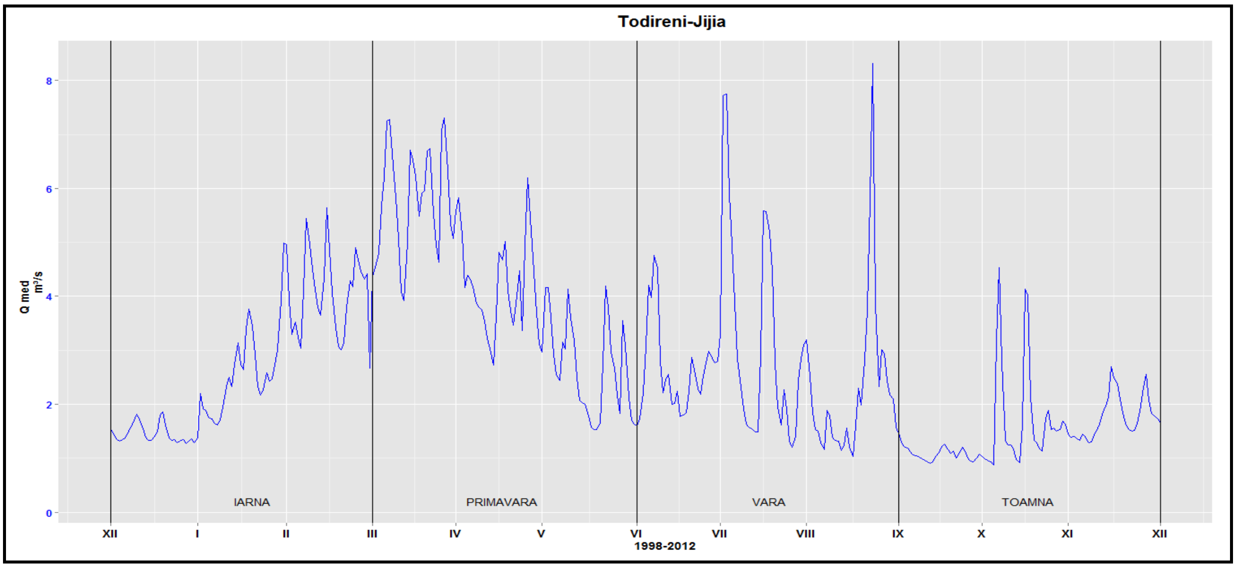
Before performing a detailed analysis of the processes and phenomena related to maximum leakage it is necessary to approach, theoretically, the distinction between high waters and floods.

The *high waters* represent the leakage that occurs in the Moldavian Plateau Rivers at the beginning of spring and are determined by snow melt as a result of air temperature increase corroborated in many cases with significant liquid precipitations quantities. The high waters period reveals increased water volumes as a result of snow melt and low intensity but abundant precipitations combination. This regime's phase does not result in sudden discharge increase and stretches on large time intervals, sometimes exceeding 2 month. The high waters can be easily identified in the average discharges hydrograph, (fig. 6.25).




Dorohoi-Jijia
Q med m³/s
8
6
4
2
0
IARNA
PRIMAVARA
VARA
TOAMNA
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1998-2012


Dingeni-Jijia
Q med m³/s
8
6
4
2
0
IARNA
PRIMAVARA
VARA
TOAMNA
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1998-2012


Todireni-Jijia
Q med m³/s
8
6
4
2
0
IARNA
PRIMAVARA
VARA
TOAMNA
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
1998-2012

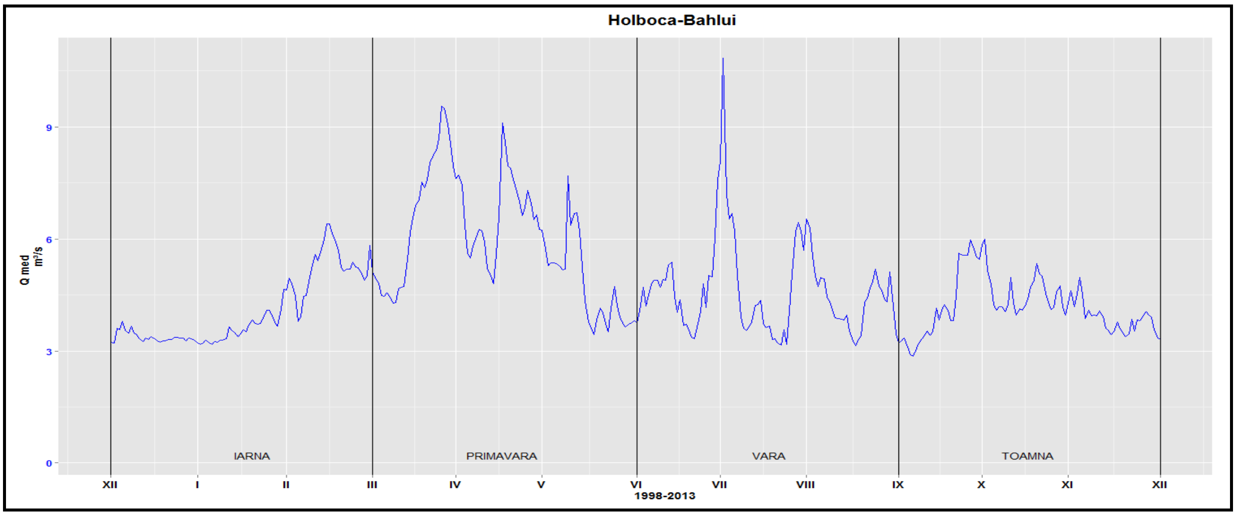


Fig. 6.25 The average discharges' hydrograph at some hydrometric stations in the Moldavian Plain on a 14 years interval

The floods represent another characteristic form of the liquid discharge. These represent a significant and rapid increase-decrease phenomenon for the water levels, respectively for the water course discharges. The floods occur as a result of excessive rains over the hydrographic basins often superimposed on previously humid soils from former low intensity rains.

The levels and discharges variation during a flood for a certain water course section is given by the levels' and discharges' hydrograph, the so called the flood's hydrograph or the flood's overflow wave.

The flood's wave moves usually in the minor river-bed as well as in the major river-bed and produces inundations in the meadow sectors. The flood's wave may register one or more peaks as a function of precipitations manifestation and, in practice, there are mono-waves or pluri/multi-waves (Podani M.,et. al. 2002).

The floods represent phenomena that are characteristic to Romanian rivers. On the majority of rivers in the historical region of Moldavia and the alpine zone, except the winter interval, the floods occur all along the year. The highest frequency is recorded in the March-June period and the lowest frequency is recorded in January and the August-September period.

Over the time, there were various definitions for the floods, depending on the causes and the associated implications:

- the flood is a relatively big leakage which originating in precipitations and resulting in water overflow outside the river-bed (Chow, 1973);
- the flood represents any leakage which exceeds the river banks (Rostvedt ş.a., 1968);
- the flood represents that water body which rises over a usually non-submerged territory.

The appearance of a rapid discharge increase as reported to the normal situation on a river is the result of source conditions and leakage conditions interactions.

According to the hygrograph's form and the occurrence conditions there are two types of floods: simple and compound.

The simple floods have a one peak hydrograph and are clearly evident along rising and lowering periods (fig. 6.26).

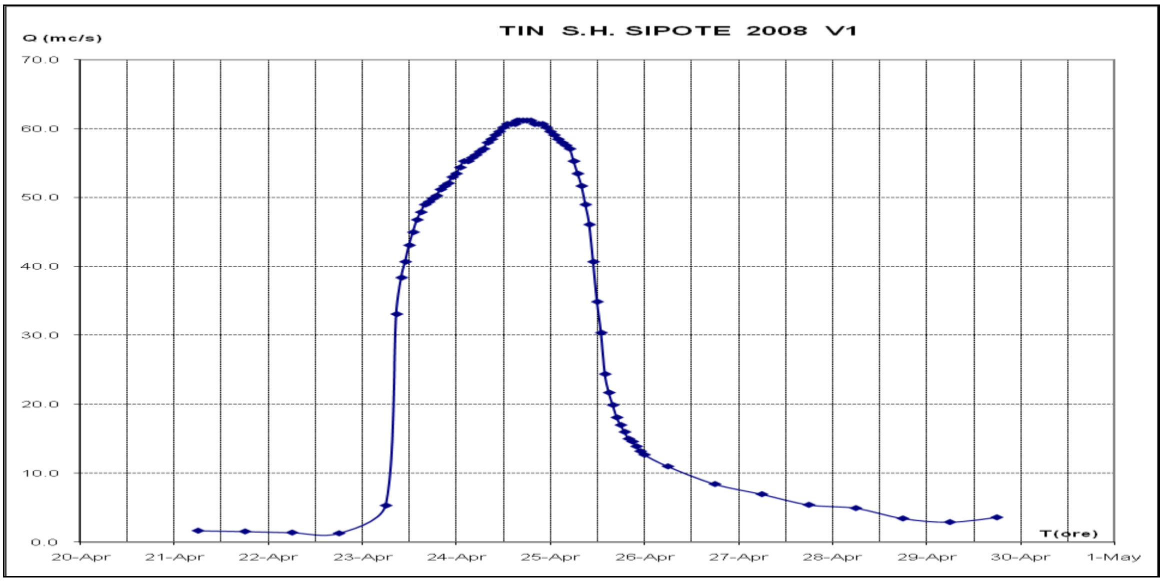


Fig. 6.26 The hydrograph of a simple flood on the Miletin river at the Şipote hydrometric station, 2008

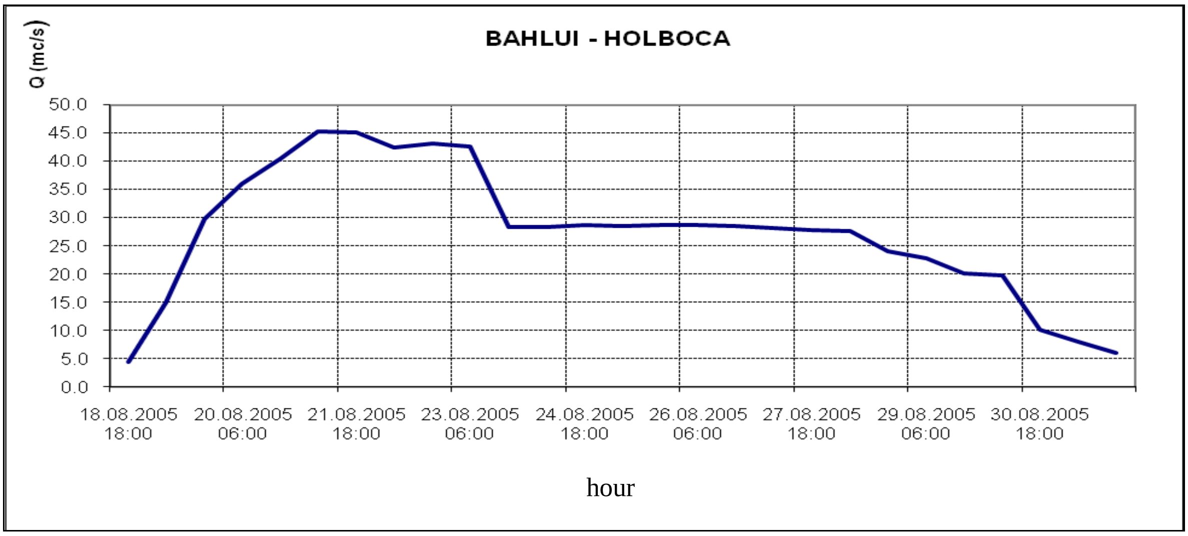


Fig. 6.27 The hydrograph of a compound flood on the Bahlui River at the Holboca hydrometric station, 2005

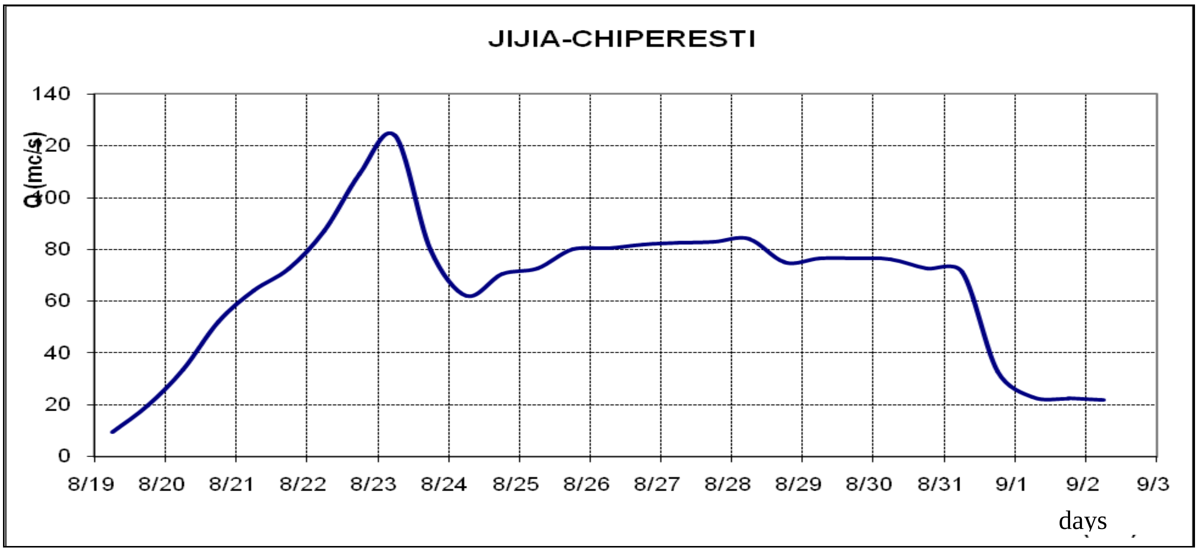


Fig. 6.28 The hydrograph of a compound flood on the Jijia River at the Chipereşti hydrometric station, 2005

The **compound floods** are specific to large and branched rivers with many first order affluents or rivers that cross various relief units and various climatic regions. Their hydrograph displays a saw shape with two or more peaks. In Romania compound floods are specific to high waters in spring and autumn. They are characteristic to basins affected by repeated torrential rains at short intervals when the floods from the affluents do not reach the main collector in the same time.

Depending on the causes that determine floods they may be classified as: natural floods and accidental floods.

The *natural floods* are caused by factors that do not depend on the human activities: abundant precipitations, snow or ice melt.

The *accidental floods* are determined by anthropic cause:

- modifications of the basin's parameters that lead to natural discharge amplification;
- river-bed modifications that determine the obstruction of the leakage section;
- earth tremors induced by modification works;
- un-effective exploitation of water accumulations at high waters;
- inducing new phenomena via damaging or breaking the hydrotechnical systems and the associated constructions;

6.5.1. Maximum multi-annual discharge

The statistical analysis of maximum discharge at the level of the Moldavian Plain is performed on the data recorded at the main hydrometric stations between 1950 and 2011. This analysis allows the extraction of practical information which may lead to the implementation of measures in the projection phases, the execution phases and the exploitation of hydrotechnical constructions in order to diminish the effects of hydrological hazards, especially in the vulnerable zones.

As a phase of the hydrological regime, the maximum discharge represents floods, in general and it can appear in any period of the year, yet with different intensities, causes and spatial repartitions. It can occur in the winter as a consequence of Mediterranean air masses invasion, in the SW and W Romania and in all the other seasons at torrential rains. In the spring, the maximum discharge occurs at the *high waters* of spring as a result of snow melt superimposed on the rains of this season.

The maximum discharge is the most important regime phase via its destructive effects percentage and via its characteristics which must be taken into consideration when projecting, executing and exploiting hydrotechnical works (Geografia României, *Geography of Romania*, I, 1983). Inside this regime phase the most spectacular in development and as volumes of water we notice the floods. They are sudden and short term water level accessions and discharge peaks of the rivers in comparison with the usual, average values. The genesis of the maximum overflows or floods is directly linked with the climatic conditions and can occur as a result of superficial leakage from rains, snow melt or a mix of the two phenomena or in case of hydrotechnical constructions failure. The rains, especially the torrential ones, are described as great precipitations quantities in very short time so as the infiltration capacity of the soil is rapidly overpassed and almost all the mass of water leaks very fast in the valleys network generating floods where the transport capacity of the minor river-bed is exceeded and the water overspills in the major river-bed.

An important characteristic of the rivers' discharge regime in Romania is the presence of certain periods of the year when discharges are high and induced by atmospheric precipitations in great quantities or the melting of the snow are, in many cases by these two phenomena combination.

The most representative parameters of the maximum discharge to be analysed refer to the maximum discharges (overflows) and the maximum volumes associated, as well as the floods and inundations.

Due to the fact that the hydrometric stations were not put in place in the same time there are differences in recorded data of the historical maximum overflows as it is shown in tables 6.7 and 6.8

Table 6.7 Maximum discharge records at the hydrometric station of the Moldavian Plain

Nr crt	River	Hydro station	Q mc/s	Occurrence date
1	Prut	Radauti	4240	28.VII.2008
2	Prut	Stanca	1050	31.VII.2008
3	Prut	Ungheni	731	19.VII.1969
			710	13.VIII.1991
4	Prut	Prisacani	755	12,13.VIII.1991
5	Volovat	Manoleasa	69.0	5.VI.1988
6	Baseu	Stefanesti	330	14.VIII1969
			100	25.VII.1973
7	Jijia	Dorohoi	170	13.VII.1969
8	Jijia	Dangeni	346	14.VII.1969
9	Jijia	Todireni	394	14.VII.1969
10	Jijia	Vladeni	199	20,21.VI.1985
11	Jijia	Victoria	325	18.VII.1969
12	Jijia	Chiperesti	185	23.V.1985
13	Buhai	Padureni	96.0	20.VIII.1998
14	Drislea	Drislea	57.8	23.VII.2008
15	Sitna	Botosani	76.9	10.VI.1969
16	Sitna	Catamarasti	11.2	5.VI.2006
17	Sitna	Dracsani	101	9.IV.1979
18	Sitna	Todireni	290	10.VI.1965
19	Miletin	N Balcescu	87.1	19.IV.1969
20	Miletin	Sipote	204	19.VI.1985
21	Miletin	Halceni av	40.4	3.IV.1996
22	Bahlui	Vama cu tabla	59.9	24.VII.2008
23	Bahlui	Parcovaci av	24.4	25.VII.2008
24	Bahlui	Harlau	119	2.VII.1971
			42.4	25.VII.2008
25	Bahlui	Belcesti	152	9,10.IV.1979
26	Bahlui	Podu Iloaiei	125	13.VII.1969
27	Bahlui	Iasi	182	9.VI.1975
28	Bahlui	Holboca	61.3	8.V.2005
29	Magura	Carjoaia	83.1	25.VII.2008
30	Bahluet	Tg. Frumos	95.0	24.VII.2008
31	Bahluet	Podu Iloaiei	18.3	3.VIII.1991
32	Voinesti	Cucuteni	8.80	10.V.2005
33	Nicolina	Iasi	92.5	27.IV.1963

Table l 6.8 Maximum rates records at the hydrometric stations of the Moldavian Plain

Nr crt	River	Hydro station	H max	Occurrence date
1	Prut	Oroftian	867	7/26/2008
2	Prut	Radauti Prut	1230	7/28/2008
3	Prut	Stanca av.	612	7/31/2008
4	Prut	Ungheni	754	8/13/1991
5	Prut	Prisacani	722	6/10/1988
10	Volovat	Manoleasa	410	6/5/1988
11	Baseu	Stefanesti	425	4/11/1979
12	Jijia	Dorohoi	780	6/5/2006
13	Jijia	Dangeni	619	7/14/2000
14	Jijia	Todireni	519	8/22/2005
15	Jijia	Andrieseni	560	1/30/2002
16	Jijia	Vladeni	478	8/23/2005
17	Jijia	Victoria	598	6/9/1988
18	Jijia	Chiperesti	533	6/10/1988
19	Buhai	Padureni	530	7/1/1991
20	Drislea	Drislea	224	4/23/2008
21	Sitna	Catamarasti	250	8/19/2005
22	Sitna	Dracsani	448	8/3/1991
23	Sitna	Todireni	504	6/19/1985
24	Miletin	N.Balcescu	406	8/16/1979
25	Miletin	Sipote	530	6/19/1985
26	Miletin	Halceni	321	7/5/1991
27	Bahlui	Vama cu Tabla		
28	Bahlui	Parcovaci av	234	7/25/2008
29	Bahlui	Harlau	694	7/25/2008
30	Bahlui	Belcesti	530	4/9/1979
31	Bahlui	Podu Iloaiei	456	6/8/1975

32	Bahlui	Iasi	468	6/19/1985
33	Bahlui	Holboca	411	6/19/1985
34	MAagura	Carjoaia	246	6/17/1992
35	Bahluiet	Tg. Frumos	497	6/7/1975
36	Bahluiet	Pd.Iloaie	xxx	1975
37	Voinesti	Cucuteni	213	3/6/1988

38	Nicolina	Iasi	476	4/27/1963
39	Locii	Ciurbesti	333	6/3/1988
40	Ciric	Iasi	170	11/5/2005
41	Vamesoaia	Iasi	350	7/21/1974

As mentioned above, the statistical analysis of the maximum discharges and volumes recorded at the hydrometric stations in the Moldavian Plain is performed for the 1950-2011 period. The multi-annual variability of the maximum overflows reveals that, at the level of the study area, there are a series of years with the highest discharges (1954, 1969, 1975, 1980, 2008, 2010) and a series of years with low maximum discharges (1959, 1963, 1964, 1986). A detailed analysis of the values of the monthly maximum discharges recorded at the main pluviometric post and stations indicate certain spatial differences as generated by local conditions and the pluvial-thermic conditions of the occurrence period (fig. 6.29).

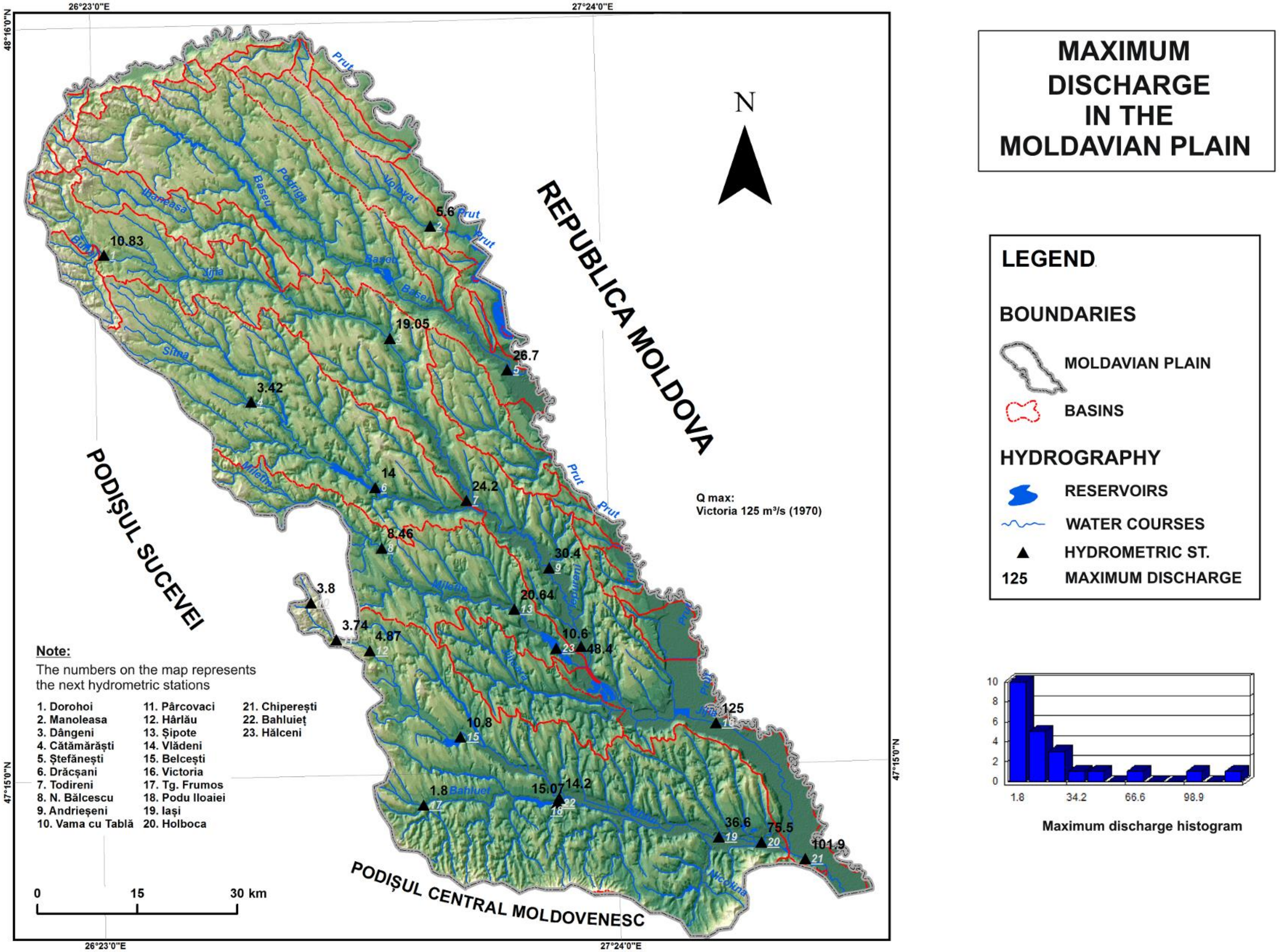


Fig. 6.29 Maximum discharge in the Jijia hydrographic basin

In the Başeu hydrographic basin the biggest overflow recorded in the 1950-2011 period (the maximum maximorum discharge) was 330.0 m^3/s, on 14.07.1969 at the Ştefăneşti hydrometric station. This discharge appeared as a result of torrential rains above the entire Moldavian Plain. Other maximum discharges were recorded in 2005 (124 m^3/s), 1973 (100 m^3/s) and 1979 (83,1 m^3/s) (fig. 6.30 - 6.31).

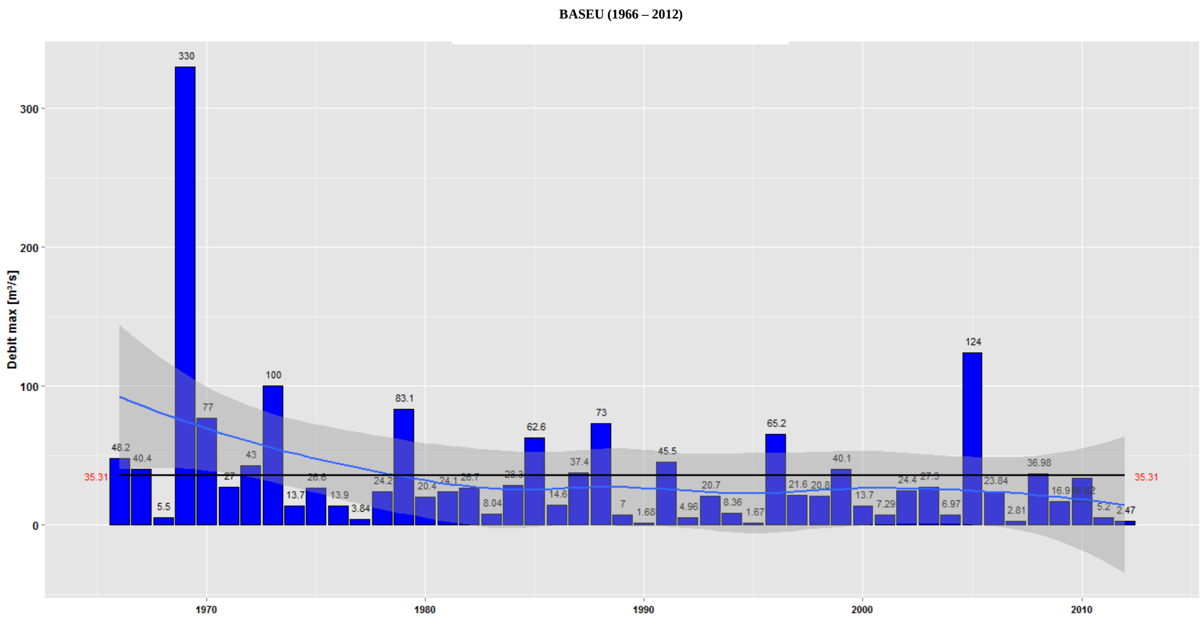


Fig. 6.30 Maximum annual discharges at the Ştefăneşti hydrometric station, Başeu River

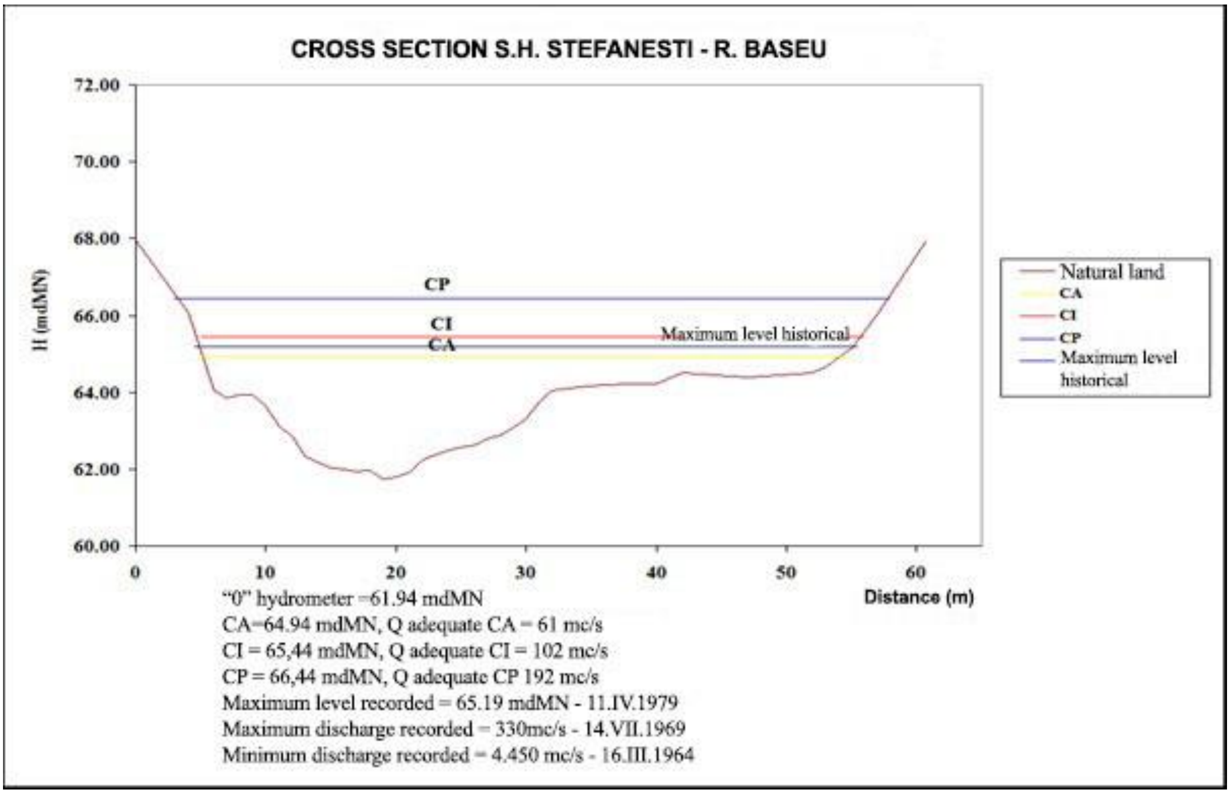


Fig. 6.31 Transversal profile at the Ştefăneşti hydrometric station

For the Volovăţ hydrographic basin the maximum discharges, at the Manoleasa hydrometric station, are recorded in 1980. The maximum maximorum is recorded on 05.06.1988 when the discharge was 69 m^3/s. Very high discharges were recorded in 2010 (31.9 m^3/s), 2003 (29.9 m^3/s), 2000 (26.3 m^3/s) (fig. 6.32).

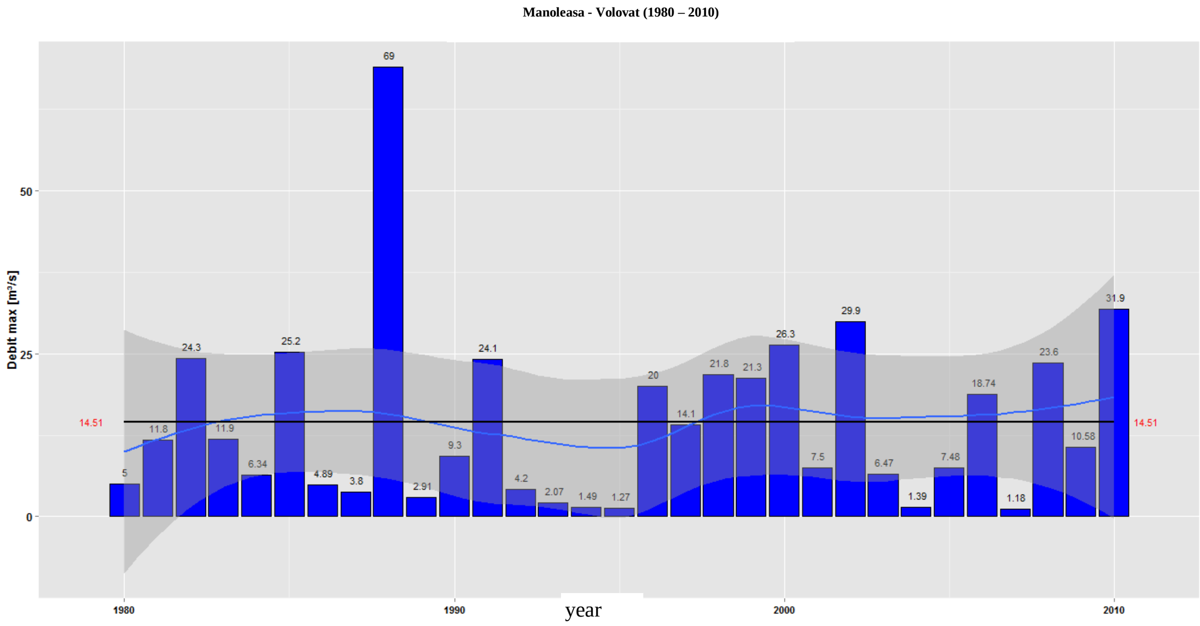


Fig. 6.32 The annual maximum discharges at the Manoleasa hydrometric station, Volovăţ River

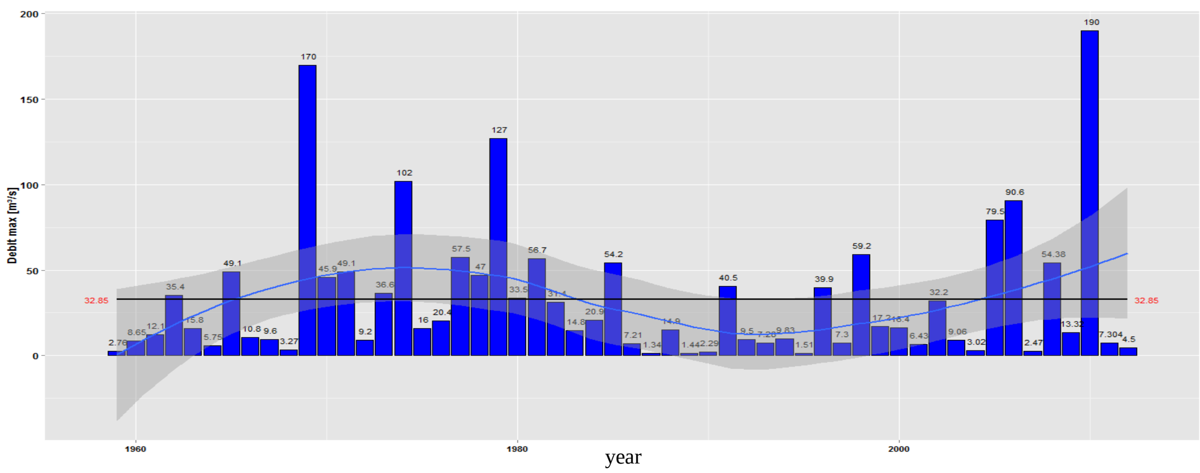
In the Jijia hydrographic basin the highest discharges occurred in the spring of 1932. Even if indirectly determined these discharges were 492 m^3/s at Victoria on Jijia River and 440 m^3/s at Iaşi, on Bahlui River (Pantazică, 1974). The discharges were not directly recorded but the descriptions and the photographs of the event show the amplitude and the important losses that occurred as conclusive (fig. 6.33).

"From the sky enemy, it rains over the city, all the rains of the centuries. The pouring that comes from the Ioloaia's Bridge had sunken all the lower part of Iaşi. On the Red Bridge no tram is crossing. The rain falls and the pouring is growing. At night, cavalry squadrons are sent in the lowland quarters to wake-up the citizens and evacuate the houses. The women cry, the children scream and the men curse" *Water Towers,* Sandu Teleajen.

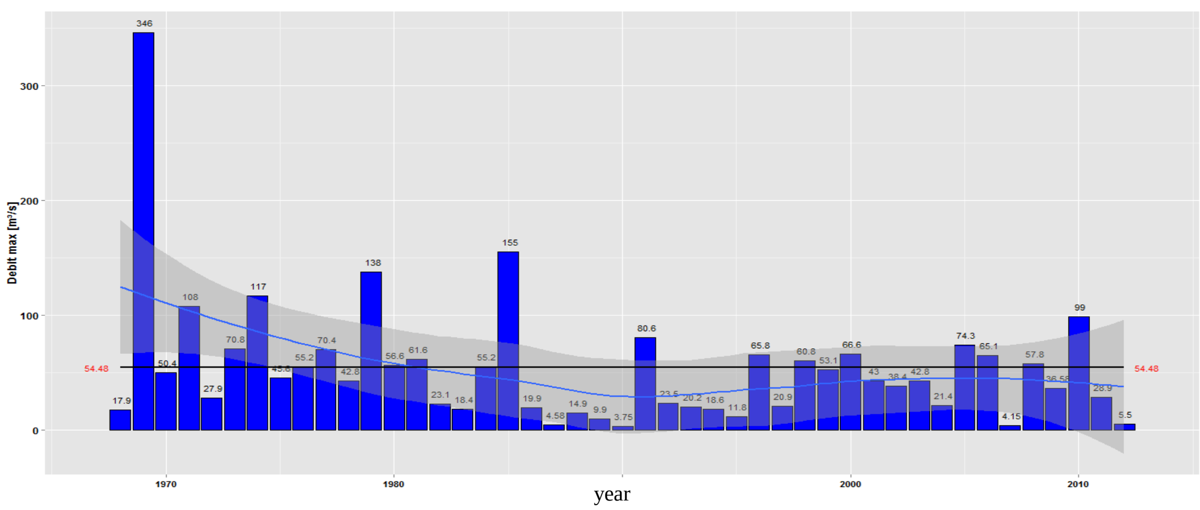
Fig. 6.33 Inundations in Iaşi, 1932 (National Archives photos)

For the 1950-2011 period the highest discharges were recorded in 1969. In the summer of 1969, more precisely between 12th of July and 3rd of August, in the Moldavian Plain extremely abundant precipitations were recorded (locally over 100 mm/24 hours) which resulted in strong floods on every water course. The maximum overflow measured on the main water course in the Moldavian Plain was 394 m^3/s on the 14th of July at the Todireni hydrometric station. In the same time a maximum discharge of 170 m^3/s was recorded upstream the Dorohoi hydrometric station (13th of July) and 325 m^3/s (downstream on 18th of July 1969, at the Victoria hydrometric station) (fig. 6.34, 6.35). In the Bahlui hydrographic basin, the main Jijia affluent, the highest discharge recorded in this period was 182.0 m^3/s, on 9th of June 1975, as a result of torrential rains in the south-eastern Moldavian Plain with 46.0 l/m^2, at the Iaşi meteorological station, 75.8 l/m^2 at Iloaia's Bridge, 48.5 l/m^2 at Strunga and 57.4 at the Cotnari meteorological station.

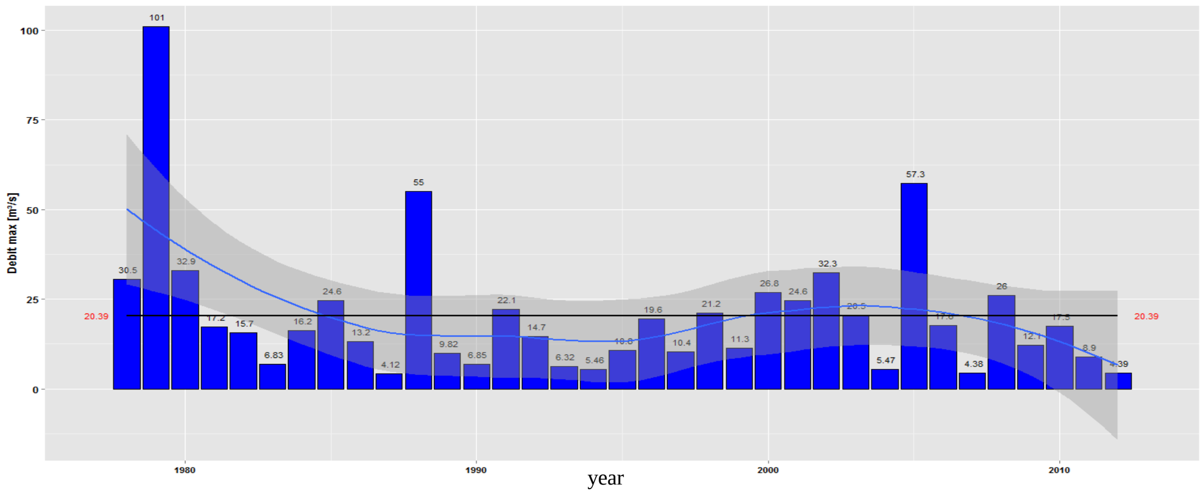
Dorohoi - Jijia (1959 – 2012)



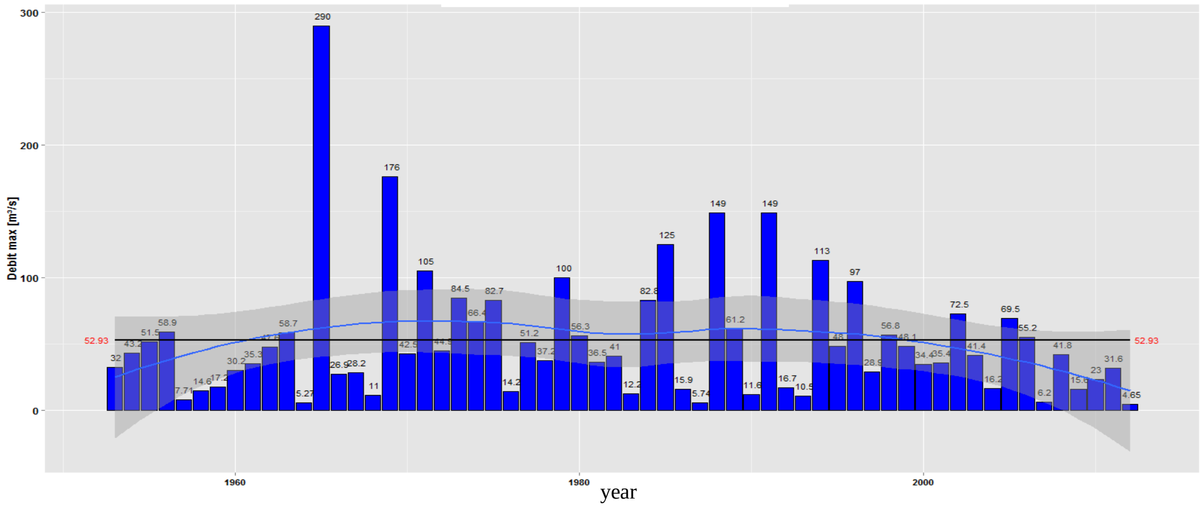
Dingeni - Jijia (1968 – 2012)



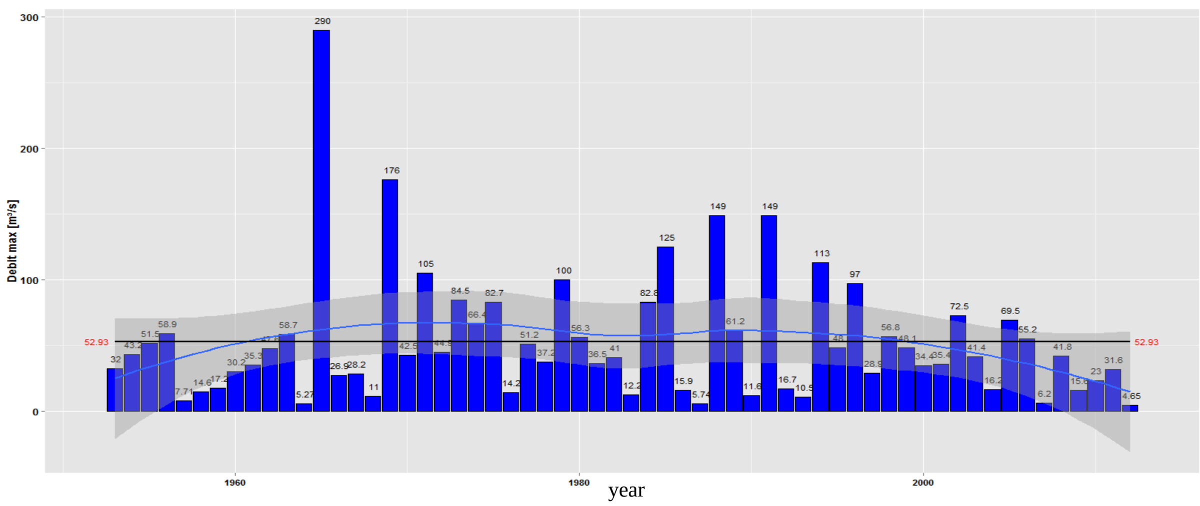
Todireni - Jijia (1978 – 2012)



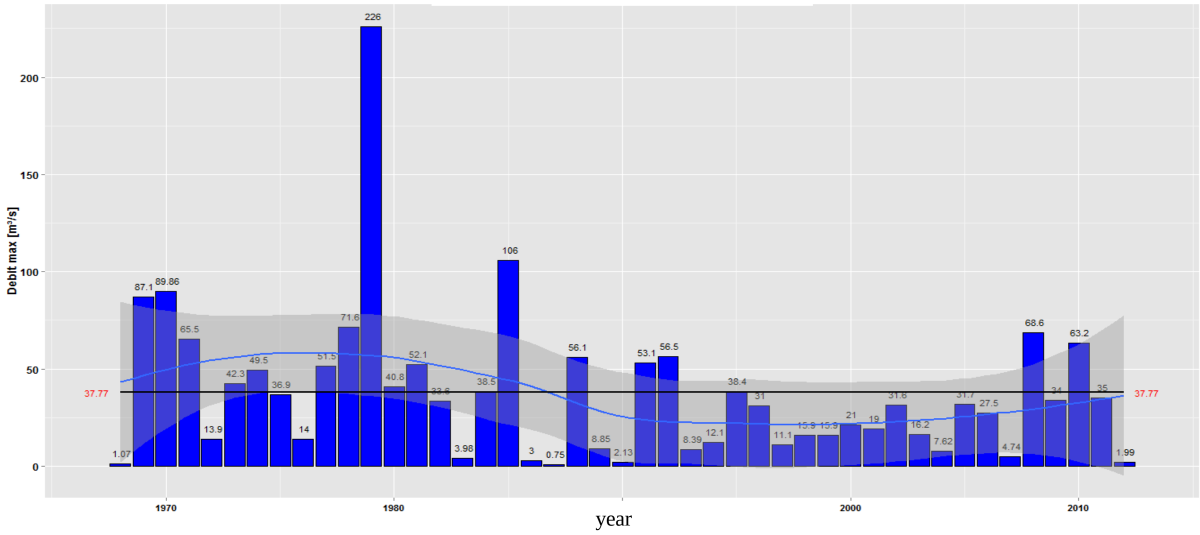
Dracsani - Sitna (1953 – 2012)



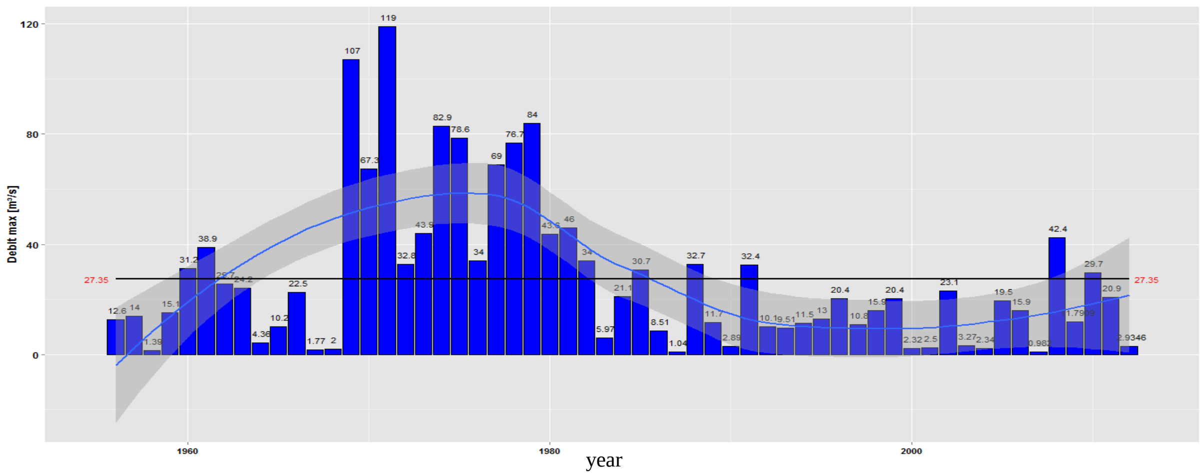
Dracsani - Sitna (1953 – 2012)



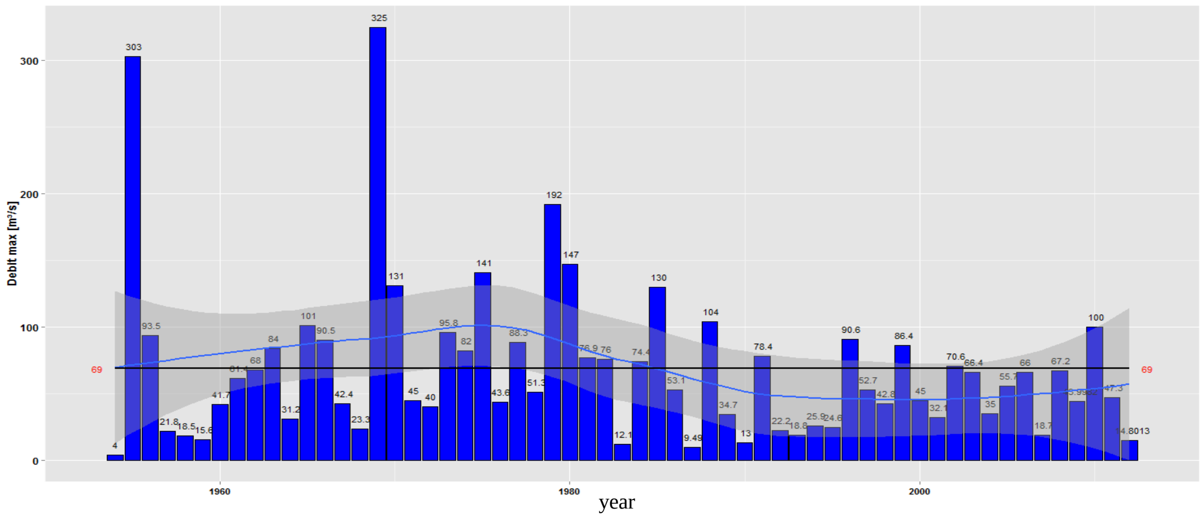
N. Balcescu - Miletin (1968 – 2012)



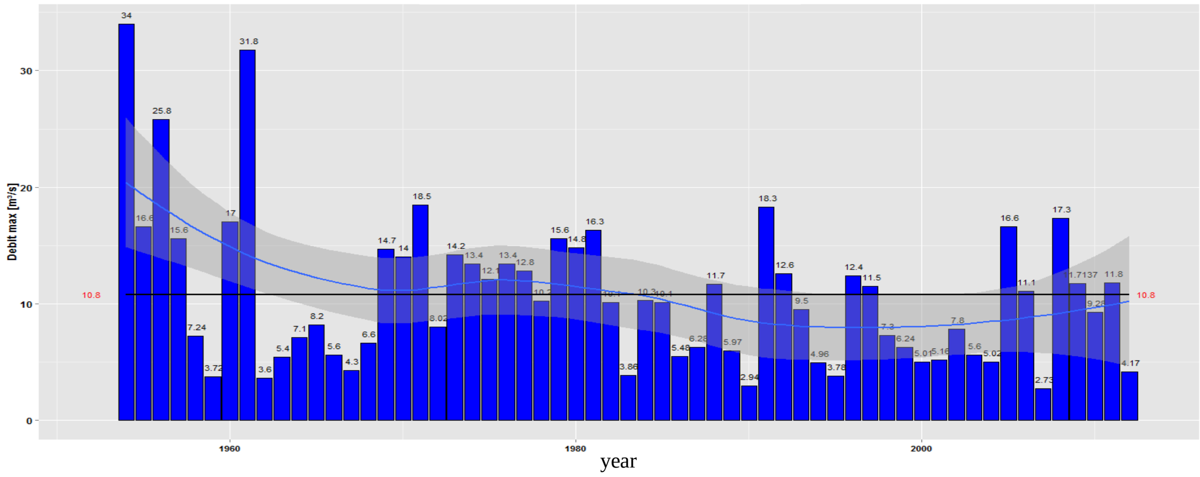
Harlau - Bahlui (1956 – 2012)



Victoria - Jijia (1954 – 2012)



Podu Iloaiei - Bahluiet (1954 – 2012)



Iasi - Bahlui (1954 – 2012)

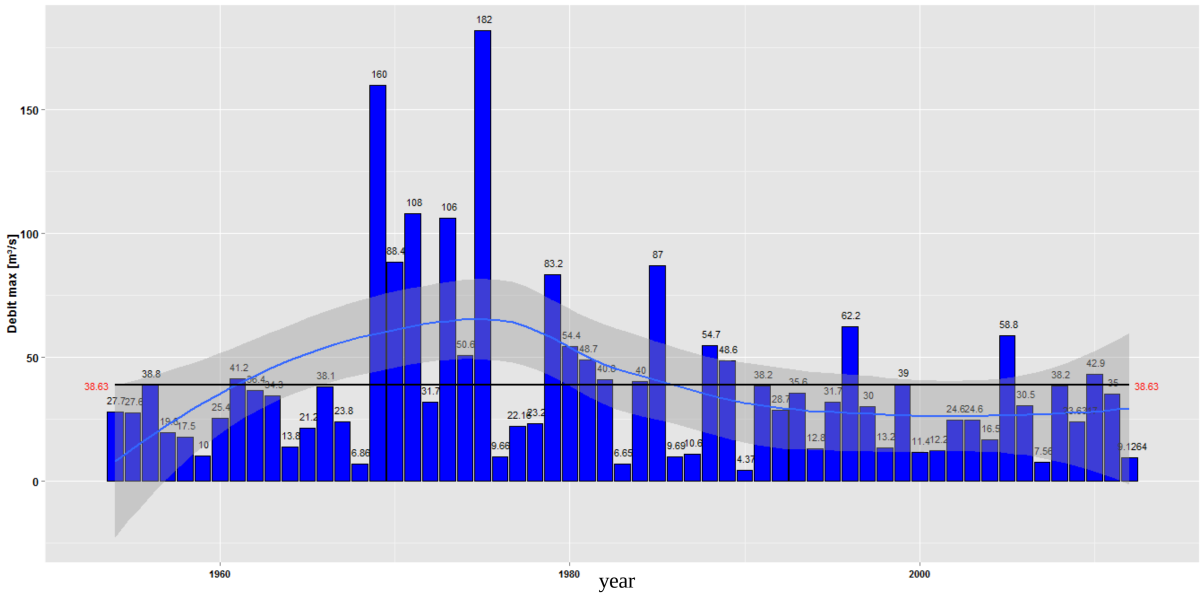


Fig. 6.34 The maximum annual discharge at the Jijia hydrometric station

One important aspect as far as the maximum discharges analysis is concerned is their manifestation condition with respect to the realization of hydrotechnical works (dams, accumulations, embankments, polders or river regulation). Thus, if one analyses the values of maximum recorded it is obvious that the middle and lower hydrometric stations, beginning with the sixties and the seventies, the general tendency is of reduction of these maximum discharges values (the period corresponds with the intensification of the hydrotechnical works interval). Consequently, on Bahlueţ, at the Iloaia's Bridge hydrometric station, in two distinct periods 1950-1964 and 1965-2011, depending on the period of accumulation construction (1964) we notice that the average value of the maximum discharges lowers from 16.4 m^3/s, in the first period to 10.2 m^3/s, in the second period.

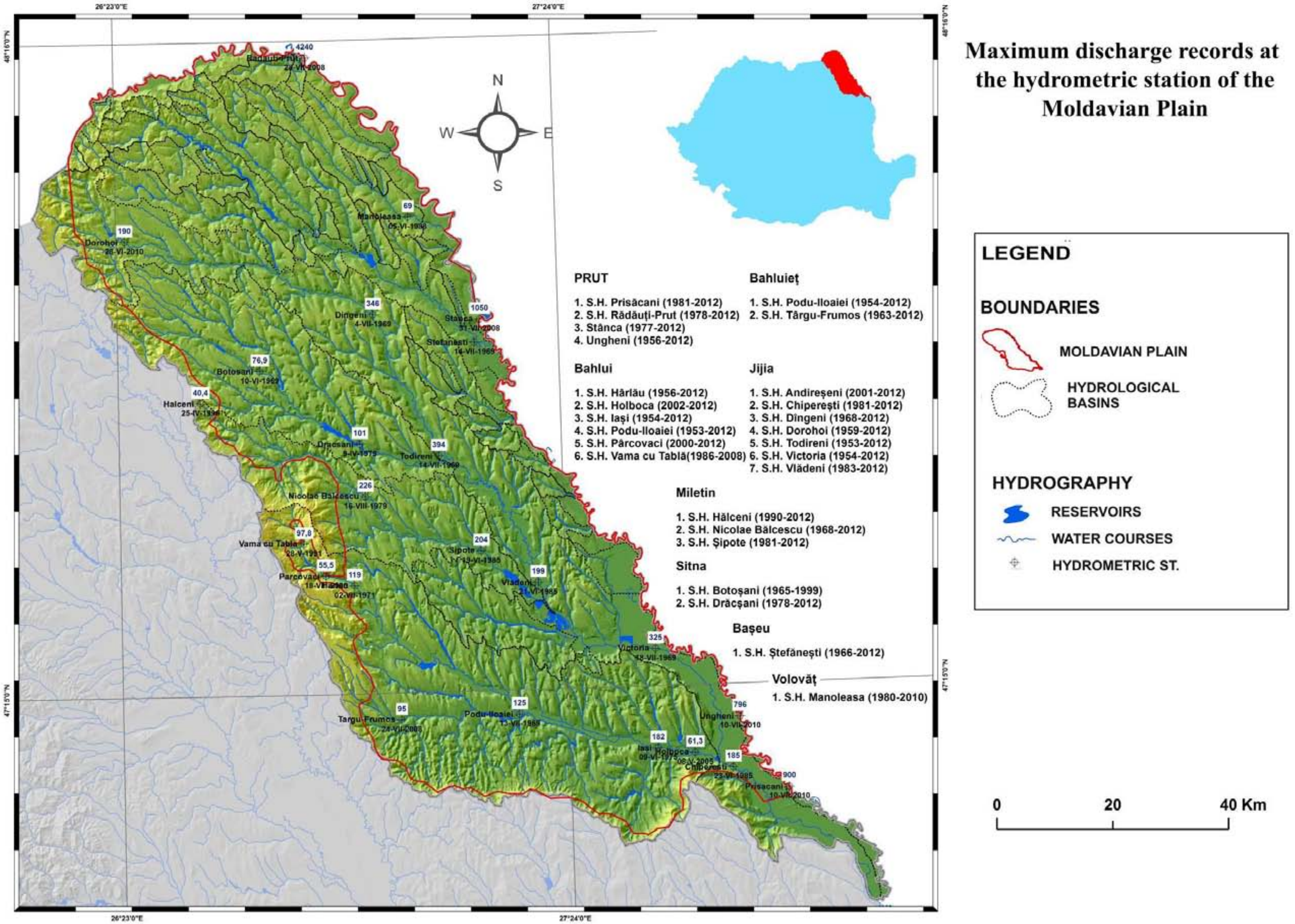


Fig. 6.35 Maximum multi-annual discharges in the Jijia hydrographic basin

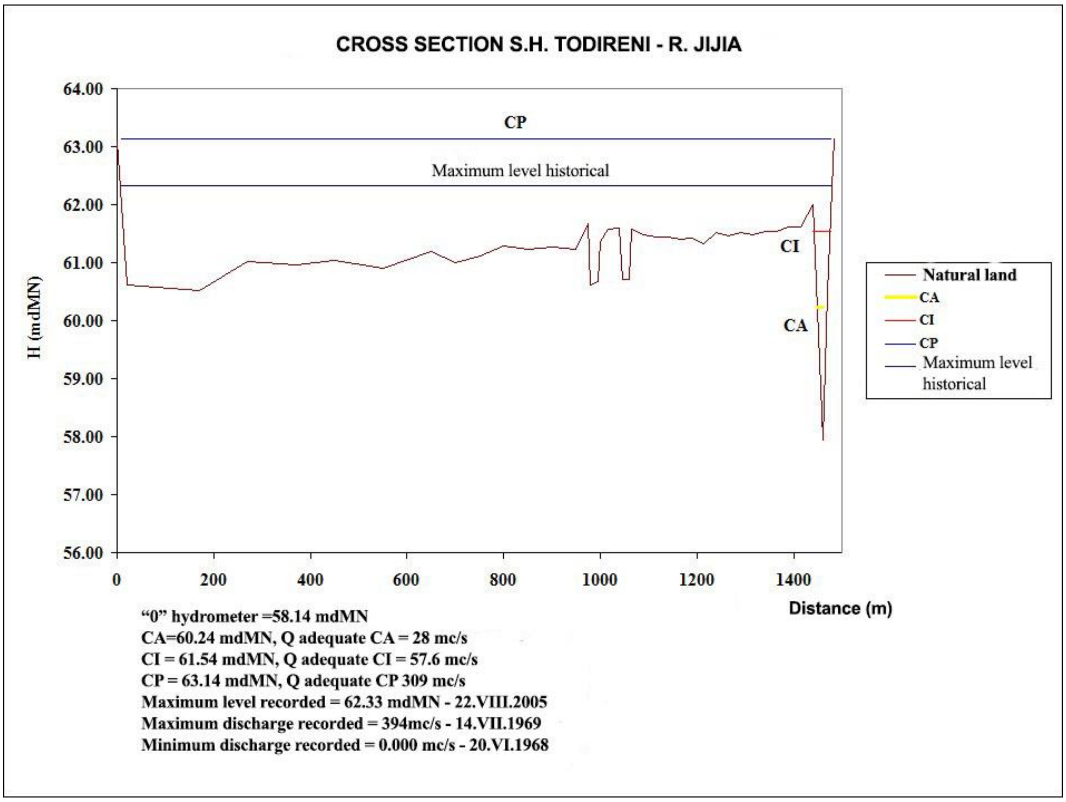


Fig. 6.36 Transversal profile at the Todireni hydrometric station, Jijia River

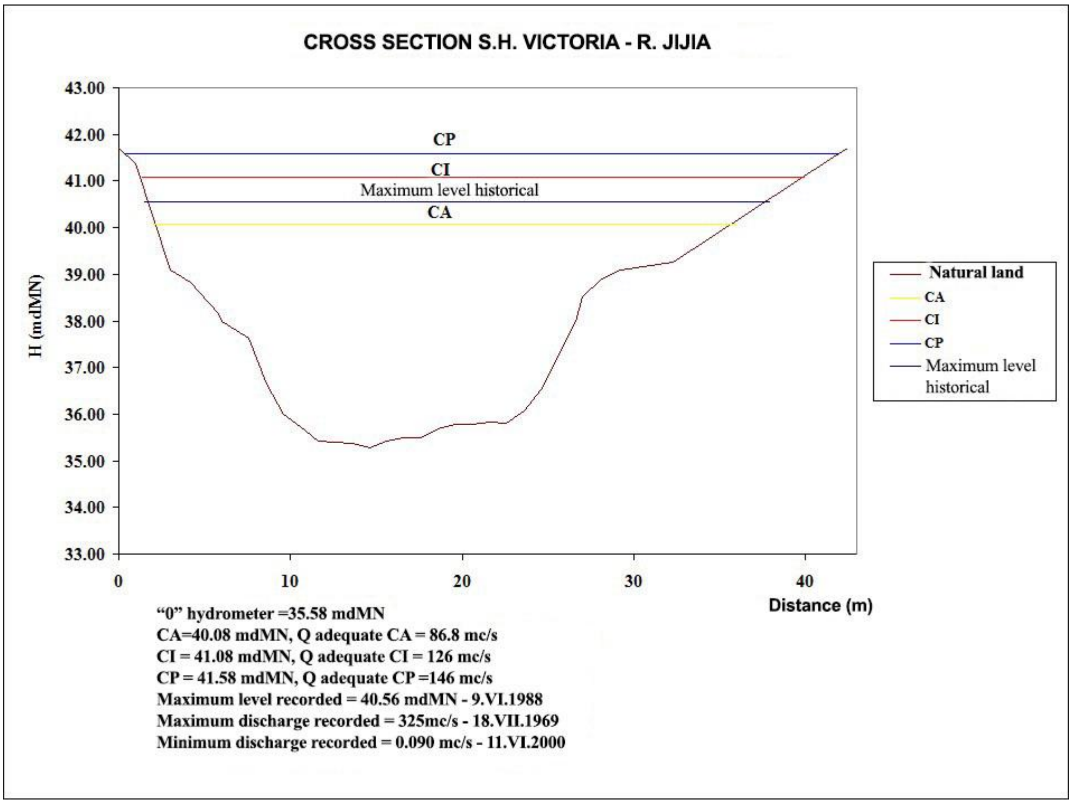


Fig. 6.37 Transversal profile at the Victoria hydrometric station, Jijia River

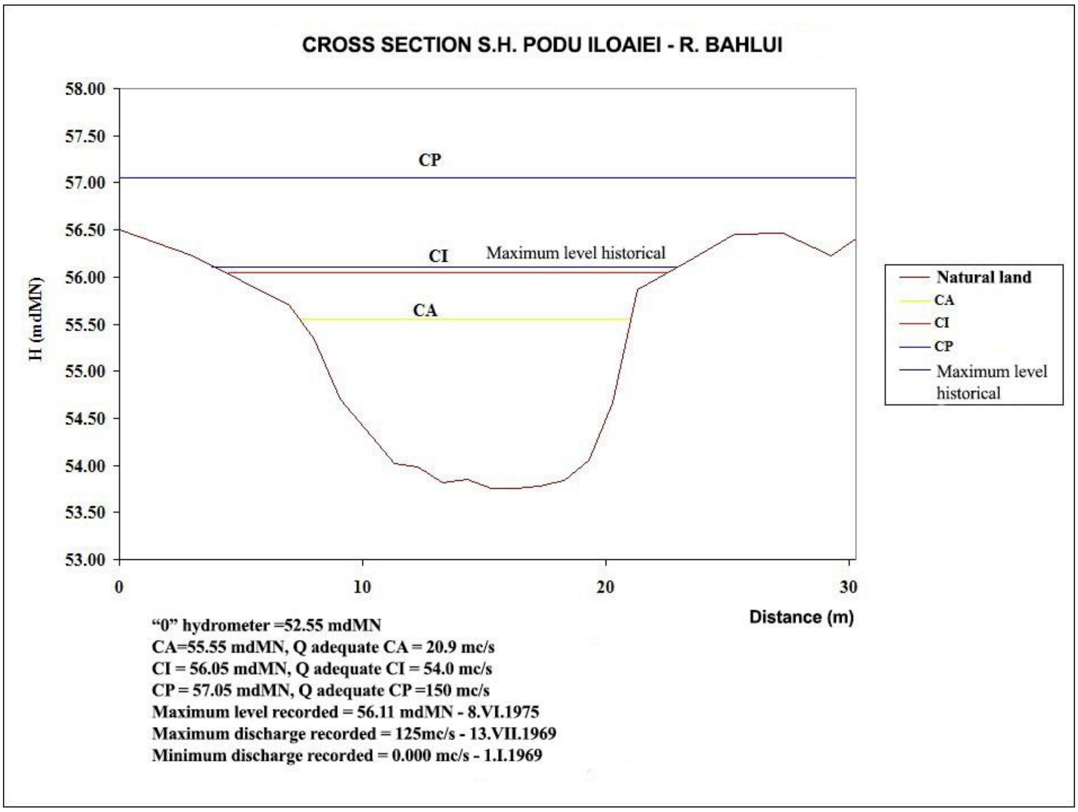


Fig. 6.38 Transversal profile at the Iloaia's Bridge hydrometric station, Bahlui River

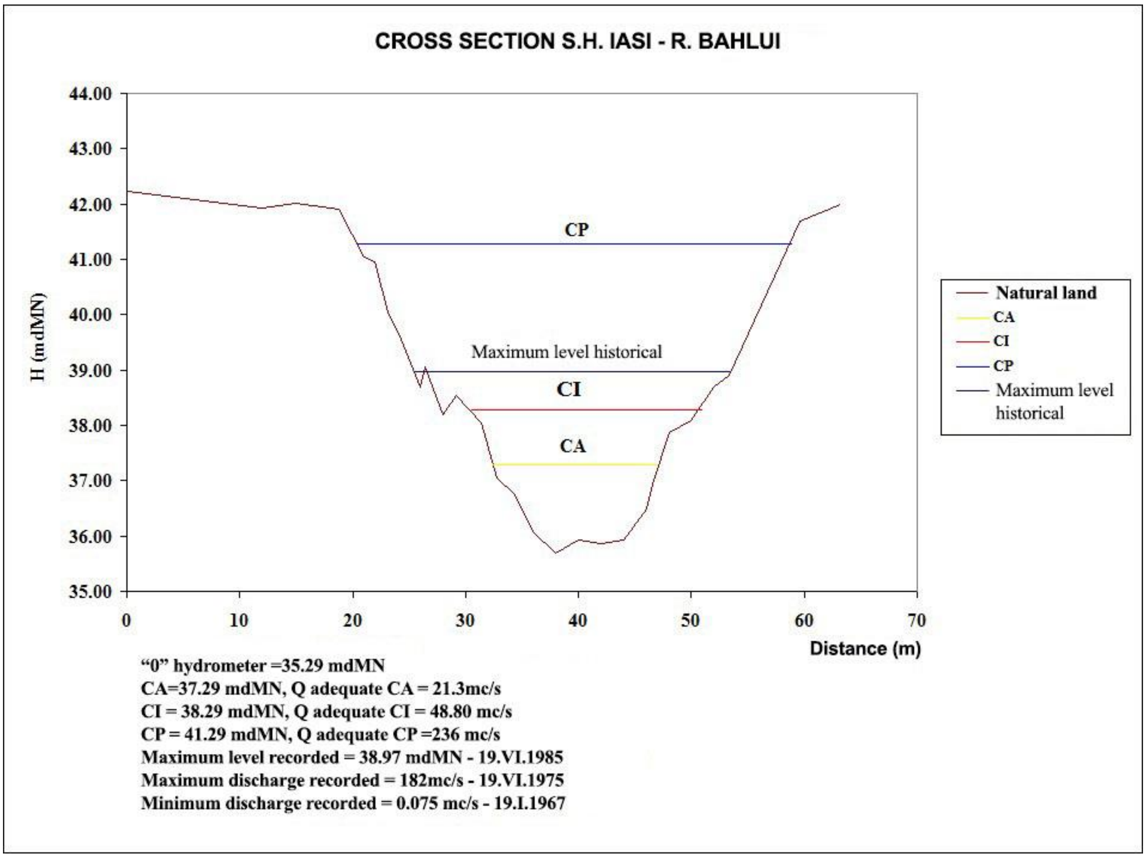


Fig. 6.39 Transversal profile at the Iaşi hydrometric station, Bahlui River

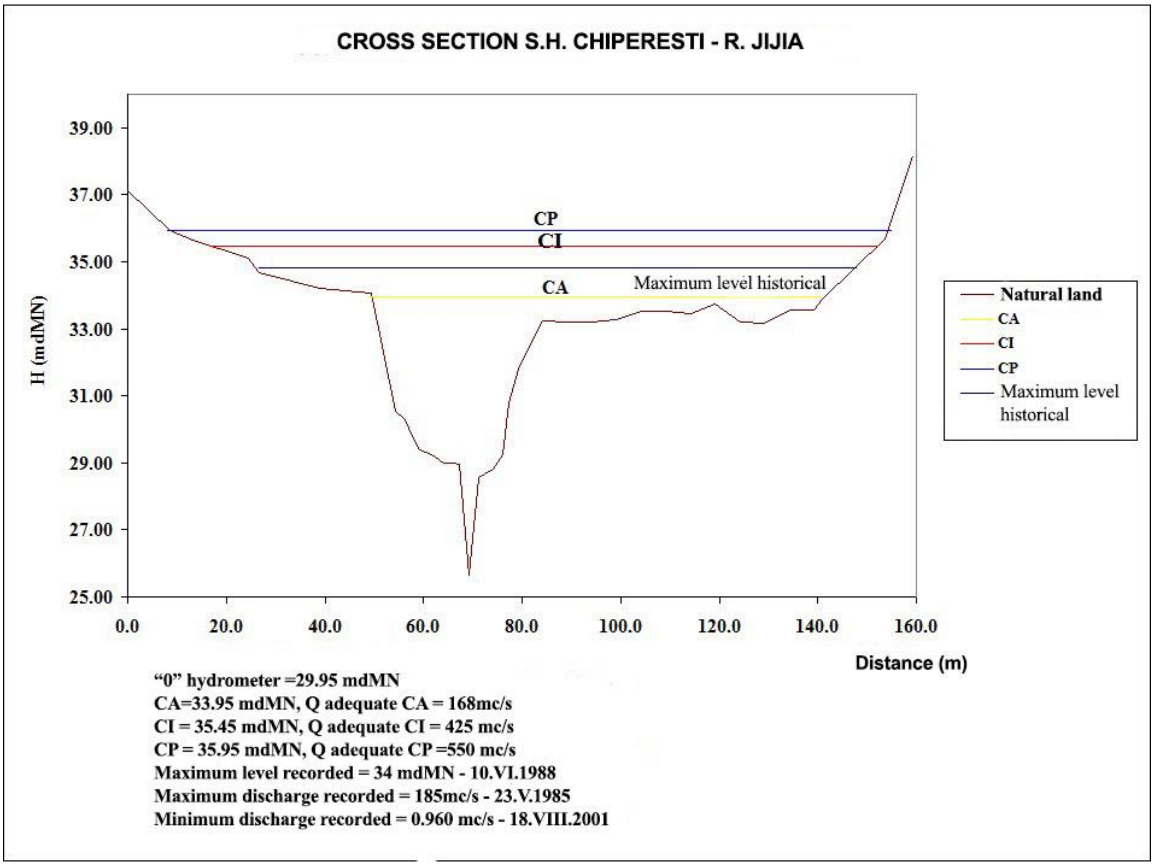
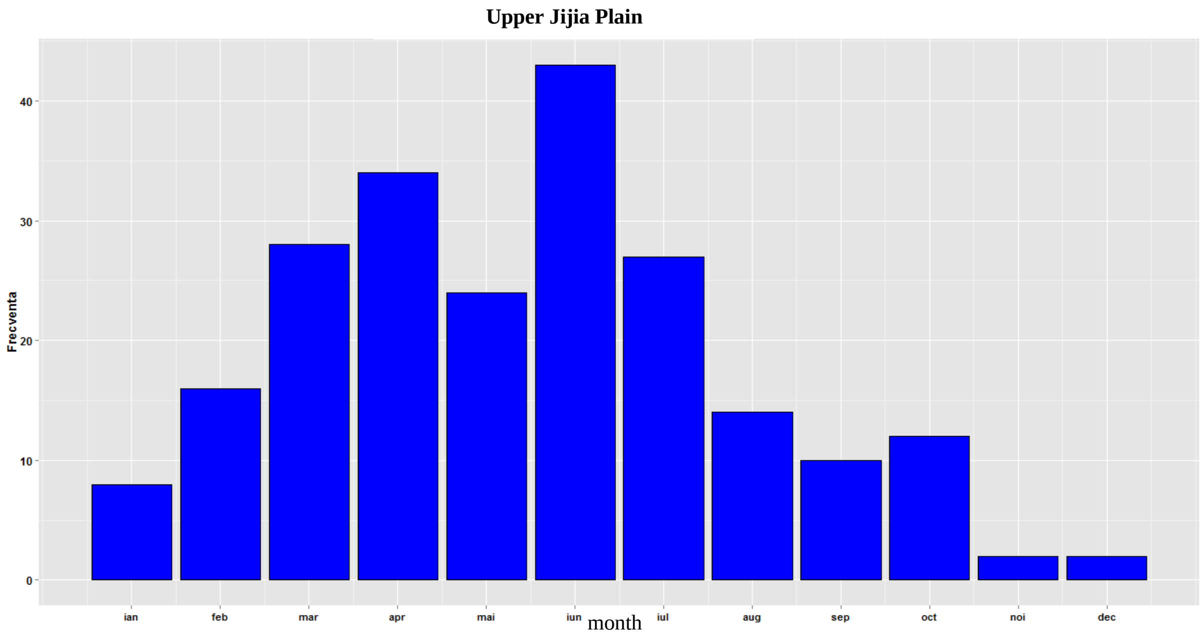


Fig. 6.40 Transversal profile at the Chipereşti hydrometric station, Jijia River

6.5.2. Maximum annual discharge

Along the year, the maximum discharges present larger or narrower variations from one month to another as a result of the pluviometric particularities. At the level of the Moldavian Plain, the maximum discharges occur, more frequently, in the May-July interval (40% of the cases), followed by the March-April interval (30% of the cases). The month of June holds a percentage of 20 in the Upper Jijia Plain and 19 in the Lower Jijia Plain (fig. 6.41).



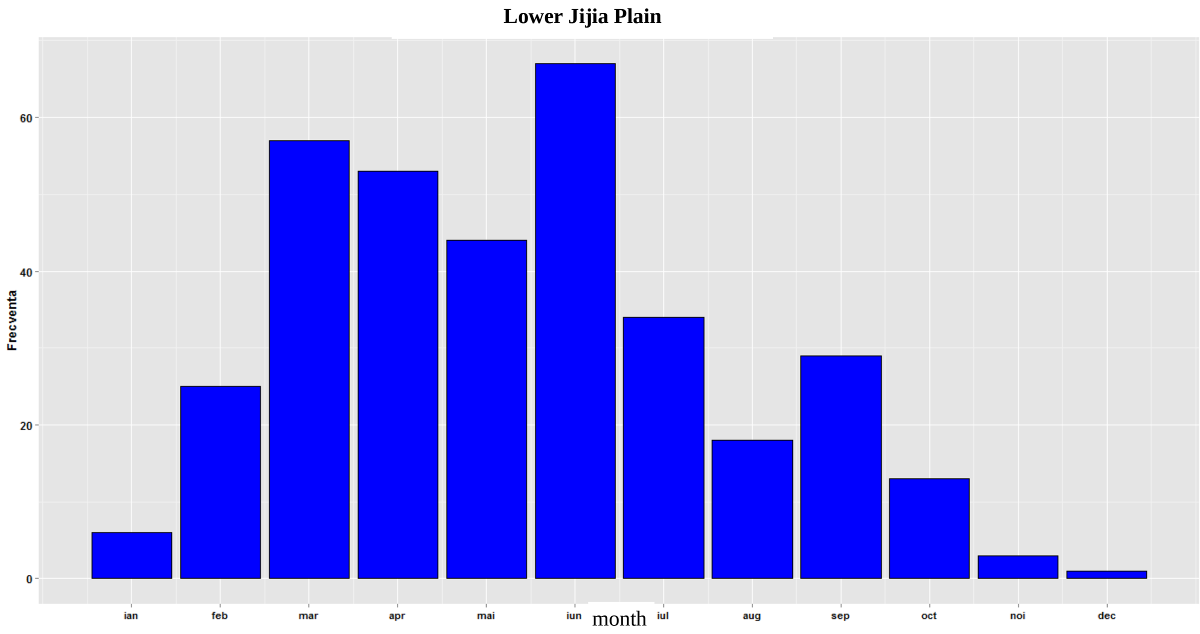
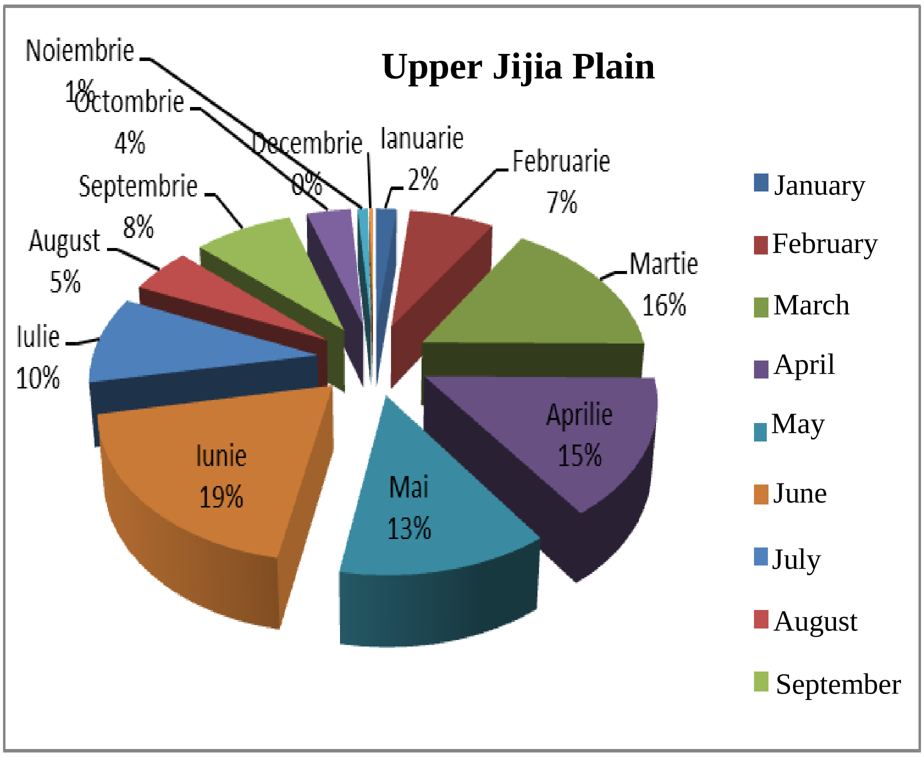


Fig. 6.41 Monthly maximum discharges variation in the Moldavian Plain

The lower values of the maximum discharges were recorded in the winter time (December-February), at the end of summer and at the beginning of autumn. (August-October), fig. 6.42.



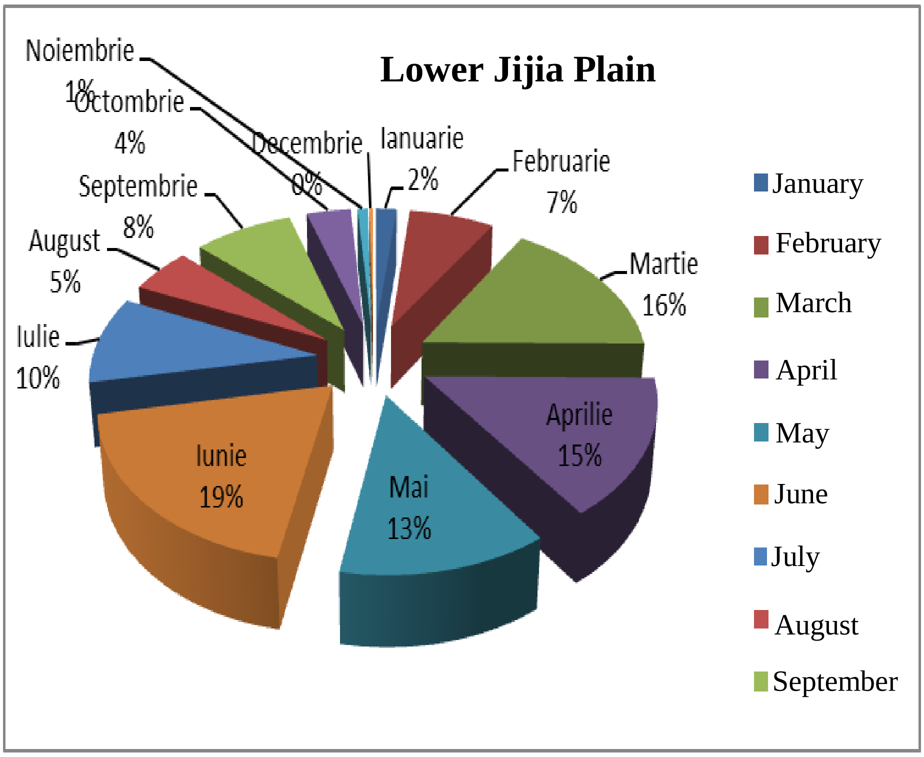


Fig. 6.42 The percentage monthly variation for the maximum discharges in the Moldavian Plain

In order to project and construct the hydrotechnical works and for a more efficient management of the water resources within a hydrographic basin, it is necessary to calculate the maximum discharges with certain exceedence probabilities. In this respect, for the main water courses in the Moldavian Plain the maximum discharges were calculated at different exceedence probabilities (0,1%, 1%, 2%, 5%, 10% şi 20%), table 6.9.

Table 6.9 Maximum discharge at different probabilities (0,1%, 1%, 2%, 5%, 10% şi 20%)in the Moldavian Plain

No.	River	Section	F (km^2)	H (m)	$Q_{max\ p\%}$ (m^3/s)					
					0,1%	1%	2%	5%	10%	20%
1	Volovat	Upstream confluence river Prut (S.H. Manoleasa)	214	178	385	210	160	105	65,0	40,0
2	Baseu	Upstream dam accumulation Cal Alb (downstreamconfl. river Ciolac)	179	200	300	175	138	95,0	65,0	40,0
3	Baseu	SH Stefanesti	917	168	610	330	255	165	100	60,0
4	Podriga	Upstream accumulation Mileanca	126	184	252	147	115	80,0	55,0	34,0
5	Jijia	Acumularea Iezer (upstream confluence river Buhai)	102	244	315	170	130	85,0	55,0	30,0
6	Buhai	Upstream confluence river Jijia	134	279	350	190	145	95,0	60,0	33,0
7	Ibaneasa	Upstream confluence river Jijia	189	184	370	200	155	100	60,0	35,0
8	Jijia	SH Dangeni	840	196	690	375	290	185	115	70,0
9	Sitna	Upstream dam Catamarasti	148	213	300	175	138	95,0	65,0	40,0
10	Morisca	Upstream dam Stauceni	190	169	315	170	130	85,0	55,0	30,0
11	Dresleuca	Upstream confluence river Sitna	135	172	275	150	115	75,0	45,0	26,0
12	Burla	Upstream dam Sulitoaia	143	152	240	140	110	76,0	51,0	32,0
13	Sitna	SH Todireni (Upstream confluence river Jijia)	943	166	695	380	295	185	115	70,0
14	Jijia	SH Andrieseni	2183	176	1030	600	470	325	220	135
15	Miletin	Downstream accumulation acumularea Campeni	330	202	540	320	250	175	125	75,0
16	Miletin	Upstream dam accumulation Halceni	673	166	605	360	285	200	140	85,0
17	Jijioara	Upstream confluence river Jijia	237	117	240	140	110	75,0	50,0	30,0
18	Pais	Upstream confluence river Jijoara	52,0	123	105	60,0	47,0	32,5	22,0	13
19	Jijia	Upstream confluence river Jijioara	3045	167	1030	600	470	325	220	135
20	Jijia	SH Chiperesti	5535	155	860	500	395	270	185	115
21	Bahlui	Am. dam Parcovaci (downstream confluence Valea Cetatuiei)	96,0	349	415	240	190	130	88,0	55,0
22	Magura	Upstream confluence river Bahlui	78,0	252	220	127	100	70,0	46,5	30,0
23	Bahlui	Upstream dam Tansa Belcesti (downstream confluence Putina)	340	256	505	295	232	160	110	67,0
24	Gurguiata	Upstream dam Plopi (downstream confluence Valea Nucului)	117	145	200	115	90,0	62,5	42,5	26,0
25	Bahlui	SH Podu Iloaiei	588	202	530	310	245	170	115	70,0
26	Bahluet	SH Targu Frumos	68,0	252	230	135	105	73,5	50,0	30,0
27	Valea Oii	Upstream dam Sarca	97,0	166	190	112	88,0	60,0	40,0	25,0
28	Bahluet	Downstre accumulation Iloaia Bridge	523	159	485	282	220	153	105	65,0
29	Voinesti	Upstream dam Cucuteni (downstream confluence river Sauzeni)	135	131	240	140	110	75,0	50,0	30,0
30	Nicolina	SH Nicolina Iasi	173	139	325	190	150	105	70,0	45,0
31	Bahlui	SH Iasi	1717	150	815	475	375	260	175	110
32	Bahlui	SH Holboca	1922	155	830	483	380	260	175	110

SH – hydrometric station

6.5.3. Hydrological risks associated with maximum discharge, flash floods and inundations

The maximum discharge, through its particular effects upon the rivers' hydrologic regime, represents the most important phase. However, inside this regime's phase, the most spectacular as evolution, effects and volumes of transported water are the floods.

The floods genesis is directly linked with the momentum climatic conditions within a certain hydrographic basin and can be determined by the superficial discharge from rains (pluvial floods), the melting of snow (snow floods) or a mix of the two (pluvial-snow floods) or, in other situations, by the accidents that may occur at the hydrotechnical constructions (*Zăvoianu,* 1999).

The climatic characteristics of the Moldavian Plain with respect to the maximum precipitations quantities in 24 hours (over 100 l/m^2 at the local stations) and in conjunction with the high deforestation degree represent the main sources of floods occurrence in the region. The maximum precipitations quantities in 24 hours are controlled by the local dynamic convection, of front and orogenetic types that may occur all over the year and by the thermic convection, manifested especially in the warm semester (*Mihăilă,* 2002). Usually, the greatest precipitations quantities in 24 hours occur in the summer months when the air has an increased capacity of water vapours storage and when the atmospheric fronts movement over the Atlantic cross Europe on a west to east general direction an display, behind unstable and humid air masses, frequently affected by the thermic and dynamic convections at local level, with maximum values in this period. The pluvial-snow floods and the snow floods have a more reduced frequency.

Beside the climatic factor, an important role in the floods occurrence is hold by the soil temperature and humidity degree, the terrain's vegetation cover, the discharge slope and the morphometric and morphologic characteristics of the reception basins.

The most important floods in the Moldavian Plain in the 1960-2011 interval, occurred, usually in the summer, between June and July (fig. 6.43). In the above mentioned period important floods took place in the following years: 1961, 1965, 1969, 1970, 1973, 1974, 1978, 1979, 1980, 1981, 1985, 1988, 1989, 1991, 1993, 1996, 2005, 2008 and 2010 with certain differentiations according to the local conditions (table 1, Annex 1).

As far as the floods' average duration is concerned we notice that, on the rivers inside the Moldavian Plain, they rarely exceed 4 days, most of them lasting one day or two. In return, on the main collector, the rut River the floods' duration extends on several days and displaying the backwaters phenomenon with an extended pressure on the hydrotechnical works meant to defence against inundations. The highest number of floods occurred on the inside rivers, respectively 62.9% and only 27.1% on Prut. Between 2000 and 2011, according to the data of the Prut-Bârlad Water Basinal Administration, there were 130 floods in the Moldavian Plain with maximum discharges that exceeded the 20% exceedence probability.

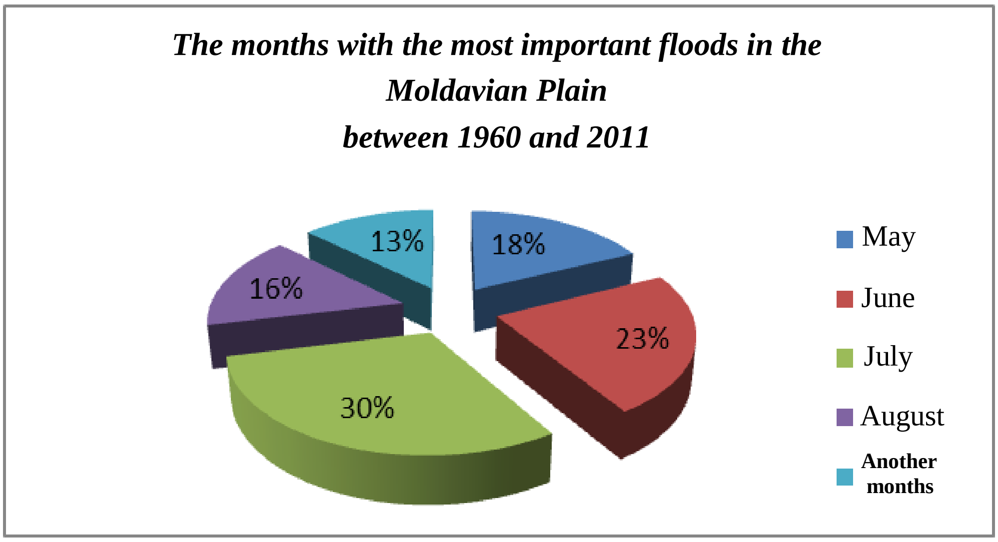


Fig. 6.43 The months with the most important floods in the Moldavian Plain between 1960 and 2011

6.5.4. The analysis of maximum discharge in the summer of 2008 and 2010

Between 2008 and 2010 the hydrologic regime of the rivers in the Moldavian Plain was over the multi-annual average values. In these years, in the summer months, all the NE Romania was affected by precipitations, almost in continuous form and in high quantities. These precipitations succession determined the occurrence of exceptional inundations on the majority of water courses and the reaching or overriding of the historical thresholds. Even if is not a part of the Moldavian Plain we chose to characterize also the Prut floods in this subchapter as the main collector of the study zone.

The Prut river spring from the Carpathian Mountains on the NE versant of Cernahova at 2068 meters altitude, in Ukraine. Until effluencing in the Danube it crosses Ukraine, Republic of Moldavia and Romania.

In Ukraine, the river basin is 8300 km^2, in Republic of Moldavia ha basin is 8250 km^2 while in Romania the Prut basin covers 10900 km^2 (approximately 40%of the total surface). Until entering Romania the river has 251 kilometres and receives the most important affluents from the Beschido-Maramureşan Carpathians: the Little Prut, Liuciuca, Piştinka and Ceremuş; the other 695 kilometres, until discharging in the Danube represent the natural border between Romania and the Republic of Moldavia. North of Oroftiana locality the river enters Romanian territory and crosses 704 kilometres. The Prut River collects all the main streams of the Moldavian Plain: Volovăţ, Başeu, Corogea and Jijia.

The maximum discharge are recorded in the warm part of the year, often at the beginning of April due to the high precipitation quantities superimposed on the snow melting and result in spring-summer high waters. More exactly, the analysis of the high waters in the last 70 years shows the appearance of floods at a frequency of 30-50% in the spring and 10-20% in the autumn and only 5-10% in the winter. The relief's particularities and the increased deforestations result in floods at the maximum discharge and constitute a very important hydrological element. Due to the climatic changes that occur at global level or with local character, in the last period we notice hydrological regime modifications that alternate between drought periods and flood periods with high water quantities (2008) or composite floods with discharges higher than the those registered up to recent times (2010).

The 2008 year

The meteorological causes of the 2008 July flood

The extent of the 22nd of July flood of 2008 was favoured by the abundant precipitations between 21st and 24th of July resulting from the temperate cyclone that affected Maramureş, North Moldavia, the Republic of Moldavia and Ukraine. In its trajectory this cyclone of high altitude circled the Carpathian Arch via the Romanian Plain and presented a retrograde moment and became occlusive in the NW of the Black Sea (M. Bujor – INHGA, 2013), Fig. 6.44.

The precipitations fallen between 21st and 28th of July had high values and the rain nucleus was in Ukraine (fig. 6.45, 6.46). The maximum quantities of precipitations were recorded on 25th and 26th of July at the Verhovina (186 mm), Putila (128 mm) and Kuti (133 mm) meteorological stations. At the northern Romanian meteorological stations the precipitations' sums exceeded 100 l/m^2 while the maximum quantities in 24 hours recorded between 651 $liters/m^2$ at Stânca Ştefăneşti station and 203 $liters/m^2$ at the Cotnari station.

On 24th of July 2008 due to the high precipitations quantities, at the hydrometric station of Rădăuţi Prut, the discharges were rising, consequently on 26th of July they reached 1000 m^3/s while on 28th, in just three hours, they reached the historical maximum discharge of 4240 m^3/s (fig. 6.46). Upstream of the Prut entrance in Romania, at the Cernăuţi meteorological station the maximum discharge was 3020 m^3/s on the 26th of July 2008 while the Prut River reached, at the entrance in Romania, discharges as high as the Danube River.

Fig. 6.44 The clouds system on Radar for 22nd of July 2008 (according to ANM)

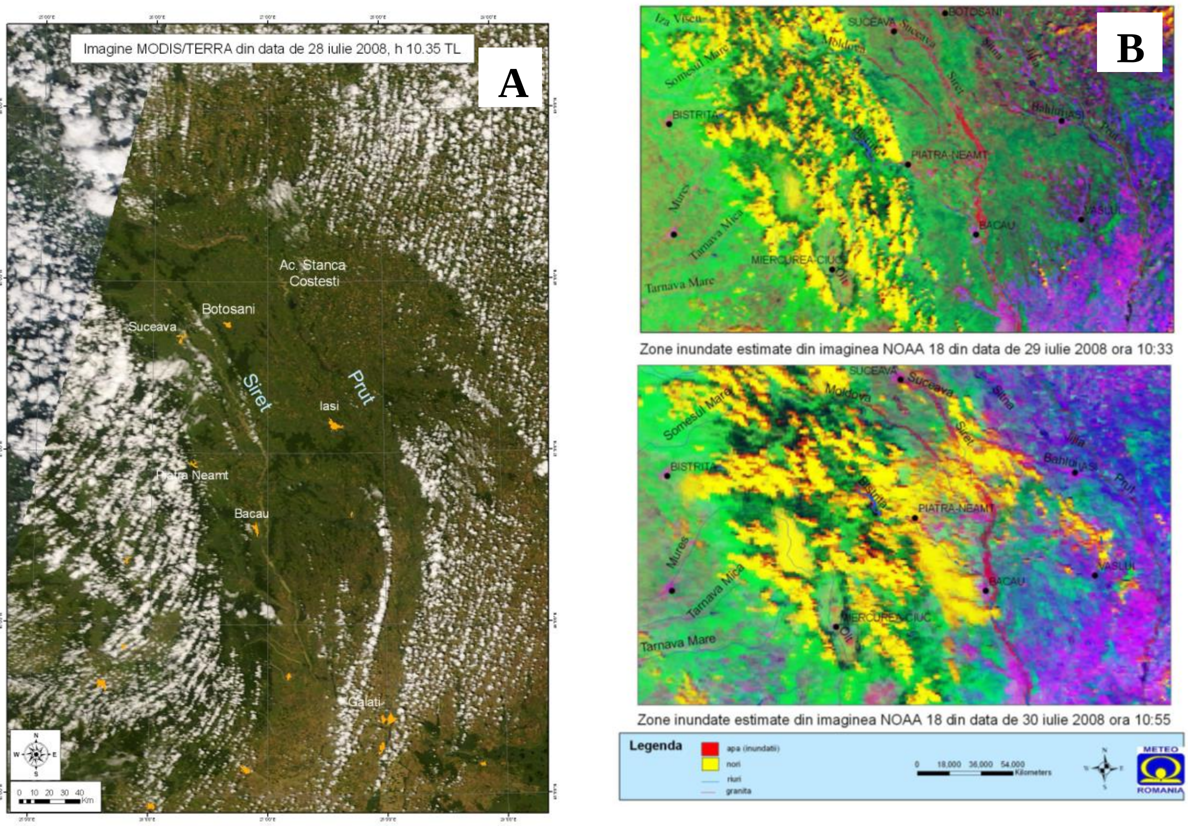


Fig. 6.45 MODIS/TERRA image on 28th of July (A) and estimated flooded zones from NOAA 18 on 30th of July 2008 (B)

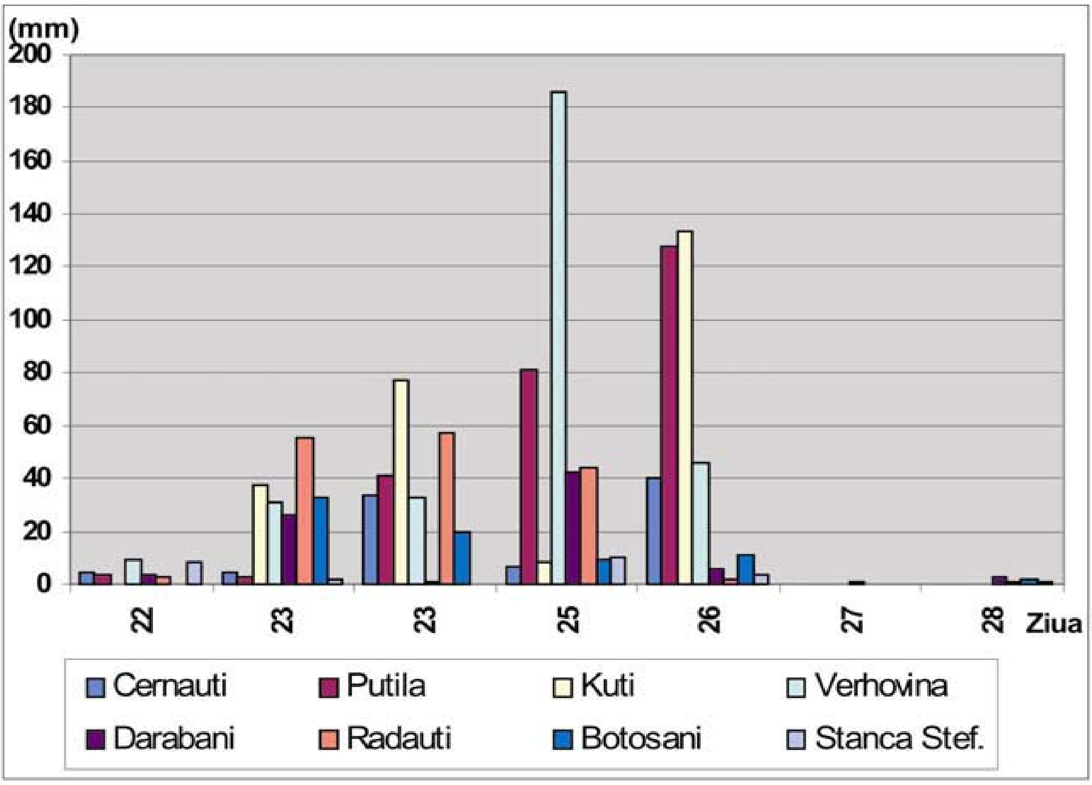


Fig. 6.46 Repartition of precipitations at the hydrometric stations in north Romania and Ukraine between 21st and 28th of July 2008 (INHGA)

Overflow evolution on Prut River in July 2008

At the Oroftiana hydrometric station section, where Prut enters Romania, on 23rd of July, between 13^{00} - 15^{00} , the water level exceeded the peril quota while the inundation quota was exceeded for 136 hours.

At the Rădăuţi Prut hydrometric station, the maximum recorded level, on 28th of July, between 21^{00} - 24^{00} exceeded with 5.3 meters the peril quota while the inundations quota was exceeded 116 hours.

At the Stânca-downstream station which is at the exit from the Stânca Costeşti Lake, the flood peak occurred on 29th of July at an overflow of 1040 m^3/s due to the flood attenuation in the lake.

The statistical processing according to the Person's III theoretical curve for the records values array at the Rădăuţi Prut hydrometric station, situated upstream of the Stânca Costeşti Lake indicates the position of the highest flood. We notice that the floods of 2008, 2005 and 1991 had exceptional peak overflows as far as the statistical frame is concerned where they are the first on the probabilities curve, in the above mentioned order (Fig. 6.47).

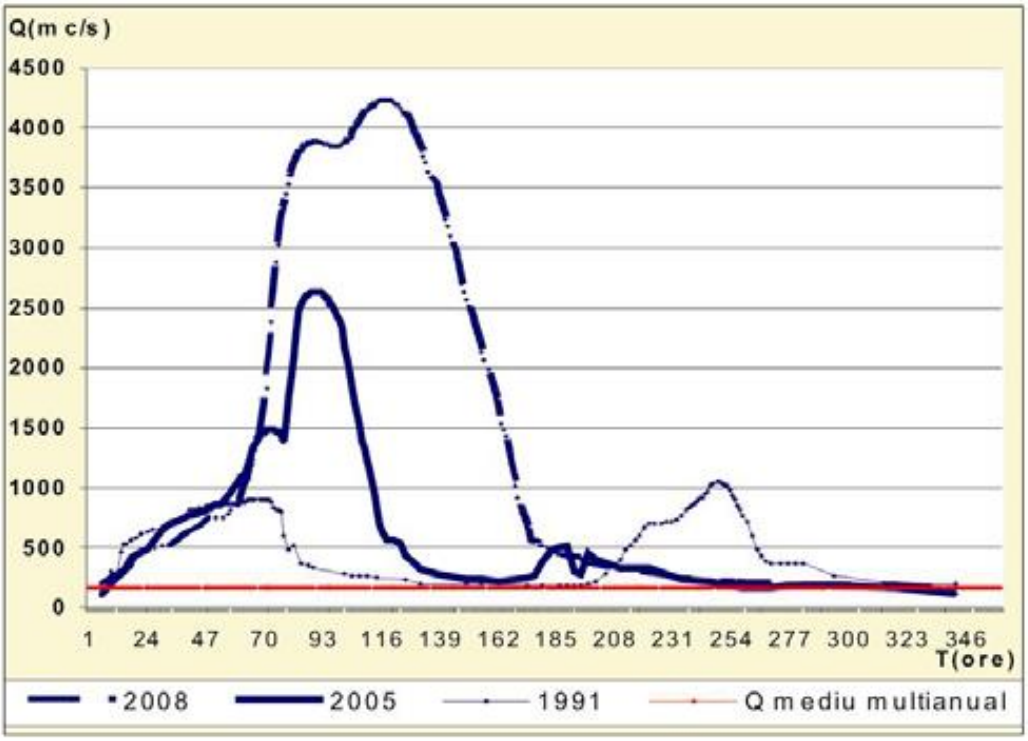


Fig. 6.47 The exceptional flood in July 2008 compared with the ones in 1991 and 2005 at the Rădăuţi-Prut hydrometric station (according to INHGA).

The probabilistic analysis of the annual maximum values array between 1960 and 2008 at the Rădăuţi Prut hydrometric station reveals that the values corresponding to the above mentioned years record probabilities between 2% and 10%. It is noticeable that for the flood of July 2008 the probability that corresponds to the peak overflow (4240 m^3/s) overrides the threshold of 2% which means that such an overflow is to be recorded once in 50 years (Fig. 6.48).

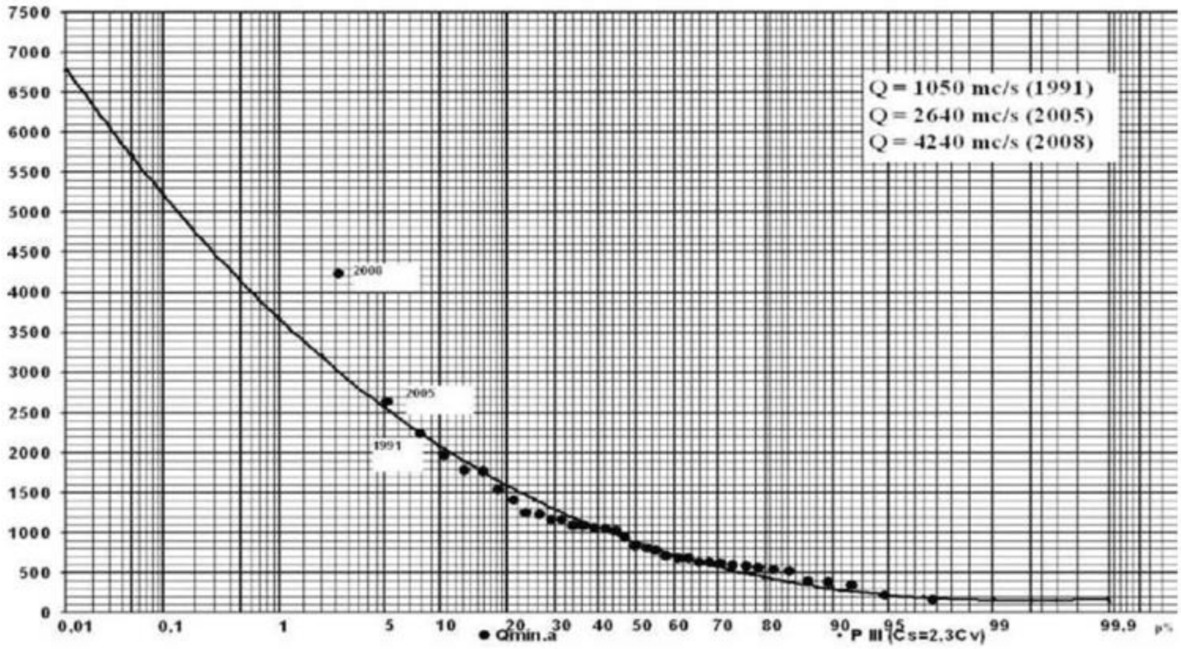
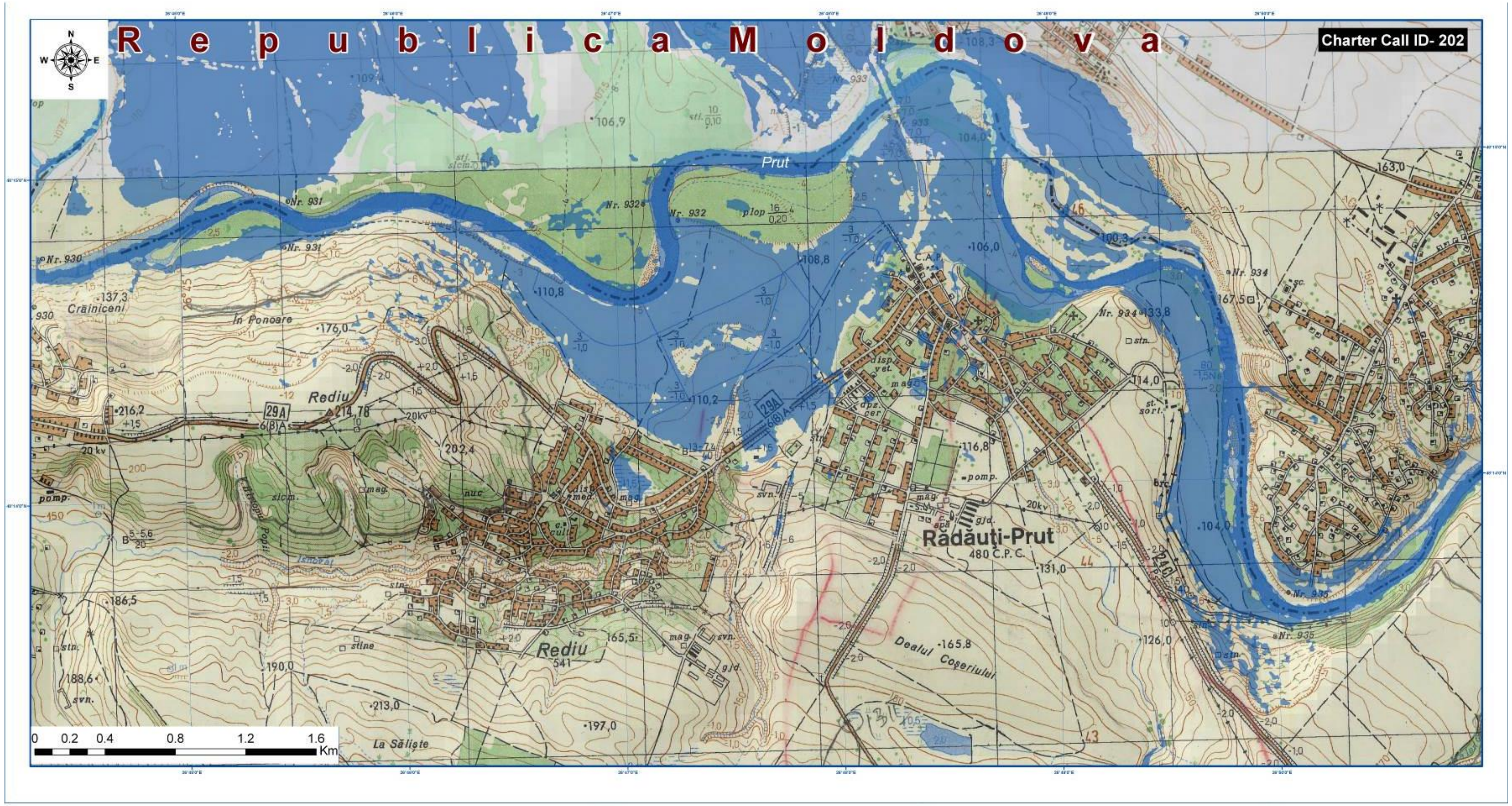


Fig. 6.48 The probability curve for the maximum overflows at the Rădăuţi Prut hydrometric station (according to INHGA)



LEGEND

flooded surfaces

Fig. 6.49 Rădăuţi Prut locality flooded surfaces at 29.07.2008

The direct data from observations and measurements offer the remarkable floods situation of the last century and depict the production events similar with the ones in 1991, 2005 or, the most recent in 2008. We notice the long periods of high waters from July to September as descriptive intervals. The floods produced in the above mentioned years resulted from abundant precipitations, fallen in short time (tab. 6.10). In the table, the differences between the overflows recorded at the Rădăuţi Prut and Stânca Costeşti hydrometric stations, can be observed. As far as the floods' occurrence is concerned over the year we notice their presence in the warm period.

Table 6.10 Maximum discharges and occurrence dates at hydrographic stations in the Prut watershed (INHGA)

River	H.S.	Recorded overflow (mc/s)	Occurrence date
Prut	Rădauţi Prut	1050	30 May 1991
		2640	21 August 2005
		4240	28 July 2008
	Stânca-downstream	672	7 August 1991
		570	22 August 2005
		1050	31 July 2008

The 2010 year

During 2010 the hydrological regime in the Moldavian Plain was over the values of the multi-annual averages while the maximum overflows (discharge) at floods had exceptional values in June and July.

In the analyzed period the floods produced in the Moldavian Plain can be compared with the floods in 2005 and 2008 when historical values were recorded, except the river of Jijia at the Dorohoi hydrometric station, the river of Buhai at the Pădureni hydrometric station, the river of Miltein at the N. Balcescu, Sipote and Hălceni hydrometric stations and the river of Sitna at the Todireni hydrometric station where the historical values occurred in 2010.

In the second half of June and the beginning of July the north-eastern part of Romania was affected by almost continuous precipitations, in abundant quantities that conducted to successive floods of high amplitude. Especially on the Prut River, at the entrance in Romania, a number of 4 consecutive maximum overflows were recorded at shot intervals of time (fig. 6.50 – 6.52).

In 2010 the maximum overflow evacuated from Stânca Costeşti accumulation was 885 mc/s, lower than 2008, yet the longer transition period of the flood conducted to the recording of historical overflows and levels down to the confluence with Danube (downstream the confluence with Jijia at the Prisacani hydrometric station, 900 mc/s).

For many hydrometric stations in the Moldavian Plain the maximum floods were recorded in this period (tab. 6.11). The high instability recorded at the level of the entire region with precipitations concentrated in short time periods determined the formation of versant leakages, torrents and creeks and flash floods with important human and goods losses.

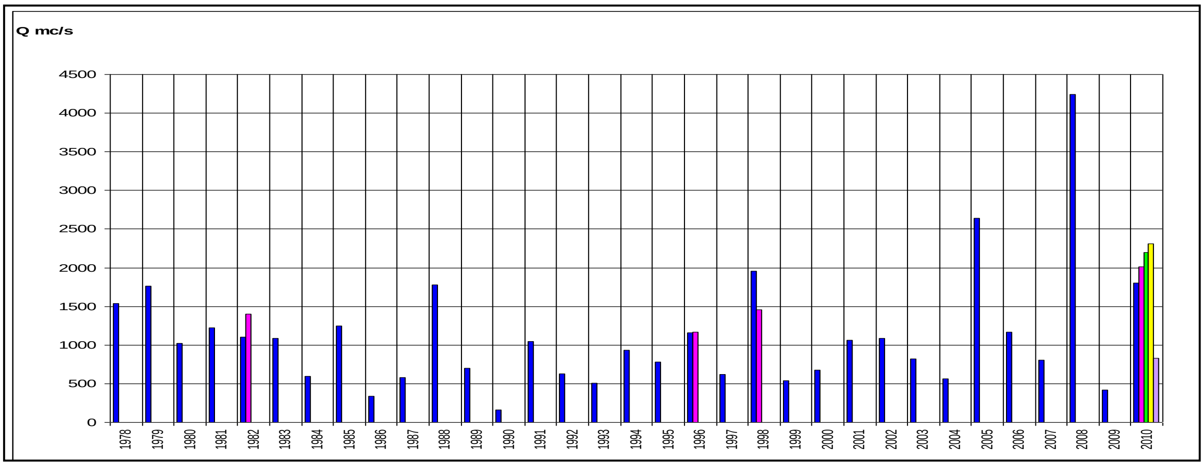


Fig. 6.50 The annual maximum overflows recorded at the Rădăuţi Prut station, on Prut River

Table 6.11 Flood parameters on Prut River between June and August 2010

No.	H.S.	H max (cm) /data	Q max (mc/s)	W (mil mc)	Time Propagation hours
1	Oroftiana	797 / 0 9.07	-	-	
2	Radauti Prut	744 / 10.07	2310	1840	510
3	Stânca aval	461 / 03.07	885	1772	744
4	Ungheni	663 / 10.07	796	1875	1023
5	Prisacani	675 / 0 9.07	900	2152	1032

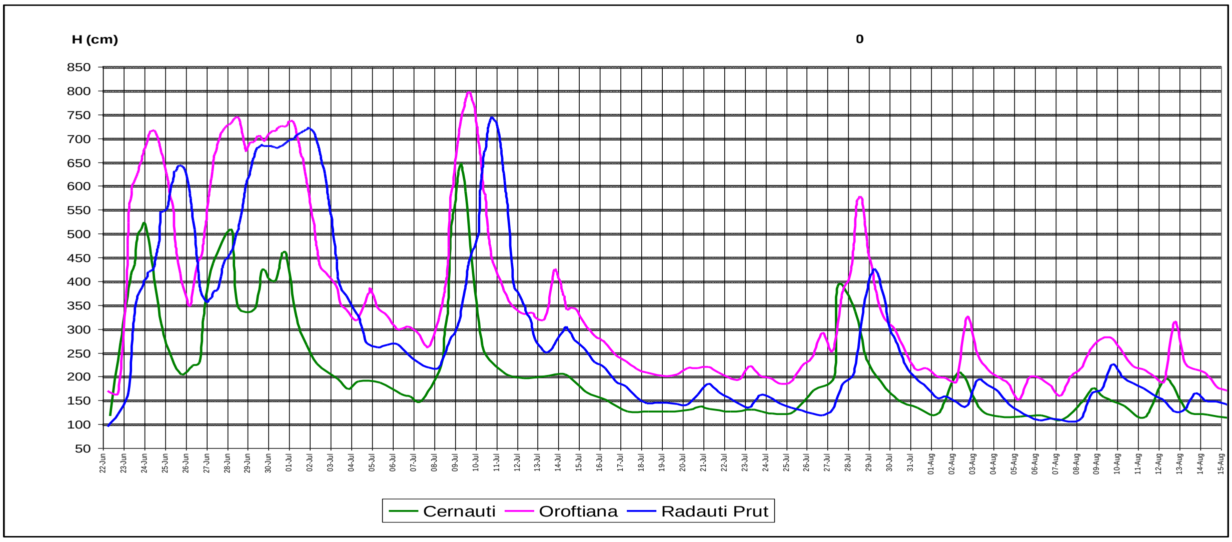


Fig. 6.51 The Prut River flood hydrograph upstream Stânca Costeşti accumulation between June - August 2010

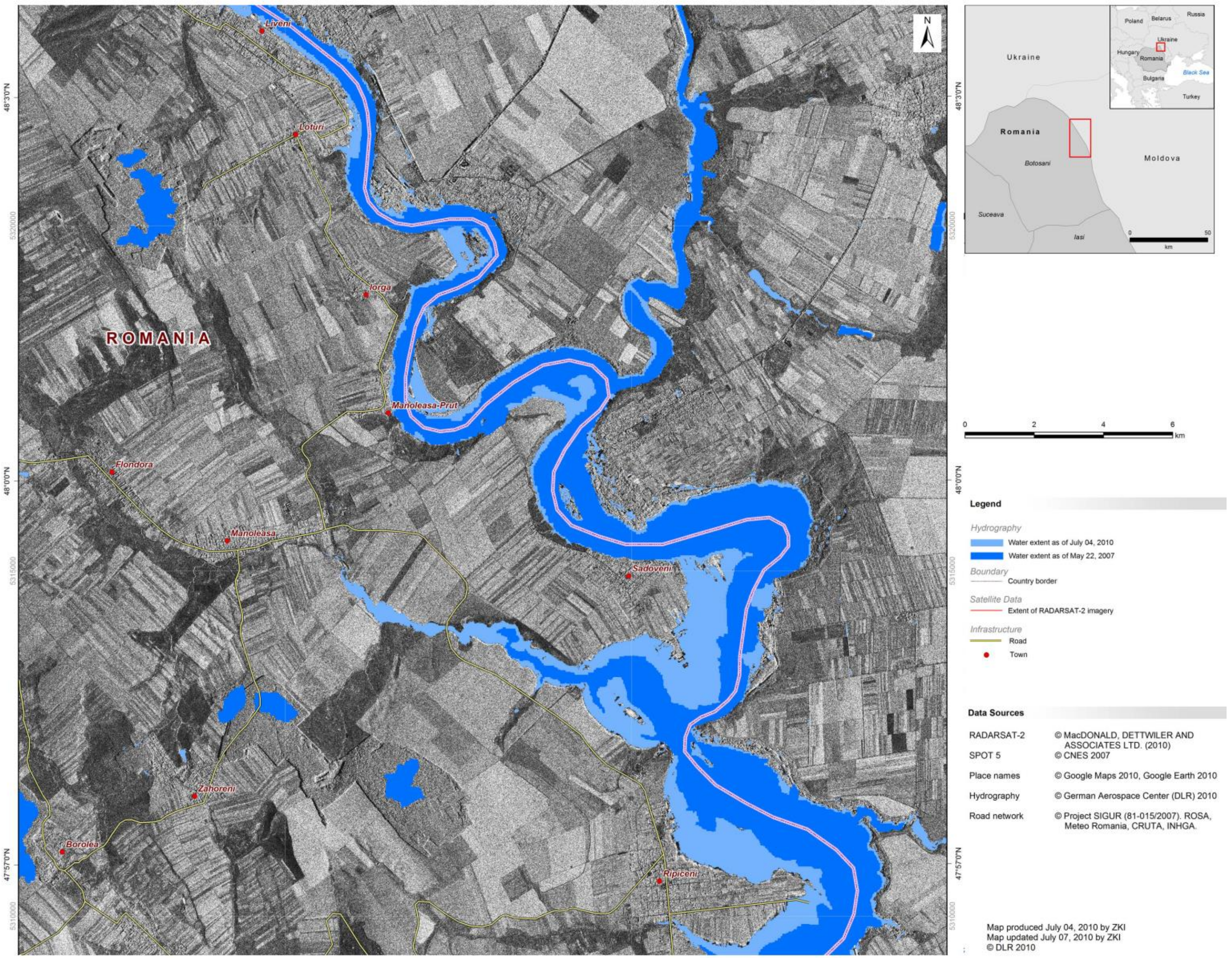


Fig. 6.52 The inundability band of the 4th of July 2010, on Prut

Table 6.12 Precipitations circumstances in Botosani County 22.06.2010 – 30.06.2010 interval

No.	Pluviometric or meteorological station	23.06	24.06	25.06	26.06	27.06	28.06	29.06	30.06	Cumulated (l/mp)
1	SM Botosani	14.8	21.4	0.4	15.2	21.0	-	9.8	29.4	112,0
2	Ac. Catamarasti	23.8	32.2	-	16.8	15.4	-	9.9	35.2	133,3
3	Roma	61.0	21.9	-	14.3	7.2				104,4
4	N. Balcescu	18.8	23.8	-	16.5	35.8	-	37.0	8.5	140,4
5	Bucecea	88.1	20.8	-	16.4	5.4	-	-	35.2	165,9
6	Ac. Dracsani	12.6	9.6	-	8.3	13.2	-	32.3	7.5	83,5
7	Ac. Campeni	25.0	15.5	-	3.9	16.3	-	10.0	6.2	76,9
8	Hlipiceni	21.0	2.6	-	10.8	21.5	-	-	11.0	66,9
9	SM Stanca	15.6	18.8	-	19.0	13.9	-	13.7	24.0	105,0
10	Dangeni	22.5	23.0	-	19.6	14.4	-	8.0	29.0	116,5
11	Todireni	12.3	12.9	-	8.0	15.5	1.8	9.5	6.5	66,5
12	Rauseni	19.0	19.5	-	11.4	10.6	3.5	16.4	-	80,4
13	Ac. Negreni	84.5	27.8	-	12.1	8.2	-	9.5	45.6	187,7
14	Radauti Prut	35.6	15.8	-	18.3	6.7	-	17.9	41.1	135,4
15	Pomarla	46.4	25.9	-	14.7	6.9	-	114.8	37.8	246,5
16	Oroftiana	63.0	42.4	1.2	23.9	16.1	-	60.5	51.0	258,1
17	Ac. Cal Alb	27.6	21.4	0.5	11.0	4.7	-	41.7	30.2	137,1
18	Ac. Ezer	43.6	19.4	1.0	14.0	6.6	-	113.0	67.3	264,9
19	Padureni	28.7	24.5	-	13.2	8.8	-	163.3	41.2	279,7

Between 22.06.2010 - 30.06.2010, on the Jijia basin territory, but mostly the northern part the weather was generally unstable (fig. 6.53, 6.54). As an example, the Botoşani county was under continuous meteorological warnings of Yellow Code (14 in total) while on 30.06.2010 the ORANGE CODE warning (for Dorhoi and Săveni areas) was received from ANM, CRM Bacău and hydrological warnings of RED, ORANGE and YELLOW CODES (24 in total) on Jijia, Buhai, Sitna and Miletin received from M.M.P.- I.N.H.G.A (tab. 6.12). Due to abundant precipitations the Jijia river reached the inundation quota at the hydrometric station of Dorhoi even at the beginning of July the 23rd 2010 and, in the following night, 22.00 hours exceeded the with 28 centimetres the inundation quota, Thus, the maximum height of 488 cm and the 35.9 mc/s were reached.

Even maintained all along in the warning procedure, the inundation quota was only reached at the end of 28.06.2010 (18.00 hours, H = 460 cm). Yet, I only five hours, Jijia recorded the maximum level of 874 centimetres (274 cm over the peril quota) and an overflow of 190 cm/s (fig. 6.55).

In fact, the high precipitation quantities that fell in the basin, on the affluents formed a rapid flood on the Buhai river which, cumulated with one on the Întors Creek brought a volume of water which could not be overtaken by Jijia. Thus, the muddy waters run over the bridge on the Mihai Viteazu Street and rapidly continued on the street surprising many inhabitants in their homes. The small flow section (due to subdimenshioned bridges and the floats) resulted in the flooding of the lower part of Dorohoi and in the accumulation of a water body, downstream the Ezer Pond.

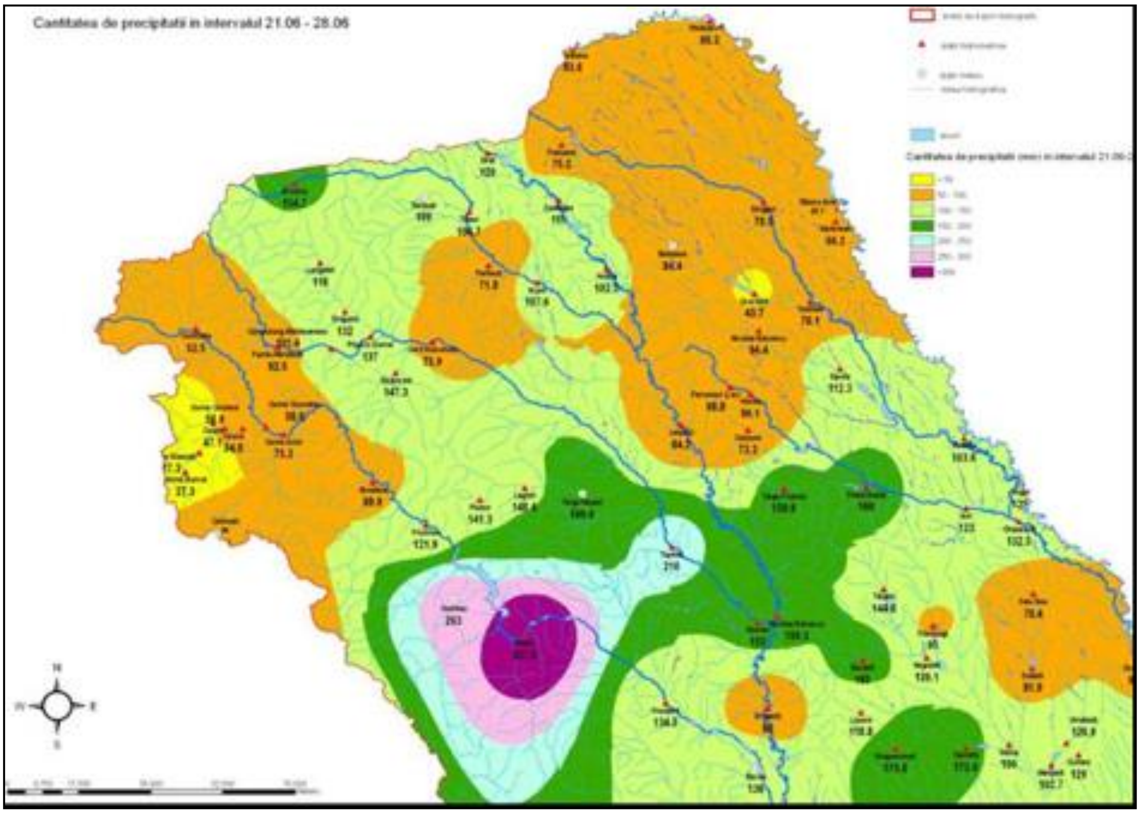


Fig. 6.53 Cumulative precipitations quantities between 21st and 27th of July 2010, NE Romania (source ANM)

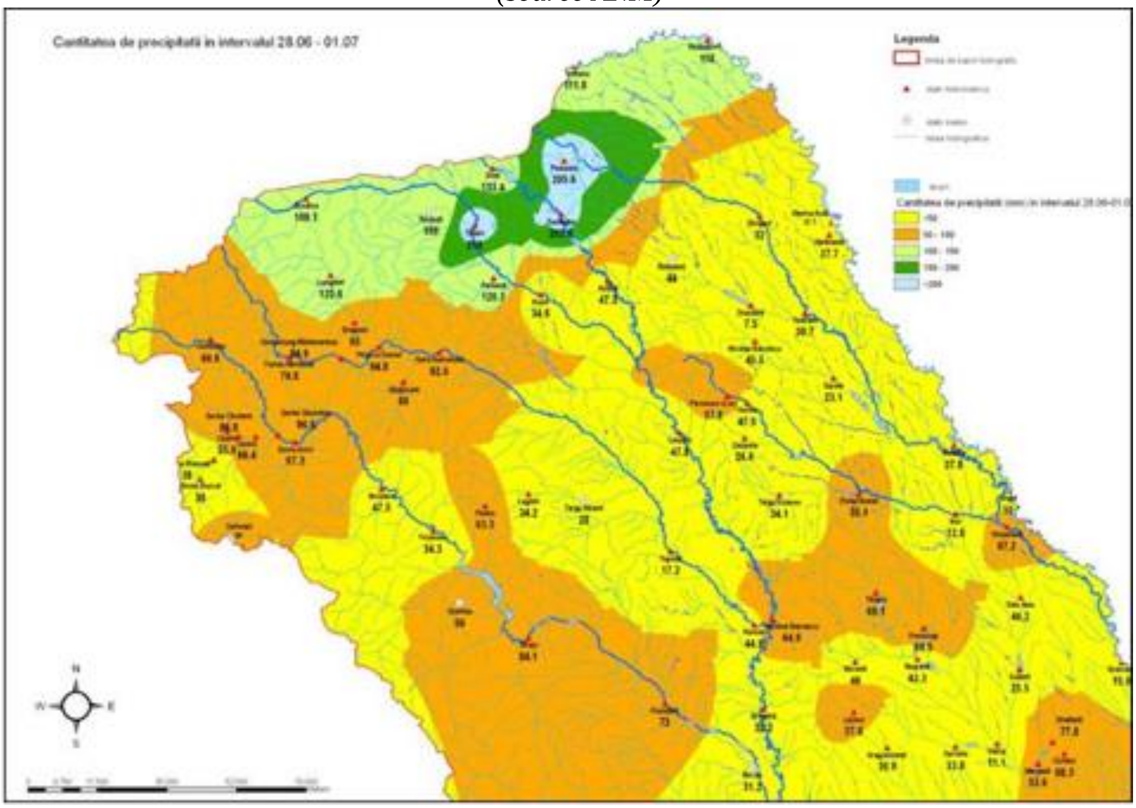


Fig. 6.54 Cumulative precipitations quantities between 28th of June and 1st of July 2010 in NE Romania (source ANM)

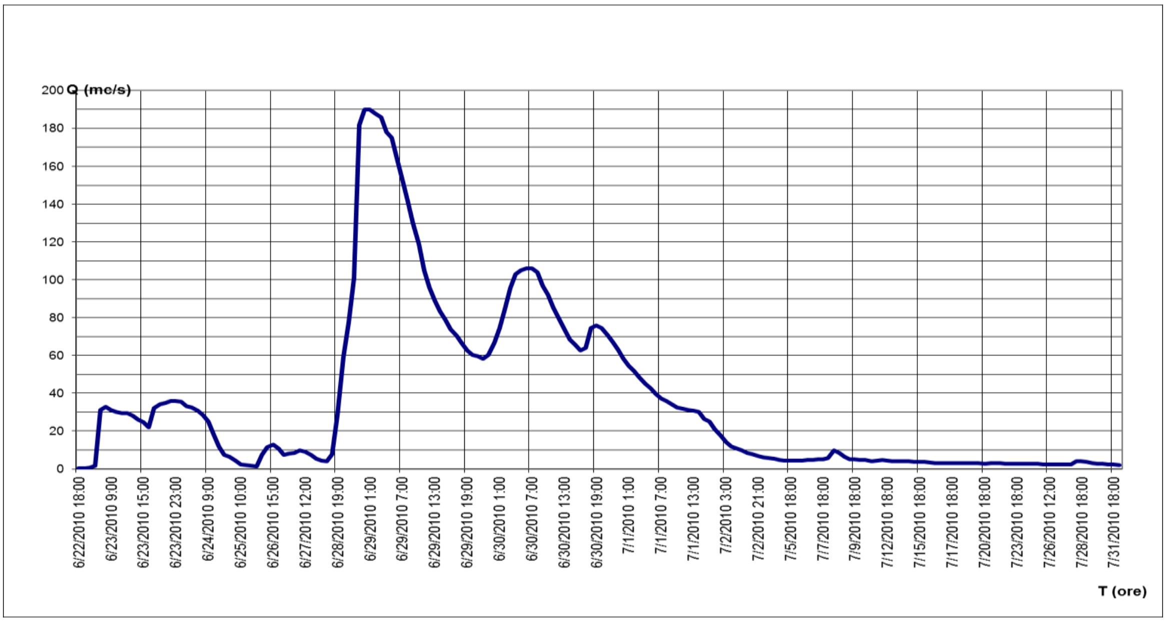


Fig. 6.55 Jijia flood at Dorohoi, June-July 2010 (according to A.B.A. Prut-Barlad)

Starting with 29.06.2010, at 10.00 hours the level of the water in the artificially created accumulation, downstream dam's body overpassed the first stage of the high water discharge quota (153.00 mdMN) and resulted in the downstream to upstream discharge over the line of the discharge device until 01.07.2010, at 12.00 hours. The maximum height of the discharge blade was with 93 cm over the first discharge stage for the height waters download (153.00 mdMN) and with 43 cm over the second stage discharge quota for height waters (153.50 mdMN) (fig. 6.56, 6.57).

Fig. 6.56 Orotoplans for Dorohoi Municipality


Fig. 6.57 Ezer Pond – dam's body – flooded downstream bench — *Discharge blade from downstream toward upstream*

As a result of the flood six persons died, 53 houses were totally destroyed and 437 houses remained in collapse peril.

6.6. Inundations in the Moldavian Plain

Inundations are described as a territory with stagnant water or water in movement as a result of water level elevation or ascend over the quota for the respective territory.

Inundations are classified according to the production manner: surface inundations that occur when water courses get to overspill or from waters leaked from versants and sub-inundations that result after water levels ascend over the terrain level (Chiriac V., et. al., 1980).

According to their genesis, inundations are classified as provoked by: natural phenomena, accidental phenomena and as a result of human activities (table 6.13) (Şelărescu M., Podani M., 1993).

Table 6.13 Floods classification based on their genesis

Nr. crt.	Genesis classification	Type of phenomenon
1.	natural phenomena induced inundations	water courses overspill; water from precipitations or snow melt, stagnant waters or waters from versants; ascend of subterranean waters over the terrain level; maritime storms or typhoon; volcanic eruptions and submarine eruptions
2.	accidental phenomena induced inundations	Breaking or damaging of dams or other hydrotechnical works; misconducted manoeuvres or not according with the hydrological situation in the basin when evacuating waters; sudden versants slides into the lakes
3.	human activities induced inundations	filling the lakes' basins; damaging dams on purpose; irrigation system with high water losses and bed drainage measures; inundations from accumulations earthquakes

After the analysis of climatic data between 1960 and 2011 we notice that the inundations regime in the region is controlled by the water resulted from snow melt and from ice accumulations during spring (for the last years) while there is an intercalated situation with the abundant summer rains (in other recent years). Consequently, most of the inundations occur between late spring and early autumn. Nevertheless, cases where summer inundations were present along with persistent drought during late spring are numerous. The analysis of inundations recorded between 1981 and 2011 reveals 187 events, most of them cause by:

- flashlight inundations on versants that affect vulnerable communities;
- prolonged inundations on main water courses and confluences due to marsh-stagnant effect in depression zones;
- rapid floods due to rapid flow and of complex terrain model

Referring to the causes that conducted to inundations in the Moldavian Plain between 1991 and 2011 we notice 79 overspills of water course, 62 from versant leakages only and 46 mix overspills. We add to this the events on Prut and the losses for the last 30 years are shown in table 6.14.

Table 6.14 Losses induced by rivers outrush and versants discharge in the Moldavian Plain between 1981 and 2011 (data of A.B.A. Prut-Barlad and ISU Botosani and Iasi)

No.	Inflicted losses	Units of measure
1	Human lives losses	27
2	Number of affected houses, from which:	8549
3	- destroyed	1437
4	- partially affected	7112
5	Number of household annexes	4679
6	Number of social-economical objectives	584
7	Number of bridges and crosses	1621
8	Km DN	279
9	Km DJ + DC	3023
10	Km roads	74
11	Km forestry road	87
12	Ha agricultural terrain	210623
13	Forestry fond	1209
14	Km water supply pipes	17
15	Nr. affected wells	5237
16	Dead animals	3693
17	Dead birds	8610
18	Number of hydrotechnical works	107
19	Electrical networks	2492
20	Road-side channels	11
21	Cars	87
22	Roofs’ rain evacuation plots	47

6.6.1. Identification of significant potential inundations risk zones

The inundation risk management risk concept

The administration of inundations risks refers to the application of politics, procedures and practices that fulfil the objectives of *risk identification, risk analysis and evaluation, risk treatment, risk monitoring and re-evaluation* in order to obtain risk reduction that the human communities, all citizens are able to live, work and satisfy their needs and aspirations in a sustainable physical and social environment.

The inundation risk is characterized by its nature and appearance probability, receptor exposure degree (number of people and goods), susceptibility of receptors to inundations and their value and, implicitly resulting in for risk reduction one must take action upon the above mentioned issues.

The essential problem of the inundations risk management is the one of the *acceptable risk* for population and decision makers, acknowledging that there is no integral protection against inundations (the zero risk) as there is no consensus on the acceptable risk. Consequently, the acceptable risk must be equilibrium between the risks and the benefits of a certain activity as a result of risk reduction or a governmental regulation. For the urban zones the long term concept is adopted which implies the defence for floods frequencies of apparition of 1 to 100 years in order to insure the sustainable development of the localities.

Damages diminishing and reduction of human lives loss as a result of inundations do not solely depend on the response actions performed during the event, actions that are sometimes achieved separately under the phrase *emergency situations management.* The reduction of inundations' consequences is the result of a complex combination between the measures and the actions that are prior to the event, the event moment management and post event actions (reconstruction, experience from the event characteristics).

Inundations risk evaluation

The evaluation of inundations risks assumes the identification of historical significant events that resulted in important consequences on: human activities, environment, cultural patrimony and economic activities and also on potential risk zones delineation for significant events, in other work those areas to be vulnerable at inundations in the future.

On the ground of the accumulated information we attempt a primary evaluation of inundations risk in the Moldavian Plain and the identification of significant potential risk zones as far as floods are concerned. Thus, all the level of the study zone we covered 3 distinct stages:

1. Collecting the information on historical inundations, identification of historical events and the selection of significant events according to the INHGA proposed criteria.
2. Cartographic processing of the historical floods (GIS)
3. Identification of the significant potential risk zones using data, studies and results of available projects and their integration in GIS environment.

Identification and selection of historical significant floods was performed considering the hydrological criteria (for the identification of significant floods from the hazard view point) and the criteria on the effects amplitude (criteria for historical significant floods form the losses view point). The selection of the affected zones for historical significant floods consists in the analysis of the following elements:

- available information on the damages at localities level, the selection criteria being the households affected per settlement (minimum 10) and when more localities are affected; the criteria is corroborated with other associated losses (inundation of social and economical objectives – school, hospital or other and/or a local road, a county road or of important terrain surfaces flooding or important cultural objectives);

- maximum recorded discharges (maximum discharges discharges criteria > Qmax10%); with the mention that for all the river sectors that are not under supervision, the exceedence probability of the discharges was estimated on the basis of A.N.A.R. data;

Based on the above mentioned criteria we identified 13 historical events of significant level which are presented in table 6.15.

Table 6.15 Summary of significant historic events

Nr. crt	Name of the flooded location	Flood type	Date of event beginning	Event duration	Flooded surface (km^2)	Length of the flooded river segment (km)	Frequency
1	r. Prut – downstream Oroftiana upstr. acc. Stânca Costeşti	historical	2008-07-24	8	51.830		0.1%
2	r. Prut – downstream Oroftiana upstr. acc. Stânca Costeşti	historical	2010-06-21	20	36.543		0.7%
3	r. Prut - downstream Zaboloteni	historical	2010-06-21	60		337.250	10
4	r. Jijia - sector loc. Hilişeu-Crişan Dorohoi	historical	2008-07-24	4		25.873	10%
5	r. Jijia - sector loc. Hilişeu-Crişan Dorohoi	historical	2010-06-21	7		25.873	10%
6	r. Jijia – downstream Rediu şi affl. Miletin, Jijioara	historical	2008-07-24	4		213.357	10%
7	r. Buhai - downstream Pădureni şi affl. Pârâul Întors. – downstream Văculeşti	historical	2010-06-21	3	8.046		1%
8	r. Bahlui - downstream Pârcovaci	historical	2008-07-24	5		104.384	10%
9	r. Bahlui - downstream Pârcovaci upstr. confl. Băhlueţ	historical	2010-06-21	7		60.657	10%
10	r. Băhlueţ - av. confl. Păşcănia	historical	2008-07-24	3		36.576	10%
11	r. Băhlueţ - av. confl. Păşcănia	historical	2010-06-21	7		36.576	10%
12	loc. Cucuteni - r. Cucuteni	historical	2008-07-24	3		0.986	10%
13	loc. Brăeşti - r. Albeşti	historical	2008-07-24	3		1.548	10%

Identification of significant potential risk zones for inundations in the Moldavian Plain

In the delineation of the potential and significant risk zones inside the Moldavian Plain we considered the INHGA applied criteria, respectively:

• potential floodable zones. Reported to the extreme historical inundations;

• potential impact evaluation of the inundation (potential consequences).

The elements considered for the losses evaluation are: inhabitants, roads and railways, bridges, flood control works, buildings, and agricultural surfaces.

The evaluation methodology of the losses at inundations performs the following stages:

- the average financial value of the potential average losses for each separated good;

- extraction of the number of goods per zone, affected by inundations for the chosen inundation scenarios, within GIS;
- counting (accountability) of the goods quality according to the GIS units considered (number, density, surface, length) inside de affected zones which are attached to the scenario.

The extraction of the average losses is partial and it was possible only for those goods categories that could be identified clearly as being relevant for Romania and had a sufficient number of elements for a statistical analysis. In the same time we considered the defended zones against inundations that have hydrotechnical works, on the basis of:

- the technical up to date norms;

- STAS 4273/83 regarding the constructions categories and the importance class determined from the value of the flooded houses or the number of affected or evacuated people and the surfaces defended for inundations, considering the exceedence probability for the calculated discharges.

- the present technical state of the hydrotechnical works as a result of the terrain inspections performed within the periodical verifications.

In other words, all the former inundations were considered if they had significant negative impact on the human health, the environment, the cultural patrimony and the economical activities without eliminating from the respective list the floods to occur in the hydrotechnically modified river sectors. To the same extent, the technological risk was considered for the dams and other hydrological works in those areas which, even if protected for certain events categories (that were not inventoried as historical floods affected zones) may be flooded if:

- potential dams' breaking (especially those of C and D type) or embankments breaking;

- extreme events, more powerful than the established protection objective as projected.

Based on the above mentioned criteria 12 zones were identified to have significant potential risk of inundations, table 6.16, fig. 6.58.

Table 6.16 Zones of significant potential risks for floods in the Moldavian Plain

Nr. crt.	Name of the potential significant risk zone
1	r. Prut - sect. downstream locality Oroftiana am. loc. Miorcani
2	r. Prut - downstream locality Crasnaleuca am. loc. Cucuneştii Vechi
3	r. Prut - sector downstream locality Stânca am. loc. Româneşti
4	r. Prut - downstream locality Zaboloteni
5	r. Jijia - sect. downstream . confluence Pârâul lui Martin am. cfl. Jirinca
6	r. Buhai - av. Pădureni şi afl. Pârâul Întors av. Văculeşti
7	r. Miletin - downstream. confluence Valea Rea
8	r. Bahlui - downstream locality Pârcovaci am. confl. Băhluet
9	r. Bahlui - downstream locality Pârcovaci
10	r. Băhlueţ - downstream confluence Păşcănia
11	r. Cucuteni - downstream locality Cucuteni
12	r. Albeşti - downstream locality Brăeşti

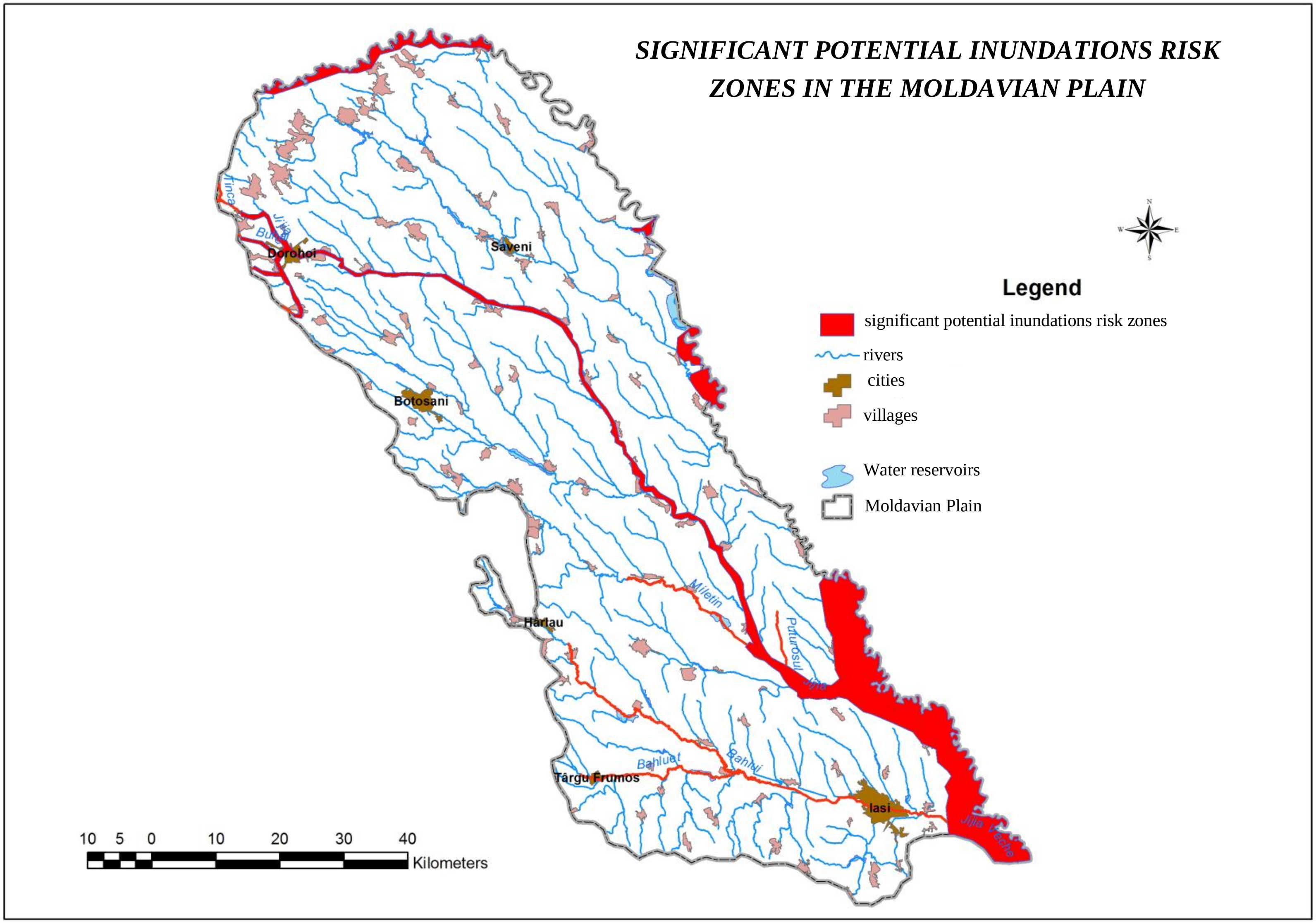


Fig. 6.58 Significant potential inundations risk zones in the Moldavian Plain

6.6.2. Management of inundations risks in the Moldavian Plain

Inundations and especially big inundations constitute one of the natural phenomenons that marked and are still marking the development of human society. They represent, from the geographic point of view, the most widespread disasters on Earth and, in the same time, the phenomena to record the highest number of casualties. In this respect, inundations constitute the triggering and catalyst factor for important changes in the manner of approach for this events, starting with the acceptance of inundations as nature's caprice to the attempt to control them via approaches like "the fight against inundations" or "defence against inundations" and, recently, "inundations prevention".

The inundations produced in numerous countries in the last years and their consequences, on the background of an increased social responsibility for the risk management, developed in awareness and implication of the human communities as essential parts in the reduction of human lives and material losses. This approach is today quasi-generalized and is the one which opened the way to face the upcoming challenges via introduction of new concepts like, *more space for the rivers* or *cohabitation with floods* and, moreover, the need for conceptual assimilation of sustainable development in the inundations risk management.

The inundations' risk management means application of politics, procedures and practices that have as objectives the identification of risks, the analysis and their evaluation, the treatment and monitoring and the re-evaluation of risks in order to reduce them to such extent that the human communities, the citizens can live and work and satisfy their need and aspirations in a durable physical and social environment.

The risk of inundations is characterized according to its nature and its production probability, to the extent of receptors exposure (number of people and goods), to the susceptibility at inundations of the receptors and their value resulting in categories of interventions for risk reduction.

A comprehensive approach for the main activities and inundations management consists in:

- preventive activities (prevention, protection and preparing);
- operative management activities (emergency situations management) during floods occurrences;
- activities to be done after the inundation events.

Considering the evolution and the tendencies in the inundation phenomenon production and, moreover, the consequences of this phenomenon it results clearly that there is a need of change in the approach scheme as defence against floods, passing from defensive forms to management forms.

The climate changes in the last years influence the engineerical solutions to be considered and understood in the relations between physical and biological processes and the measures that affect water courses. The major decision and pressure factors that modified the pluviometric and the hydrologic regimes determined the increase of inundations' risks as a consequence of higher frequencies and amplitudes of the extreme hydrologic pulses via the modification of the structural configuration of the lotic systems (water courses and flood plains) and of the hydrographic basins along with climate modifications.

People must understand to cohabit with rivers without losing from sight the main scope of protecting life and property from the floods' disastrous impact. This challenge implies the realization of an equilibrium in such a way that medium term benefits be subtract while where solutions are not at hand the environment be less modified.

A good flood risk management is assured through the results of intersectorial activities which include water management, territorial planning and urban development, nature protection, agricultural and silvicultural development, transport infrastructure protection, building and leisure zone protection, individual communitarian protection where each sector has responsibilities and specific activities. In this context, one must consider the insurance of equilibrium between the structural measures and the lotic protection measures and reorganizing the biophysical infrastructure of the natural capital in the hydrographic basins in order to rehabilitate the control capacity of the hydrological fluxes.

For risk management at inundations politics, procedures and practices are to be applied that have, as objectives, risk identification, analysis and evaluation, treatment, monitoring and risks re-eavluation in order to reduce their effects to such an extent that the human communities, all the inhabitants cand live, work and satisfy their needs and aspirations in a physical and social durable environment.

In conclusion the inundations' risk management comprises, on assembly, actions at national level and basinal level that include: planification, programation, frame politics, coordination, facilitation, awareness rise and social consolidation. One can also propose local actions for inhabitant's education in the risk zones, training sessions, regulatory protection plans against floods (on localities and units), reporting, prognosis, warning and information of populations in the risk zones. Insurances, evaluations, financing and rehabilitations must be also included in this respect.

6.6.2.1. Inundations risks' identification, hazard and risk analysis and evaluation on hazard and risk maps

On the background of climatic changes manifested at global level, in the last years there have been an increase of extreme events frequency. The rapid alternation between abundant precipitations and inundations, severe heats and pronounced droughts and triggered major effects upon economy and social life (human lives losses and important goods losses). The evolution and the tendencies in this phenomenon production and, moreover, its consequences impose changes in the approaching manner for risk inundations' management, going from prevention and protection to effects diminishing actions.

The hazard maps and the risk maps for inundations represent an important source of information that is necessary for communitarian purposes for the identification of risks, their analysis and evaluation, their treatment and monitoring and for their re-evaluation for the purpose of effects reduction.

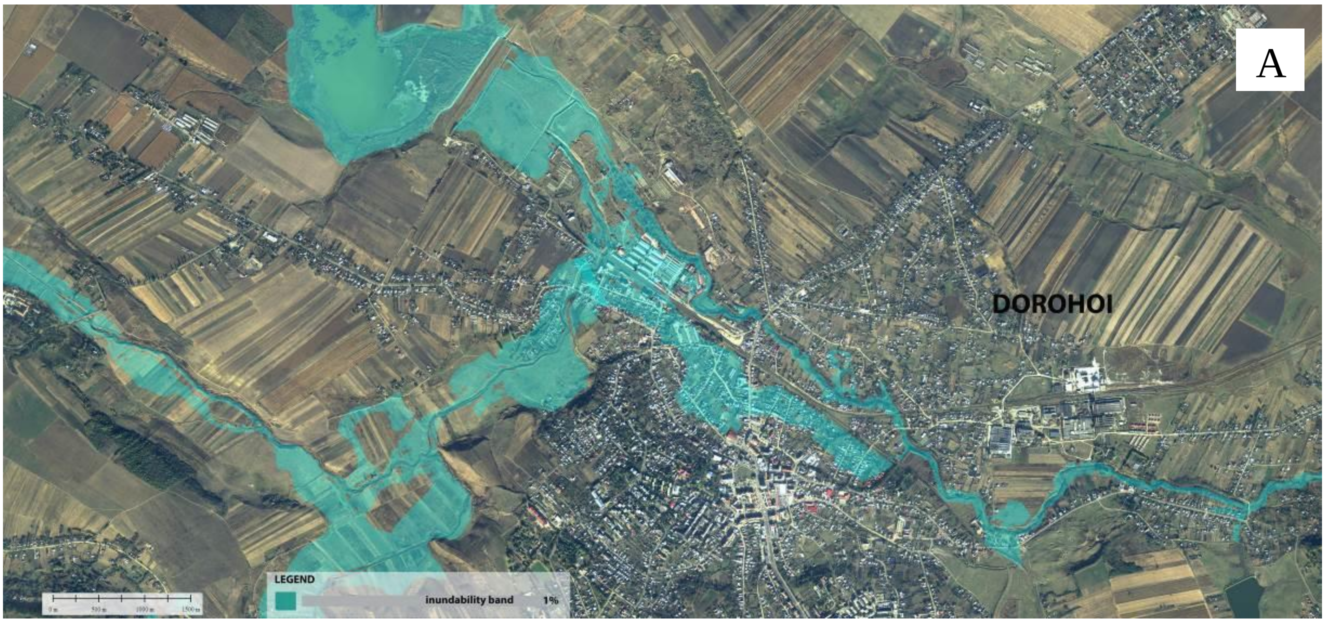
The hazard maps

The hazard is defined as the probability of a phenomenon appearance, phenomenon that can generate potential losses in a certain period of time for a certain zone. The elements exposed to hazard are: the population, the buildings, the engineerical works, the economic activities, the public services and the infrastructure.

The hazard map for inundations constitutes the document used to express the extension of the potential floodable zones in the major river bed sectors (including depths) for floods which record the maximum discharges at certain probabilities: 0.1% (low exceedence probability), 1% (medium exceedence probability) and 10% (high exceedence probability).

To produce the hazard maps and the risk maps for inundations we used GIS procedures for the elaboration and the interpretation of the primary data sets obtained from the following sources: county and local councils, public institutions and the Romanian Waters Administration. The hazard maps were elaborated for the assigned zones as characterized by a *potential significant inundation risk* in the first stage of the implementation of the *2007/60/CE Directive* – the primary evaluation of the inundation risks. Consequently, in the Moldavian Plain, the main streams were taken into consideration, except the Prut River which could not be mapped due the absence of an administrative protocol with the neighbouring countries fig. 6.59 - 6.61, fig. 1 and 2 in Annexe 2.

The hazard map is meant to support the decisional frame, the flood management plans elaboration and the public awareness. The hazard map warns against possible inundations in for those areas, near rivers, that are exposed to flood risks. This map does not offer a high precision degree for the projection and planning of flood control constructions, especially those of industrial type, roads, water treatment stations or other. The flood hazard map incorporates, for each exceedence probability, the limit of the flood (the water extension for each simulated case), the depth and the water level and the leakage speed.



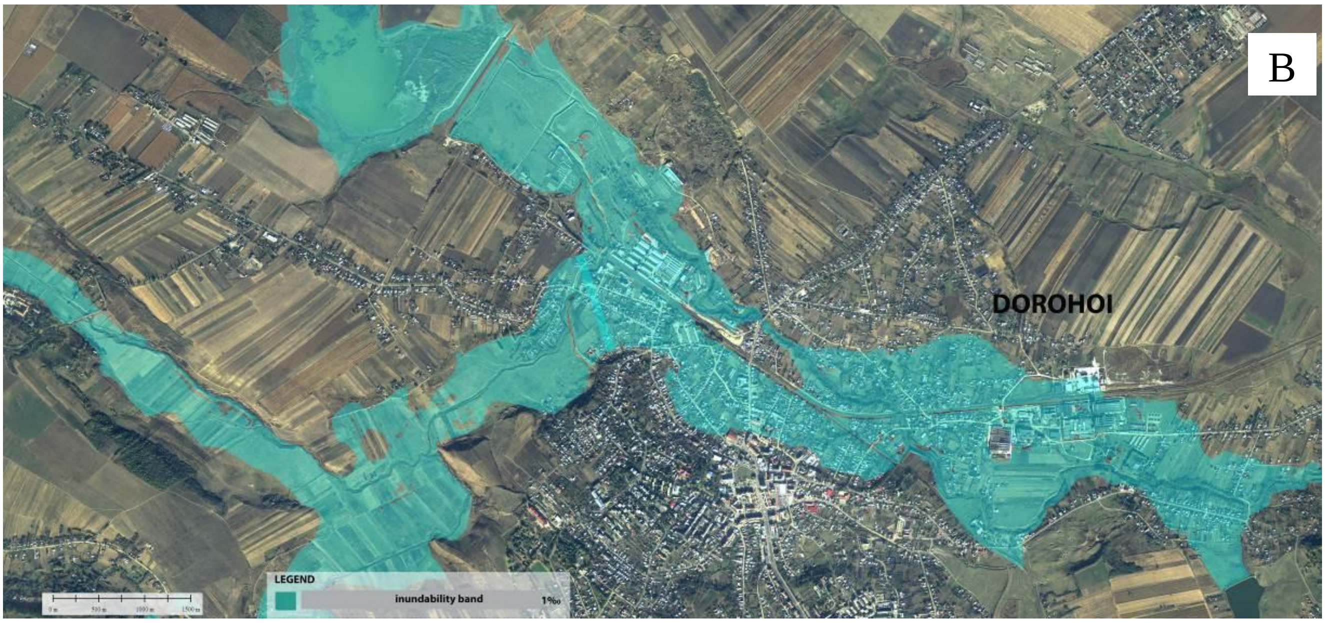


Fig. 6.59 Map extract – inundability band 1% (A); inundability band 1‰ (B) Jijia river, Mun. Dorohoi

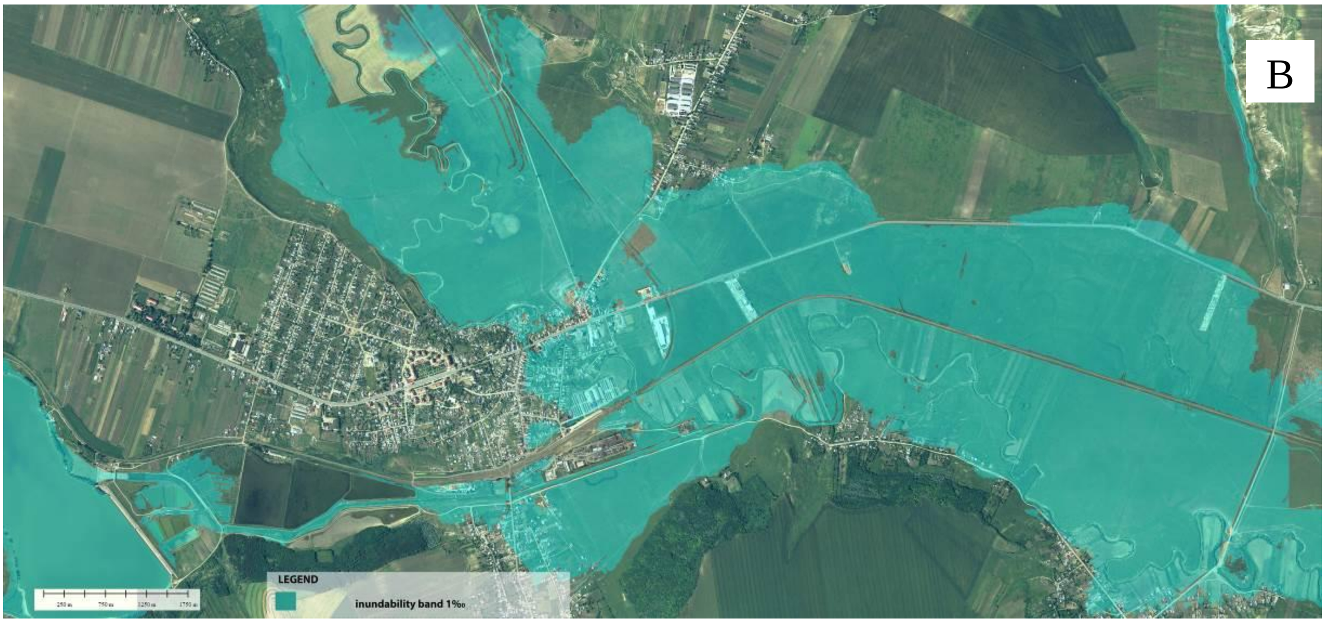


Fig. 6.60 Map extract – inundability band 1% (A); inundability band 1‰ (B) Bahlui river, Iloaia's Bridge

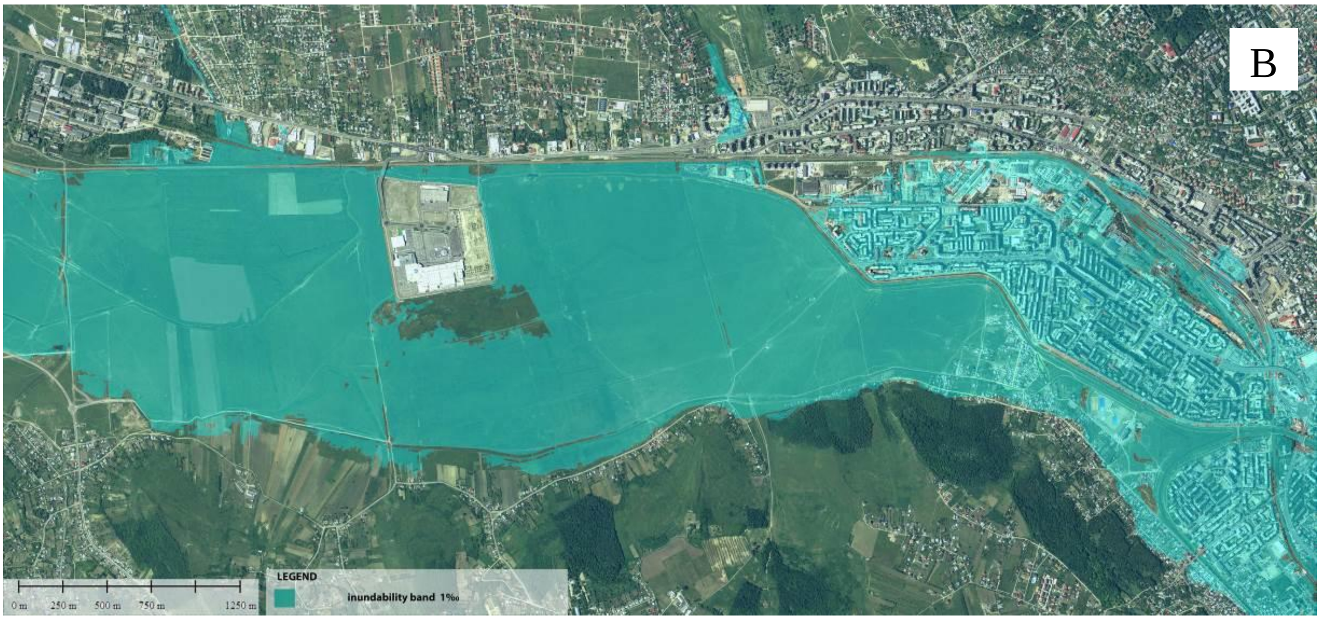


Fig. 6.61 Map extract – inundability band 1% (A); inundability band 1‰ (B) Bahlui river, upstream Iaşi Municipality

The risk maps

The inundation risk represents the report between the probability of inundations appearance probability and the potential negative effects for human health, environment, cultural patrimony and the economic activity that are associated with inundations. The risk can be expressed as a product of hazard (probability) and consequences, which are dependent upon exposure degree, vulnerability and value. In order to dispose of applicable results, in practice, one must consider that there is no generally adequate method to be used for a specific country, a specific hydrographic basin that would measure the vulnerability with the same precision degree, thus, the vulnerability is different from the geographic and social points of view.

The risk map for inundations incorporates, mainly, the delineation of the following zones:

- Zones where the imposing of interdiction for permanent buildings is required, where the inundations frequency, the water depth and speed and the inundations duration result in high waters leakage
- Built zones which present a major risk for inundations, zones that are prone to be defended via structural and non-structural measures according to the *National Strategy for the Management of Inundations Risks on Medium and Long Terms.*

The elaboration of inundations risk maps in the Moldavian Plain is based on the hazard maps for inundations and on the hazard exposed elements analysis, along with their associated vulnerabilities. According to the requirements of the Inundations Directive, the inundations risk maps indicate potential associated negative effects and are expressed in the following terms: the approximate number of affected inhabitants, the type of economical activity in the affected zone, the IPPC installations (96/61/CE Directive on integrated pollution control) that can lead to accidental pollutions in case of floods and the protected potential zones fig. 3 Annex 2 and fig. 6.62.

The risk maps for inundations were elaborated for 3 distinct scenarios:

- the low probability scenario (for maximum discharges with 0.1% exceedence probability, respectively inundations to occur once in 1000 years);
- the medium probability scenario (for maximum discharges with 1% exceedence probability, respectively inundations to occur once in 100 years);
- the high probability scenario (for maximum discharges with 10% exceedence probability, respectively inundations to occur once in 10 years);

The maps of inundation risks can be used for the immediate management via the implementation of a preventive politic by the responsible institutions that are involved in emergency situations response at extreme events on water courses. Furthermore, through a qualitative identification of the flood risks exposed factors, the county and local councils and other interested institutions may proceed to the quantitative evaluation of losses using specific evaluation methods assigned to different purposes.

The risk evaluation is realized through an intersection between the following elements:

- The risk zones (low, medium, high) generated from the floodable bands using the flood magnitude

- The vulnerable parameters to inundations (population, economic activities, water supply).

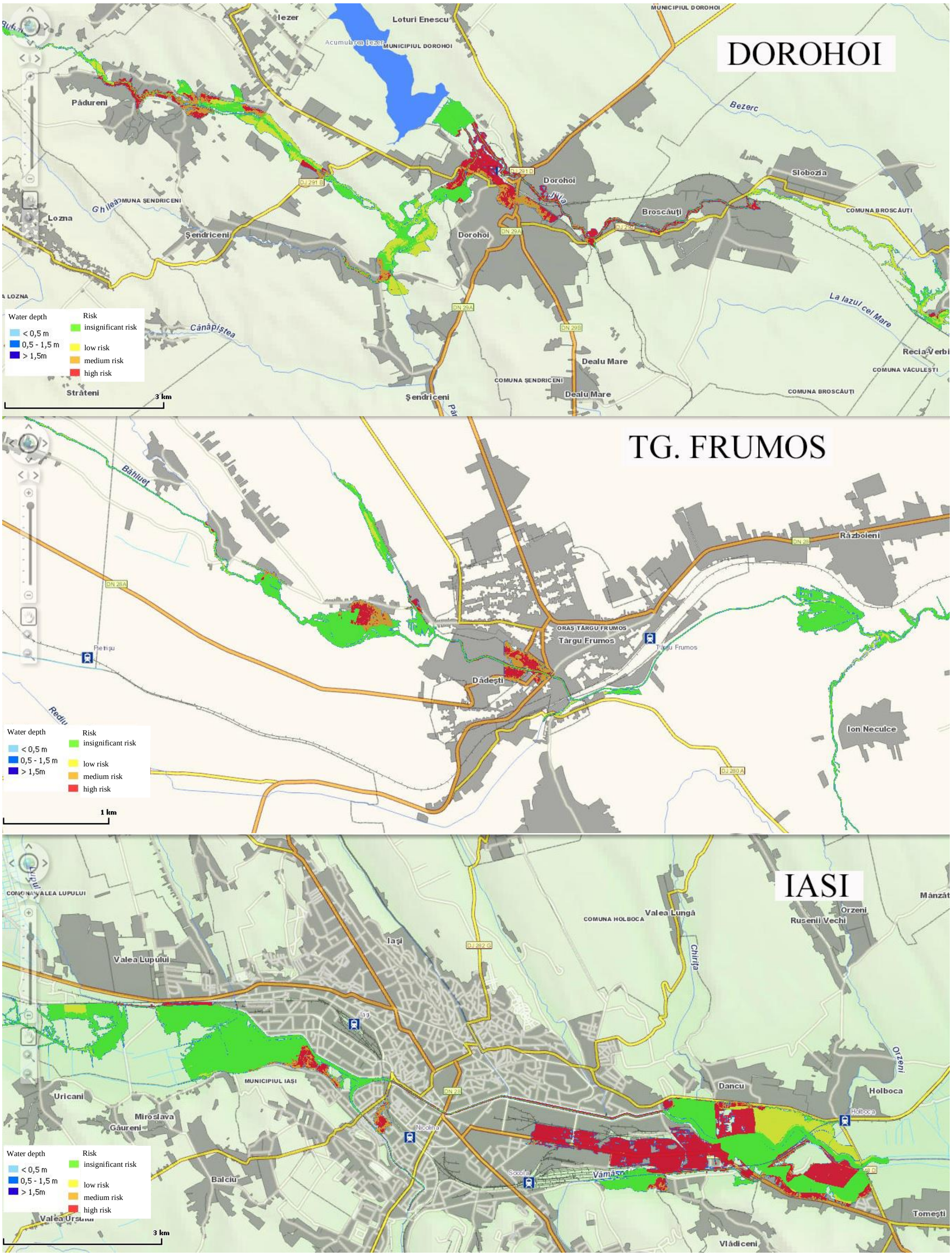


Fig. 6.62 Extracts from the inundations risk map (1%)for three settlements in the Moldavian Plain

The inundation risk maps allow the insertion of certain measures categories in order to prevent flood production and to minimize inundations effects, mainly through:

• the control of land use

• restrictions and, by case, interdictions of constructions location or land use, dependent on the land use category and imposing limits for inundations risks

• insertion of structural measures (dams, barriers and wetland zones) and of non-structural measures (control of the minor bed use, elaboration on the basinal management plan, warning systems and alarms) as the cases require

• elaboration of programs for material insurances and people insurances in case of inundations

• monitoring of inundations for prognosis and warning systems;

• wise allocation of funds for the application of measures that minimize inundations risks;

• elaboration of flood control plans.

On the basis of GIS spatial analysis the intersections of floodable bands for (with different probabilities) and the contours of localities in the Moldavian Plain we identify the potentially vulnerable localities at floods. Furthermore, these intersections can lead to estimations of inhabitant's numbers that are vulnerable to floods for each locality. For this calculus we start from the inhabitant's total number per each settlement and uniform distribution of inhabitants inside the localities limits. In conclusion, from the total number of inhabitants 1 000 286 for the Moldavian Plain, 29 237 are prone to be affected by floods with 1% probability fig. 6.63.

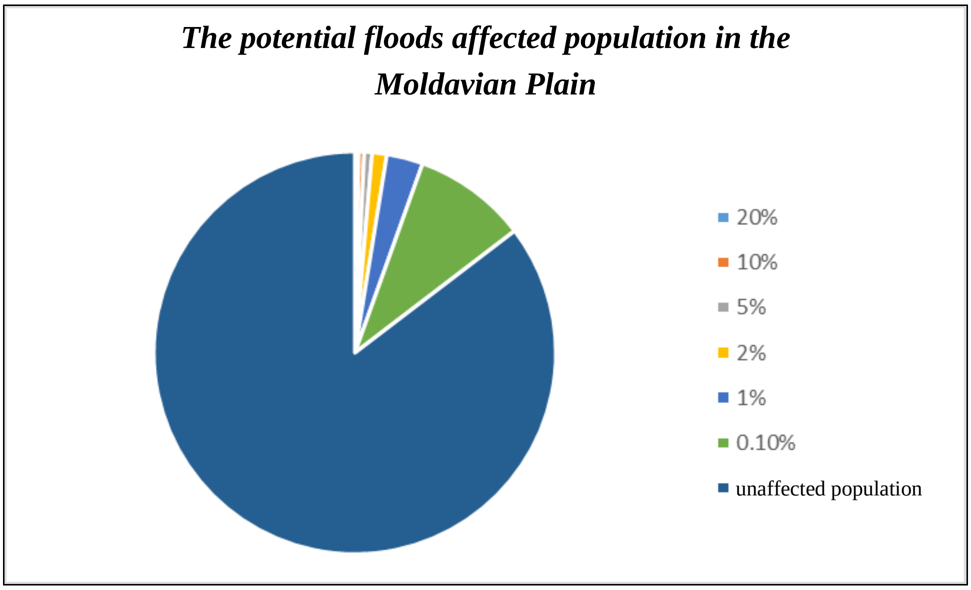


Fig. 6.63 The potential floods affected population in the Moldavian Plain

6.6.2.2. Systematization works on flood control in the Moldavian Plain

The historical approach on water management

In the Moldavian Plain, starting with the middle Palaeolithic, when the initial presence of human is recorded the contact with waters was permanent. Since the 15th and the 16th centuries tens of ponds and lakes were built for better valorisation of precipitations waters which are characterized by large variations due to the excessive continental climate.

Documents form the 17th and the 18th centuries show a long tradition in ponds and lakes construction not only by the peasants but also by specialized constructors associated in teams. In the chorography published at Vienna in 1541 wrote, after some diplomatical missions in the time of Petru Rareş, the Transylvanian Reicherstrof describes, amongst other material goods – the ponds with selected fish breeds.

Amongst the numerous water accumulations, in Moldova, the most remarkable either by their history or their wide extension, there are: the King Ponds of Iaşi, the first of them built by Stephen the Great on Bahlui River just under the court's walls; the Ponds of Orhei Mills, in times of Lăpuşneanu and the Jijia Pond, over 30 kilometres long from Dorohoi, first mentioned in 1587.

The Great King Pond on Bahlui is mentioned in the travel notes of the Englishman Newberrie, in 1582, the French Fourquevauls, in 1585, in the times of Peter the Bum, then by Petru Bogdan Baksic, in 1640, in the times of Vasile Lupu and by Paul of Alep, after just few years.

In the 17th century the number of ponds and lakes in the Moldavian Plateau exceeded 1500 with 200,000 hectares total surface. This resulted in the reduction of the arable land not mentioning the fact that the dams were precarious and presented risk at floods and being affected by chain dams' destruction and flooding villages as it was in 1659 for a pond on Sitna River that flooded the Pipaleştii, Blândeştii, Lieştii and Ionăşeştii. Restrictive measure were taken at the beginning of the 18th century under the rule of Ieremia Movilă (1595-1606) when he ordered the breaking of dams, yet it is believed with no notable impact.

Dimitrie Cantemir writes, at the beginning of the 18th century, about the Dorohoi Tarn on Jijia. Ion Ionescu de la Brad refers to the same tarn in a wide hydrological and economical study from 1866. Located at the confluence of Buhai and Jijia rivers with a surface of 215 hectares and maximum depth of 8 to 10 meters it had an important hydrologic role to control the Jijia's discharges and it was also used for cattle water take and the mills functioning.

The hydrotechnical works assembly of strategic importance for water management started to develop in the second half on the 19th century.

The political and economical problems delayed their realization. Only in 1785 a scheme of great extension was realized which was meant to solve the problem of navigation between the Baltic Sea and the Black Sea through a possible link between Vistula and Dnistr via San and another artificial channel with a length of 6.4 kilometres. Then the Prut would have been connected with Dnistr.

In 1787 the d'Hauterive Count notes that the Siret River should be linked with the Prut River for the purpose of navigation. The Organic Regulation, in the chapter on the Communication Ways (art. 158) foresaw the navigability of Prut and Siret rivers and their link via Bahlui River.

In 1859, in the Union Act we find an article which stipulates the fact that, in order that Iaşi to renounce its position as Romanian capital "the Prut will become navigable and be linked with Iaşi which will have the porto-franco status.

In 1933, professor Andreescu Cale presents a well-documented scheme, with technical arguments and economical reasoning, which solves the navigation problem on Prut, Bahlui and Bahlueţ and also includes systematizations for flood control, water supply and the valorisation of the hydro-power resources.

For the discharges control on Prut river a dam was proposed " a dam at Ştefãneşti with the heights of retention up to the 100 level with a surface of 7850 hectares and a volume of 1300 millions of cubic meters and a dam at Sirauţ with a 140 meters level with 18200 hectares and a volume of 3000 million cubic meters". The two dams were meant to have effluences at high waters and be controlled by Stoney type hatches and with a ladder gate for navigation fluency. The study also proposes navigation solutions for Prut up to Cernăuţi and for the link with Dnistr.

The first attempts to realize assembly hydrotechnical works were projected performed by Romanian engineers. Even if these studies did not cover entire basinal schemes they covered large surfaces and were complex studies that would exceed sole local issues. As seen through a modern approach these studies proved great engineerical skills in the hydrotechnical domain. On the other hand the studies show a lack of holistic approach on water management.

Between 1959 and 1962 the first layout plans were realized for hydrographic basins and, in 1976 the Law on the National Layout Program for the Romanian basins was published. The National Programme foresaw complex water accumulations and flood control for the Prut-Bârlad basins.

In order to avoid flood effects in the Iaşi city, in 1960 the *Bahlui river flood control works* was put up and approved by the Ministry Council in 1962 with a first intervention stage between 1961-1966, with the following works:

- five dams with complex role (maximum discharges control on Bahlui near Iaşi with a total volume of 63 million cubic meters and the water supply for fisheries, population and industry at volume of 12,3 million cubic meters)
- control works on Nicolina river (4.4 km) and Repedea river (3.9 km)

For the diminishing of floods on Prut River, in 1972, the Romania-URSS Agreement on common construction of the Stânca-Costeşti hydrotechnical node was signed. Through this node realization two advantages were obtained: flood control for settlements and agricultural lands in the Prut Meadow which was calculated in correlation with the upstream accumulation and permitted terrain drainage and irrigation, also on the Prut terraces; the industrial water supply was also solved. The total volume of the accumulation is 1400 million cubic meters and the flood control volume is 665 million cubic meters and the effective volume is 450 million cubic meters (for water supply, irrigations and electric power).

The demographic grow and the economic development in the NE region conducted to the enlargement of uses and, implicitly, of the necessary of water for different uses and, in the same time, to the growth of the number of people and economical objectives that may be affected by floods. Considering the water resource which is extremely variable in time and space, in this area and due to the torrential character of the water course, for the duration curve of the water necessary and flood control a complex accumulations and control works were performed to manipulate the flood discharges. Thus, in the Moldavian Plain, along the years, important hydrotechnical works were performed and complex accumulation of water (for flood control, water supply, fisheries, irrigations and leisure) and also dams and enclosures constructions for irrigations and water drainage.

The main water accumulations in the Moldavian Plain are:

- in the Prut hydrographic basin, the Stânca-Costeşti accumulation with a volume of 450 million m^3;

- in the Başeu hydrographic basin: the White Horse accumulation with 4.9 million m^3; the Mileanca accumulation 4.9 million m^3 and the Negreni accumulation with 8.8 million m^3;

- in the Jijia hydrographic basin: Ezer accumulation with 2.8 million m^3; the Cătămărăşti accumulation with 7.5 million m^3 and Hălceni with 11.6 million m^3;

- in the Bahlui hydrographic basin: Pârcovaci accumulation with 6.0 mil. m^3, Tansa accumulation with 7.0 mil m^3, Plopi accumulation with 4.6 mil m^3, Sârca accumulation with 3.0 mil m^3, Iloaia's Bridge accumulation with 1.8 mil. m^3 and Cucuteni with 3.0 mil. m^3 (all volumes are effective).

Table 6.17 Main dams by height in the Moldavian Plain

Nr. Crt.	Name of the dam	Year	River	Height (m)	Dam length (m)	Vol. (mil.m^3)	Surface.(ha)	Purpose*
1	Stânca Costeşti	1978	Prut	43	3000	1400	7700	CSIHF
2	Pârcovaci	1985	Bahlui	25	290	9,4	58	SCI
3	Ciurea	1981	Nicolina	18	750	8,4	150	C
4	Sarca	1984	Valea Oii	17	343	23,3	238	IFC
5	Catamaresti	1979	Sitna	15	540	17,5	270	IFC
6	Cal Alb	1970	Başeu	14	296	16,3	260	IFC
7	Cucuteni	1964	Voineşti	14	377	14,2	210	FIC
8	Podu Iloaiei	1964	Bahlueţ	14	630	33,0	450	FCI
9	Tansa-Belceşti	1977	Bahlui	14	4890	30,3	44	ICF
10	Ciurbeşti	1964	Locii	13	438	14,4	208	CIF
11	Mileanca	1975	Podriga	13	453	14,4	215	IFC
12	Bârca	1981	Locii	12	410	8,7	112	C
13	Câmpeni	1985	Miletin	12	675	11,0	82	C
14	Cornetu	1980	Cornet	12	250	3,9	47	C
15	Plopi	1978	Gurguiata	12	330	22,8	339	IFC
16	Negreni	1974	Başeu	11	995	25,0	27	CSIF
17	Hâlceni	1986	Miletin	10	1013	41,1	620	SFIC
18	Ezăreni	1964	Ezăreni	9	273	4,3	94	C
19	Cârlig	1981	Cacaina	8	225	3,1	86	C

**C -attenuation; I -irrigation; H –hydro-power; F -fisheries; S –water supply.*

The Iaşi city, the main urban, economic, cultural and social centre of the Moldavian Plain is set on the Master Plan (from 7th of October 2010) as vulnerable to the highest degree as matter of material losses at floods. The flood control infrastructure on Bahlui river and the Iaşi municipality was old (1970), settled, with landslides and erosional forms inducing a low transport capacity. Thus, various works were projected and executed: river regularization along Iaşi city, polders construction on Bahlui, upstream and downstream Iloaia's Bridge and realization of water enclosures. Strictly for Iaşi the investments for flood control consisted in 11 kilometres of clog-ff works, 6.13 kilometres of river profile rearrangements, 3 kilometres of protection dam, 2.3 kilometres of river bed stabilization, 2.35 kilometres of minor river bed gabion walls and 2.5 concrete walls.

On the main water course of the Moldavian Plain there is a multitude of control works (non-permanent, regulation, damming, derivations for high waters) meant for flood control. Tables 6.18, 6.19, 6.20 and fig. 6.64.

Table 6.18 Non-permanent water bodies and polders in the Moldavian Plain

No.	Flood control works	B.H. Water course	County	Wat. la asig. calc. (mil. mc.)
1	Ac. Câmpeni	Prut-Miletin	Botosani	11.20
2	Polder IV Tigănaşi	Prut-Jijia	Iaşi	2.46
3	Polder V Tigănaşi	Prut-Jijia	Iaşi	2.57
4	Polder VI Tigănaşi	Prut-Jijia	Iaşi	3.21
5	Polder Vămăşoaia	Prut-Vămăşoaia	Iaşi	0.306
6	Ac. Vânători	Prut-Cacaina	Iaşi	3.70
7	Ac. Cârlig	Prut-Cacaina	Iaşi	3.20
8	Ac. Bârca	Prut-Locii	Iaşi	8.70
9	Ac. Cornet	Prut-Cornet	Iaşi	3.90
10	Ac. Ciurea	Prut-Nicolina	Iaşi	7.65

Table 6.19 Riverbeds flood control in the Moldavian Palin

No.	Flood control works	B.H. Water course	County	Length (km)
1	Reg. Başeu	Prut-Başeu	Botoşani	63.7
2	Reg. Miletin	Prut-Miletin	Botoşani	41.7
3	Reg. Sitna	Prut-Sitna	Botoşani	30.2
4	Reg. Podriga	Prut-Podriga	Botoşani	21.5
5	Reg. Morişca	Prut-Morişca	Botoşani	7.3
6	Reg. Varnita	Prut-Varnita	Botoşani	6.8
7	Reg. Martin	Prut-Pr. lui Martin	Botoşani	5.7
8	Reg. Luizoaia	Prut-Luizoaia	Botoşani	4.0
9	Reg. Dresleuca+afl.	Prut-Dresleuca	Botoşani	4.9
10	Reg. Cordun	Prut-Cordun	Botoşani	2.5
11	Reg. alti afl. Robu, V. Rea, Scânteia	Prut	Botoşani	1.7
12	Reg. Jijia	Prut-Jijia	Iaşi	43.0
13	Reg. Bahluiet	Prut-Bahluiet	Iaşi	2.9
14	Reg. Bahlui	Prut-Bahlui	Iaşi	31.322
15	Reg. Ciric	Prut-Ciric	Iaşi	1.4
16	Reg. Nicolina	Prut-Nicolina şi V. Adâncă	Iaşi	6.28
17	Reg. Rediu	Prut-Rediu	Iaşi	3.9
18	Reg. Vămăşoaia	Prut-Vămăşoaia, Repedea, Vlădiceni	Iaşi	9.77
19	Reg. Miletin	Prut-Miletin	Iaşi	6.3

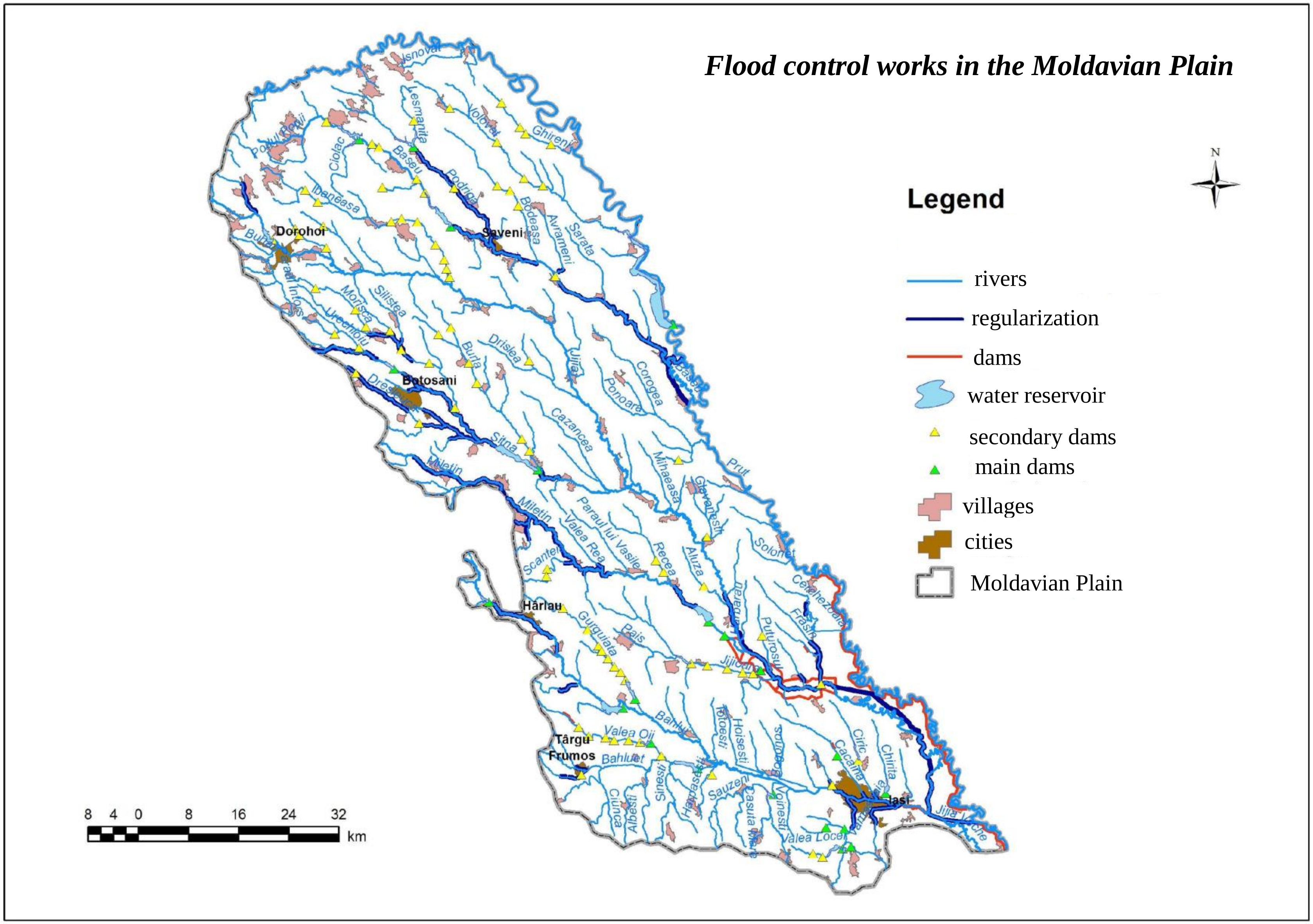


Fig. 6.64 Flood control works in the Moldavian Plain

Table 6.20 Riverbed enbankments in the Moldavian Plain

Nr. Crt.	Water control works	B.H. Water course	County	Length (km)	Controlled surfaces (ha)
1	Ind. r. Prut Trifeşti-Sculeni-Gorban	Prut	Iaşi	105.67	17.684
2	Ind. r. Jijia Cârniceni-confl.Prut	Prut	Iaşi	70.4	27.484
3	Ind. r. Miletin	Prut-Miletin	Iaşi	7.1	460
4	Ind. r. Nicolina	Prut-Nicolina	Iaşi	6.5	Inside Iasi
5	Ind. r. Bahlui	Prut-Bahlui	Iaşi	32.32	1.995
6	Ind. r. Vămăşoaia	Prut-Vămăşoaia	Iaşi	6.0	400

In the Chipereşti locality, Ţuţora department of Iaşi, the present river bed (regulated and dammed) for the Jijia river, avoids the old route and effluences in Prut next to Oprişeni locality. The river downstream Chipereşti until the old effluence with Prut, along 49 kilometres is called now the Old Jijia. In order to partially channel the high floods waters on the Old Jijia, in cases of inundation, the new river bed has a hydrotechnical node at Chipereşti with a 6 m^3/s capacity. This node can be used also at droughts to insure the old river bed of Jijia with the necessary water supply for irrigations, fig. 6.65.

Fig. 6.65 The hydrographic node at Chipereşti (photo A.B.A. Prut-Bârlad)

For the Moldavian Plain inundations constitute the main hazard that generates material losses and casualties. The hydrological hazards are favoured by the high density of the drainage network, the specific conditions and the human activity (constructions in floodable zones, bridge sub dimensioning, river bed delayed management, small bridges). To this we add the supply conditions, the morphographic and the morphometric parameters of the hydrographic basins (surface, relief fragmentation, average altitude, form, slope, the forestation degree) which control the duration, the discharges and the maximum volumes of the floods.

The present approach of the risk management for inundations in the Moldavian Plain is concentrated, mainly, on the protection against inundations and the response to the emergency situations not favouring prevention and risk reduction.

Many water courses were straightened extensively which resulted in new erosional models and new forms of deposition. Erosion conducts to massive clogging within water accumulations. Consequently, the water storage of numerous accumulations shortens with tens of years. Even if the present dams and channels are projected to reduce the risk for localities, the modelling and the evaluation of conditions denote that they are vulnerable, especially if these flood control works are not regularly maintained at required standards.

Inundations warning and emergency situations management

The warn and the response to inundations in emergency situations for the flood plains are, in general, well-coordinated and all the institutions function efficiently in order to counteract inundations. Nevertheless, the communities in the upper basins, where flash floods are very intense, suffer from inefficient warning procedures. The present practices within the inundations management offer, mainly, inhabitants protection in the flood plains settlements in the lower water courses. The losses reports show that people that live and their activities in the upper basins are significantly exposed to flash floods. Conversely, the cities and towns in the lower streams include the most important economic activities, increasing the risks (industry and infrastructure) and they are directly exposed to economic losses. In conclusion, there is the need of complex approach for the inundations risks for the high- lands and the low-lands, separately.

The social vulnerability in the upstream communities can be reduced via:

- a better inundations prognosis as support systems for decision that offer rapid warning, hours before the event
- Improvement of dissemination for inundations warning in vulnerable communities
- Improvement of education for avoidance, resistance and resilience at inundations effects regarding houses and communications
- Improvement of rehabilitation programs after the flood events
- Improvement of the existent planning and control and the subscription to a planning politic in order to discourage the development of flood exposed communities
- Improvement of basinal management in order to reduce the flood speed and the volume of surface water from intense precipitations.

6.6.3. Identification of flash floods susceptible zones in the Moldavian Plain

On the basis of the spatial repartition for the dynamic generator factors, of the extension and the particularities of floods propagation and the infliction risk for the economical and social objectives, in Romania, inundations present distinct regional features (România. Spaţiu, *Societate, Mediu, 2006*):

a) The central-western Romania inundations are a result of western air masses circulation via the eastern extension of the Iceland Depression or via the movement of the humid air masses on the Azores Anticyclone Ridge. The inundations are triggered by floods after torrential rains preceded by low intensity rains but with long duration which saturates the soil.

b) The southern Romania inundations result from abundant rains with torrential character generated by the Mediterranean cyclones.

c) The eastern Romania inundations are generated by the torrential rains of the blocking circulation on the eastern versants of the Eastern Carpathians and the Moldavian Plateau and the formation of the retrograde cyclones in the north-western Black Sea. In the last 50 years there were enormous floods, on wide surfaces in 1969, 1970, 1975, 1991, 1995, 1997, 1999, 2000, 2002, 2005, 2006, 2007, 2008, 2010.

At generalized rains, in small basins and on short durations (2-3 hours or less) very intense rains may occur. The generalized rains result in regional floods while the torrential rains that connect and have high intensity, along small hydrographic basins result in rapid floods or flash floods and local inundations.

A inundation (break-through) is considered a flood when the following conditions are met:

- the surface of the reception basin in between few square kilometers and few hundreds square kilometers;
- the flood is generated by a torrential precipitation which exceeds 100 mm;
- the rain duration is, in general, lower than the Basinal concentration time which is maximum 3 hours.

6.6.3.1. Flash floods favourable conditions and inundations in small watersheds

A.The appearance of flash floods in small basins is conditioned by the processes that take place on versants and the torrential forms (gullies). The elements that favour floods appearance may be grouped in:

a) The physic-geographic characteristics of the basin and the hydrographic network

Among the physic-geographic conditions there are: basin’s surface, form, slope inclination, inclination of the main stream, drainage network density, forestation degree, land use, soil’s texture and the storage capacity of soil’s column.

The physic-geographic characteristics influence:

1) the value of surface leakage (the production function);

2) the surface and hypodermic leakage concentration speed in the river network (the transfer function);

3) flood’s downstream movement (the propagation function).

The production function is strongly dependent upon soil texture and the land use (including the forestation degree) which determine, in consequence, the storage capacity of the non-saturated zone. The versants’’ inclination and the basin’s slopes, the basin’s form and drainage network density, the slope of the secondary hydrographic network influence the transfer function while the main river bed characteristics influence the propagation function.

b) Aggravating factors:

- natural factors: the soil’s initial humidity in the basin, rock’s friability, the existence of the deepened erosional forms (gully erosion);

- anthropic factors: frequent deforestations combined with the misuse of the silvicultural norms for tree cutting and wood deposition, lack of anti-erosional measures and lack of erosional forms control, inadequate agricultural practices, buildings and constructions very close to river banks.

The initial soil humidity in the basin plays an important role in the leakage generation at the surface. The rock's friability favours erosional phenomena inside the basin which results, first, in the lowering of the storage capacity where floods occur; the solid transport affects in the same time the transit capacity in the river beds. The deep erosional forms result in rapid concentration of the surface leakage in the permanent hydrographic network; additionally, the torrential forms accelerate the leakage conditions down-stream because of the solid charge it generates.

The lack of anti-erosional measures and the torrential forms lack of control contribute to the torrentiality and solid transport increase. Irrational deforestation and inadequate agricultural practices (ploughing along the relief's isolines, lack of terraces) result in the increase of the leakage coefficient with direct influences upon the volumes and the maximum discharges of the flood, respectively of the solid transport.

6.6.3.2. Flash floods genesis in small watersheds

The exceedence probability corresponding to the flash flood generating rain.

The triggering factor for flash floods in small basins is related to torrential rains of great intensity and short duration, usually shorter the basin's concentration time.

To define the precipitations that trigger flash floods we start from the observation that, in the last years, the small basins with such floods had precipitations over the threshold of 100 mm per hour. On the other hand, in practice (INMH, ANM) it is considered that the hourly precipitation in the 100-300 mm interval corresponds to a 1% exceedence probability (Fig. 6.66).

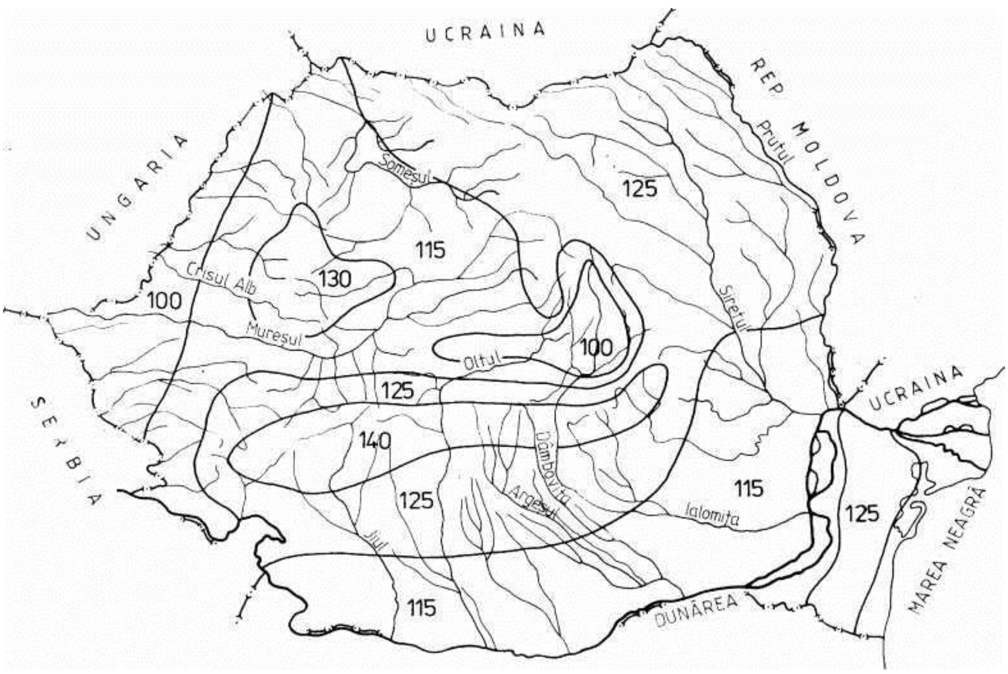


Fig. 6.66 Zoning of the hourly maximum precipitation with 1% exceedence probability (Diaconu et al, 1995)

Considering the above observations we consider as reference precipitation the 1% precipitations. For this probability of exceedence we consider different durations of the generator rain, along with form of the hieto-grams that correspond for the identification of the most unfavourable situation regarding the maximum discharge. Furthermore, taking into consideration the fact that in Romania and at international level the highest values of human life loses appear at flash floods we recommend the analysis of the leakage conditions in the main river bed also for floods with p%, 5%, 2% and 0.5% exceedence capacity.

To identify the most unfavourable situations of the flash flood production that corresponds to 1% probability or, in the general case of p% we consider more scenarios of precipitation productions. Thus, for each analyzed basin we pick various rain durations that generate flash floods, between 5 minutes and 3 hours. The interval on which the rain lasts is chosen according to the torrential precipitations records in the studied zone and the physical-geographic characteristics of the hydrographic basin.

The magnitude of the flash flood generator rain

Diaconu and Serban (1994), based on the spatial and temporal probabilities of exceedence and also on the regionalisation studies (Fig. 6.69) proposed for other values, the h% precipitations which represent the precipitation stratum with 1% exceedence probability in basins of 10, 100 and 1000 km^2 for durations between 15 minutes and 6 hours (Table 6.21).

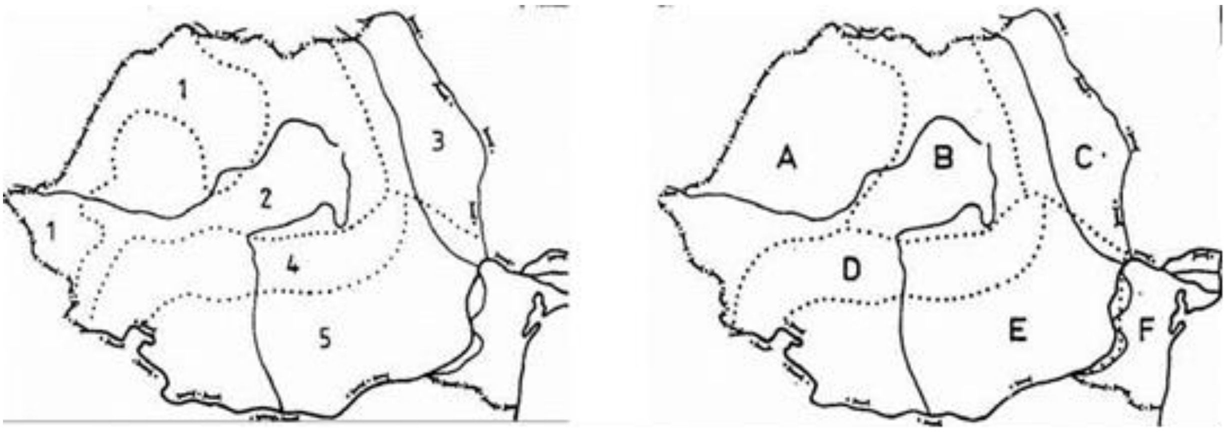


Fig. 6.67 Maximum precipitation regionalization in Romania (Diaconu & Serban, 1994)

Table 6.21 Values of maximum precipitations with 1% overflow probability in sub -1000 km2 watersheds (Diaconu şi Şerban, 1994)

F (Km^2)	t (hours)	Z O N E S						
		1A	2A	2B	3C	4D	5E	5F
10	%	62.3	72.4	72.4	75.1	84.8	76.8	81.4
	1	100	117	107	119	136	124	127
	6	135	157	147	181	206	179	179
100	%	56.5	63.7	63.7	67	74.7	68.3	72.4
	1	91.1	103	93.8	106	121	111	113
	6	122	138	129	162	182	159	159
1000	%	49	52.6	52.6	56.3	63.3	58.5	61.9
	1	78.9	84.7	77.4	89.2	102	94.6	96.3
	6	106	114	107	136	154	136	136

6.6.3.3. Flash floods bias conditions and inundations in small watersheds

To preliminary sort the flash floods susceptible basins, based on the Physic-geographic method, uses the elements revealed by the GIS mapping analysis (in digital format) for the Moldavian Plain and contains:

- The sub-basins map (up to the 6th order with maximum 200 km^2 surfaces);
- Land use map
- Soil map

The hydrologic groups of soils are widely used in the United States of America as major influence factor for the leakage for the most hydrological models. The soil classification prompts the evidence of the soils leakage potential. Dependent upon the texture (clay, silt or sand proportions) the soils are classified in four hydrological groups: A, B, C, D. Group A consists in coarse texture soils with the lowest leakage potential while group D with fine texture (clay) have the maximum leakage potential and, respectively minimum infiltration.

The Romanian system of texture classification is identical with USA's system, this classification being adapted to the Romanian conditions (Cehndeş 2007) and based on the ICPA textural practices (fig. 6.68).

By superimposing the layers mentioned above we obtain the digital map of the CN index (Curve Number) from the SCS model. CN (Curve Number) is a dimensionless index which can take values between 0 and 100. CN depends on the land use and on the soil's hydrological group and reflects the leakage potential for water for various terrains. The values of CN vary in direct proportion with the leakage potential and in inverse proportion with infiltration coefficient; it takes maximum values for the D soils group or in urban surfaces that are impermeable. The classification and the values assigned for the CN were adapted and realized (Chendeş 2007) on the basis of USDA manuals and on the basis of other classifications that exists in the international specialized literature. To establish the values that are specific for Romania we the Corine Land Cover 2000 were used (realized for Romania at INCD Danube Delta – Tulcea). For a given basin the global CN index is obtained as a balanced average with the partial surfaces F_i which are characteristic to the CN_i index (fig. 6.69)

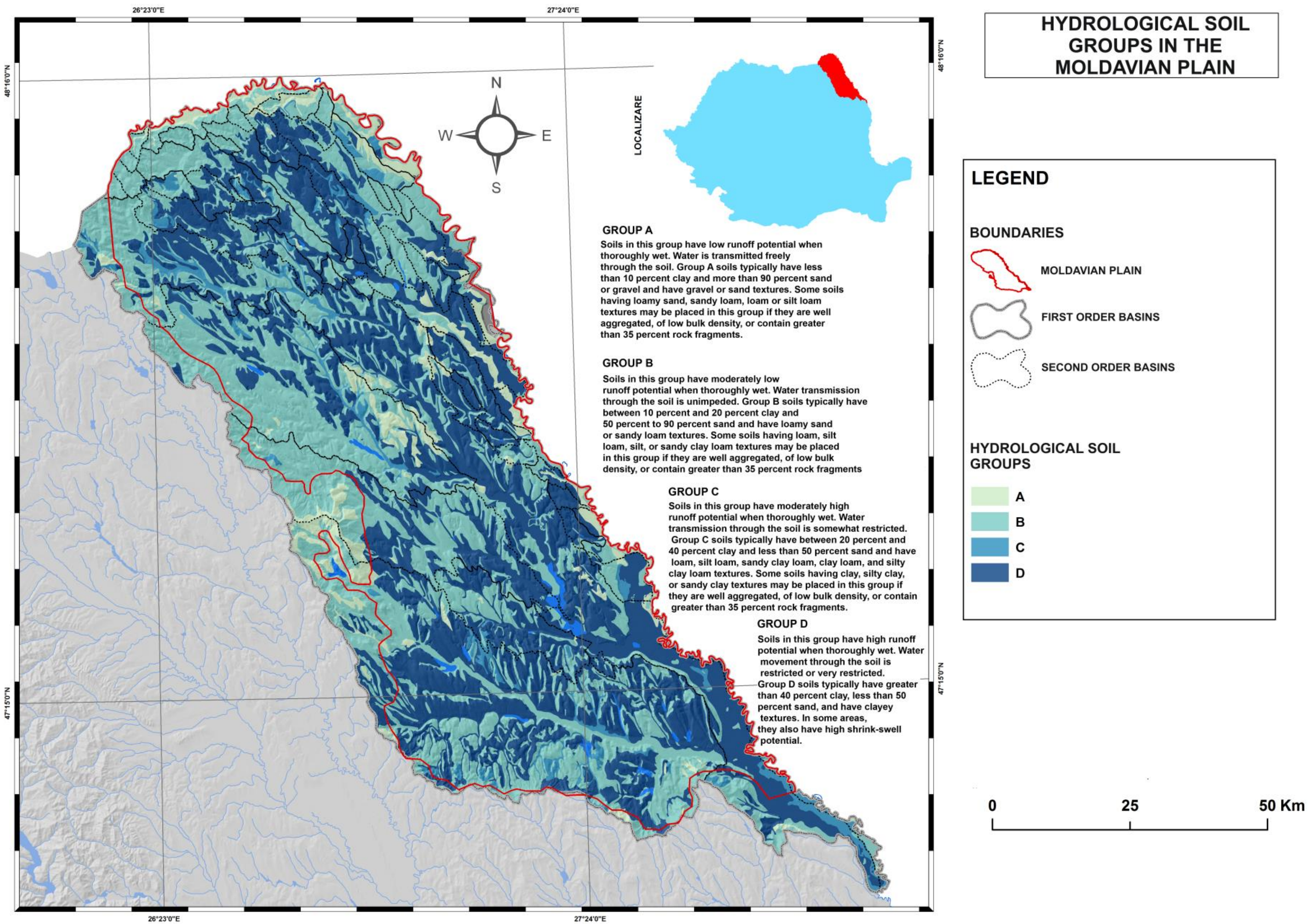
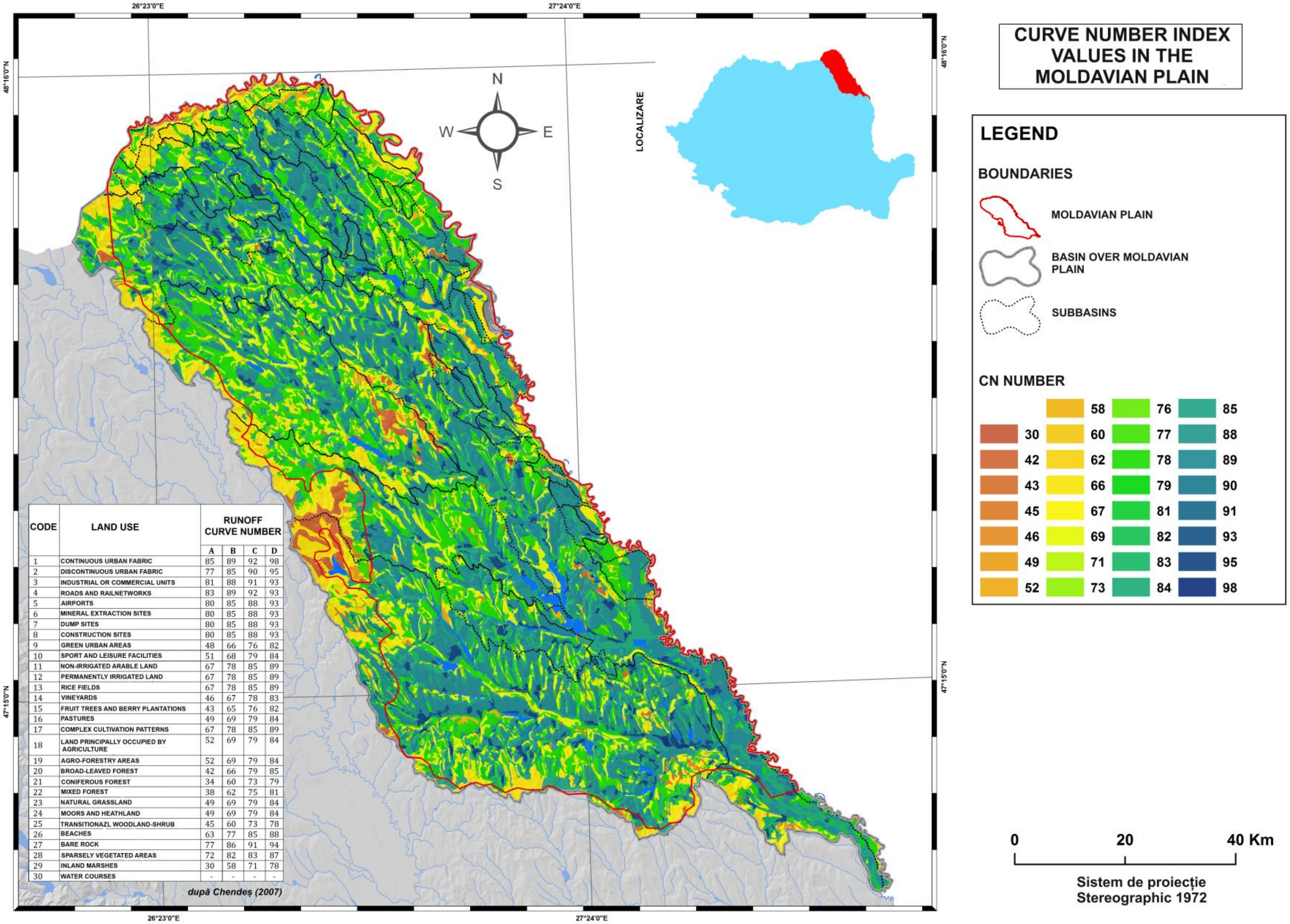


Fig. 6.68 Hydrological soil groups in the Moldavian Plain



CODE	LAND USE	RUNOFF CURVE NUMBER			
		A	B	C	D
1	CONTINUOUS URBAN FABRIC	85	89	92	98
2	DISCONTINUOUS URBAN FABRIC	77	85	90	95
3	INDUSTRIAL OR COMMERCIAL UNITS	81	88	91	93
4	ROADS AND RAILNETWORKS	83	89	92	93
5	AIRPORTS	80	85	88	93
6	MINERAL EXTRACTION SITES	80	85	88	93
7	DUMP SITES	80	85	88	93
8	CONSTRUCTION SITES	80	85	88	93
9	GREEN URBAN AREAS	48	66	76	82
10	SPORT AND LEISURE FACILITIES	51	68	79	84
11	NON-IRRIGATED ARABLE LAND	67	78	85	89
12	PERMANENTLY IRRIGATED LAND	67	78	85	89
13	RICE FIELDS	67	78	85	89
14	VINEYARDS	46	67	78	83
15	FRUIT TREES AND BERRY PLANTATIONS	43	65	76	82
16	PASTURES	49	69	79	84
17	COMPLEX CULTIVATION PATTERNS	67	78	85	89
18	LAND PRINCIPALLY OCCUPIED BY AGRICULTURE	52	69	79	84
19	AGRO-FORESTRY AREAS	52	69	79	84
20	BROAD-LEAVED FOREST	42	66	79	85
21	CONIFEROUS FOREST	34	60	73	79
22	MIXED FOREST	38	62	75	81
23	NATURAL GRASSLAND	49	69	79	84
24	MOORS AND HEATHLAND	49	69	79	84
25	TRANSITIONAZL WOODLAND-SHRUB	45	60	73	78
26	BEACHES	63	77	85	88
27	BARE ROCK	77	86	91	94
28	SPARSELY VEGETATED AREAS	72	82	83	87
29	INLAND MARSHES	30	58	71	78
30	WATER COURSES	-	-	-	-

Fig. 6.69 Curve Number index values in the Moldavian Plain

On the basis of the above map the time of concentration according to the diagramme is calculated figure 6.70:

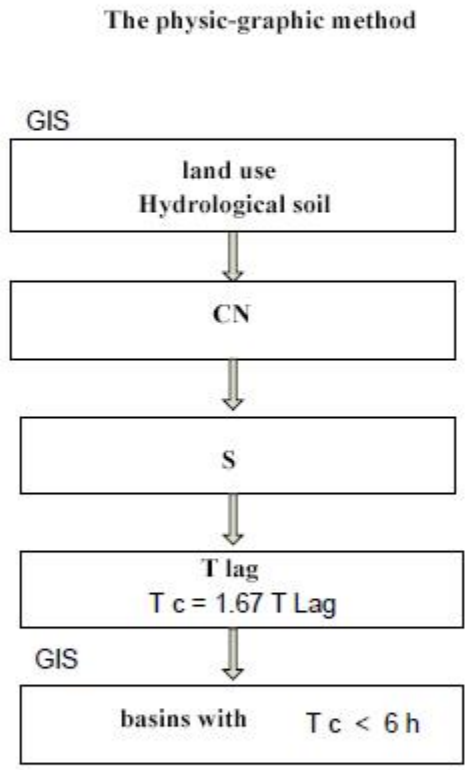


Fig. 6.70 The physic-graphic method for the identification of the flash floods susceptible basins

After the CN retrieval the storage capacity is calculated, according to following relation:

S = 25,4 (1000/ CN – 10)

On the basis of these elements the delay time is determined T_L (T-lag), defined as the time that passes between the rain's interval centre and the moment when flood peak appears with the following relation (US Department of Agriculture, 1997):

$$T_{LAG} = (3{,}28084 * L)^{0{,}8} * \frac{(S+1)^{0{,}7}}{1900\sqrt{I_B}}$$

where:

T_L – delay time in hours;

L – the length of the main river bed in meters;

I_B – basin's average inclination in %.

Based on the delay time the concentration time is calculated (defined as the longest time for a drop of water which reaches the basin to arrive at the effluence or the time that passes between the end of the rain and the appearance of the inflection point on the descendent curve of the hydrograph) with the following relation:

$T_C = 1{,}67\ T_L$

The basins are identified with $T_C \leq 6$ hours by superimposing over the stratum that contains the human settlements which includes the spatial distribution of the CT (concentration time) sub-basins shorter than 6 hours that generates a new stratum which indicates those settlements in the Jijia basin that are susceptible of flash floods (fig. 6.71).

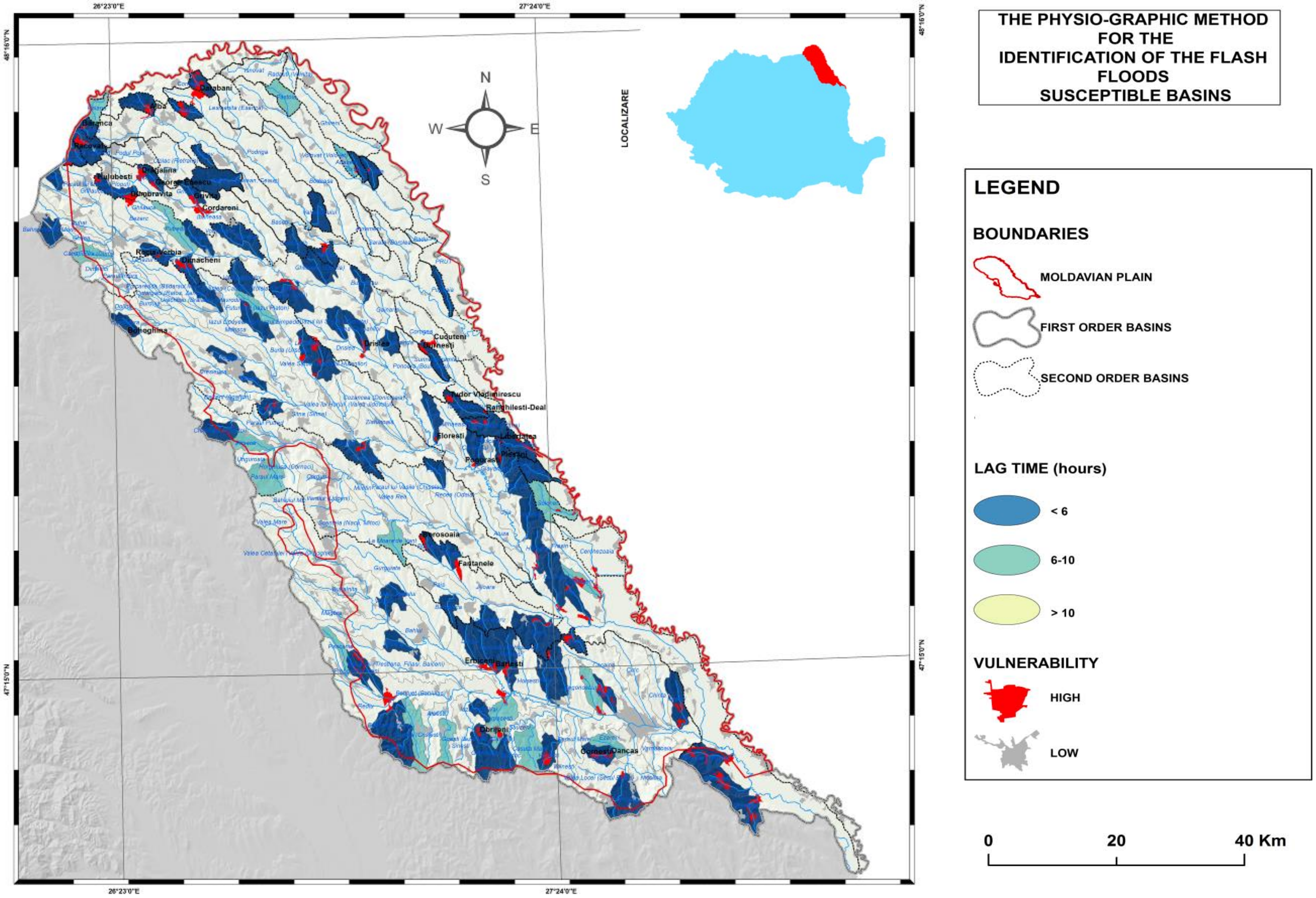


Fig. 6.71 The susceptible basins for flash floods in the Moldavian Plain based on the physio-graphic method

As a result of flash floods susceptible generator basins sorting via the physic-graphic method we identified 73 sub-basins, of different orders, that are vulnerable to rapid/flash floods production. These basins are distributed all across the Moldavian Plain and especially in the areas where the basins slope allows the concentration of water at the level of the minor river bed.

After superimposing the concentration stratum for settlements with the stratum of spatial and temporal distribution of concentration we identified 49 settlements located in different sub-basins which are vulnerable at flash floods production.

This kind of study represents a preliminary evaluation of the vulnerabilities for flash floods in the Moldavian Plain, study that indicates the settlements that can be affected by torrential rains. Following this study there is the possibility to develop a GIS methodology to model the rain-leakage process to anticipate the necessary water quantity for leakage and the integration of versant leakage in order to estimate the expected flash flood magnitudes. It is possible though to forecast the precipitations for a certain day and, by knowing the previous conditions oh humidity and the terrain characteristics, to estimate the quantity of water which will contribute to the flash flood; then the spatial and temporal leakage of the respective quantity can be modelled.

The geographic position of the analyzed zone and the torrential rains determined by the cyclonal activity specificity in this area generate favourable conditions which may trigger flash floods in all the 73 sub-basins. The increased precipitations in short time produce very high discharges that, in most of the cases, cannot be overtaken by the minor river beds. In the case of direct exposed localities the maintaining of the transit capacity in the river bed plays a maximum importance role to prevent inundations.

Based on certain correlations one can establish thresholds of the precipitations characteristics (quantity, duration) that can trigger flash floods. During forecasting or recording in the operative sector for the previous established values there is the possibility of immediate warning for the decision-makers which can also estimate the gravity of the event’s risks.

7. CONCLUSIONS

In the Moldavian Plain and the immediate vicinities the annual precipitations average is 521.7 mm. On this relatively narrow space of the studied zone the precipitations' territorial variations are significant with respect to quantities which results in the delineation of some distinct, general view points:

- the atmospheric precipitations decrease slightly from west to east as a consequence of altitude lowering in this direction and the higher frequency of humid masses of air in the west; the air masses are in general of Atlantic origin and, toward east, they become slightly drier and thus imposing the west to east difference. The presence of foehnization on the western side controls the precipitations differences which, in consequence, do not become notably higher on the eastern side as related to the vertical pluviometric gradients in the Moldavian Plateau;

- the higher altitude zones have an increased pluviometric input (Ibăneşti Hills and Darabani Hills, in the north: Pomârla 623.8 mm; Copalău- Cozancea - Guranda Hills, in the centre: Cristeşti 585.3 mm and Nicolae Bălcescu 564.8 mm);

- the lower altitude zones record the most reduced precipitations quantities over the year. Among them we notice: a north-eastern sector in the Upper Jijia Plain, ac. White Horse 456 mm, Stânca 459 mm and a south-western sector, "in the shadow" of Great Hill-Hârlău (at Tansa 467.20 mm, Goat's Horns 473 mm). A third sector of low precipitations runs along the Prut Valley;

- there is a stretch of alternating sectors with higher precipitations at increased altitudes and lower precipitations at decreased altitudes; this succession is well evidenced on the NW – SE direction. The versants exposed to the more humid air masses for NW receive more precipitations while the versants exposed to SE, receive less precipitations and both types of air masses are controlled by foehnization processes in their movement; notable differences between the versants exposed to air advection and the ones not exposed to air advection are observed in the case of maritime origin air masses.

The semestral precipitation quantities display irregular distribution over the year and from one year to another while the sums evolution presents increases and decreases correlated with the annual sums of precipitations. The long term evolution emphasizes a stabilizing tendency and, on the whole, the increase of annual precipitations is a result of the higher precipitations quantities in the warm semester. In the warm semester (1st of April to 30th of September) the dynamics of air masses, very active especially in the western part and the thermic and dynamic convections, at the maximum of their manifestation, in this period, determine the discharge of 2 thirds of annual precipitations.

The annual precipitations regime is complex, yet one can notice the existence of two pluviometric maximums (a main one in June and a secondary one in November) and two pluviometric minimums (a main one in January and secondary one in October);

On the Moldavian Plain territory the number of days with high precipitations or precipitations that equal certain thresholds do not differ much between extreme points and there is a direct link between the annual average quantities and the number of days with distinct values of precipitations. In the more humid areas the number is higher and in the drier areas the number of precipitation days is lower reported to an average year.

In the case of torrential rains we notice a relative uniformization of the frequencies' values that develop on a wide intensities interval with higher values toward the mid-summer. For rains, the maximum intensities did not exceed the 1.01-2.00 interval at any station in the Moldavian Plain; the intensities tend to be closer to the low values interval and, at Cotnari, the maximum intensities did not exceed the threshold value of 1.01. As far as the vulnerability is concerned, in the Moldavian Plain, as reported to the rains' intensity we notice that the northern half of the Plain is under medium vulnerability while the southern half is under high vulnerability.

In the Moldavian Plain, depending on the weather states, snow cover conditions with various thicknesses may occur from the first decade of October and until the last decade of April. The snow cover sickness is determined, in the first place, by the air temperature and soil temperature and the snow-fall character (mild or blizzard) and the snow density.

The increase of the average annual discharge from spring to effluences, in direct report with increase of the tributaries number and the surface of the watershed surface is a general characteristic of the Moldavian Plain. For example, Jijia, the main collector of the studied sub-region records 0.67m^3/s at Dorohoi, 2.25 m^3/s at Todireni, 6.83 m^3/s at Victoria and 12.3 m^3/s at Chipereşti. The increase gradient is, in average, 1.75 m^3/s on 1000 km^2. Due to the physical-geographic conditions where the hydrographic basins develop the increase in discharge as reported to the overall surface is biased with noticeable differences. These situations are described in the specific discharges differences report. Thus, if we report the discharge to the accumulation surface we notice a decrease of values at basins enlargement. This situation indicates that, in reality, the input of rivers as reported to basin down-stream extension is decreasing, especially as a result of climate manifestation that restricts the discharge. In average, the highest water quantity discharges on Jijia from the right side affluents. Between the affluence there are Bahlui, Miletin and Sitna which transport approximately 50% of the total basin discharge contributing to the overall Jijia discharge with 70%.

In-between the years, the average annual discharges oscillate, on long term, especially as a function of climate elements variation. Thus, the variation in precipitations, which is the main input source for rivers and the variation in temperatures and air humidity control the yearly annual discharges.

Analysing the cyclic character of the leakage for the hydrometric stations in the Moldavian Plain with the aid of 5 years moving averages for the average annual discharges we notice that two periods of leakage increase on the rivers, 1965-1984 and 1995-2010, are controlled by precipitations increase. In the case of the first period there are important peaks for the rivers leakage in 1969 and 1982. In the same time, analysing the 5 years moving averages we can easily identify one decrease between 1985 and 1989.

For the rivers in north-eastern Moldova the values of the variation coefficient at medium annual discharges oscillate between 0.70 on Bahlui at Hârlău and 0.78 on Jijia at Victoria. Comparing these two records with the ones calculated by S. Dumitrescu (1964) for 38 characteristic national we can deduce that in the main hydrographic basins of the Moldavian Plain the medium annual discharges present a high stability, especially because of the continental excessive character of the climate.

The annual variability of the maximum discharges emphasizes, for the analyzed hydrographic basins in the Moldavian Plain, a series of years when the highest maximum discharges were recorded (1954, 1969, 1975, 1980, 2008, 2010) and a series of years when the lowest maximum discharges were recorded (1959, 1963, 1964, 1986). An detailed analysis of the maximum discharges values per moths, recorded at the main hydrometric stations, indicates spatial differences generated by the local conditions and the pluvio-thermal characteristics of the periods when they appeared.

The most important floods in the Moldavian Plain, between 1960-2011, appeared, in general in summer from June to July. In the above mentioned period, important floods appeared in: 1961, 1965, 1969, 1970, 1973, 1974, 1978, 1979, 1980, 1981, 1985, 1988, 1989, 1991, 1993, 1996, 2005, 2008 and 2010 with certain differences as a function of local conditions.

Regarding the medium duration of the floods we notice that on the rivers of the Moldavian Plain they rarely exceed 4 days, in great majority one day or two. On the other hand, on the Prut River the floods extend on more days with frequent afflux phenomenon which inflicts pressure on the hydro-technical works that control inundations.

The most floods were registered on the interior rivers, respectively 62.9% and only 27.1% on Prut. Between 2000 and 2011, according to the Prut-Bârlad Water Basinal Administration records, a number of 130 floods produced in the Moldavian Plain with maximum discharges that exceeded the 20% probability.

Based on the historical events there were identified 12 potential zones of significant inundation risk.

In the Moldavian Plain the hydrologic risk is considerable and it manifests not only on the main streams but also on the affluents. The geographic position of the plain and the torrential rains determined by the cyclonical activity specificity of this zone creates favourable conditions for the appearance of flash floods in 73 basins. The increased precipitations quantities in short time produce very high discharges, discharges which, in the majority of occasions cannot be delivered by the minor river beds. In the case of the 49 localities that are directly exposed the maintaining of the transit capacity for the river bed is of maximum importance to prevent inundations.

The climatic change and irregular territorial development that is insufficiently planned for inundations prevention and the increased erosion potential result in economical and social vulnerabilities as far as the floods risk in concerned is the Moldavian Plain.

APPENDIX

Annex 1

Table 1 Main floods recorded in the Moldavian between 1960 – 2011 (according A.B.A. Prut – Bârlad Administration)

No.	Main stream of the flood	Affected localities	Date of flood commence	Flood duration (days)
1	Prut June July 1969	Oroftiana-Santa Mare		
2	Prut-1969	-	05.06.1969	72
3	Albesti-1970	loc. Albesti, com.Albesti	01.05.1970	8
4	Prut May 1987	Oroftiana-Radauti Prut	24.05.1987	1
5	Prut June 1988	Oroftiana-Radauti Prut	3.06.1988	5
6	Prut June 1988	Stanca - Santa Mare	3.06.1988	6
7	Prut September 1988	Oroftiana-Radauti Prut	9.09.1988	2
8	Miletin June 1988	Cosula-N.Balcescu	5.06.1988	1
9	Prut May 1989	Oroftiana-Radauti Prut	16.05.1989	1
10	Prut July 1991	Oroftiana-Radauti Prut	28.07.1991	2
11	Prut August 1991	Oroftiana-Radauti Prut	4.08.1991	2
12	Prut August 1991	Stanca - Santa Mare	5.08.1991	8
13	Prut May 1993	Oroftiana-Radauti Prut	20.05.1993	10
14	Prut June 1994	Oroftiana-Radauti Prut	7.06.1994	3
15	Prut June 1995	Oroftiana-Radauti Prut	29.06.1995	2
16	Prut April-May 1996	Stanca - Santa Mare	24.04.1996	13
17	Prut April 1996	Oroftiana-Radauti Prut	17.04.1996	14
18	Prut September 1996	Oroftiana-Radauti Prut	9.09.1996	3
19	Prut August 1997	Oroftiana	4.08.1997	2
20	Prut September 1997	Oroftiana	2.09.1997	1
21	Prut May 1998	Oroftiana-Radauti Prut	19.05.1998	4
22	Prut May 1998	Stanca - Santa Mare	22.05.1998	6
23	Prut June 1998	Oroftiana-Radauti Prut	19.06.1998	4
24	Prut June 1998	Stanca - Santa Mare	19.06.1998	8
25	Prut July 1998	Oroftiana	9.07.1998	2
26	Jijia May 1998	Dorohoi	19.05.1998	2
27	Buhai May 1998	Padureni	19.05.1998	2
28	Prut April 1999	Stanca - Santa Mare	21.04.1999	2
29	Prut May 1999	Stanca - Santa Mare	3.05.1999	3
30	Prut July 2000	Oroftiana-Radauti Prut	15.07.2000	2
31	Jijia July 2000	Dangeni-Rauseni	14.07.2000	2
32	Prut March 2001	Oroftiana-Radauti Prut	5.03.2001	4
33	Prut April 2001	Oroftiana-Radauti Prut	24.04.2001	3
34	Prut June 2001	Oroftiana-Radauti Prut	20.06.2001	10
35	Prut August 2002	Oroftiana-Radauti Prut	16.08.2002	5
36	Jijia March 2002	Dorohoi-Rauseni	25.03.2002	6
37	Prut August 2003	Oroftiana-Radauti Prut	15.07.2003	3
38	Prut August 2003	Oroftiana-Radauti Prut	1.08.2003	2
39	Prut August 2004	Oroftiana-Radauti Prut	2.08.2004	3

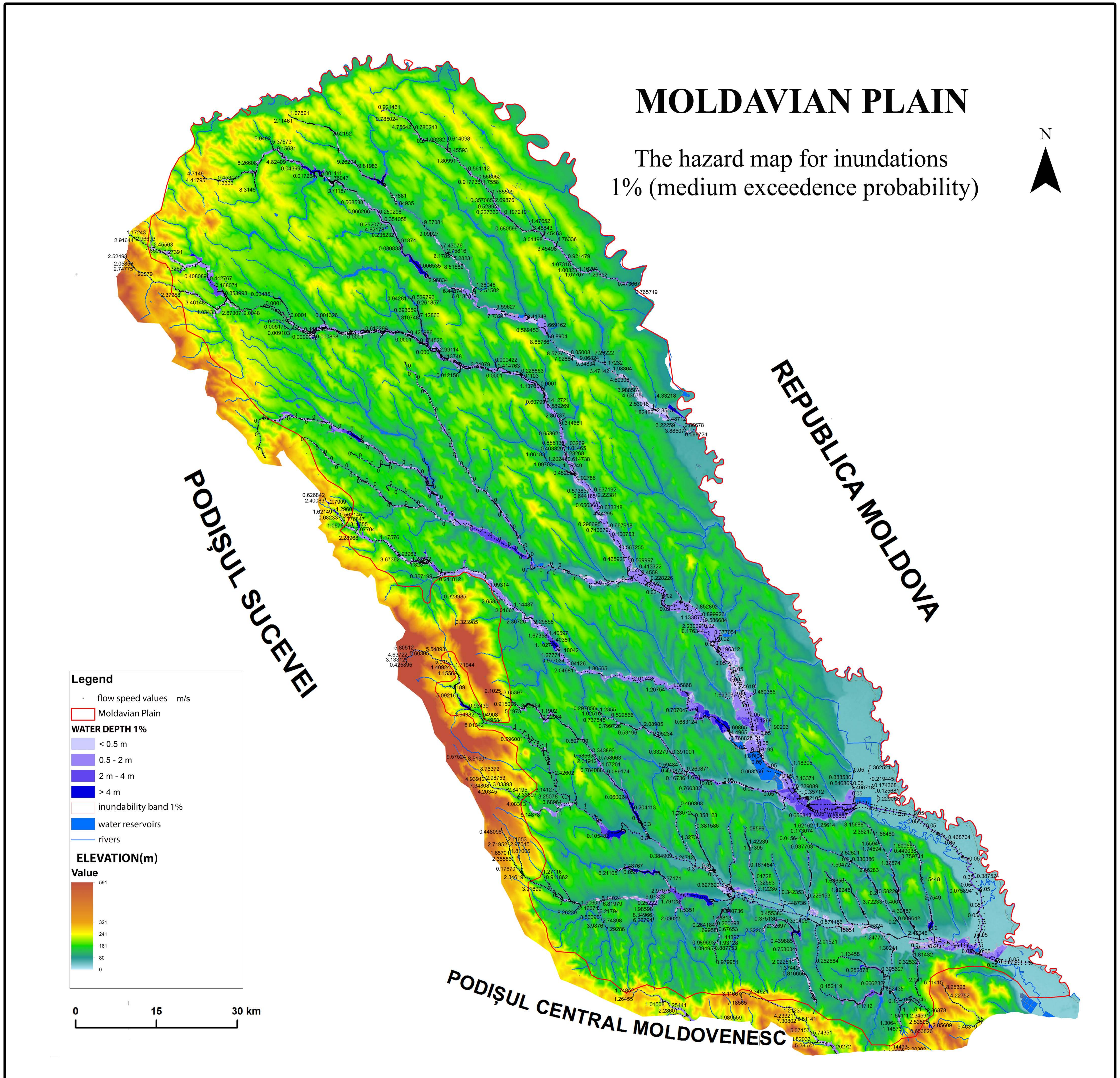
40	Prut August 2004	Oroftiana-Radauti Prut	6.08.2004	4
41	Prut August 2005	Oroftiana-Santa Mare	14.08.2005	12
42	Jijia + affluents August 2005	Vladeni	22.08.2005	1
43	Jijia + affluents August 2005	Deleni	19.08.2005	1
44	Jijia + affluents August 2005	Gropnita	22.08.2005	1
45	Jijia + affluents August 2005	Harlau	19.08.2005	3
46	Jijia + affluents August 2005	Costesti, Ion Neculce, Tg. Frumos, Baltati	19.08.2005	1
47	Jijia + affluents August 2005	Cucuteni	19.08.2005	1
48	Jijia + affluents August 2005	Iasi	21.08.2005	1
49	Baseu August 2005	Havarna-Stefanesti	19.08.2005	5
50	Jijia + affluents August 2005	Hiliseu Horia-Rauseni	19.08.2005	6
51	Jijia + affluents August 2005	Dersca-Dorohoi	18.08.2005	3
52	Jijia + affluents August 2005	Manastireni-Blandesti	19.08.2005	6
53	Jijia + affluents August 2005	Cosula-N.Balcescu	19.08.2005	2
54	Raioasa May 2005	Bivolari	25.05.2005	1
55	Jijia May 2005	Andrieseni	09.05.2005	1
56	Jijia May 2005	Vladeni	09.05.2005	1
57	Jijia May 2005	Golaesti, Ungheni	09.05.2005	1
58	Jijia May 2005	Prisacani	09.05.2005	1
59	Jijia May 2005	Costuleni	09.05.2005	1
60	Jijia May 2005	Victoria	25.05.2005	1
61	Miletin May 2005	Sipote	08.05.2005	2
62	Scanteia April 2005	Deleni	30.04.2005	1
63	Frasin May 2005	Probota	09.05.2005	1
64	Putina April 2005	Belcesti	30.04.2005	1
65	Albesti August 2005	Braesti	19.08.2005	1
66	Horlesti April 2005	Horlesti	30.04.2005	1
67	Nicolina May 2005	Barnova	07.05.2005	1
68	Vamasoaia May 2005	Municipiul Iasi	07.05.2005	1
69	Prut and affluentsJune 2006	Oroftiana-ac.Stanca	1.06.2006	6
70	Prut and affluentsJune 2006	Santa Mare	3.06.2006	6
71	Jijia and affluentsJune 2006	Harlau	05.06.2006	1
72	Jijia and affluentsJune 2006	Dorohoi-Rauseni	2.06.2006	6
73	Jijia and affluentsJune 2006	Padureni	2.06.2006	2
74	Prut April - August 2006		03.07.2006	35
75	Prut April 2006	Trifesti	04.04.2006	3
76	Prut April 2006	Golaesti	05.04.2006	2
77	Prut April 2006	Tutora	05.04.2006	2
78	Prut April 2006	Prisacani	06.04.2006	1
79	Solonet April 2006	Bivolari	02.04.2006	1
80	Jijia March 2006	Andrieseni	31.03.2006	1
81	Cucuteni March 2006	Cucuteni	29.03.2006	1
82	Sinesti March 2006	Sinesti	30.03.2006	1
83	Voinesti April 2006	Voinesti	02.04.2006	1
84	Voinesti August 2006	Voinesti	10.08.2006	1
85	Cacaina March 2006	Romanesti	29.03.2006	1

86	Upper Prut July 2008	Oroftiana-acStanca	24.07.2008	8
87	Upper Prut July 2008	ac.Stanca-Santa Mare	26.07.2008	21
88	Prut July 2008	Sipote	24.07.2008	3
89	Prut July 2008	Fantanele, Gropnita, Movileni	24.07.2008	3
90	Jijia and affluentsJuly 2008	Harlau, Scobinti, Ceplenita, Belcesti, Erbiceni, Podu Iloaiei, Dumesti, Letcani, Miroslava	24.07.2008	4
91	Jijia and affluentsJuly 2008	Cotnari	24.07.2008	1
92	Jijia and affluentsJuly 2008	Cucuteni	24.07.2008	2
93	Jijia and affluentsJuly 2008	Braesti	24.07.2008	2
94	Jijia and affluentsJuly 2008	Sinesti	24.07.2008	8
95	Jijia and affluentsJuly 2008	Popesti	24.07.2008	2
96	Jijia and affluentsJuly 2008	Costesti, Ion Neculce, Targu Frumos, Baltati, Lungani	24.07.2008	5
97	Jijia and affluentsJuly 2008	Romanesti	24.07.2008	4
98	Jijia and affluentsJuly 2008	Rediu	24.07.2008	4
99	Prut July 2008	Popricani	24.07.2008	5
100	Prut July 2008	Aroneanu	24.07.2008	3
101	Jijia and affluentsJuly 2008	Andrieseni Vladeni	24.07.2008	3
102	Prut July 2008	Bivolari, Trifesti, Comuna Probota, Comuna Victoria, Comuna Golaesti, Comuna Ungheni, Comuna Tutora, Comuna Prisecani, Comuna Grozesti, Comuna Gorban,	24.07.2008	3
103	Upper Prut July 2008	Hiliseu Horia-Broscauti	26.07.2008	2
104	Jijia + affluents July 2008	Padureni	26.07.2008	1
105	Upper Prut July 2008	Manastireni-Blandesti	26.07.2008	2
106	Pais July 2008	Coarnele Caprei	24.07.2008	3
107	Oii July 2008	Bals	24.07.2008	3
108	Miletin April 2008	Cosula-N.Balcescu	23.04.2008	2
109	Raioasa May 2009	Bivolari	12.05.2009	1
110	Glavanesti februarie 2009	Andrieseni	10.02.2009	1
111	Bahlui June 2009	Scobinti	28.06.2009	1
112	Bahlui July 2009	Comuna Scobinti	12.07.2009	1
113	Buhalnita June 2009	Ceplenita	28.06.2009	1
114	Gurguiata June 2009	Deleni	28.06.2009	1
115	Bahluet January 2009	Costesti	29.01.2009	1
116	Albesti June 2009	Lungani	28.06.2009	1
117	Valea Oii June 2009	Bals	28.06.2009	1
118	Hoisesti June 2009	Romanesti	28.06.2009	1
119	Sauzeni June 2009	Dumesti	28.06.2009	1
120	Prut May 2010	Oroftiana-Baranca	19.05.2010	4
121	Prut and affluents June 2010	Oroftiana - . Dunarea	25.06.2010	66
122	Prut June-July 2010	zona Oroftiana-ac.Stanca	21.06.2010	20
123	Prut June-July 2010	ac.Stanca-Santa Mare	24.06.2010	34
124	Prut July 2010	Trifesti	03.07.2010	10
125	Prut July 2010	Victoria	04.07.2010	8

126	Prut July 2010	Golaesti	05.07.2010	7
127	Prut July 2010	Ungheni	06.07.2010	6
128	Prut July 2010	Gorban	10.07.2010	2
129	Prut August 2010	Tutora	01.08.2010	6
130	Bahlui + affluents June 2010	Deleni, Scobinti, Ceplenita, Belcesti, Erbiceni, Oras Podu Iloaiei, Holboca.	24.06.2010	7
131	Bahlui + affluents June 2010	Bals	28.06.2010	5
132	Bahlui + affluents June 2010	Costesti, Baltati	28.06.2010	1
133	Bahlui + affluents June 2010	Cucuteni	28.06.2010	1
134	Bahlui + affluents June 2010	Targu Frumos	28.06.2010	1
135	Bahlui + affluents June 2010	Braesti	28.06.2010	1
136	Bahlui + affluents June 2010	Sinesti	29.06.2010	1
137	Bahlui + affluents June 2010	Horlesti	29.06.2010	1
138	Bahlui + affluents June 2010	Barnova, Ciurea	29.06.2010	1
139	Bahlui + affluents June 2010	Mogosesti - Iasi	24.06.2010	1
140	Bahlui + affluents June 2010	Popricani, Aroneanu	30.06.2010	1
141	Volovat June-July 2010	Manoleasa-Ripiceni	21.06.2010	20
142	Jijia June-July 2010	Hiliseu Horia -Rauseni	28.06.2010	5
143	Buhai June-July 2010	Dersca-Dorohoi	28.06.2010	3
144	Burla June -July 2010	Manastireni-Unteni	28.06.2010	5
145	Solonet July 2010	Bivolari	01.07.2010	1
146	Jijia May 2010	Prisacani	25.05.2010	3
147	Jijia July 2010	Andrieseni	01.07.2010	5
148	Jijia July 2010	Vladeni	02.07.2010	5
149	Jijia July 2010	Prisacani	10.07.2010	2
150	Jijia July 2010	Grozesti	11.07.2010	2
151	Jijioara July 2010	Fantanele	03.07.2010	1
152	Jijioara July 2010	Movileni	03.07.2010	1
153	Pais July 2010	Focuri	02.07.2010	1
154	Frasin July 2010	Roscani	03.07.2010	1
155	Buhalnita May 2010	Scobinti	20.05.2010	1
156	Magura May 2010	Cotnari	20.05.2010	1
157	Putina May 2010	Belcesti	20.05.2010	1
158	Bahluet May 2010	Costesti	22.05.2010	1
159	Bahluet May 2010	Ion Neculce	22.05.2010	1
160	Cucuteni May 2010	Targu Frumos	22.05.2010	1
161	Volovat July 2010	Manoleasa-Ripiceni	24.07.2010	8

Annex 2

Moldavian Plain The hazard map for inundations 1% (medium exceedence probability)



MOLDAVIAN PLAIN
The hazard map for inundations
1% (medium exceedence probability)
N
REPUBLICA MOLDOVA
PODIȘUL SUCEVEI
PODIȘUL CENTRAL MOLDOVENESC
Legend
flow speed values m/s
Moldavian Plain
WATER DEPTH 1%
< 0.5 m
0.5 - 2 m
2 m - 4 m
> 4 m
inundability band 1%
water reservoirs
rivers
ELEVATION(m)
Value
591
321
241
161
80
0
0
15
30 km

Annex 3

Moldavian Plain - The risk map for inundations 1% (medium exceedence probability)


MOLDAVIAN PLAIN
The risk map for inundations
1% (medium exceedence probability)
N
REPUBLICA MOLDOVA
PODIȘUL SUCEVEI
PODIȘUL CENTRAL MOLDOVENESC
Legend
The potential floods affected population
< 100 people
100 - 1000 people
> 1000 people
Economic activities potentially affected
agriculture
extractive industry
manufacturing
gas supply
water supply
constructions
trade
transport and storage
hotels and restaurants
telecommunications
financial service
estate transactions
scientific activities
administrative services
education
healthcare
cultural activities
other activities
Supply of drinking water
catchment
distribution
water management
Potentially polluting units
potentially polluting units
Alluviums sections
alluviums sections
Important objectives
cultural house
schools
city Hall
public institutions
hospital
veterinary dispensary
stations
protected areas SCI
protected areas SPA
Risk
low
medium
high
rivers
railroads
dams
main roads
industrial areas
localities
0
15
30 km

List of Figures

List of Tables

BIBLIOGRAPHY

1. Apetrei M., Bojoi I., Lupascu Gh., Rusu C. (1990), *Considerații privind unele proprietăți ale depozitelor de suprafață din sudul Câmpiei Moldovei*, Lucrările Seminarului Geografic „Dimitrie Cantemir”, nr. 9, 1988,Iasi.
2. Apopei V., Pantazi Elena (1985), – *Variația cantiativă a scurgerii medii specifice în partea de nord-est a teritoriului României*, Bul.St.II. S., Suceava, pag. 103-112.
3. Apostol L. (1987) *Considerații asupra raportului între cantitățile semestriale de precipitații în România,* Lucrările Seminarului Geografic „Dimitrie Cantemir”, nr.7, 1986, Iasi.
4. Apostol L. (1990), *Anomalii ale temperaturii aerului pe teritoriul Moldovei*, Lucrările Seminarului Geografic „Dimitrie Cantemir”, nr.9, 1988, Iasi. pag. 101-109.
5. Apostol, L. (2000), *Precipitaţile atmosferice în Subcarpaţii Moldovei*, Editura. Universităţii, Suceava.
6. Apostol, L.; Machidon, Dana; Machidon, O.; Buruiană, D. (2012), Characteristics of precipitations trends în the area of Iaşi, Bacău, and Suceava airports over the last 50 years, în vol. conf. int. „Aerul şi apa – componente ale mediului”, Univ. „Babeş-Bolyai”, Presa Universitară Clujeană, Cluj-Napoca, pp. 252-259, ISSN 2067-743X.
7. Barbu N. (1974), *Raporturi pedo-geomorfologice în Câmpia Moldovei*, Anal.St. univ „Al.I.Cuza”, Iasi (serie nouă) secțiunea II, c.geogr., tom XX, 1974, pag. 77-82.
8. Barbu N. (1985), *Regionarea pedogeografică a Podisului Moldovenesc*, Stud.si cercet., s. geogr., XXXII, Bucuresti.
9. Barbu N., Băcăuanu V. (1977), *Evoluția reliefului din Podisul Moldovei sub acțiunea proceselor de versant*,Comunic. Col. Franco-român de geogr., Aix en Provence.
10. Barbu N., Băcăuanu V. (1985), *L'evolution du relief dans le Plateau de la Moldavie sous l*action des processus versant*, Anal.st. Univ. „Al.I.Cuza” (serie nouă), secț.II, tom XXXI, s.-b, Iasi.
11. Băcăuanu V. (1964), *Terasele din regiunea de confluență a văii Jijiei cu Prutul*, Anal.st. Univ. „Al.I.Cuza” (serie nouă), secț.II, geol.-georg., tom X, Iasi, pag.129-135.
12. Băcăuanu V. (1967), *Microrelieful de eroziune torențială din Câmpia Moldovei*, Stuida Universitatis Babes-Bolyai, series geol-geogr. Fasc.2, Cluj-Napoca. Pag. 135-140.
13. Băcăuanu V. (1968), *Câmpia Moldovei -studiu geomorfologic*, Edit. Academiei, R.S.R., Bucuresti.
14. Băcăuanu V. (1970), *Evoluția văilor din partea nord-estică a Podisului Moldovei*, Anal. Univ. „Al.I.Cuza”, Iasi, secț.II-b, tom. XVI, Iasi.
15. Băcăuanu V., Barbu N., Pantazică Maria, Ungureanu Al., Chiriac D. (1980), *Podisul Moldovei-Natură, om,economie*, Edit. Stiințifică şi enciclopedică, Bucuresti.
16. Băican V. (1970), *Iazurile din partea de est a României în documentele istorice şi cartografice din sec. XVXIX*,An. St.Univ. „Al.I.Cuza”, seria c. geografie, t. XVI, Iasi. pag 65-75.
17. Băican V. (1974), *Elemente de hidrografie în documentele cartografice din sec. Al XVIII-lea asupra*
18. *Moldovei*, An. St.Univ. „Al.I.Cuza”, seria c. geografie, t. XX, Iasi.pag.129-135.
19. Băican V. (1987), *Hidronimia Moldovei pe hărțile anterioare secolului al XIX-lea*, Lucr. Sem. „DimitrieCantemir”, nr.9 -1988, Iasi.
20. Băican V. (1996), *Geografia Moldovei reflectată în documentele cartografice din secolul al XVIII-lea*, Edit.Academiei, Bucuresti.
21. Băluță D. (1979), *Tipizarea regimului apelor freatice pe baza reacției acviferelor la excesele pluviale*, I.M.H., Studii şi cercetări, partea a II-a, Hidrologie, XLVII, Bucuresti.
22. Bâgu Gh., Mocanu Al. (1984), *Geologia Moldovei*, Edit. Tehnică, Bucuresti.
23. Blidaru V., Blidaru Ecaterina, Găbjilă M. (1961), *Stadiul actual al lucrărilor hidroameliorative în Podisul Moldovenesc şi propuneri de viitor*, Hidrotehnica nr.4, Bucuresti.
24. Bogdan, O. (1978), *Fenomene climatice de iarnă şi de vară,* Editura Ştiinţifică şi Enciclopedică, Bucureşti.
25. Bogdan, O. (1983), *Suprafaţa subiacentă activă.* Geografia Romăniei, vol. I. Editura Academiei Române, București
26. Bogdan, O. (1992), *Asupra noţiunilor de hazarde, riscuri şi catastrofe meteorologice/ climatice,* SCGeografie, XXXIX.
27. Bogdan, O., Niculescu, E. (1999), *Riscurile climatice din România,* Academia Română,Institutul de Geografie, Bucureşti.
28. Bogdan, O., Marinică, I. (2007), *Riscuri meteoclimatice din zona temperată,* Editura Lucian Blaga, Sibiu.
29. Brândus C., Brândus Filipina (1994), *Procese denudaționale ce afectează versanții de pe dreapta văilor Bahlueț şi Bahlui între Târgu Frumos şi Miroslava (Iasi),* Anal.stiințifice ale Univ. „Stefac cel Mare”, secț. Geogr.geol. anul III, Suceava, pag. 56-60.
30. Brândus C., Grozavu A. (2001), *Natural hazard and risk în Moldavian Tableland*, Revista de geomorfologie, nr.3, Bucuresti, pag. 15-24.

31. Brânzilă M. (1999), *Geologia părţii sudice a Câmpiei Moldovei*, Ed.Corson, Iasi.
32. Bofu C., Giurmă Raluca (1999), *The Geographical Information System for the Tinoasa basin în the catchment area of Bahlui river*, B.I.P., Tomul XLV (IL), fasc. 1-4, sec. Hidrotehnică, Iasi, pag. 89-93.
33. Bofu C., Crăciun I. (2004), *Sistemele Informatice Geografice, instrument modern de determinare a scurgerilor pe bazine hidorgrafice*, ICDPM, nr.1, Edit Performantica, Iasi, pag. 33-37.
34. Bojoi I. (coord) (1997), *Dinamica peisajului geografic din Câmpia Moldovei*, Contract nr. 7011/47/677/1997, Cercetări asupra dinamicii peisajului geografic din Moldova extracarpatică pentru stabilirea categoriilor de favorabilitate economică şi protecţie a mediului, etapa 1997, Univ. „Al.I.Cuza", Iasi.
35. Bojoi I., Apetrei M., Vârlan M. (1994), *Analysis and modelling of morphometrical parameters of the floodplains în the upper Jijia drainage basin*, Anal. St. Univ. „Al.I.Cuza", serie nouă, geogr., tom XLI, Iasi.
36. Bojoi I., Apetrei M., Vârlan M. (1998) *Geomorfometria Luncilor. Model de analiză în bazinul superior al Jijiei*, Edit. Academiei Române, Bucuresti.
37. Buruiană, D.; Apostol, L.; Machidon, Dana; Buruiană, M. (2012), *Some aspects of hidrological risk manifestation în Jijia basin*, în vol. conf. int. „Aerul şi apa – componente ale mediului", Univ. „Babeş-Bolyai", Presa Universitară Clujeană, Cluj-Napoca, ISSN 2067-743X, pp. 9-17.
38. Buruiană, D.; Apostol, L.; Machidon, O.; Buruiană, Mihaela (2012), *The identification of vulnerable localities to flash flows from the inferior basin of Jijia River through the physiographic method*, Annals of DAAAM for 2012 & Proceed. of the 23rd International DAAAM Sympos., vol. 23, No.1, ISSN 2304-1382, ISBN 978-3-901509-91-9, CDROM version, ed. B. Katalinic, published by DAAAM International,Vienna, Austria, pp. 707-710, ISI.
39. Buruiană, D.; Apostol, L.; Machidon, D *Risks associated with rainfall and floods in the Moldavian Plain,* GEOREVIEW: Scientific Annals of Stefan cel Mare University of Suceava. Geography Series, Vol. 24, 2014
40. Cantemir D. (1973), *Descrierea Moldovei*, Edit. Acad. Bucuresti.
41. Catrina Virginia (2008), *Studiul hidrogeochimic al cursului inferior al râului Bahlui*, Teză de doctorat, Universitea "Al.I.Cuza" Iasi.
42. Cădere R., Podani M. (1969), *Studiul resurselor de apă din R.S.România*, H.G.A.M., nr.9, Bucuresti.
43. Călinescu Gh., Călinescu Niculina, Soare Elena (1997). *Caracteristici şi tendinţe ale precipitaţiilor maxime căzute în diferite intervale de timp în Moldova*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.1314, 1993-1994, Iasi.
44. Chiang W.H., Kinzelbach W. (1998), *Processing MODFLOW. A simulation system for modelling groundwater flow and pollution*, Manual de utilizare.
45. Chelaru C., Gorincioi P. (coord.) (1980), *Iasi-monografie*, Edit. Sport-Turism, Bucuresti.
46. Teodoreanu Elena, Voiculescu M. (2003), *Indici şi metode cantitative utilizate în climatologie*, Edit. Universităţii din Oradea.
47. Chiriac V. (1956), *Vântul din orasul Iasi şi împrejurimi*, Probleme de hidortmeteorologie, Sibiu.
48. .Chiriac V., Cires C., Rădulescu Sirena (1968), *Variaţia de lungă durată a precipitaţiilor şi temperaturii aerului la Ias*i, Culegere de lucrări ale Institutului Meteorologic, Bucuresti.
49. Chiriac V., Filotti A., Teodorescu I. (1976), *Lacuri de acumulare*, Editura Ceres, Bucuresti.
50. Ciulache S.- (2002) *Meteorologie şi Climatologie*-Edit. Universitara,Bucureşti;
51. Ciulache S., Ionac Nicoleta (2006) *Esential în meteorologie şi climatologie*, Edit. Universitara, Bucureşti;
52. Ciulache S., Ionac Nicoleta (1995) *Fenomene atmosferice de risc* – Edit.Stiintifica, Bucureşti;
53. Condorachi D. (2004), *Utilizarea Sig în analiza morfometrică a bazinelor hidrografice de ordinul IV (system Horton –Strahler)*, Lucr. Seminarului Geografic „Dimitrie Cantemir", nr.23-24, 2002-2003, Iasi, pag.35-48.
54. Crăciun S. (1984), *Cu privire la cedarea apei din stratul de zăpadă şi posibilităţile de corelare cu temperatura maximă zilnică*, I.M.H., Probleme de hidrometrie, Bucuresti, pag.33-38.
55. Diaconu C., (1975), *Despre utilizarea corelaţiilor condiţionate în hidrologie*, Meteorology and Hydrology, vol.5, nr.1, Bucuresti.
56. Diaconu C. (1978), *Restoration of the river runoff*, Meteorology and hydrology, vol.8, nr.2, Bucuresti.
57. Diaconu C. (1980), *Prognoza viiturilor pe baza datelor asupra precipitaţiilor folosind bazine reprezentative indicatoare*, I.M.H., Probleme de hidrometrie, Bucuresti, pag. 3-14, Hidrotehnica, vol.32, nr.11, Bucuresti.
58. Diaconu C. (1992), *Probleme de metodica determinării curbelor teoretice ale probabilităţilor de depăsire (asigurare) în hidrologie*, Hidrotehnica, vol.37, nr.4-5, Bucuresti.
59. Diaconu C., Muscanu M. (1974), *În problema determinării timpilor de concentrare a scurgerii din ploi în bazine mic*i, Studii de hidrologie, vol.42, Bucuresti. pag.83-98.
60. Dragotă Carmen (2006), *Precipitaţiiile excedentare din România*, Edit. Academiei Române, Bucuresti.
61. Dragotă Carmen, Vaseciuc Felicia (1998) *Impactul factorilor de hazard climatic generat de precipitaţiile atmosferice excedentare căzute în intervalul 1 ianuarie-1 octombrie 1997 pe teritoriul României, cu referire specială la Moldova*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr 17-18, 1997-1998, Iasi.
62. Dragotă Carmen, Săraru L. (2001), *Parametrii îngheţului în aer la staţia meteorologică Iasi*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr. 19-20, 1999-2000, Iasi.
63. Drobot R. (1997), *Bazele statistice ale hidrologiei*, Edit. Didactică şi pedagogică, Bucuresti.
64. Drobot R. (2007), *Metode de determinare a bazinelor hidrografice torenţiale în care se află asezări umane expuse viiturilor rapide*, raport de cercetare, Univ. Politehnică, Bucuresti.

65. Dumitrescu, S. (1958), *Repartiția scurgerii pe sezoane la râurile din România*, Meteorologia, hidorlogia şi Gospodărirea apelor, vol.3, nr.1, Bucuresti.
66. Erhan Elena (1967), *Stratul de zăpadă la Iasi în perioada 1921-1966*, Anal.st. Univ. „Al.I.Cuza", secț.II, b, tom XIII, Iasi, pag. 197-204.
67. Erhan Elena (1968), *Dinamica atmosferei şi regimul vântului în zona orasului Iasi*, Anal.st. Univ. „Al.I.Cuza", secț.II, b, tom XIV, Iasi, pag. 207-212.
68. Erhan Elena (1979), *Clima şi micorclimatele din zona orasului Iasi şi din împrejurimi*, Edit. Junimea. Iasi.
69. Erhan Elena (1983), *Fenomenul de secetă în Podisul Moldovei,* Anal.st. Univ. „Al.I.Cuza", secț.II, b, tom XXIX, Iasi, pag. 67-72.
70. Erhan Elena (1987), *Considerații asupra precipitațiilor atmosferice din partea de est a României*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.8, 1987, Iasi, pag. 91-98.
71. Erhan Elena (1988), *Clima județului Iasi, „Locuri balneo-climaterice. Nămoluri şi ape minerale din Județele Iasi şi Vaslui*", Iasi, pag.74-87.
72. Erhan Elena (1992), *Particularitățile meteorologice ale anilor 1989-1990 în România*, Lucrările Seminarului geografic „Dimitrie Cantemir", nr.10, 1990, Iasi, 1992.
73. Erhan Elena (1993), *The thermal Potential of the Moldavian Plain*" Anal.st. Univ. „Al.I.Cuza", secț.II, c, tom XXXVIII-XXXIX, Iasi.
74. Erhan Elena (1997), *Nebulozitatea şi durata de strălucire a Soarelui la Iasi în ultimii 50 de ani*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.13-14, 1993-1994, Iasi.
75. Erhan Elena, (2002), *Ninsoarea şi stratul de zăpadă pe teritoriul Moldovei*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.21-22, 2000-2001, Iasi, 2002.
76. Erhan Elena, Stefan Valentina (1990), *Considerații asupra fenomenelor de brumă şi îngheț din Câmpia Moldovei,* Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.9, 1988, Iasi.
77. Giurma I. (2003), *Viituri şi măsuri de apărare*, Edit. „Gh.Asachi", Iasi.
78. Giurma I. (2004), *Hidrologie specială*, Edit. Politehnium, Iasi.
79. Gugiuman I. (1945), *Stațiuni meteorologice şi hidrografice în Moldova*, Rev. Geografică (I.C.G.R.), vol. II, Iasi.
80. Gugiuman I. (1946), *Frecvența inundațiilor la Bahlui*, Rev. „V.Adamachi", vol. XXXII, Iasi.
81. Gugiuman I. (1956), *Inundațiile Bahluiului şi pericolul lor pentru dezvoltarea spațială a orasului Iasi*, Probleme de Geografie, vol.III, Iasi, p. 169-181.
82. Gugiuman I. (1975), *Influența reliefului asupra diversificării climei din România*, Lucrările coloviului național de Geomorfologie aplicată şi catografiere geomorfologică, Iasi, pag.77-83.
83. Gugiuman I., Erhan Elena (1960), *Regimul precipitațiilor atmosferice la Iasi în perioada 1921-1955,* Anal.st. Univ. „Al.I.Cuza" (serie nouă) secț. II tom VI, fasc.1, Iasi, pag.211-222.
84. Gugiuman I., Petras Eugenia (1963), *Rolul dinamicii atmosferei şi al factorilor geografici în determinarea regimului temperaturii aerului în partea de est a R.P.R.*, Anal.st. Univ. „Al.I.Cuza" (serie nouă), secț.II, tom IX, Iasi.
85. Gugiuman I., Davidescu, G. (1965), *Variations de la temperature de l'air a Jassy pendant la periode 18941963*, Anal.st. Univ. „Al.I.Cuza" (serie nouă), secț.II, tom XI, Iasi.
86. Gugiuman I., Davidescu G. (1966), *Les particularites du regime pluviometrique dans la zone dela ville de jassy pendant la periode de 70 ans (1894-1963),* Anal.st. Univ. „Al.I.Cuza" (serie nouă), secț.II, tom XII, Iasi.
87. Haidu I. (2002), *Analiza de frecvență şi evaluarea cantitativă a riscurilor*, Riscuri şi catastrofe, casa Cărții de Stiință, Cluj-Napoca, pag. 180-207.
88. Haidu, I., Farcas, I. (1986), *Studiul variației de lungă durată a parametrilor hidroclimatici în scopul elaborării prognozei prin extrapolare analitică*, Probleme de geografie aplicată, Bucuresti.
89. Haidu I., Xu, C.Y. (1999), *Modelarea bilantului hidric al bazinului hidrografic la scară lunară*, Studii şi cercetpri de geografie, tom. XLV-XLVI, Bucuresti. pag.61-69.
90. Hârjoabă I., Ciubotaru Maria (1981), *Regimul zilnic al ploilor la Iasi*, Lucrările Seminarului geografic „Dimitrie Cantemir", nr.1, 1980, Iasi.
91. Hârjoabă I., Amăriucăi M., (1998), *Raportul dintre alimentarea de suprafață (S) şi subterană (U) la râul Bahlueț*, Lucr. Sem.Geogr. „Dimitrie Cantemir", nr.16-17, 1995-1996, Iasi, pag.69-74.
92. Hengl T., Reuter H.I. (2007), *Geomorfometry. Conceps-Software-Aplication*, http//gisstar.gsi.go.jp.
93. Iațu C. (1992), *Regimul precipitațiilor atmosferice în valea Jijiei*, Lucrările Seminarului geografic „Dimitrie Cantemir", nr.10, 1990, Iasi.
94. Ioniță I. (2000), *Relieful de cueste din Podisul Moldovei*, Edit. Corson, Iasi.
95. Ioniță I., Mărgineanu R. (2004), *Results on the nonconventional assesment of erosion and sedimentation from Moldavian Tableland*, Sustainable utilization of soil and water resources on sloping land, research results, Edit. Tiparul, Bârlad, pag 73-79.
96. Lăzărescu D. (1972), *Prognoza scurgerii în timpul viiturilor din ploi pe teritoriul României*, I.M.H., Studii de hidrologie, vol.XXXII, Bucuresti.
97. MACHIDON, O.; APOSTOL, L.; MACHIDON, Dana; BURUIANĂ, D. (2012), *Study of the evolution of the air temperature în Moldavia region (Romania), over the last 76 years,* Annals of DAAAM for 2012 & Proceed. of the 23rd International DAAAM Sympos., vol. 23, No.1, ISSN 2304-1382, ISBN 978-3-901509-91-

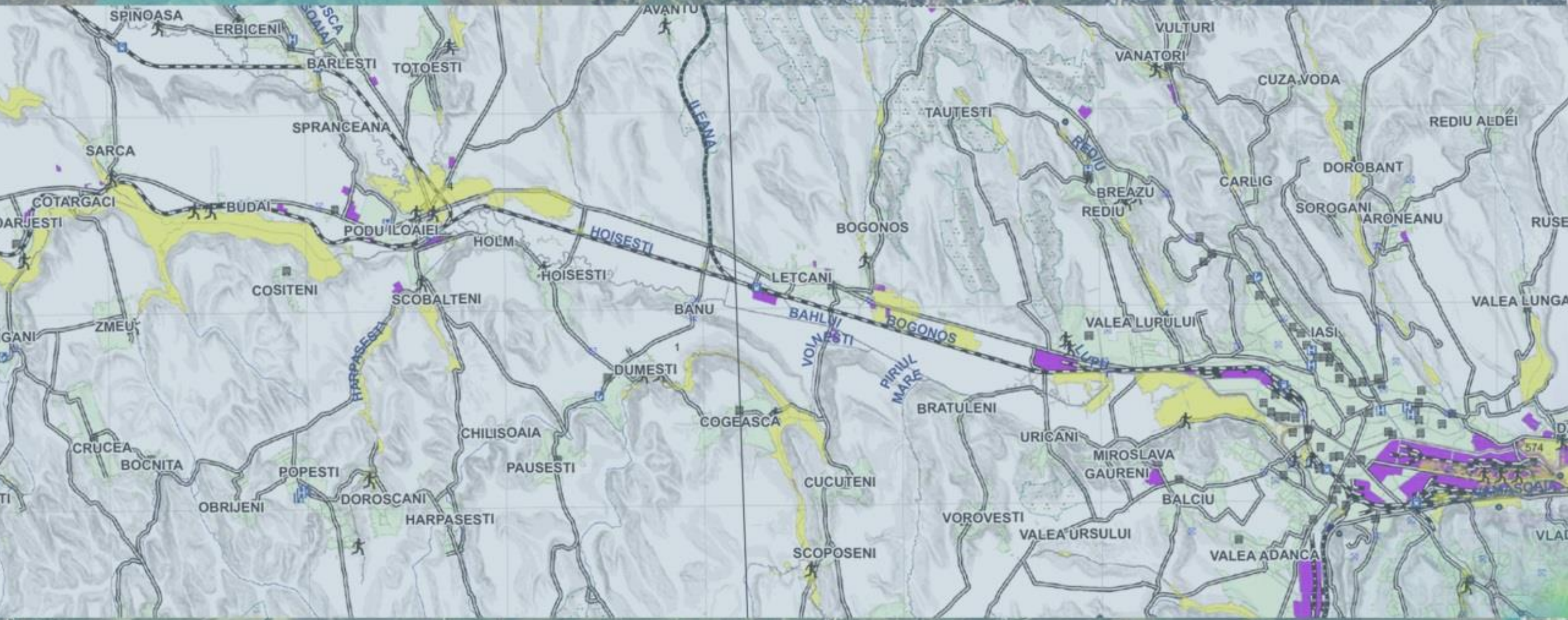
9, CDROM version, ed. B. Katalinic, published by DAAAM International, Vienna, Austria, pp. 688-692, ISI
98. Martiniuc C. (1955), *Podisul Moldovei, privire fizico-geografică,* în volumul „geografia Fizică a R.P.Române", Edit. Ministerul Învățământului şi culturii, Bucuresti. pag. 493-549.
99. Martiniuc C., Ungureanu Al. (1970), *Județul Iasi caracterizare geografică*, Terra, nr.1, Bucuresti. pag. 41
100. Mateescu Elena, Dragotă Carmen, Oprisescu Rodica (2001), *Impactul excedentelor de precipitații asupra culturilor de câmp din sudul Câmpiei Jijiei*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr. 1920, 1999-2000, Iasi.
101. Mărgărint M.C. (2000) *Aplicații GIS în studiul pedogeografic al teritoriului județului Iasi*, Anal.st. Univ. „Al.I.Cuza", supl. Simp.S.I.G., nr.6" Iasi.pag 67-72.
102. Mărgărint M.C. (2005), *Utilizarea teledetecției în studiul geografic al teritoriului județului Iasi,* Teză de doctorat.
103. Mihăilă D., Iftinca I. (1997), *Câteva aspecte legate de circulația maselor de aer în nordul Câmpiei Moldovei,* Lucrările Seminarului Geografic „Dimitrie Cantemir", nr.13-14, 1993-1994, Iasi.
104. Mihăilă D. (2002), *Clima Câmpiei Moldovei*, Teză de doctorat, Univ. „Al.I.Cuza", Iasi.
105. Minea I. (2004), *The evaluation of the hydric potential of Bahlui basin*, Anal.St. ale Univ. „Al.I.Cuza", tom XLIX-L, seria IIc, pag. 72-78, Iasi.
106. Minea I. (2004), *Caracteristicile scurgerii medii ale râului Bahlueț*, Sem.Geogr. „Dimitrie Cantemir", nr. 23-24, pag. 137-144, Iasi.
107. Minea I., (2009), *The analysis of flooding risk în Bahlui basin*, Studia Universitatis Babes-Bolyai, Geographia volume 54 (2009) no.3, Cluj Napoca.
108. Minea I. (2009) Bazinul hidrografic Bahlui – studio hidrologic, Teză de doctorat, Univ. "Al. I.Cuza" Iaşi
109. Minea I., Stângă I.C. (2004), *Analiza variabilității spațiale a unor indici de apreciere a secetelor,* Riscuri şi Catastrofe III, Editor Victor Sorocovschi, Edit. Casa Cărții de Stiință, pag. 138-149, Cluj-Napoca.
110. Minea I., Stângă I.C. (2004), *Evaluarea perioadelor secetoase în Câmpia Moldovei*, IC.DMP.1., „Gh.Asachi" Tehnical University, Edit. Performantica, pag. 131-142, Iasi.
111. Minea I., Stângă I.C., Vasiliniuc I. (2005), *Consideratii privind fenomenul de seceta în Podisul Moldovei*, Comunicari de Geografie, volumul IX, Edit. Univ. Bucuresti. pag. 215-220.
112. Miță P. (1977), *Regimul termic şi de îngheț al cursurilor de apă din România*, Rezumatul tezei de doctorat, Bucuresti.
113. Miță P., Muscanu M., Mustață L. (1988), *Determinarea principalilor parametri ai formulelor pentru calculul debitelor maxime în bazine mici*, Studii şi cercetări de hidorlogie, vol.57, Bucuresti. pag. 33-42.
114. Mociorniță C. (1964), *Unele rezultate ale studierii scurgerii maxime pluviale pe râurile din România,* Studii de hidorlogie, vol.5, Bucuresti. pag.35-54.
115. Mociorniță C. (1965), *Calculul debitelor maxime pe râurile României*, Meteorologia, hidorlogia şi gospodărirea apelor, vol.10, nr.1, Bucuresti.
116. Mociorniță C., Dincă A., Nițulescu M. (1963), *Repartiția scurgerii pe sezoane şi luni în cadrul anului mediu pe râurile din R.P.R.,* Studii de hidrologie, vol. V., Bucuresti, pag. 3-24.
117. Mustață L. (1964), *Cu privire la metoda de calcul a precipitațiilor maxime pe teritoriul R.S.R.,* Hidrotehnica, Gosp. Apelor şi Meteorologie, nr.2, Bucuresti.
118. Mustață L. (1964), *Cu privire la debitele maxime din ploi pe râurile din România*, Hidortehnica, gospodărirea apelor şi meteorlogia, vol.9, nr.3, Bucuresti.
119. Mustață L. (1964), *Analiza formării şi metodica de calcul a hidrografelor viiturilor pluviale pe râurile României*, Studii de hidrologie, vol.11, Bucuresti.pag55-80.
120. Mustață L. (1974), *În problema determinării debitelor maxime din ploi pe râuri mici*, Hidrotehnica, vol.5, Bucuresti.
121. Mustață L. (1979), *Unele considerații privind fenomenele de iarnă pe râurile mici*, I.M.H., Studii şi cercetări, partea a II-a, Hidrologie, XLVII, Bucuresti. pag 63 -73.
122. Mustață L. (1984), *Contribution aux problemes de la determination des debits maxima engendres par les pluies sur le petites rivieres*, Meteorology and Hydrology, vol.4, nr.2, Bucuresti.
123. Mustață L. (1984), *Du probleme de la determination de l'ecoulement moyen multiannuel*, Meteorology and Hydrology, nr.1, Bucuresti, pag. 21-25.
124. Mustață L., Ani E., Stănculescu S., Ungureanu E. (1962), *Contribuție la precizarea provenienței celor mai mari debite pe râurile din România,* Studii de hidrologie, vol.2, Bucuresti, pag. 91-108.
125. Mustață L., Miță P. (1969), *Variația debitelor maxime pe râurile din România*, Studii de hidorlogie, vol.36, pag. 133-148.
126. Mustățea, A. (2005), *Viituri excepționale pe teritoriul României*. Geneză și efecte. I.N.H.G.A., București;
127. Musy A. (1998), *Hidrologie appliquee*, Edit. H.G.A., Bucuresti.
128. Mutihac V., Ionesi L. (1974), *Geologia României*, Ed.Tehnică, Bucuresti.
129. Niculescu Elena (1999), *Ani şi luni deficitare pluviometric în România în ultimul secol, Revista geografică,* Acad. Română, institutul de Geografie, t.V, serie nouă, Bucuresti. pag. 41-48.
130. Pandi G., Moldovan F. (2003), *Importanța prognozelor în diminuarea riscurilor meteorologice şi hidrologice*, Edit. Casa Cărții de Stiință, Cluj-Napoca. pag 287-302.
131. Pantazică Maria (1958), *Raionarea hidrologică a bazinului râului Bahlui*, Anal.st. Univ. „Al.I.Cuza", (serie

nouă), Secţ. II., tom IV, anul 1958, fasc.1, Iasi, pag. 237-240.

132. Pantazică Maria (1966), *Contribuţii la studiul hidrologic al râurilor din partea de nord-est a Moldovei*, Anal.St. Univ. „Al.I.Cuza", secţ.II., b.geol-geogr., tom XII, Iasi, pag. 157-164.
133. Pantazică Maria (1967), *Regimul de îngheţ al râurilor din nord-estul Moldovei*, Anal.st. Univ. „Al.I.Cuza", secţ. II, b, tom XIII, Iasi, pag. 155-161.
134. Pantazică Maria (1971), *Scurgerea minimă pe râurile din nord-estul Moldovei*, Anal.st. Univ. „Al.I.Cuza", secţ.II, c, tom XVII, Iasi, pag. 51-59.
135. Pantazică Maria (1974), Hidrografia Câmpiei Moldovei, Edit.Junimea, Iasi. 359.Pantazică, Maria, Schram, Maria (1967), Contribuţii la cunoasterea hidrologică a bazinului râului Miletin,Hidrobiologia, tom 8, Bucuresti.
136. Patriche Emilia-Isabela (2002), Consideraţii asupra regimului termic multianual în Câmpia Moldovei, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr 21-22, 2000-2001, Iasi
137. Platagea Maria (1974), Caracteristicile de calcul ale ploilor torenţiale necesare în determinarea debitelor maxime pe versanţi şi în bazinele hidorgrafice mici de pe teritoriul României, Hidrotehnica, vol.2, Bucuresti.
138. Platagea G. (1959), Studiul ploilor torenţiale pe teritoriul R.P.R şi influenţa lor asupra scurgerii, Meteorologie, Hidrologie şi Gospodărirea Apelor, nr.4, Bucuresti.
139. Platagea G. (1961), *Consideraţii asupra genezei şi frecvenţei viiturilor cu aplicaţie la teritoriul R.P.R.,* Probleme de geografie, vol.VIII, Bucuresti. pag. 325-346.
140. Platagea G., Platagea Maria (1958), *Distribuţia teritorială şi calculul debitelor maxime pluviale pe râurile din România,* Meteorologia, Hidrologia şi gospodărirea apelor, vol.3, nr.2-3, Bucuresti.
141. Platagea G., Platagea Maria (1958), *Unele probleme cu privire la determinarea debitelor maxime pluviale pe râurile din R.P.R.,* Studii de hidrologie, I:SCH, vol XVII, Bucuresti.
142. Platagea Gh., Platagea Maria (1981), *În problema determinării debitelor maxime de apă generate de ploi torenţiale în bazine hidrografice mari de pe teritoriul României*, Hidrotehnica, vol.12, Bucuresti.
143. Romanescu Gh. (2002), *Inundaţiile – între natural şi accidental*, Riscuri şi catastrofe, II, Editor Victor Sorocovschi, Casa Cărţii de Ştiinţă, Cluj-Napoca, pag.130-138.
144. Romanescu Gh. (2004), *Caracterele hidrologice ale Coastei de tranziţie a Iasului*, Lucr. sem. „Dimitrie Cantemir", nr.23-24, 2002-2003, Iasi, pag.127-136.
145. Romanescu Gh. (2006), *Inundaţiile ca factor de risc. Studiu de caz pentru viiturile Siretului din iulie 2005*, Editura TERRA NOSTRA, Iaşi, ISBN 973-8432-49-9, 978-973-8432-49-9, 88 pag
146. Romanescu Gh. (2009), *Evaluarea riscurilor hidrologice,* ISBN 978-973-1888-15-6, Editura Terra Nostra, Iaşi, pag. 177
147. Romanescu Gh. (2009), *The risk of wetlands disappearance în the Moldavian Plateau under the conditions of rudimentary agricultural techniques use,* Riscuri şi Catastrofe, An VIII, Nr.7, Editor Victor Sorocovschi, Editura Casa Cărţii de Ştiinţă, Cluj-Napoca, ISSN 1584-5273, pag.179-192
148. Secu C.V. (2003), *Bazinul râului Baseu. Studiu fizico-geografic*, Edit. Terra Nostra, Iasi.
149. Secu C.V., Niacsu L., Vasiliniuc I., Rosca B., Parnău R. (2007), *Atlasul culorilor şi semnelor convenţionale pentru legenda hărţii solurilor. Propunere pentru utilizatorii de S.I.G.*, Edit. Terra Nostra, Iasi.
150. Sevastos R. (1913), *Formaţiunea geologică a solului Iasului şi împrejurimilor sale*, în N.Bogdan, Orasul Iasi, Iasi, pag. 54-62.
151. Sevastos R. (1922), Depozitele cuaternare din sesul Prutului şi al Jijiei, Anuarul Inst. Geol., IX, 1915-1920, Bucuresti.
152. Sfîcă L. (2008), Synoptic conditions for the occurence a monthy extreme temperature on Siret Coridor, Anal.st Univ. „Al.I.Cuza", secţ.II, tom LVI, sect.II, geografie, Iasi, pag. 49-58.
153. Sfîcă L., Minea I. (2006), Les quantites maximalles de precipitations en 24h dans le basin hidrographique de la riviere de Bahlui, Sem.Geogr. „Dimitrie Cantemir", nr. 26, pag.79-86, Iasi, 2006

154. Sorocovschi V. (2003), Complexitatea teritorială a riscurilor şi catastrofelor, Riscuri şi catastrofe, Edit. Casa Cărţii de Stiinţă, Cluj-Napoca. pag 27-38.
155. Sorocovschi V. (2002), Riscurile hidrice, Riscuri şi catastrofe, Edit. Casa Cărţii de Stiinţă, Cluj-Napoca. pag 55-64.
156. Stănescu I., Băcăuanu V. (1979), *Câteva consideraţii de geomorfologie asplicată privind teritoriul comunei Strunga-Judeţul Iasi*, Anal.st Univ. „Al.I.Cuza", secţ.II, b, tom XXV, Iasi. pag.129-133.
157. Stanga I. -*Riscul natural – intre hazard şi catastrofa* (2004), Lucr. Seminarului Geografic Dimitrie Cantemir, Nr.23-24, Iasi.
158. Stângă I.C. (2007), Riscuri naturale – noţiuni şi concepte, Edit. "Al.I.Cuza" Iasi.
159. Serban P. (1984), *Metoda de calcul a cedării apei din stratul de zăpadă*, Hidrotehnica, vol.29, nr.3, Bucuresti.
160. Serban P. (1984) *Modele matematice pentru prognoza undelor de viitură în bazine amenajate hidrotehni*c, Studii şi cercetări de hidorlogie, vol.51, Bucuresti, pag. 269.
161. Serban P. (1984), *Model conceptual pentru determinarea hidrografului unitar instantaneu*, Hidrotehnica, vol.29.nr.4 Bucuresti.
162. Serban P. (1986), *Modele hidrologice operaţionale*, Studii şi cercetări de hidrologie, vol.55, Bucuresti.

163. Topor N. (1964), *Ani ploiosi şi secetosi în România*, Bucuresti.
164. Trofin N., Oprea, A. (2004), *Apărarea împotriva inundațiilor, fenomenelor meteorologice periculoase şi accidentelor la construcțiile hidrotehnice la nivelul județului Iasi*, ICDPM, nr.1, Edit. Performantica, Iasi. pag.99-105.
165. Trufas V. (1969), *Quelques aspects du regime thermique des rivieres de Roumanie,* RRGGG-geogr., tom 13, nr.4, Bucuresti.
166. Tufescu V. (1935), *Inundațiile Bahluiului*, Rev.St. „V.Adamachi"vol. XXI, nr 2-3, Iasi. pag. 99-103.
167. Tufescu V. (1937), *Dealul Mare-Hârlău,* Bul.Soc.de geografie, tom LVI, Bucuresti, pag. 48.
168. Ujvari I. (1957), *Alimentarea râurilor din R.P.R*., Meteorologia şi Hidrologia, nr.1, Bucuresti.
169. Ujvari I. (1957), *Despre bilanțul apei pe teritoriul R.P.R.,* Meteorologia şi Hidrologia, nr.4, Bucuresti
170. Ujvari I. (1959), *Hidrografia R.P.R*., Edit.Stiințifică, Bucuresti.
171. Ujvari I. (1972), *Geografia apelor României*, Edit. Stiințifică, Bucuresti.
172. Ujvari I. (1980), *Les types de regime hydrique des rivieres de la Roumanie*, RRGGG, geogr., tom 24, Bucuresti.
173. Ujvari I., Gâstescu P. (1958), *Evaporația de pe suprafața lacurilor din R.P.R., Meteorlogia, hidorlogia şi gospodărirea apelor,* nr.1, Bucuresti.
174. Ujvari I., Nițulescu M., Păduraru Aneta (1958), *Secarea râurilor din R.P.R şi condițiile specifice acestui fenomen*, Meteorologia, Hidrologia şi Gospodărirea apelor, nr.4, Bucuresti.
175. Ujvari I., Pandi, G. (1985), *Suprafețele adiacente în prognoza scurgerii solide*, Hidrotehnica, vol.30, nr.2, Bucuresti.
176. Ungureanu Al. (1993) *Geografia podisurilor şi câmpiilor României*, Univ."Al.I.Cuza", Iasi.
177. Ursu A., Sfîcă L., Niacsu, L., Minea I., Vasiliniuc I., Stângă I.C. (2007), *The changes occured în the land use from the eastern part of Romania after 1989–remote sensing and GIS application,* Present Enviroment and Sustainable Development vol.1/2007, Edit. Univ. „Al.I.Cuza" Iasi, pag. 312-320.
178. *Ursu A., Sfică L., Stoleriu C., Rosca B., Stoleriu Oana, Niacsu L., Minea I., Patriche C.V., Căpățână V., Stoica D.L. (2007), Corine Land Cover 2000-2006, Anal.St. ale Univ. „Al.I.Cuza", tom LIII, s.II supliment,* Lucr. Simpozionului Sisteme Informaționale Geografice, nr.13, Iasi, pag.161-170.
179. Vartolomei F. *(2008), Bazinul Prutului – studiu de hidrologie, Rezumatul tezei de docotrat.*
180. Vârlan M., Apetrei M. (1992), *Aspecte ale morfometriei albiilor majore în Podisul Moldovei*, Anal. St. Univ. „Stefan ce Mare", secț.geogr.geol., an II, Suceava. pag.76-85.
181. Vasenciuc Felicia, (2001), *Impactul precipitațiilor excedentare, din intervalul 01.01-31.08.1999 asupra mediului din România*, Lucrările Seminarului Geografic „Dimitrie Cantemir", nr. 19-20, Iasi.
182. * * * *Anuarele hidrografice 1922-1951*, Direcția Generală Hidrologică.
183. * * * *Anuare hidrologice 1953-1963*, I.S.C.H. Bucuresti.
184. * * * *Anuare meteorologice 1961-1972*, Institul meteorologic, Bucuresti
185. * * * (1960), *Monografia geografică a R.P.R*., vol.I, Edit. Academiei R.P.R., Bucuresti.
186. * * * (1961), Clima României, vol.I, Institutul Meteorologic, Bucuresti
187. ** * (1964), Atlasul cadastrului apelor din R.S.R., vol.I, Rețeaua hidrografică, Comitetul de stat al apelor, Bucuresti.
188. * * * (1966), *Clima R.S.R.*, vol. II, *Date climatologice*, Institutul Meteorologic Bucuresti.
189. * * * (1966), *Îndrumări metodologice pentru calcule hidrologice asupra râurilor,* I.D.-32-66, Bucuresti.
190. * * * (1971), *Râurile României*. *Monografie hidrologică*, I.M.H., Bucuresti 458.* * * (1974), *Atlasul climatologic al României*, Institul meteorologic, Bucuresti.
191. * * * (1982), *Geografia României*, vol.I., Edit. Academiei R..S.R., Bucuresti.
192. * * * (1992), *Geografia României*, vol.IV., Edit. Academiei R..S.R., Bucuresti.
193. * * * (1992), *Atlasul Cadastrului apelor din România*, Ministerul Mediului, Bucuresti.
194. * * * (1997), *Îndrumar pentru stațiile hidrometrice pe râuri*, I.N.M.H., Bucuresti.
195. * * * (2008), *Clima României,* Institutul de geografie, Bucuresti.
196. http://www.mmediu.ro/beta/domenii/managementul-apelor-2/managementul-riscului-la-inundatii/
197. http://www.rowater.ro/HH%20si%20HRI/Harti%20de%20hazard%20si%20risc%20la%20inundatii.aspx
198. http://www.rowater.ro/Continut%20Site/Planuri%20bazinale.aspx
199. http://www.ancpi.ro/pages/wiki.php?lang=ro&pnu=hartiSiPlanuri 468.http://www.apeprut.ro/
200. http://www.swstechnology.com/groundwater-software/groundwater-modeling/visual-modflow
201. http://wetteryentrale.de/topkarten/fsreauer.html 471.http://www.hidro.ro/
202. http://www.CENTRUL_METEOROLOGIC_REGIONAL_MOLDOVA-who1973414.html


SPIÑOASA
ERBICENI
BARLESTI
TOTOESTI
AVANTU
SPRANCEANA
SARCA
COTARGACI
BUDAI
PODU ILOAIEI
HOLM
COSITENI
SCOBALTENI
HOISESTI
ZMEU
HARPASESTI
CRUCEA
BOCNITA
POPESTI
DOROSCANI
OBRIJENI
HARPASESTI
CHILISOAIA
PAUSESTI
DUMESTI
BANU
COGEASCA
CUCUTENI
SCOPOSENI
ILEANA
HOISESTI
LETCANI
BAHLUI
VOINESTI
BOGONOS
BOGONOS
PIRIUL MARE
TAUTESTI
VULTURI
VANATORI
CUZA VODA
REDIU ALDEI
REDIU
BREAZU
REDIU
CARLIG
DOROBANT
SOROGANI
ARONEANU
VALEA LUPULUI
IASI
VALEA LUNGA
BRATULENI
URICANI
MIROSLAVA
GAURENI
BALCIU
VOROVESTI
VALEA URSULUI
VALEA ADANCA
574