Assessment of flood runoff and land cover changes in the Căinari river basin

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ABSTRACT: The present research is dedicated to assessment of flood runoff of the Căinari river situated in the northern part of the Republic of Moldova. A special attention is paid to evaluation of flood runoff temporal and spatial distribution and its changes due to different factors. Direct and indirect methods were used in order to perform the research tasks. General and statistical analysis was applied to estimate temporal evolution, trends, cycle fluctuations and to calculate statistical parameters and values of different return period of the Căinari river flood runoff characteristics measured at Sevirova station (1954-present). Spatial distribution of flood runoff and its changes due to land use management activities from the last 3 decades was performed using SCS-CN model. Analysis of temporal dynamics shows that in the last 60 years the trend of peak discharges is decreasing while the one of flood runoff depth is slowly increasing. Main flood runoff characteristics are: average peak discharge - 16.3 m^3/s, depth - 4.41 mm, volume - 3.6 mln. m^3, total duration - 9.0 days. Flood events monthly distribution is as follows: June – 34 %, July – 25 %, May – 14 %. Flood runoff modeling was performed for ungauged tributaries of the Căinari river in condition of equal rainfall of 100 mm, land cover for 1982 and 2013 and 3 soil moisture conditions: dry, wet and average. Average modeled flood runoff values are 58 mm, 28 mm in case of dry soil and 84 in case of wet soils. General dynamics shows that for the last 3 decades the flood runoff has slightly decreased due to increasing grassland and orchards areas and decreasing share of arable land.

KEY WORDS: flood runoff, the Căinari river, land cover impact.

1. Introduction

In conditions of actual climate and landscape dynamics caused by different factors, main being human impact, floods continue to be main hydrological disasters on the territory of the Republic of Moldova. From the flood types which occur in the country limits the biggest damage is caused by flash floods as well as by river floods on large rivers: the Dniester and Prut. In conditions when river flood hazard/risk areas, to a large extent, are known and different flood protection measures are undertaken, flash floods and floods on smaller rivers continue to be a challenge.

Main flood generation factors, as usual, are heavy rains, the effect being amplified by physical-geographical features, soils moisture and texture state, vegetation as well as anthropogenic factors. Heavy rains, specific for warm period, increase up to 150-200 mm/day. Maximal precipitation values cannot be regionalized because the whole country is affected by this phenomenon, however northern and south-eastern regions are more impacted. Country topography is represented by succession of hills and plains from the north to the south, the highest elevation and the steepest slopes are specific for central part of the country. Land use is mostly characterized by agricultural land (≈70 %). Natural cover (forest and grassland) as well as orchards are predominant for central part of the republic, the northern and southern being arable area (Jeleapov, 2018).

In the Republic of Moldova, experiences of flood runoff estimation are based on application of direct and indirect methods. Direct methods, mainly statistical analysis, are used for assessment of the database collected at the hydrological stations of national monitoring network. From indirect methods applied for modeling of different flood characteristics, reduction and genetic models are historically mainly recommended and used (DCHCRM, 2013; EMUCRM, 2009; PSIRM, -2002; Jeleapov, 2017a; Melniciuc, 2012). However, in the last decade, application of larger number of methods for estimation of ungauged rivers flood runoff is observed, from them SCS-CN, InfoWorks, HEC-RAS can be mentioned (MFPP, 2014; Jeleapov, 2014, 2016a, 2016b, 2017b, 2018).

Regional evaluation of flood runoff (Jeleapov, 2018) shows that more affected zones are central and northern part of country. Present study aims to perform an evaluation of flood runoff and its changes over the last decades generated in one of the rivers situated in the northern part of the country - the Căinari river. Main research activities are oriented to analysis of flood runoff times series; identification of trends and probable maximal discharges; estimation of flood characteristics values; development of flood runoff cartographic models for different cases/scenarios. A special attention is paid to evaluation of changes in land cover for the last 3 decades and its impact on flood runoff of ungauged tributaries.

2. Study area

Assessment of flood runoff, its changes and modeling for ungauged rivers was performed for the Căinari river as well as its tributaries (Fig. 1, 2). The Căinari river flows through the northern part of the Republic of Moldova, it springs from the Northern Moldova Plateau (Boboc, 2009), flows through the Dniester Hills and Cubolta Plain and flows into the Răut river. The Căinari river length is 99.8 km, sinuosity is 1.41, slope - 1.68°, gradient - 168 m, the river basin - 836 km^2. River flow is measured at Sevirova station, located in the downstream part of the river, beginning from 1954 till present (CSA, 2006). Average annual discharge is 1.4 m^3/s, volume - 43.7 mil. m^3. Spatial distribution of flood hazard area, performed as a result of assessment of precipitations, slope and accumulation capacity of the floodplain is estimated to be of 17.3 km^2, while flood depth is up to 2.5 m (Fig. 1).

River stream is hydromorphologically modified by river training activities performed in the 50-70s of the last century as well as construction of flood protection dykes and irrigation channels in the floodplain. Reservoirs, as indicators of river morphology change, were built for different purposes (fishery, recreation, irrigation), one of them being river flow regulation. In total, 10 reservoirs are constructed on the Căinari river stream, the largest ones being situated in the middle part of the river. Unfortunately, information regarding actual state of all reservoirs and ponds is missing. However, it should be mentioned that all reservoirs are subject to siltation process. From existed information, the volume of reservoir situated near Cotova village decreased from 1.14 mil. m^3 in

1984 to 0.8 mil. m^3 in 2000, of the one near Zgurița - from 1.64 mil. m^3 in 1980 to 1.2 mil. m^3 in 2000 (RARM, 2007). Volume reduction is estimated to 30% for 16-20 years, thus actual reservoirs capacity to regulate runoff is practically totally reduced and dam failure in case of large floods represents a real risk.

Assessment of flood runoff generated on the Căinari river tributaries, which flow is not monitored but can be estimated using indirect methods, represents one of the main task of present research. 9 main tributaries were taken into account (Fig. 2, Tab. 1), the longest is the Bolata (Bulata), with a length of 45.2 km, the shortest is the Zgurița - 6.84 km. Average tributaries lengths is 14.8 km, basins area - 55.6 km^2. The river streams are also modified and river flow is regulated by reservoirs operation. The biggest number of reservoir is observed on the Bolata - 6 and on the Berezovca - 4 reservoirs.

The highest river basins altitudes and slopes are specific for tributaries from upper part of the Căinari basin (>200 m.abs. average altitudes - 6 river basins) while the lowest elevation and slope is present for 2 tributaries from downstream part - the Valea Viei and Valea Frumușica rivers.

Main soils are chernozems. From the perspective of runoff potential and infiltration rates, the region is characterized by fine-texture soils with high runoff potential and slow infiltration capacity (estimated based on FNDG geoportal.md). Soil classification was performed according to the soil texture into 4 groups from coarse-textured or sandy soils (A group) to fine-textured or clayey soil (D group) (SCS, 1956, 1972, 2004; Stematiu and Drobot, 2007). The biggest portion of the study area is occupied by the C group soils – 70 %. Soils of A and B groups - coarse-texture soils - are practically absent or in low proportion in the tributaries basins. Soils of D group have a share from 1.5 % to 44.3 %, average being – 28 %. The share of 60-70% of C soil group and 20-30 % of D soil group is specific for Berezovca, Visoca, Bolata, Valea Viei, Valea Frumușica and Căinari river basins. The soils of the Sudarca river basin are mainly of C soil group. In the Teleșeuca and Zgurița river basins C and D soil groups are of aprox. equal share (tab. 1).

Table 1 Characteristics of the Căinari River tributaries and their basins.

Rivers	**Lengths, km**	**Basin area, km²**	**Basin mean elevation, m. abs.**	**Number of reservoir on the stream**	**Hydrologic soil group, %**			
					A	**B**	**C**	**D**
Berezovca	8.96	22.7	230	4	0.0	0.0	67.3	32.7
Sudarca	8.98	23.3	222	3	0.0	0.1	98.4	1.5
Teleșeuca	12.4	32.3	220	3	0.0	0.0	55.7	44.3
Visoca	13.9	40.4	214	1	0.0	0.0	71.4	28.6
Zgurița	6.84	20.1	210	1	6.8	12.1	47.6	33.4
Bolata (Bulata)	45.2	237.7	200	6	0.0	6.9	64.4	28.7
Valea Viei	11.6	33.6	174	2	0.0	4.8	61.5	33.7
Valea Frumușica	10.4	35.0	159	2	0.0	2.2	71.5	26.3
Căinari	99.8	835.9	191	10	0.2	4.1	71.8	23.9

The Căinari river basin is a typically agrarian region. Arable area occupies over 60 % of the basin territory. Other lands are covered by orchard – 9 %, settlements - 7 %. Grassland forms 13 % and forest – 4 % of the total area (estimated based on FNDG).

It should be mentioned that in the limits of the Căinari river basin there is only one meteorological station situated in the downstream part of the river in the same location with hydrological post. In these conditions, it is possible to make only some general conclusions regarding heavy rains at the basinal scale. Average value of daily sum of maximal precipitations is 47 mm. In general, the daily sum of precipitation over 50 mm were measured only 16 times for the period of 1970-2010 (Tab.

2). Month with the biggest number of cases of such phenomena is July with 7 cases of heavy rains, followed by June with 4 cases. Daily sum of precipitation over 50 mm was also observed in August and September. Heavy rains are characteristic only for summer period and September. Precipitations in the other months are of lower values.

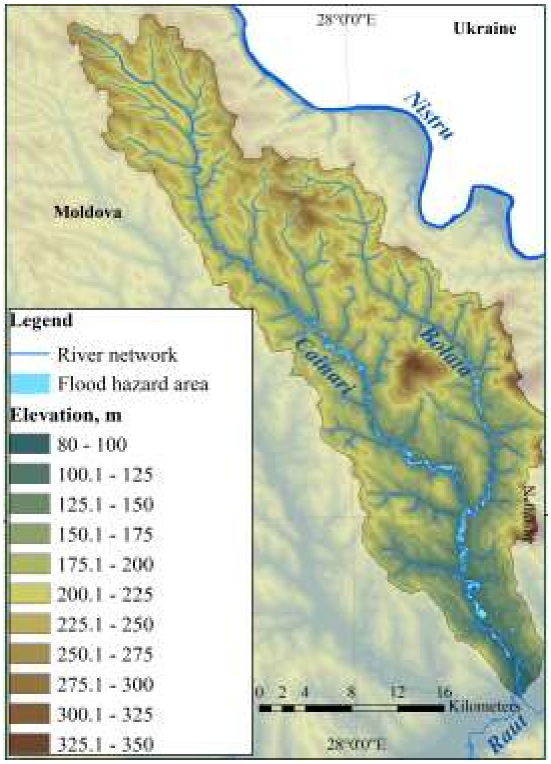

Figure 1 The Căinari river basin.

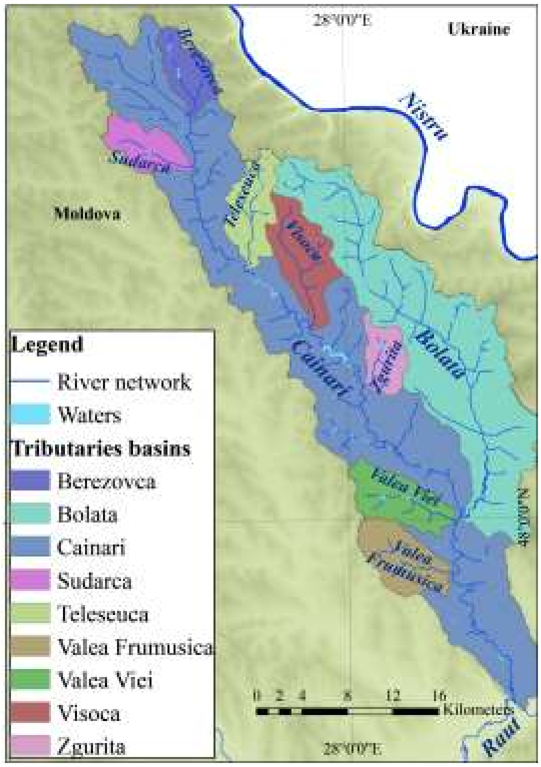

Figure 2 Main rivers and basins.

Table 2 Number of cases of daily sum of precipitation over 50 mm, Sevirova st. 1970 – 2010.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
Nr. of cases	0	0	0	0	0	4	7	2	3	0	0	0	16
Share, %	0	0	0	0	0	25	43.75	12.5	18.75	0	0	0	100

The highest registered daily sum values increase up to 97 mm at Sevirova st., however these were observed only once, on July 4, 1991. Analysis of time series of the nearest meteorological station, Dodnușeni, showed that the daily sums can be much higher, as for example, at this station the maximal value during 1970-2010 increased twice the value of 100 mm: on June 18 1985 -104.4 mm, and on June 19 1971 - 111.4 mm (estimated based on Arhiva SHS 1945-2012; WMO, 2019).

3. Methods and materials

Assessment of flood runoff and its changes was performed using both direct and indirect methods. Statistical methods were applied to perform variational analysis of flood runoff measured at Sevirova station. At first stage, the time series were generally analyzed, the most significant registered pluvial floods events were extracted and cyclical fluctuation, annual and monthly trends were evaluated. Subsequently, the maximal rainfall, peak discharges and flood runoff time series were analyzed in terms of quality: homogeneity and stationarity, as well as, statistical parameters: average values, coefficient of variation, skewness, autocorrelation and error were calculated. Finally, flood runoff values of different return periods were estimated. Application of main statistical methods was performed based on recommendation from national normative documents (DCHCRM, 2013; ICSMBM, 1997). The time series confidence level was estimated using homogeneity and stationarity tests based on Fisher criteria and autocorrelation coefficients. Estimation of return period values was performed using probability theory laws and construction empirical (Weibull equation) and theoretical assurance (Pearson III / Kritski-Menkel distribution) curves. Cyclical fluctuations were analyses by integral curves construction.

For estimation of flood runoff values for ungauged rivers and modeling its spatial distribution for the entire Căinari river basin, the SCS-CN model was applied (SCS, 1956, 1972, 2004). This model application on other rivers of the Republic of Moldova in order to determine flood runoff values showed plausible results and was validate on gauged rivers (Jeleapov, 2016b, 2017b, 2018). The SCS-CN model integrates several factors that influence on flood runoff generation: soil, precipitation, land cover. All these factors, as well as modeled flood runoff can be spatially represented and the model can be applied using GIS techniques.

Main material used in the research refer to hydrological and meteorological times series which were extracted from the archive of State Hydrometeorological Service, National water cadastre and WMO database, as well as, to information regarding spatial distribution of land cover types, soil types, texture which was extracted from National Geospatial Data Fund www.geoportal.md. Land cover was digitized from topographic maps at 1:50000 developed in 1982 and in 2013 and corrected using Landsat satellite images (USGS, 2019). The land cover was classified in 9 types:

1. Settlements 2. Orchards 3. Vineyards 4. Arable area 5. Forest
6. Shrubs 7. Grassland 8. Wetlands 9. Water (reservoirs)

Specific changes in the spatial structure of land cover were estimated using comparative analysis highlighting increasing or decreasing area occupied by different types of land cover for the last 3 decades. Spatial modeling was performed using QGIS (QGIS, 2019).

4. Results and discussion

4.1. Measured flood runoff trends

In accordance with monitoring observations at Sevirova gauging station, the Căinari average flood runoff characteristics are as follows: average peak discharge - 14.7 m^3/s, flood runoff depth - 4.1 mm, average flood volume - 2.5 mln. m^3, total flood duration - 12.8 days (from which average rising limb - 4.1 days). In comparison with average values, the most significant pluvial floods registered for the period 1954-2018 were observed in 1991 with the highest ever recorded peak discharge of 166 m^3/s, a flood depth of 38 mm., volume of 30.7 mil. m^3, as well as in 1971 with a peak discharge of 84.8 m^3/s, a flood depth of 24 mm, volume of 19.5 mil. m^3. The duration of the largest flood event was 20 days, and 10 days for the other high flood. The flood hydrographs are of a typical triangular shape, the rising limb being much shorter than the falling one (Fig. 3). The characteristics of 8 highest flood events are shown in the table 3.

To some extent, it can be assumed that flood runoff is regulated by the reservoirs situated in the upper and middle part, however, information on this regard is missing and no monitoring is performed on the inflow and outflow of any reservoirs in the Căinari river basin. In any case, reservoirs impact on higher flood events regulation is considered very low, their capacity being even very reduced to make any control of smaller floods, considering the fact that the largest reservoirs constructed on the stream can accumulate a total volume of max. 1 mil. m^3. and their number are only 2, the others being much smaller.

Table 3 The most significant registered pluvial floods events of the Căinari river, Sevirova st.

Empirical P., %	Peak discharge, m^3/s	Flood depth, mm	Flood volume, mln. m^3	Period, days	Empirical P., %	Peak discharge, m^3/s	Flood depth, mm	Flood volume, mln. m^3	Period, days
2	166	38.0	30.7	2.07-22.07.1991	9	39.1	5.3	4.3	27.06-9.07.1955
3	84.8	24.0	19.5	2.07-12.07.1971	10	38.0	11.0	9.2	31.05-15.06.1970
5	55.7	16.7	13.6	25.07-8.08.2008	12	36.2	7.2	5.9	02.06-8.06.1975
7	43	23.0	18.9	17.06-3.07.1985	14	33.8	19.0	15.2	6.05-31.05.1981

Analysis of monthly distribution of peak discharges of the highest flood events, that occurred in those 65 years of monitoring period considered in the present study, shows that more frequent period for this phenomenon is June - 22 cases, followed by July - 16 cases, and May - 9 cases. Floods monthly dynamics were estimated by counting the cases with the highest discharges for 3 periods from 20 to 20 years: the first is from 1954 till 1970, the second is 1971-1990 and the third is 1991-2018 (Tab. 4). Thus, analysis of the share of flood events for the first period shows that the biggest number of flood events if specific for June – 35 % and July – 24 %. 12 % of floods occurred in May as well as in August. In the second period the highest frequency is maintained for June and July, however, the share for June increased by 5 %. In this period, April is highlighted, with 15 % of floods. During the third period, 1991-2018, almost equal share of flood events – 21 %, 29 %, 25 % - can be observed for May, June and July. Also, an increase of number of cases is seen for October - 14 %. As a result, it can be concluded that June continues to be the months with the occurrence of the most significant floods, however, a higher share of these phenomena in the last years for May and October can show the direction of change of occurrence of these hazards in the future.

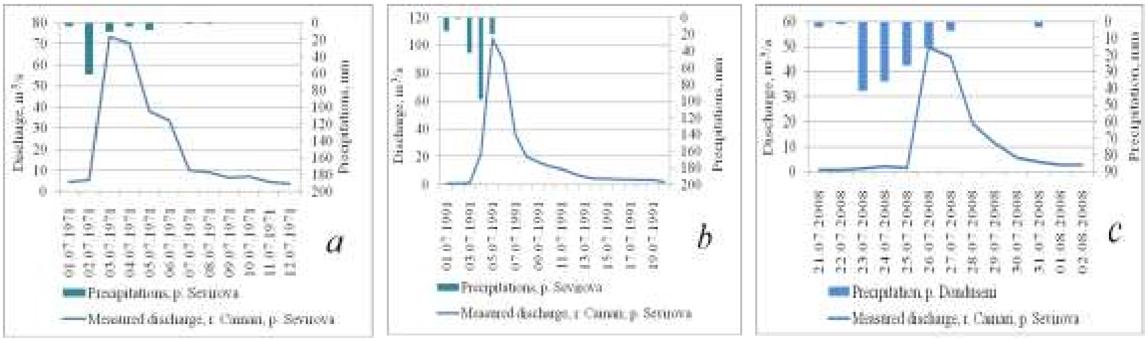

Figure 3 Pluvial flood hydrographs of the Căinari river from (a) 1971, (b) 1991, (c) 2008.

Table 4 Monthly distribution of flood runoff, the Căinari river - Sevirova st.

Period	Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
1954-1970	Nr. of cases	0	0	0	1	2	6	4	2	1	0	1	0	17
	Share, %	0	0	0	6	12	35	24	12	6	0	6	0	100
1971-1990	Nr. of cases	0	0	0	3	1	8	5	2	0	1	0	0	20
	Share, %	0	0	0	15	5	40	25	10	0	5	0	0	100
1991-2018	Nr. of cases	0	0	0	0	6	8	7	1	2	4	0	0	28
	Share, %	0	0	0	0	21	29	25	4	7	14	0	0	100
Total	Nr. of cases	0	0	0	4	9	22	16	5	3	5	1	0	65
	Share, %	0	0	0	6	14	34	25	8	5	8	2	0	100

The trends of annual peak discharges and flood runoff depth shows a slow decrease of the first and a slow increase of the second parameter (Fig. 4). The highest peak discharges values can be observed in 1971, 1991, 2008, in general, once in 20 years. Smaller floods with discharges of approx. 30-40 m^3/s are more often, these were registered in 1955, 1963, 1964, 1970, 1975, 1981, 1985. Thus, for the period from 1954 till 1991 their general frequency is once in 5-7 years, however, after 1991 such events were not observed, the maximal values of peak discharges reached 10 m^3/s in 2012, and 9.88 m^3/s in 2009. Rainfall values are characterized by an increasing trend (Fig. 4) which is observed to be much higher in comparison with the one of flood runoff. Comparison of hydrological and meteorological time series resulted in the fact that flood runoff and rainfall are highly correlated for the period 1954-1991, and hydrological system have a normal reaction to climate parameters. However, as it can be seen from figure 4, in the last analyzed decade (1991-2012) almost no signal is shown by flood runoff to increasing rainfall.
Cyclical nature of the Căinari river flood runoff characteristics and their main generation factor - heavy rains - was analysed by construction of integral curves (Fig. 5). As it can be observed, cyclical fluctuations of hydrological parameters have the same shape, are interdependent and are ruled by the same laws. Peak discharge fluctuations form 2 cycles, one of 16 years (1954-1970) - not very well delineated, and another one of 49 years (1970-2018) - very good distinguished. The second cycle is divided in 2 phases by the record flood event from 1991, the phases being of 21 and 27 years. Averages of peak discharge for 1954-1970 is 14.9 m^3/s, for 1971-1991 is 25.7 m^3/s and for 1992 - 2018 - 6.35 m^3/s. Flood runoff depth fluctuations form also 2 cycles, however, the first cycle is longer, from 1954 till 1990 and the second is shorter from 1991 till 2018. First cycle is more pronounced, the 2 phases are divide by 1969 flood event, thus, first is 15 and the second is 22 years long. The average value of the first cycle is 4.1 mm (the I[st] phase - 1.8 mm and the II[nd] phase - 6 mm), and of the second cycle - 4 mm. Heavy rains form only one long cycle for the entire period which, in general, is in line with distribution of flood runoff.

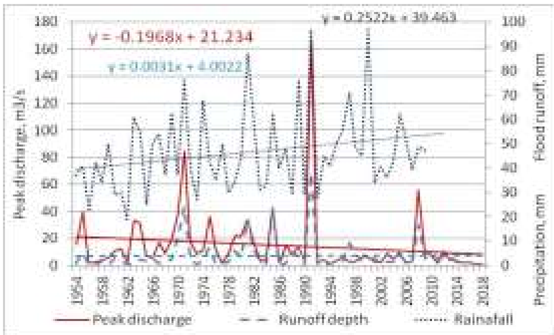

Figure 4 Annual peak discharge and flood runoff depth, Căinari r., Sevirova st., 1954-2018.

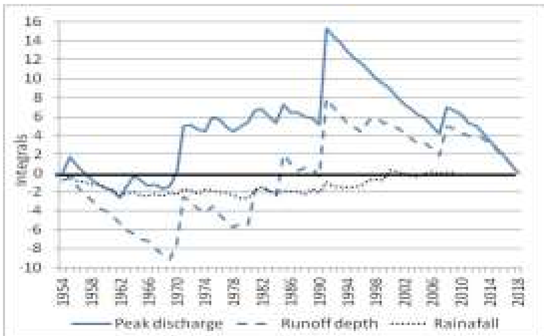

Figure 5 Cyclical nature of the Căinari river flood runoff and heavy rains, Sevirova st. 1954-2018.

After application of homogeneity and stationarity tests, it was identified that all time series are subject to respect the mentioned laws and do not need to be corrected. This fact allowed to calculate statistical parameters for the flood runoff characteristics as well as for maximal rainfall rows. Statistical parameters for rainfall time series are smaller, coefficient of variation is 0.37, of skewness - 0.96, error – 5 %. The same parameters for hydrological characteristics differ, thus coefficient of variation and skewness for peak discharge are 1.64 and 5.2 and for flood runoff depth are 1.6 and 4.56. Error for both hydrological time series are high – 20 % (Tab. 5).

Table 5 Statistical parameters of heavy rains and flood runoff time series, Căinari river - Sevirova st.

Parameter	Coefficient of variation	Coefficient of skewness	Coefficient of autocorrelation	Error, %	Fisher homogeneity criteria
Maximal rainfall	0.37	0.96	-0.16	5	+
Peak discharge	1.64	5.20	-0.003	20	+
Flood runoff depth	1.59	4.56	-0.04	20	+

As a result of evaluation of meteorological and hydrological time series quality (homogeneity and stationarity) and calculation of statistical parameters and errors, the values of maximal rainfall, peak discharge and flood runoff depth of different probabilities were calculated. The calculations are shown in Tab. 6.

Table 6 Rainfall, peak discharge and flood runoff of different probabilities, Căinari river - Sevirova st.

Parameter	Average value	Value of probability, P%							
		0.01	0.1	0.3	0.5	1	3	5	10
Maximal rainfall, mm*	47	-	168	-	-	106	91	84	74
Peak discharge, m3/s	14.7	425	243	176	149	117	74	58.0	38.9
Flood runoff depth, mm	4.10	83.8	52.0	39.4	34.2	27.6	18.5	14.9	10.4

*Determinarea caracteristicelor hidrologice pentru condițiile Republici Moldova. Normativ în construcții CP D.01.05-2012, 2013.

4.2. Flood runoff modeling and changes

4.2.1. Land cover changes

Assessment of spatial distribution of flood runoff for the entire basin as well estimation of its values for the ungauged tributaries of the Căinari river was performed using SCS-CN model, using GIS techniques (QGIS), spatial representations of the soils, land cover (FNDG), heavy rains and recommendation from the literature (SCS, 1956, 1972; 2004, Stematiu and Drobot, 2007). Next scenarios/conditions were considered: maximal precipitation was equaled to 100 mm (value of 1 % probability from table 6), land cover distribution was digitized for 1982 and for 2013, the soil conditions refer to different textures: from sandy to clayey soils, and moisture: dry, wet and average soil moisture. Thus, in total, 6 cartographic models were produced as a result of modeling application. Heavy rain value and soil cover represent natural conditions and are maintained with no change.

One of the factors that express human impact of flood runoff and is a subject to modifications is the land cover. Thus, a special attention was paid to its spatial distribution and its changes (Fig. 6, Tab. 7). Land cover dynamics for the entire river basin for the last 30 years show that the basin continues to be an agrarian area, even if the share of arable land decreases to 62 % from 73 %. Lands covered by orchards occupy now 9 % of the basin being large by 3 % in comparison with 1982. Also, for the last 30 years an increase is observed for grassland: from 8 % to 13 %, forests: from 3.2 % to 4.2 %, shrubs: from 1.4 % to 2 %, wetlands: from 0.3 % to 1.5 %. Very small decrease was estimated for regions occupied by settlements from 7.2 % to 6.9 %.

Main land cover types in the **Berezovca** river basin are arable -37.7 %, orchards – 33 % and grassland - 22.8 %. This basin is characterized by the highest processes of vegetation naturalization. The share of arable land decreased from 62.1 % in 1982 to 37.7 % in 2013 - by 24 %. The arable land seems to be abandoned because the share of grassland for the last 3 decades has increased by 20 % at the basinal level, from 2.1 % - to 22.8 %. A small increase is observed for the lands covered by orchards from 30.3 % to 33 %, and by settlements, from 0.9 % to 1.3 %.

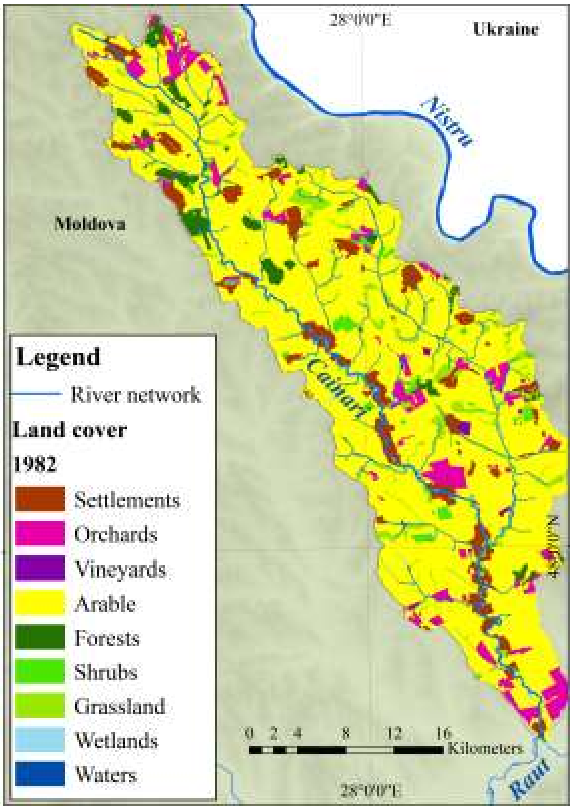

Figure 6 Land cover of the Căinari river basin, 1982.

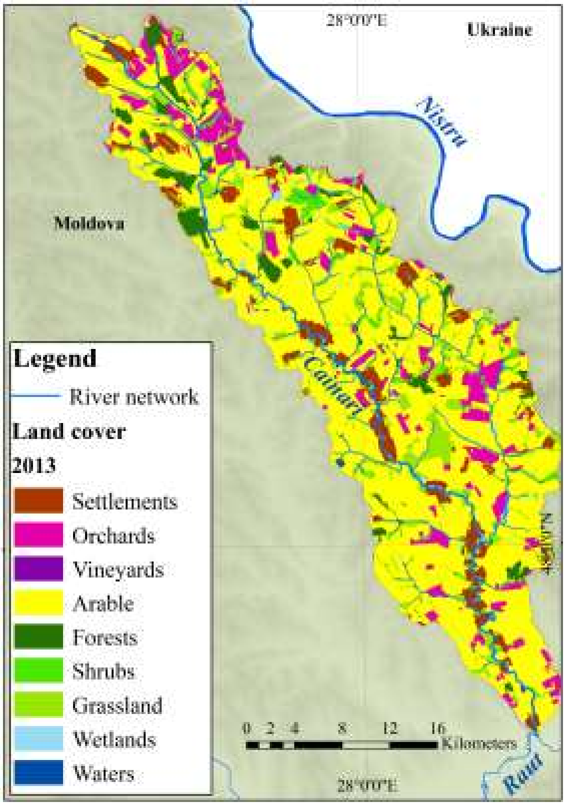

Figure 7 Land cover of the Căinari river basin, 2013.

The same trend of naturalization of land cover is observed in the **Sudarca** river basin, however, the progress is not so big as in previous basin. Thus, the share of arable area has decreased by 6.5 %, in favor of increasing grassland by the same values. The Sudarca river basin is specific by the highest share of forests, as well as settlements, in comparison with other basins, each mentioned land cover type being of 11 %. In the **Teleșeuca** river basin, arable land has also decreased, from 75.8 % to 61.2 % for the last 30 years. The land cover types that have increased in surface are the natural ones: grassland from 1.8 % to 7.3 %, shrubs from 0 to 2.4 %, wetlands from 0.2 % to 2.7 %, as well as orchards have doubled their areas. Forests, in this basin, occupy 11 %. In the **Visoca** river basin arable area is also characterized by reduction, however, the share of this land cover type continues to be very high - 70.7 %. For the last 3 decades, arable area has decreased by 10 % in favor of increasing grassland, orchards, shrubs, wetlands, each by 2 %. The settlements occupy 9.8 % of the basin. In comparison with other basins, the **Zgurița** river basin is the only one where the arable land has increased. The highest decrease is observed for orchards - by 3 times - from 21.9 % to 7.3 %. On the other hand, a 2 times growth is specific for grassland - from 7.1 % to 13.9 %. The **Bolata** river basin is an agrarian region, the same as others. Main land cover types after arable area are grassland and orchards. A 12 % reduction of arable land is estimated, in favor to a 2-6 % increase of grassland, orchards, forests, shrubs areas. The **Valea Viei** and **Valea Frumușica** basins are characterized by the highest shares of arable areas -72.9 % and 80.5 %, respectively. No high dynamics in land cover types are observed. Small shares are occupied by grassland - 9.75, orchards, 6.4-8 %, the other areas being even much smaller (Tab. 7).

Table 7 Land cover changes for the last 3 decades, %.

River basin	Settlements		Grassland		Orchards		Forests		Arable		Shrubs		Wetlands		Water	
	1982	**2013**	**1982**	**2013**	**1982**	**2013**	**1982**	**2013**	**1982**	**2013**	**1982**	**2013**	**1982**	**2013**	**1982**	**2013**
Berezovca	0.9	1.3	2.1	22.8	30.3	33.0	2.9	3.0	62.1	37.7	0.0	0.0	0.4	0.9	1.3	1.2
Sudarca	13.8	11.8	5.8	12.2	5.5	6.9	11.1	11.1	62.7	56.2	0.4	0.0	0.0	0.9	0.5	1.0
Teleșeuca	6.0	5.6	1.8	7.3	4.6	9.1	10.9	11.0	75.8	61.2	0.0	2.4	0.2	2.7	0.7	0.7
Visoca	11.1	9.8	4.0	6.0	0.2	2.7	1.1	1.5	80.3	70.7	3.0	6.6	0.1	2.5	0.2	0.2
Zgurița	1.6	1.0	7.1	13.9	21.9	7.3	4.0	7.0	60.1	66.9	3.4	2.2	0.0	0.3	1.7	0.6
Bolata	5.4	4.5	11.7	14.1	3.9	10.4	1.6	3.1	74.1	61.8	1.9	4.1	0.1	1.6	0.4	0.5
Valea Viei	4.3	4.4	10.2	9.6	1.5	8.1	0.0	4.1	79.3	72.9	3.8	0.0	0.0	0.0	0.5	0.8
Valea Frumușica	2.4	2.3	5.7	9.8	7.7	6.4	0.0	0.0	82.1	80.5	0.0	0.2	0.7	0.3	0.3	0.5
Căinari	7.2	6.9	7.9	13.2	6.2	9.2	3.2	4.2	72.9	62.3	1.4	2.0	0.3	1.5	0.5	0.7

As a result of assessment of land cover types distribution in the limits of the tributaries basins, it can be seen that the highest share of the basins is occupied by arable area, which, generally, is observed to decrease for the last 3 decades from basin to basin by up to 24 %. From the other hand, the second place after arable areas is occupied mainly by grassland - for 5 basins with the share of 9.6 to 14 %, orchards - for 1 basin - 33 %, forests - 1 basin – 11 %, settlement - 1 basin - 9.8 %. The lowest share in the basins is occupied by shrubs, wetlands, water.

4.2.2. Flood runoff changes due to land cover management

Simulation of flood runoff depth resulted in 6 cartographic models (Fig. 8 a, b, c, 9 a, b ,c) which can be easily used by regional and local authorities for different purposes, like urban planning, agricultural management, flood protection activities, infrastructure and hydrotechnical structures construction and others. Average flood runoff values in case of 100 mm of heavy rain are 58 mm in conditions of average soil moisture, 28 mm in case of dry soil and 84 in case of wet soils. The changes of flood runoff under the land cover management activities for the last 3 decades was estimated to be in decrease of 2-3 mm at basinal level.

The lowest values of flood runoff were estimated for the **Zgurița** and **Berezovca** rivers being of 55 mm in case of average soil moisture, twice lower in case of dry soil and 81 mm in case of wet soils. In conditions of the **Zgurița** river, one factor that influences on generation of lower values is the soil, which in this basin is characterized by lower values of C and D soil groups and presence of A and B soil groups that allow higher infiltration. From the other hand, land cover is also an influencing factor of flood runoff distribution. In comparison with present situation in case of land cover from 1982 flood runoff is lower by 2-3 mm. Increase of flood runoff due to land cover changes is caused by decrease of areas covered by orchards and increase of those covered by grassland and arable area. In conditions of the **Berezovca** river the soil texture has a share of C and D soil groups of 70% and 30%. It can be assumed that lower values of flood runoff are determined by lower share of arable area and higher share of grassland and orchards. Dynamics of land cover types influence on decrease of flood runoff in conditions of actual land cover in comparison with the one from 1982 (Tab. 8).

Table 8 Flood runoff changes under impact of land cover and soil moisture conditions**.**

River basin	Flood runoff in case of rainfall of 100 mm					
	Land cover for 1982 Soil moisture conditions			Land cover for 2013 Soil moisture conditions		
	Average	**Dry**	**Wet**	**Average**	**Dry**	**Wet**
Berezovca	57.4	26.4	83.01	54.5	23.9	81.3
Sudarca	59.2	27.8	84.81	57.5	26.9	83.2
Teleșeuca	63.1	31.6	87.61	60.4	29.1	85.8
Visoca	63.6	31.9	87.98	61.2	30.0	86.0
Zgurița	52.5	24.2	77.75	54.9	25.1	80.9
Bolata	60.2	28.8	85.45	57.6	26.7	83.5
Valea Viei	61.1	29.7	86.09	60.4	29.2	85.6
Valea Frumușica	60.7	29.2	85.99	60.6	29.3	85.9
Căinari (average for the basin)	60.2	28.9	85.43	58.4	27.5	84.0

Flood runoff values are subject to no change for the **Valea Viei** and **Valea Frumușica** rivers, also no land cover dynamics are specific for these basins, shares of soils textures area: 70 % of C soil group and 30 % of D soil group.

Higher values of flood runoff were calculated for the **Teleșeuca and Visoca** rivers. Here, soils have the same share of 70 % and 30 % of C and D soil groups. Land cover is formed mainly by arable land of 60-70 % which decreases by 10-15 % for the last 3 decades. The other land cover types are forests – 11 %, orchards – 9 % for the Teleșeuca, settlements - 9.8 %, grassland – 6 % for the Visoca. The increase of natural vegetation cover for the last 30 years makes favorable conditions for decreasing of flood runoff, fact that is seen on example of these basins, which runoff was reduces by 3 mm for each.

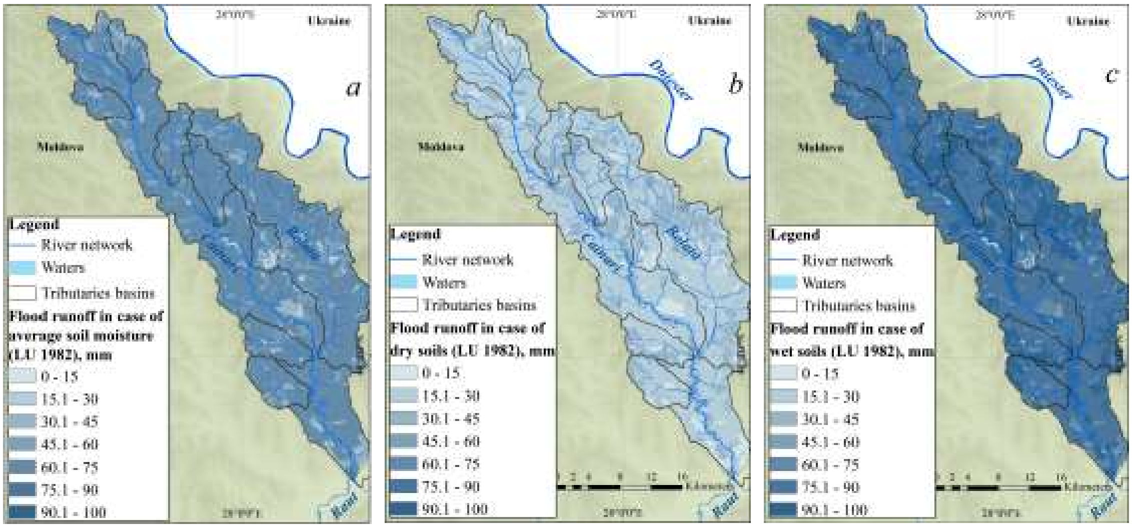

Figure 8 Flood runoff formed under land cover from 1982, in case of different soil moisture: (a) average soil moisture, (b) dry soils, (c) wet soils, heavy rain = 100 mm.

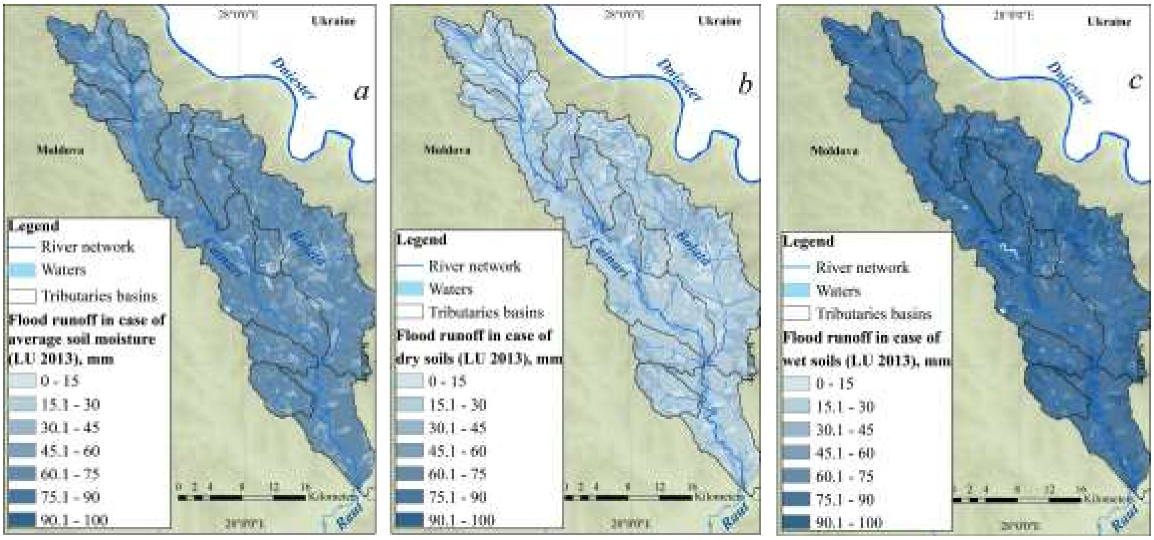

Figure 9 Flood runoff formed under land cover from 2013 in case of different soil moisture: (a) average soil moisture, (b) dry soils, (c) wet soils, heavy rain = 100 mm.

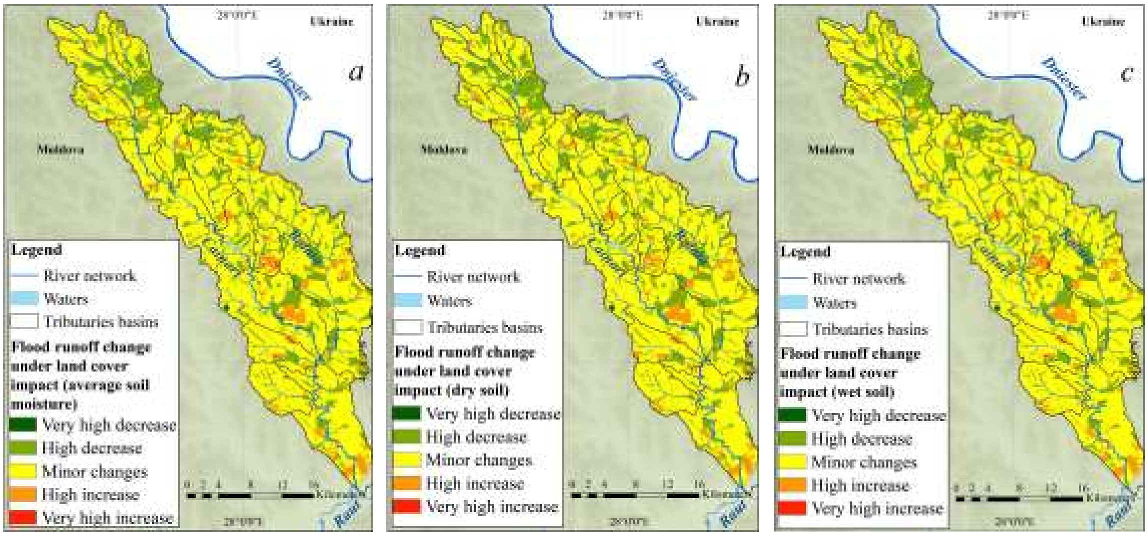

Figure 10 Flood runoff changes due to land cover modifications in case of different soil moisture: (a) average soil moisture, (b) dry soils, (c) wet soils.

As it can be observed, from those 100 mm which were considered to fall over the tributaries of the Căinari river in extreme conditions, the flood runoff forms about 60 % of the precipitation, increasing up to 85 % in case of wet soils and decreasing twice to 30 % in case of dry soils. Generally, land cover dynamics do not influence dramatically of flood runoff on the basinal level, but at local level the changes are very high up to ±90 % (Fig. 10 a, b, c).

5. Conclusion

Assessment of flood runoff generated in the Căinari river basin was performed by using direct and indirect methods. Analysis of temporal dynamics shows that, in the last 60 years, the trend of peak discharges is decreasing while the one of flood runoff is slightly increasing and of heavy rains is highly increasing. Flood events monthly distribution is as follows: June – 34 %, July – 25 %, May – 14 %. Main flood runoff characteristics are: average peak discharge - 16.3 m^3/s, depth - 4.41 mm, volume - 3.6 mln. m^3, total duration - 9.0 days. Cyclical fluctuations and record flood events influence of statistical parameters of flood runoff.

During the study some management and monitoring problems were identified. One of the main issues is lack of representative hydrological and meteorological monitoring network. Measures of flow and precipitation are performed only in the downstream part of the river and no observations are done in the upstream part of the basin. Nearest meteorological stations are situated farther than 10 km from the basin limits. Also, the lack of data as well as observation error are specific for different times series.

The problem of state and management of reservoirs needs more attention, especially, in regard with hydrotechnical structures, real volumes and siltation process. Reservoirs represent a source of water at local level, and serve for different purposes as fishery, irrigation, recreation. However, in case of flood events, they can be, on the one hand, measures to regulate the flow, on the other - they represent real danger in case of mismanagement and dam collapse.

Assessment of 3 decades land cover dynamics shows an increase for grassland: from 8 % to 13 %, forests: from 3.2 % to 4.2 %, shrubs: from 1.4 % to 2 %, wetlands: from 0.3 % to 1.5 %. Very small decrease was estimated for regions occupied by settlements from 7.2 % to 6.9 %. At the level of tributaries basins, the dynamics differ from one to another, the land cover for half of the tributaries basins have no significant changes, prominent dynamics are observer in the Berezovca, Zgutia river basins. Main land cover type which is subject to change is arable land which is decreasing by 10% for most basins, up to 24 %, in the Berezovca basin, and grassland which is increasing in area, from several percents up to 20 %. Naturalization of vegetation cover of the river basins is caused by abandonment of the lands by local population due to massive emigration to more economically developed regions.

Flood runoff spatial modeling was performed for ungauged tributaries of the Căinari river in condition of equal rainfall of 100 mm, land cover for 1982 and 2013 and 3 soil moisture conditions: dry, wet and average soil moisture. General dynamics shows that for the last 3 decades the flood runoff has slightly decreased, by 2-3 mm, due to increasing territory covered by grassland and orchards and decreasing share of arable land. It should be mentioned that a much higher impact is determined by the state of soil moisture. Thus, at basinal level, wet and dry soils can increase or decrease the flood runoff by ±50 % in comparison with the formed in conditions of average soil moisture. At local level, the changes of soil moisture and land cover cause very high variation of flood runoff, thus measures against flash floods and erosion process should become of first importance.

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