Fenomene şi procese climatice de risc

PLUVIAL HAZARDS AND GEOMORPHOLOGICAL CONSEQUENCES IN THE SEBEŞ BASIN

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ABSTRACT. Pluvial hazards and geomorphological consequences in the Sebeş basin. A thorough analysis of the pluviometric conditions worked out on the average precipitations points out non-periodical as well as periodical variations, as a result of the general atmospheric instability. The high precipitation variability is accounted for by the absolute maximum amounts of rainfall for 24 hours, as well as by the intensity of such amounts. While studying pluvial hazard, we undertook to analyse the seasonal variability and the status of the maximal extreme behaviour. As a general rule, such precipitations occur as showers that are capable of exceeding in a matter of a few hours 50% of the precipitation average for the month in which they occur. The pluvial hazard in the Sebeş basin is liable to generate other hazards (hydrological and geomorphological), leading to a positive-feedback reaction and a dis-balance in the geomorphological system.

Key words: pluvial hazard, pluviometric surplus, torrentiality, Sebeș-River Basin.

1. General remarks and work methodology.

A good knowledge of the precipitation conditions, as well as of the hazard and/or risk for these conditions, have come to be acknowledged as an actual necessity over the last years. Substantial precipitations that occur in a brief period has produced an acceleration of geomorphological processes as pluvial denudation, as well as frequent freshets, especially in the warm season, initiation of erosion in riverbeds, as well as floods. 'Hazard', according to IDNDR, is "a threatening event, or the probability for a location and during a given time, of a natural occurrence that is potentially destructive (that implying damage in the infrastructure and in the environment, and/or human losses)". As a consequence, pluvial hazards are such meteorological and climatic phenomena/events of a random nature, of high amplitude, and having a destructive potential, that are the result of precipitation excess (Octavia Bogdan and Elena Niculescu, 1999; F. Moldovan, 2003).

The climate of the Sebeș-river basin is consistent with the general regional climate, as it is subjected to the same laws derived from altitude display and exposure to air mass circulation. We have worked out an analysis of pluvial hazards in the Sebeş-river basin based on a characterisation of precipitation conditions, considering both the evolution of the phenomenon in space and in time, over long periods, on the one hand, and the nature and the specific features of precipitations over short and very short periods, on the other.

The description of the precipitation conditions was accomplished on account of relevant data collected from the meteorological stations in Păltiniş (1450 m) and Sebeș (240 m). Mention should be made that the Păltiniș station is located elsewhere, namely on the northern slopes of the Cindrel Mountains, and it shares the same bio-climatic conditions as the basin area under analysis here. For complementing features of hydro-climatic manifestations, as well as for highlighting some particular cases, the Păltiniș data were doubled by data from the hydrometric stations Frumoasa (1250 m altitude) and Valea Mare (1180 m), which are positioned on the valleys of streams bearing the same names, tributary to the Sebeș, in the proximity of the gulfs extant in the Oașa storage reservoir. As regards the lower Sebeş basin, climatic information from the Sebeș station was used, which is representative of the Sebeș – Apold Depression. The period under analysis spans at least 20 years, certain differences being the case, as follows: Păltiniș (1970 – 2007); Frumoasa (1990 – 2006); Valea Mare (1985 – 2006); Sebeș (1980 – 2007).

The analysis of pluvial hazards was effected in a comparative manner, with a particular interest for the differentiation between each sector of the basin: the upper (Carpathian) and the lower (depression). The pluvial hazard particularisation is based specially on the maximum absolute amounts of rainfall per 24 hours.

The introduction of geo-morphological effects following pluvial hazards was done selectively, for years considered relevant, by means of extreme events that produced an unbalanced morpho-hydrographic system, and caused various damage of settlements and infrastructure loss.

2. Absolute maximum amounts of rainfall per 24 hours

For the Sebeş-river basin, precipitations are abundant, with a torrential character and can often exceed 50% of the mean monthly figure in a matter of a few hours. That is to say, the surplus is exceptional (Carmen Dragotă, 2006). Tables 1 and 2 show an important variability of the diurnal precipitation maximum figures from one month of the year to another, but also from one year to another, within the period under analysis. The distribution of such precipitations is according to the basin distribution in altitude, namely in the mountainous region, the maximum amounts of precipitations for 24 hours account for 50 – 85% of the mean multi-annual monthly figures recorded (in 3 cases, these figures were exceeded altogether: 10 February 1984, 13 October 1998, and 3 January 2007). In the upper basin, the diurnal maximum figures occur due to an association of pressure highs and lows with altitude. Above the basin, transformations of the dominant oceanic air masses and the Mediterranean cyclones take place, upon their contact with the orographic barrier of the Southern Carpathians (Romanian "Carpaţii Meridionali"; Carmen Dragotă, 2006).

Table 1. Maximum amounts of rainfall / 24 hours

STATION	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PALTINIS 1454 m 1980–2007	55.4	54.5	62.6	68.4	**76.8**	68.6	67.4	57.4	62.4	56.4	37.8	34.7
Day/year	03/ 2007	10/ 1984	23/ 2007	30/ 1982	**08/ 1987**	23/ 1999	11/ 1994	04/ 1991	06/ 2000	13/ 1998	06/ 1995	23/ 1980
multi-ann. month.mean	39.5	40.6	52.1	85.0	119.9	143.8	134.9	124.0	89.6	53.5	46.7	40.8
SEBES 240 m 1980–1999	14.9	30.7	25.1	25.4	38.8	**61.3**	35.5	36.5	32.9	36.1	20.2	40.0
Day/year	12/ 1982	10/ 1984	28/ 1988	26/ 1992	14/ 1984	**18/ 1998**	27/ 1993	10/ 1983	29/ 1982	13/ 1998	14/ 1987	30/ 1989
multi-ann. month.mean	22.9	19.6	27.8	47.7	51.6	66.6	70.4	58.3	47.7	37.3	25.6	32.3

Source: processed data from meteorological stations.

The major thermal convection taking place in the summer along with the condensation platform that is generated by the steep mountain sides and the high summits of the basin determine the increase of the maximum precipitation amounts for 24 hours. Still, these occur within the limits of the mean multi-annual monthly figures that are recorded for the months when they occur. Compared against the warm season, the poor thermal convection of the cold season as well as the domination of the continental pressure lows determines low precipitation levels, regardless of altitude. Yet, there are exceptions, e.g. the occurrence of 10 February 1984, when the diurnal maximum reached 54.5 mm and thus exceeded the mean multi-annual monthly figure for February by 14 mm and also the occurrence of 13 October 1998, when the diurnal maximum amount was 56.4 mm, that is a minor surplus if compared against the mean multi-annual figure for October.

Table 2 .Absolute maxime annuale amounts rainfall / 24 hours

Year	PALTINIS 1450 m		SEBES 240m		FRUMOASA p.h.		VALEA MARE p.h.	
	max. amount (l/mp)	Day	max. amount (l/mp)	Day	max. amount (l/mp)	Day	max. amount (l/mp)	Day
1985	26.2	31.VIII	29.1	22. V	-	-	29.0	07. VIII
1986	30.2	07. VI	20.3	10. III	-	-	23.5	31. VII
1987	**76.8**	**08. V**	20.2	14. XI	-	-	65.0	02. VII
1988	36.6	15. IV	25.1	28. III	-	-	38.4	03. VI
1989	47.0	16. X	48.4	29. VI	-	-	67.8	08. V
1990	28.2	22. VI	23.4	04. VII	41.8	07. XII	33.8	04. VII
1991	57.4	04. VIII	45.1	03. VII	60.0	01. VII	-	-

1992	26.9	24. IV	35.4	24. VIII	51.8	24. IV	-	-
1993	51.3	21. VI	35.5	27. VII	45.1	12. IX	35.8	12. IX
1994	67.4	11. VII	19.8	20. IX	34.3	18. IV	27.9	18. IV
1995	46.0	23. V	26.0	02. VI	26.7	23. V	34.0	07. XI
1996	38.4	13. V	33.3	23. VI	41.9	17. VIII	38.5	13. IX
1997	46.4	29. V	35.0	09. VIII	47.3	31. III	44.8	31. III
1998	57.8	18. VI	**61.3**	**18. VI**	54.0	18. VI	-	-
1999	68.6	23. VI	34.3	28. VII	36.5	24. VII	**100.2**	**07. VIII**
2000	62.4	06. IX	-	-	52.0	13. VII	55.5	15. VIII
2001	59.5	24. IV	-	-	**70.9**	**24. IV**	71.3	24. IV
2002	39.6	12 . VII	-	-	46.0	14. VII	44.3	14. VII
2003	48.7	17. X	-	-	24.5	02. VIII	39.4	20. VII
2004	49.8	28. VII	-	-	52.0	28. VII	49.0	28. VII
2005	50.4	04. VIII	-	-	49.4	04. VIII	53.0	12. VII
2006	38.8	11. V	-	-	45.0	14. VIII	37.5	27. VIII
2007	62.6	23. III	-	-	-	-	-	-

Source: processed data from meteorological stations.

At low altitudes in the basin, the absolute maximum precipitation amounts for 24 hours do not exceed those for the upper basin, being more within the range of the mean multi-annual monthly figures (70 – 90%). In two cases, the mean monthly figures were exceeded, as follows: on 10 February 1984, in Sebeș, the February diurnal maximum of 30.7; on 30 December 1989, the December diurnal maximum of 40.0 mm. Such exceptions in winter are due to certain exceptional synoptic occurrences consisting of the advection of humid air masses.

Although the figures recorded for the depression areas do not exceed those in the mountainous areas, when compared against the mean multi-annual figures recorded in the according meteorological stations, in the former case the diurnal maximum figures are greater. This is possible due to the lower altitude and the northern opening of the Apold Passageway, which favours the access of the oceanic air masses. An influence in the occurrence of the maximum figures is that of the convection as well as the local föehn wind on the northern side of the Cindrel Mountains and the western side of the Apuseni Mountains (Octavia Bogdan and Elena Niculescu 1999; Marioara Costea, 2005; C. Dragotă, 2006). The northern exposure, the relief fragmentation, and the particular position of the mountain summits against the predominantly western air masses circulation, creates local perturbations of the air masses along with massive diurnal rainfall in the open depression areas (Apold Depression, Oaşa Depression), as well as small amounts in the isolated depressions and the valley corridors.

On the altitude, the highest figures for 24-hour rainfall in the Sebeș basin are recorded in the range of 1250 – 1500 m, that is the first level of condensation for the Meridional Carpathians (Octavia Bogdan, 2008). Nevertheless, precipitations fallen over 24 hours in the Păltiniş-area mountainside are not so higher (76.8 mm, 8 May 1987) as those recorded at Valea Mare station (100.2 mm, 7 August 1999). The explanation for this is twofold: the massive cyclonic circulation, and the position of the Valea Mare hydrometric station, in the proximity of the mountainous depression Oaşa. The N-S position of the Sebeş valley, the same as the movement direction of the wet air masses, as well as the funnel shape of the mountainous Oaşa minor basin are favourable to the admission and interference of the air masses carried by the Azores Highs and the Mediterranean Cyclones (Octavia Bogdan, 2008). Furthermore, the mountain sides of the Cindrel – Piatra Albă – Sălane – Smida ridges, as well as the steep sides if the Sebeş valley and tributaries determine the swift and forced air ascension, along with vapour condensation and ultimately the production of important 24-hour precipitations.

The following conclusions arise from the analysis above: maximum precipitation amounts for 24 hours are unevenly distributed in time and space across the Sebeş-river basin, as they tend to occur on an irregular and random basis, under the influence of atmospheric cyclonic activity; annual maximum figures occur at different times at the four meteorological stations, and are unevenly distributed in the February – November interval; absolute maximum figures were recorded at the aforementioned stations in May or June of different years; most cases of maximum precipitation amounts for 24 hours occur during the warm half of the year but, due to atmospheric disturbances brought about by thermal contrasts of atmospheric of relief fronts, they are present during the cold half of the year as well. Of the last decade, all-time maximum amounts were recorded in 1999, 2001, 2005, 2006.

3. Case study and risk aspects

The year 1999. According to the mean yearly figures collected from all meteorological and hydrological stations that supplied data, the precipitations in the year 1999 were within the normal. The annual figure was below the mean multi-annual of Păltiniş (952.6 mm against 970.8 mm) and also below Frumoasa (847.6 mm against 872.6 mm), or just exceeded it at Valea Mare (848.8 mm against 733.1 mm) or at Sebeş (519.2 mm against 516.9 mm). As regards the mean monthly figures, these were exceeded by 30 – 50 mm in Păltiniş (in February, April, June, July, September, and December); in Sebeş (in February, April, May, July, October, and December), as well as in Valea Mare (in February, June, July, and December). The mean maximum monthly figures were reached in July in Frumoasa (191.1 mm), in Valea Mare (195 mm), in Sebeş (95.2 mm), and in June in Păltiniş (174 mm).

These mean monthly amounts were the outcome of abundant, torrential precipitations over brief intervals, which managed to reach or exceed in 24 hours in

Sebeş one third of the respective mean monthly figure. In the Carpathian basin, things were even worse, in the sense that such maximum amounts for 24 hours reached or exceeded one half of the respective mean monthly figure. The maximum diurnal figure was recorded in Păltiniş – 68.6 mm, on 23 June 1999, and that is also the all-time maximum 24-hour figure for that station in 1986 – 2007. On 7 August of the same year, the diurnal amount of 100.2 mm was recorded at the Valea Mare hydrometric station on the bottom of the valley, as a result of local conditions of convection and of the association of low-pressure air circulation. The synoptic conditions in August were due to a Mediterranean atmospheric front that mingled with the western wet-air circulation, a weather condition that covered most of the country. The effect was amplified by the Southern Carpathians interfering as a barrier, a fact that led to abundant rainfall in the Sebeş basin.

The June of 1999 started with precipitation amounts in excess of 10 mm during the first three days, and then continued on a higher rainfall level at a 4 – 5-day interval until the 22nd, when 14.7 mm were recorded in Păltiniş. In the aforementioned synoptic conditions, the precipitation amounts suddenly rose in such a manner that 68.6 mm were recorded on the 23rd. The torrential rainfall covered mainly the Carpathian basin of the Sebeș river, by way of the hydrological phenomena associated here.

The freshets occurred on the Sebeş or on its tributaries that flow into the collecting basins did not create serious problems on the main course of the Sebeş, as they were annihilated in the said basins. Things were different only on the Sebeş tributaries: Mărtinia, Valea Groseştilor, and the minor torrent basins on the mountainsides of Sebeş valley that flow either into the main course of the Sebeş or its tributaries. These torrents, given the conditions mentioned, collected from the mountainsides and transported important amounts of solid matter (debris and wooden material) into the main basin. The mountainsides were thus intensely eroded and massive debris fan were deposited at the foot of the slopes: boulders, other matter ripped from the mountainside, and fine rock from erosion, as well as tree fragments. The debris cone blocked the beds of streams, they formed up temporary pools and also blocked the roads leading to the upper basin, upstream from Șugag. The minor riverbed of the Sebeş became too narrow for the flow collected from the mountainsides; the banks were intensely eroded; and floods occurred in the depression basins of flat areas.

Given these conditions, the wild waters of the Muşetoaia stream (Rom. "Pârâul Mușetoii") a left-hand tributary of the Dobra in the Dobra village, which normally run 20 – 30 cm deep, destroyed the households extant at the bottom of the slope near the confluence with Dobra river. The heavy rains that occurred during a month of quasi-continuous rainfall engaged on slopes such matter as eroded rock and the broken trunks of uprooted trees. As the amount of debris being translated along the torrent was considerable, its adjacent areas were involved as well. The final debris cone took a sizeable area (ca 0.15 sq km) and measured ca 3.5 m in the middle and 1 – 1.5 m at the bottom. The very steep slope and the blocking of the Dobra riverbed were disturbing the natural sorting rules of the matter in the debris cone: the bigger elements were deposited on the left-hand side of the cone, whereas lacustrine deposits of small-size matter, sand, was created on the right-hand side.

The matter having the greatest size had an extremely powerful impact force, which led to a 16-ton lorry being overturned, house walls being broken and three houses buried up all the way up to the roof, as well as the removal of annexes and implements and the death of six animals. Other effects: he high-voltage power line was endangered; the road was damaged badly, and so the place was secluded from Șugag; the natural dam formed on the Dobra flooded the households on the right bank. In the following years, the debris was re-activated and removed both naturally and by human hand, therefore the cone grew smaller. In 2001, works were initiated for the torrent-proof endowment of the Muşetoaia stream and the stabilized of its hillsides above it.

Following the above-mentioned events, the village Dobra was declared a disaster area. Other similar events took place in Alba county: the damage brought about by the torrents and floods of June 1999 were estimated at 7 thousand million ROL that time by the County Calamity Commission. On the whole, the county had over 200 ha of cultivated land covered by floods, 12 km of roads destroyed, 205 households damaged and 128 flooded, 7 houses were destroyed completely (of which, 3 in the village Dobra), and 2.5 km of bridges were also destroyed (information published by the newspaper Ziua, 24 June 1999).

Other pluvial hazards occurred in 1999, when 30 mm of precipitations over 24 hours fell in ***July*** (36.7 mm, on the 15th; 35.1 mm on the 24th) and in August (30.0 mm on the 13th). *In **August***, the synoptic conditions for the occurrence of such hazards were different, one reason being the geo-magnetic disturbances induced by the total eclipse of the sun. Octavia Bogdan (2008) shows that the falling of maximum amounts over 24 hours on the 12th and the 13th of August took place due to the interference of polar cold air from NW and tropical air from SE and the atmospheric front overlapping the border of the eclipse strip. Consequently, torrents were produced that flooded the roads in the Sebeş basin, the previous debris cones were re-activated, and the circulation was blocked.

The year 2005 is an exceptional year for Romania, given its precipitation excess. It is also representative for the Sebeş-river basin, as all stations recorded a surplus against mean multi-annual figures: 236.26 mm in Păltiniş; 37 mm in Frumoasa; 303.7 mm in Valea Mare; and 121.37 mm in Sebeş.

The mean monthly figures of 2005 exceeded the mean monthly multi-annual figures at Păltiniş in January – March, May, July – August, and November – December, with a maximum figure recorded in August (216.2 mm). At Frumoasa, it was only the summer months that recorded mean figures above the mean multi-annual monthly figures, while the highest mean monthly was July (226.6 mm), which is also the mean multi-annual monthly figure for the interval being recorded here (1990 – 2007). At Valea Mare, all throughout the year, the mean monthly figures were above the multi-annual figures, except for May, October, and November; the maximum figure was in August (197.5 mm), the double of the mean multi-annual monthly figure. At Sebeş, the mean monthly figures were above the multi-annual monthly figures in April – September, while in June they were double that (148.3 mm). 50 – 100% of the mean multi-annual monthly figures were exceeded in 2005, principally during the warm season. Major amounts of precipitations, in excess of 30 mm level over 24 hours, occurred in the Carpathian basin, especially during the spring and the summer (e.g. Păltiniş: 47.2 mm on 7 May; 39.4 on 12 July; 50.4 on 4 August 2005).

In April 2005**,** in the Carpathian basin, it rained continuously from the 12th until the 30th, to a total of 75.4 mm, which is 89% of the mean multi-annual figure for April; nonetheless, the 10 mm per day level only occurred on three different occasions (15 mm on the 14th; 10.7 mm on the 15th; and 21.7 mm on the 22nd). In such conditions as these, the heavy rains of ***May*** added up to the pluviometric surplus. This month was highly unstable in atmospheric terms, therefore precipitations occurred in three intervals: 6 – 12 May, with a diurnal maximum of 47.2 mm on the 7th; 15 – 21 May, with a 24-hour maximum of 25.6 mm on the 19th; and 23 – 28 May, with a 24-hour maximum of 19.6 mm on the 26th. The torrential rains in May and the high amount resulted (165.5 mm) determined geomorphological unbalance as torrentially as well as other slope-related processes were re-activated, and produced freshets and bank erosion on the un-managed river courses in the basin. The debris cones of the torrents extant within the Sebeş-river basin flooded the road DN 67 C within the limits of the village Șugag and blocked the access upstream on the valley. The freshet occurred on the river Dobra and the solid-matter transported by its tributaries damaged the road DJ 106 E and secluded the villages Jina, Dobra, and Șugag.

The 24-hour precipitation maximum amount occurred in ***August*** (50.4 mm, on the 4th). During this month too, the precipitations occurred during several intervals: 4 – 8; 12 – 14; 16 – 20; and 23 – 29 August. The amount of precipitations in the first interval mentioned above (five days) was 110.4 mm, that is one half of the usual amount for August. The precipitation amounts and the torrent-specific features determined the rising of the flows on the minor rivers in the Sebeș basin (namely, Pârâul Groseştilor, Mărtinie, Valea Cacului, Valea Dobrei, Valea Mare, Frumoasa etc) as well as on the elementary thalwegs (class I and II) on the mountainsides.

Conversely, on the river Sebeş, the freshet caused no trouble, as the system for the monitoring, warning, and evacuation of freshets is well managed on all reservoirs, following the hydro-energetic works. The natural flows are annihilated in the Oaşa reservoir, while the reservoirs of Tău, Obreja, and Petreşti take over the natural flows from the rest of the basin and the any other flows from one dam to the next. If the evacuation of the Oaşa reservoir and the overflow work normally, and the machining of the overflow is performed, the diminishing of the freshet into the reservoir is unlikely to create any problems. The hydro-electrical plants must work during the freshet, and the flow transit must be effected from one reservoir to the next. Exceptional freshets can give rise to maximum water levels in the reservoirs and still not lead to their being damaged.

In the Sebeş-river basin, the after-effects of such precipitations as those mentioned consisted of mountainside torrents and stream freshets, which led to serious damage for the road network in Alba County; along the valley of the Sebeş, the damage was more or less critical for households and cultivated land in the villages Şugag, Dobra, Căpâlna, Laz. The series of events that occurred in the year 2005 in the Sebeş basin are part of the meteorological, climatic, and hydrological risks, as well as of the geogmorphological risks that are characteristic for the whole of Romania. In the Alba County alone, where most of the basin is located, the damage rose to a total figure of 69,376,200 RON, which consists of damaged private and state infrastructure. The conclusions drawn by the Ministry of the Environment for this county is a reflection of the risks dimension associated with surplus in precipitations: one human victim; 1,041 houses and annexes and 7 public buildings damaged; 104 bridges destroyed; 118.3 km of county and village roads damaged; 23.4 km of streets damaged; 15,377 ha of cultivated land flooded; electrical, gas, and water networks damaged; 529 wells destroyed; dead animals.

Similar but less important situations have been found in the basins of the water courses Groseşti and Mărtinie, on the left-hand side of the Sebeş valley, and even upstream Dobra or Bistra, these being basins originating in the highly fragmented interfluves that are used also for intensive grazing: Bârsana – Curata Mare – Dealul Teascului, Porumbelu – Fântânele etc. The torrential erosion in this area, having its maximum manifestation in the interfluves and mountainsides, gave rise to instability and a medium-to-high erosion of the areas subjected to torrent activity. We have drawn an inventory for the Sebeş-river basin, consisting of 144 torrent basins that take a total area of 45,263 ha, of which forested areas amount up to over 78%, which is likely to give a greater stability to mountain sides, and to slow down the current geomorphological phenomena. Let it be noted that over 70% of the torrent basins are part of the basins for the reservoirs Tău, Bistra, and Nedeiu. From one year to the next, reactivation leads to new generations of debris cones, whose matter lies in a precarious balance. There is a permanent risk that the matter in debris cones be reactivated and block the road DN 67C as well as the minor river bed of the Sebeș, leading thus to the creation of lakes that can overflow and flood the adjacent areas. The removal of solid, sizeable material off the upper part of the mountainsides towards the bottom of the slopes brings about damage in the forests that cover the sector. The distribution of such basins tributary to reservoirs, in extreme climatic conditions, can bring about critical situations in the management of such reservoirs.

4. Conclusions

It follows from the analysis performed on the climate data and the case studies effected, that the precipitation excess in the Sebeș basin are part of the climate hazards that are liable to generate cascading hydrological and geomorphological hazards. The damage that such phenomena bring about often makes them risk phenomena. The processes generate torrents and debris flow, freshets, as well as the flooding of minor torrent and hydrographic basins of the Sebeș tributaries. In most cases, such phenomena occur during the warm season, following massive rainfall over 24 hours that happen after longer precipitation periods; prior to the pluvial maximum, the geological substratum, the soil, and the vegetation are imbibed by water, a fact that diminishes the capacity for infiltration or interception and amplifies the flowing down the mountainsides, thalwegs, and river beds. Given the current conditions of the uncontrollable deforesting, the effects of the precipitation surplus are expected to be amplified, also due to a reaction of positive feedback, and will generate hydrological, geomorphological, ecological, economic, as well as social highly risks.

REFERENCES

1. Bogdan, Octavia, Niculescu, Elena, (1999), *Riscurile climatice din România*, Acad. Română, Inst. De Geogr., Tipar Sega Internațional, București.
2. Bogdan, Octavia (2008), *Carpații Meridionali. Clima, hazardele meteo-climatice și impactul lor asupra turismului,* Edit. Univ.”Lucian Blaga”, Sibiu.
3. Costea, Mărioara (2004), *Deficitul şi excesul pluviometric ca riscuri climatice în bazinul Sebeşului,* în Rev. Geocarpathica, nr. **4**, Sibiu.
4. Costea, Mărioara (2008), *Bazinul Sebeșului. Studiu de peisaj*, Edit. Univ.”Lucian Blaga”, Sibiu.
5. Dragotă, Carmen-Sofia (2006), *Precipitațiile excedentare în România*, Edit. Academiei, București.
6. Moldovan, F. (2003), *Fenomene climatice de risc*, Edit. Echinox, Cluj-Napoca.