

THE RELEVANCE OF PLUVIAL REGIME FOR LANDSLIDES GENESIS AND EVOLUTION. CASE-STUDY: MUSCEL BASIN (BUZĂU SUBCARPATHIANS), ROMANIA

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The relevance of pluvial regime for landslides genesis and evolution. case-study: Muscel Basin (Buzău Subcarpathians), Romania

Evaluation de la signification du régime pluvial dans la définition des conditions de la genèse et d'évolution des glissements de terrain. Application dans le bassin versant de Muscel (les Subcarpathes de Buzău), Roumanie

En vue de délimiter l'intervalle de favorabilité dans le déclenchement des glissements de terrain, on a utilisé l'Index Pluviométrique Angot, considéré comme une méthode utile afin d'exprimer de la signification du régime pluvial dans le déclenchement des glissements de terrain, à partir des données mensuelles de précipitations (1961-2007) et journalières (pour les années avec des précipitations en excès significatif: 1975 et 2005), enregistrées aux stations météorologiques Pătârlagele, Buzău et Lăcăuți. Les objectifs de l'étude ont visé l'identification des mois, des saisons et des années avec une susceptibilité très élevée et très réduite des quantités de précipitations de produire des glissements de terrain, ainsi que la variation, au cours de l'année, des valeurs de l'index appliqué, afin de délimiter l'intervalle de favorabilité et l'identification du cumul des conditions pluviométriques qui peuvent induire, généralement, des processus de modélisation. Les résultats obtenus mettent en évidence la représentativité de l'Index Pluviométrique Angot dans des analyses pareilles, en soulignant l'intervalle mai-septembre, comme période de favorabilité maximale, pour le déclenchement des glissements de terrain de terrain dans le bassin Muscel.

1. INTRODUCTION

Landslides are triggered by a host of preparatory and unleashing factors, among which precipitation, alone or in combination with morphological elements, are of overriding importance. As important are frequency, magnitude, and recurrence intervals, basic elements relating directly to a certain quantitative threshold for a sliding event to take place and to predict its time-and-space development.

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1.1. Study area

The quantity of precipitation liable to triggering landslides was assessed in the Muscel Basin, a righthandside tributary of the Buzău River, confluence point Pătărlagele Town. The Muscel Basin situated on the eastern side of the Manta-Muscel summit, the Buzău Subcarpathians (Fig. 1), extends between 909 m altitude (Pătărlagele Peak) and 280 m altitude (Muscel/Buzău junction). Level difference (630 m), average basin altitude 520 m and average slope declivity ($259^{0}/_{00}$), show the Muscel to be a characteristic basin, morphologically at least, of the Carpathian-Subcarpathian area (Zăvoianu *et al.*, 1999).

Its location on the line between the Subcarpathian Hills black molasse and the Palaeogene Carpathian flysch, a contact evidenced by breaches of the valley slopes, accounts for its distinctive rock constitution mirrored in morphology and morphometry of the relief. *The upper sector* of the basin, carved in sandstone and schists, features steep summits, narrow valleys, high peaks (Pătărlagele Peak, 909 m), density of fragmentation $6-6.5 \text{ km}^2/\text{km}^2$, slope dip $30-50^\circ$ (slopes are affected mainly by sheet erosion, gully erosion, occasionally topples and rock-falls), relief energy 300-350 m, and old slide deluvia, sometimes forming actual 'landslide valleys'. *The median sector* of the basin, corresponding to clay-marls and schists formations of the Mio-Pliocene molasse, shows rounded summits, slopes affected by landslides and mud-flows, larger valleys, lower density and depth of fragmentation ($3-4 \text{ km}^2/\text{km}^2$ and 50-100 m, respectively) and geodeclivity $5-30^\circ$. *The lower sector* of the basin overlaps Quaternary terrace deposits has milder slopes (usually under 5°) and a density of fragmentation of $2-2.5 \text{ km}^2/\text{km}^2$.

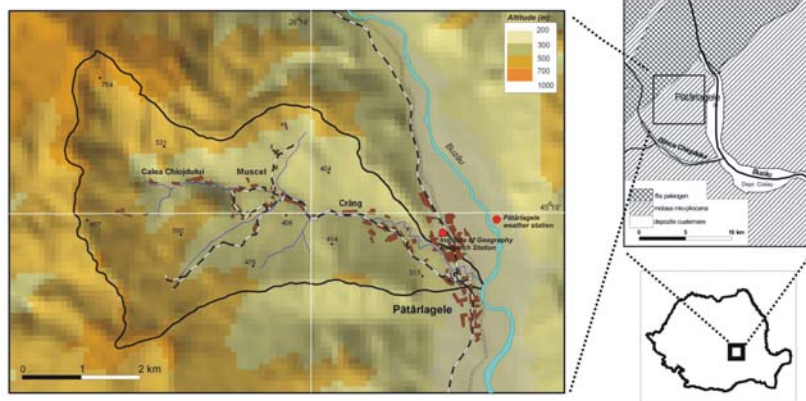


Fig. 1 - Location of the Muscel Basin and Pătărlagele weather station.
- Emplacement du bassin versant de Buzău et de la station météorologique Pătărlagele.

Most of the Muscel Basin area is forested (especially its upper part, 41.5%); there are also pastures and hay-fields (33.0%), mixed uses (degraded orchards presently turned into hay-fields, 12.4%), orchards (8.2%), arable land (1.1%), bare rock (1.1%) and settlements (2.6%).

The Muscel Basin is a relevant example of present-day relief modelling processes in the Buzău Subcarpathians e.g. a variety of mass movements (superficial landslides, medium and deep-seated landslides, mud-flows) and erosion (surface erosion, rilling, gullying).

1.2. General characteristics of the precipitation regime

A major meteorological element in unleashing, maintaining and reactivating geomorphological process is precipitation, which acts as modelling agent in active geomorphic regions. The influence of precipitation is revealed both by quantifying the value of characteristic variables (duration, frequency and intensity) and by delimiting individual and successive time-sequences highly susceptible to augmenting the action of modelling processes. Excess precipitation constitute a special segment whose occurrence and mechanical action have the greatest impact on the natural environment, as well as negative economic and social consequences by the nature and extent of the material damage incurred.

Lying in the Curvature Subcarpathians, between the Buzău and the Teleajen rivers, the Muscel Basin has a fairly moderate, even slightly deficitary pluvial regime due to the orographic barrage of the Curvature Carpathians and the high incidence of the Föhn (Bogdan, Mihai and Teodoreanu, 1974). At the same time, the interaction between the general atmospheric circulation and the local relief does influence the distribution, frequency and intensity of extreme local climatic phenomena and implicitly of extreme rainfall events.

The multi-annual mean quantities of precipitation of 640 mm (Pătârlagele weather station) fall into a regional variation range between 828 mm in the high mountains (Lăcăuți station) and 525 mm in the limitrophe plain (Buzău station). This precipitation regime (distribution type IV) shows two maxima: the main one in summer (June 93 mm) and the second one, in winter (February 30 mm). The monthly quantities of precipitation registered at Pătârlagele station (Fig. 2) mark the transition to the mountain regime (distribution type V).

The cumulated seasonal quantities of precipitation (Muset-Gausson index – IMG) in the Muscel Basin list it under S.S.W.A. variation type (Tabel 1), with maximum values in summer and minimum ones in winter. The same precipitation regime distribution showed 67.5% in the warm and 32.5% in the cold semestres.

Tab. 1 - Seasonal distribution of precipitation (Muset-Gausson index)
- Distribution saisonnière des quantités de précipitations à l'aide de l'index Musset-Gausson

Season	Quantity (mm)	IM-G index
Summer	257.8	S.S.W.A
Spring	151.2	
Autumn	129.2	
Winter	97.4	

Source: Calculated data based on the ANM Archive*.

* ANM (the National Administration of Meteorology).

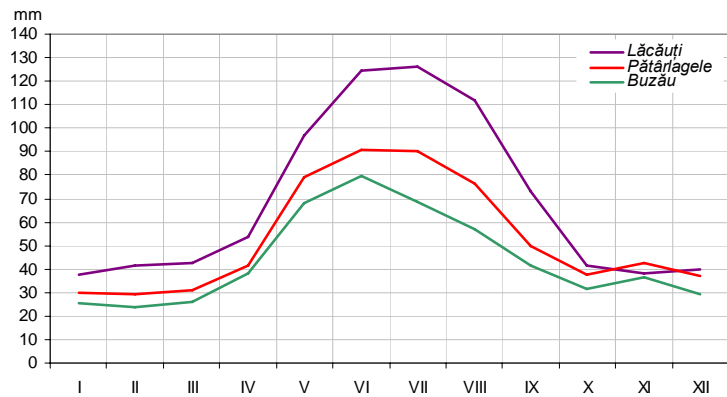


Fig. 2 - Comparative distribution of multi-annual monthly quantities of precipitation registered at Pătârlagele weather station and the limitrophe stations of the study area.
 - Distribution comparative des quantités mensuelles multi annuelles de précipitations à la station météorologique Pătârlagele et aux stations limitrophes au secteur subcarpatique analysé.

The annual quantities of precipitation registered at Pătârlagele station do not considerably vary, which is visible also in the linear trend overlapping the multi-annual mean (1961-2007) (Fig. 3). And yet, the Mann-Kendall statistical test highlights slight rain deficit, but which is not statistically significant in terms of the length of the observation data series. The findings also evidence by the dominance of negative multi-annual deviations over the positive ones.

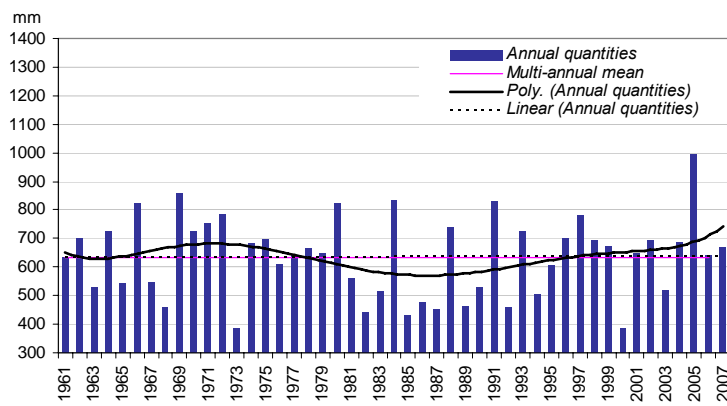


Fig. 3 - Variability of annual quantities of precipitation and their trends (Pătârlagele weather station).

- Variabilité des quantités annuelles de précipitations et la tendance d'évolution à la station météorologique Pătârlagele.

The multi-annual situation of months of highest and lowest quantities of precipitation susceptible to unleashing landslides is presented in Table 2.

Tab. 2 - Extreme precipitation months over the 1961-2007 period.
 - Mois caractérisées par une pluviométrie extrême pendant la période 1961-2007.

Weather stations	Rainiest month	Quantities of precipitation	Driest month	Quantities of precipitation
Lăcăuți	June, 1999	265.8 mm	October, 2000	0.0 mm
Pătărlagele	July, 1975	282.5 mm	August, 1962	0.0 mm
Buzău	August, 1972	197.3 mm	March, 1990	0.0 mm

Source: Calculated data based on the ANM Archive.

The same spatial distribution unevenness is shown by precipitation quantities cumulated within short-time intervals (24, 48 and 72 hours). July 1975 is considered a historical record month for the quantities cumulated within the above intervals: 177.8 mm/24 hrs (July 2); 192.9 mm/48 hrs (July 1-2); 203.8 mm/72 hrs (July 1-3) (Pătărlagele station).

2. DATA AND METHODS

Initially devised to determine the characteristic types of monthly and annual variation of precipitation, the Angot Pluvial Index (K) facilitates local and regional comparisons (*Indici și metode cantitative utilizate în climatologie*, 2003). The present work enlarges upon the climatological significance of the Angot Index in assessing precipitation conditions susceptible to affecting slope modelling dynamics and also to trigger floods/flash floods. The index calculation formula and value grid (Table 3) is:

$$K = p/P \quad (1)$$

where:

$$p = q/n \quad (2)$$

q – monthly quantity of precipitation; n – number of days/month;

$$P = Q/365 \quad (3)$$

Q – multi-annual quantity of precipitation.

Index values can be used to detect dry or rainy intervals by listing them under precipitation susceptibility classes corresponding to the precipitation attributes assigned.

Tab. 3 - Susceptibility classes of precipitation liable to triggering/reactivating landslides based on Angot Pluvial Index attributes.

- Classes de susceptibilité des précipitations de produire et réactiver des glissements de terrain, déterminés par des qualificatifs pluviométriques de l'Index Pluviométrique Angot

Pluviometric attributes	Very dry	Dry	Normal	Rainy	Very rainy
Susceptibility classes	Very low	Low	Moderate	High	Very high
Angot Index values (K)	<0.99	1.00-1.49	1.50-1.99	2.00-2.49	>2.50

Using the Angot Index individual component (k), which is an accurate indicator of the significance of precipitation over the year (by referring it to the annual quantity of precipitation), enables assessment of the territorial expansion of extreme pluvial events. It also emphasises all excess or deficit pluvial peaks involved in landslide hazard analysis in a given region.

Low susceptibility classes, with k values under unity (<0.99) illustrate slope stability under rain-deficient conditions. On the other hand, high susceptibility classes ($k > 2.00$, but especially > 2.50), indicate conditions liable to activating slope dynamics and trigger floods/flash floods under excess rainfall.

The data used to assess the relevance of the pluvial regime for slope modelling processes in the Muscel Basin, are the monthly precipitation registered at Pătărlagele station (284 m), over the 1961-2007 period. According to the observation series and to the daily precipitation data found at this weather station, which is the most representative one for the study area, 1975 and 2005 featured as excess precipitation years.

3. RESULTS

3.1. Assessing susceptibility of precipitation conditions to unleashing and sustaining landslide evolution

Looking at precipitation susceptibility classes (Pătărlagele station, 1961-2007), calculated by the individual Angot Index (k_{month}), some major aspects in evaluating landslide hazards in the Muscel Basin can be outlined:

- **The multi-annual monthly regime** (Table 4) which falls into the *very low* susceptibility class ($k_{month} < 0.99$) is the most frequent one (37%) of all cases, given that local pluvial conditions are slightly deficient;
- The months falling into the *very high* susceptibility class ($k_{month} > 2.50$) rank second in the classification of multi-annual frequencies (25%), which suggests that the region is generally prone to being fairly often affected by humid air masses, potentially triggering very active slope modelling processes, as well as floods/flash floods in small catchments and medium-sized drainage basins. This may occur in situations of retrograde cyclonic activity relating to excess rain (an activity less frequent in the multi-annual range), which affects vast areas of the studied Subcarpathian sector (Dragotă, 2006).

The individual Angot Index component (k_{month}) led us to distinguishing the rainiest (maximum k_{month} 9.11-6.27) and the driest (minimum k_{month} 0.03-0.00) five months of the year registered at Pătărlagele station:

- Rainiest months: July 1975 (9.11) and 2002 (6.95); May 1988 (6.72) and 1971 (6.43); June 1969 (6.27);
- Driest months: August 1962 (0.00); November 1990 and December 1975 (0.02); October 2000 and November 1986 (0.03).

Tab. 4 - Frequency of susceptibility classes of monthly quantities of precipitation liable to generating/reactivating landslides (1961-2007).

- Fréquence des classes de susceptibilité des quantités mensuelles de précipitations de générer et réactiver des glissements de terrain (1961-2007).

Precipitation susceptibility classes	k_{month}	Frequency	
		No. of cases	%
Very low	<0.99	206	37.3
Low	1.00-1.49	88	15.9
Moderate	1.50-1.99	69	12.5
High	2.00-2.49	54	9.8
Very high	>2.50	135	24.5

Source: Calculated data based on the ANM Archive.

A comparative seasonal approach to precipitation quantities (Fig. 4) yielded several significant aspects.

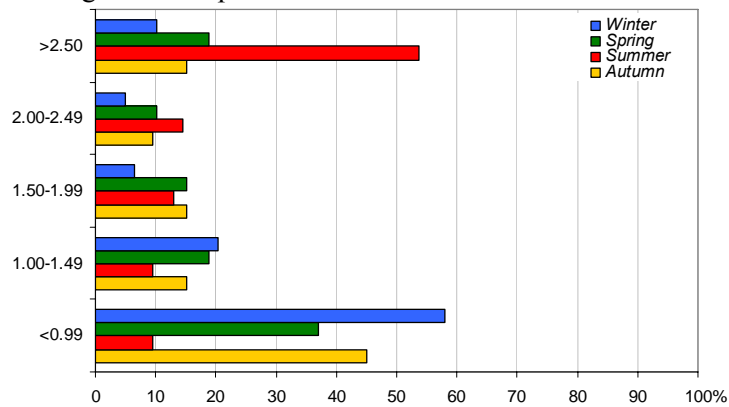


Fig. 4 - Distribution of seasonal precipitation quantities by susceptibility classes in the Pătârlagele weather station area (1961-2007).

- Distribution selon les classes de susceptibilité des quantités saisonnières de précipitations dans l'aire afférente à la station météorologique Pătârlagele (1961-2007).

Winter appears to be the most stable season with 78% average landslide frequency of all cases in the *low* and *very low* susceptibility classes (20% and 58%, respectively) (Fig. 4). There were 9 consecutive years of stable conditions in January (1967-1975), up to 8 in February (1992-1999), and mixed susceptibility classes in December. The multi-annual situation shows February to be the most stable winter month (65.2%). The stablest winter years over 1961-2007 were: 1971, 1975, 1983, 1989 and 2004 (Fig. 5).

Summer registers the highest average frequency of the *very high* susceptibility class (54%), hence maximum instability for this class to occur goes up to 65% (June), while the probability to have its opposite, namely the *very low* susceptibility class, is weaker (August 24%). June also registered the largest number of consecutive years of very high susceptibility, that is no more than 7 and

most of them in the last part of the studied interval (2000-2006): 1966, 1983, 1984, 1991, 1997, 2001 and 2004-2006 (Fig. 5).

Transitional seasons fall into the mixed susceptibility classes (Figs. 4 , 5), basically dominated by central frequency values: *low* (April and November), 11-22%; *moderate* (April and November), 4-22%; *high* (May and October), 4-11%. Stablemost transitional months ($k_{month} < 0.99$) were March (61%) and October (54%) while months with very unstable terrain conditions ($k_{month} > 2.50$) were May (46%) and September (26%). By and large, the multi-annual regome of transitional seasons falls systematically into the *very low* susceptibility class with maximum 3-5 years in row in March-April and autumn (mainly in October), while the *very high* susceptibility class registered 2-3 consecutive years only in May and September.

The **semestrial** situation, assessed in terms of frequency criteria (Table 5), suggests the following:

- The warm semestre (April 1 - November 30) registered the highest frequency (40%) of precipitation-induced land instability and only up to 20%, stability-related conditions;
- In the cold semestre (October 1 – March 31) land stability was very high, with only 10% probability for pluvial events to trigger vast geomorphological processes.

Tab. 5 - Frequency of susceptibility classes of semestrial precipitation liable to triggering landslides (1961-2007).

- Fréquence des classes de susceptibilité des quantités semestrielles de précipitations de générer et réactiver des glissements de terrain (1961-2007).

Precipitation susceptibility classes	k_{month}	Frequency			
		Warm semestre		Cold semestre	
		No. of cases	%	No. of cases	%
Very low	<0.99	53	19.2	153	55.4
Low	1.00-1.49	38	13.8	50	18.1
Moderate	1.50-1.99	40	14.5	29	10.5
High	2.00-2.49	35	12.7	19	6.9
Very high	>2.50	110	39.9	25	9.1

Source: Calculated data based on the ANM Archive.

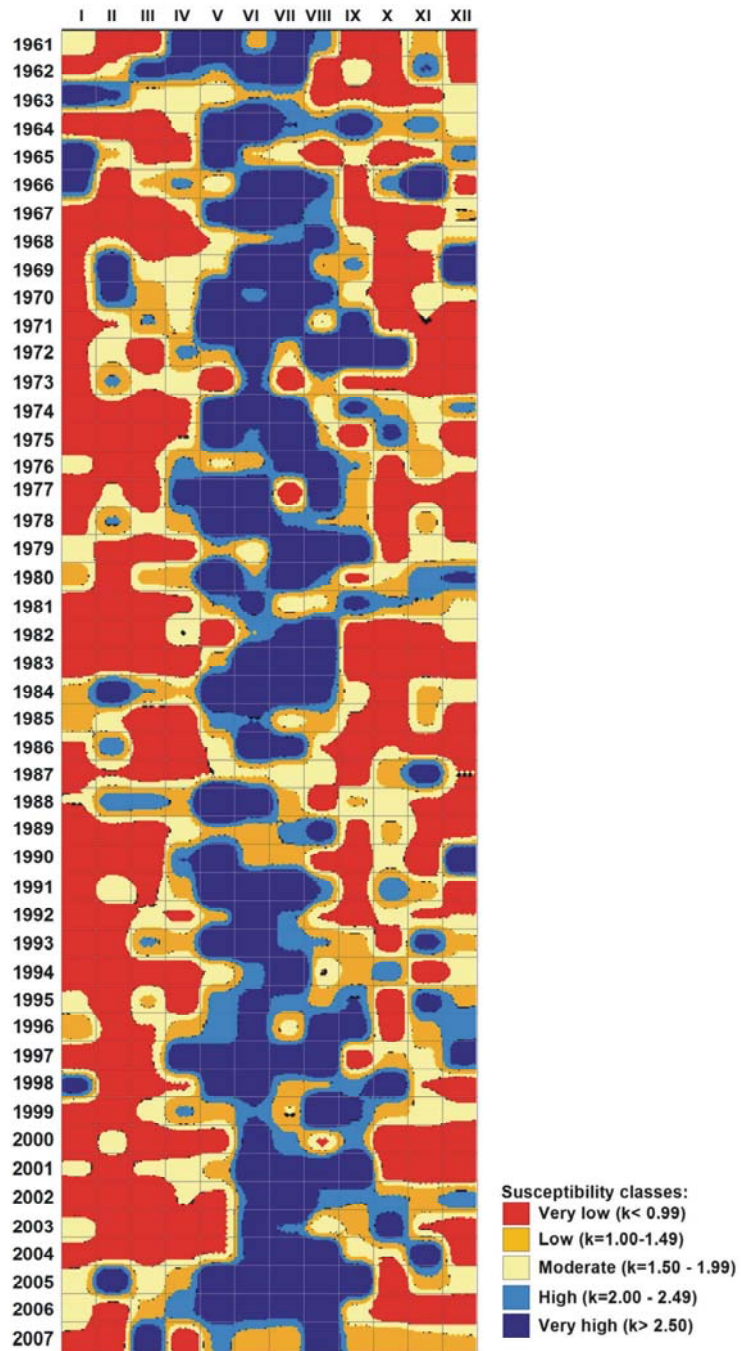


Fig. 5 - Variability of susceptibility classes of precipitation liable to triggering landslides in the Muscel Basin (Pătârlagele weather station).
 - Variabilité des classes de susceptibilité des précipitations de déclencher des glissements de terrain dans le bassin versant de Muscel (station météorologique Pătârlagele).

The *annual regime* points to the same significant susceptibility classes involved in landslide evolution (see our driest/rainiest five years classification over 1961-2007) (Tables 6a and 6b).

No very dry years ($K_{year} < 0.99$) occurred in the Muscel Basin, the maximum Angot value being 1.06 (1973). In terms of the whole period of observations studied (1961-2007), the driest five years of low pluvial impact on the terrain (unlikely to unleash landslides) were 1973, 2000, 1985, 1982 and 1987 (Table 6a), when some months registered over 50% rain deficit, but rainy months (8.3-25%) did exist as well.

Tab. 6a - The driest five years ($K_{year} < 1.49$) over 1961-2007 (Pătârlagele).
- Les plus sèches cinq années ($K_{annual} < 1.49$) pendant la période 1961-2007 (Pătârlagele).

% of months /year	No. of months	Dry months	Dry years/ K_{year}	Rainy months	No. of months	% of months /year
75.0	9	I, III, IV, V, VII, IX, X, XI, XII	1973 / 1.06	II, VI	2	16.6
75.0	9	I, II, III, IV, V, VIII, X, XI, XII	2000 / 1.07	VI, VII, IX	3	25.0
50.0	6	II, III, IV, IX, X, XII	1985 / 1.18	V, VI	2	16.6
66.7	8	I, II, III, V, IX, X, XI, XII	1982 / 1.21	VII, VIII	2	16.6
83.0	10	I, II, III, IV, V, VI, VII, VIII, IX, XII	1987 / 1.23	XI	1	8.3

Source: Calculated data based on the ANM Archive.

The rainiest five years featuring significant landslide-triggering pluvial susceptibility ($K_{year} > 2.00$) in the Muscel Basin were 2005, 1980, 1969, 1984 and 1991, with an over 2.50 K_{year} value in the first two years, suggestive of potential floods. The maximum Angot annual value (K_{year}) was 2.72 (2005) (Table 6b). Rainy months did not exceed 50%, while rain deficient ones amounted to 25% and 58%.

Tab. 6b – The rainiest five years ($K_{year} > 2.00$) over 1961-2007 (Pătârlagele).
- Les plus pluvieux cinq années ($k_{annual} > 2.00$) pendant la période 1961-2007 (Pătârlagele).

% of months /year	No. of months	Dry months	Dry years/ K_{year}	Rainy months	No. of months	% of months /year
3.3	4	I, III, X, XII	2005 / 2.72	II, V, VI, VII, VIII, IX	6	50.0
50.0	2	II, IX	1980 / 2.69	V, VI, VII, VIII, IX, XII	6	50.0
58.3	7	I, III, IV, V, VIII, X, XI	1969 / 2.35	II, VI, VII, IX, XII	5	41.7
25.0	3	IX, X, XII	1984 / 2.28	II, III, V, VI, VII, VIII	6	50.0
41.7	5	I, II, III, IX, XII	1991 / 2.28	V, VI, VII, VIII, X	5	41.7

Source: Calculated data based on the ANM Archive.

Decennially, the distribution of precipitation susceptibility classes was fairly well-balanced, the moderate class prevailing, extreme deficit/excess events being absent (Fig. 6). The rainiest decade was 1971-1980, the driest one, 1981-1990.

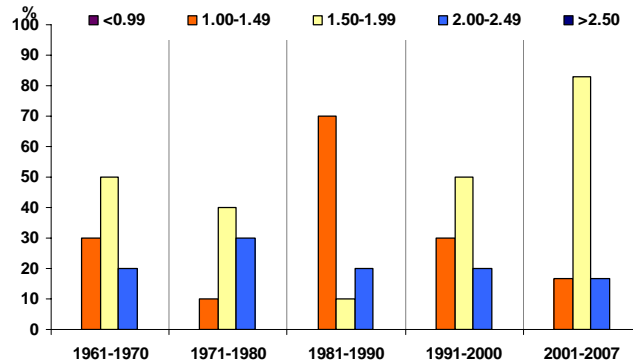


Fig. 6 - Decennial distribution of Angot susceptibility classes over 1961-2007 (Pâtârlagele weather station).

- Distribution décennale des classes de susceptibilité Angot dans la période 1961-2007 à la station météorologique Pâtârlagele.

Against the background of a general climate warming, a trend visible also in the station's observation data, especially after 1970, the frequency and intensity of torrential events got momentum. Speaking of the Muscel Basin, the susceptibility class of 2.00-2.49 had maximum occurrence (30%) in the 1971-1980 decade. In the next decade the deficitary segment (1.00-1.49) was seen to dominate the decennial evolution of the index values (70%) (Table 7).

Tab. 7 – Decennial absolute frequency and probability of precipitation quantities to occur in the area of Pâtârlagele weather station (by susceptibility classes).

- Fréquence absolue et probabilité décennale de produire des quantités de précipitations (par des classes de susceptibilité), à la station météorologique Pâtârlagele.

Susceptibility classes	1961-1970		1971-1980		1981-1990		1991-2000		2001-2007	
	No. of cases	%	No. of cases	%	No. of cases	%	No. of cases	%	No. of cases	%
<0.99	0	0	0	0	0	0	0	0	0	0
1.00-1.49	3	30	1	10	7	70	3	30	1	17
1.50-1.99	5	50	4	40	1	10	5	50	5	83
2.00-2.49	2	20	3	30	2	20	2	20	1	17
>2.50	0	0	0	0	0	0	0	0	0	0

Source: Calculated data based on the ANM Archive.

3.2. Pluvial excess in 1975 and 2005 and its impact on landslide evolution

Variability of the precipitation regime over the 1961-2007 period was marked by the exceptional years 1975 (cumulated monthly quantities and within short-time intervals - July) and 2005 (cumulated annual quantities).

July 1975 ranked first among the five rainiest months of the studied period, given that the individual Angot Index reached the maximum value of 9.11. Unlike other excess rain years, 1975 registered only one major peak: 177.8 mm on July 2 (Fig. 7), by far higher than the pluvial threshold supposedly triggering flood events in the hill and mountain regions under dry soil condition (≥ 30.0 mm/24 hrs) (Milea, 1976).

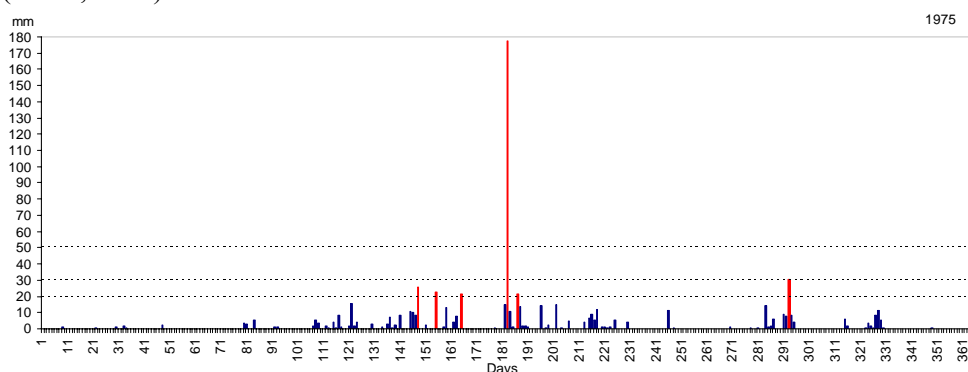


Fig. 7 - Daily variation of precipitation quantities in 1975 (Pătârlagele station).

- Variation de quantités journalières des précipitations pendant l'année 1975 à la station météorologique Pătârlagele.

As a result of those exceptionally high quantities of precipitation vast areas were overflowed by catastrophic floods on the Buzău and the Bâsca Rozilei rivers, rock-falls on the Lupului and Sbiciul valleyside slopes, landslides in Muscel, Via, Croitorul, Porcăreața and Bâsca Chiojdului basins, and landslides turning into mud-flows on the Via Hill (Bălțeanu, 1983).

In Romania generally, and also in the Muscel Basin, 2005 stood out by the cumulated precipitation quantities of the warm season and their impact on society and the environment. The monthly and semestrial quantities gathered in the Muscel Basin (Pătârlagele station) did not reach the alarm thresholds registered in the regions with similar physical-geographical conditions. However, four of the 2005 months, namely, May, July, August and September had an over 130 mm record, and 100 mm in February due to early snowmelt (Fig. 8). In terms of the multi-annual mean (635.1 mm), 2005 may indeed be considered a historical record year at Pătârlagele weather station (993.5 mm), moreover so as only in 13% of the cases annual quantities over 800 mm were recorded throughout the 1961-2007 period.

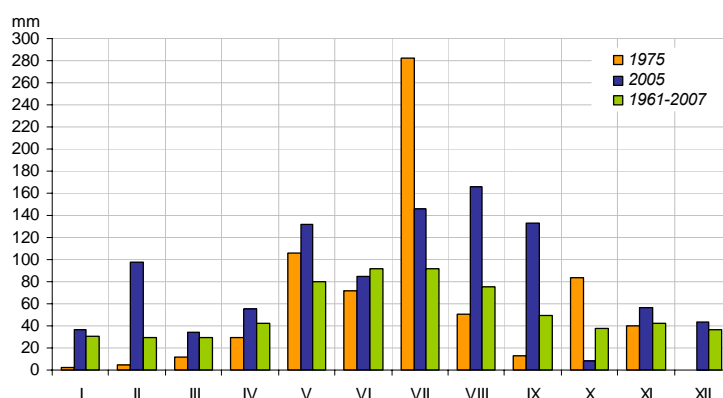


Fig. 8 - Monthly quantities of precipitation in 1975 and 2005 referred to the multi-annual mean, 1961-2007 (Pătârlagele weather station).

- Quantités mensuelles de précipitations enregistrées dans les années excédentaires 1975 et 2005 rapportées à la moyenne multi annuelle (1961-2007), à la station météorologique Pătârlagele.

The 2005 maximum quantities of precipitation fallen over short time-intervals (24, 48 and 72 hours) liable to triggering geomorphological process, cannot be classified as historical records, because they fall below of the magnitude of the 1975 ones (Table 8). However, they were more evenly distributed over the year, a reality revealed also by the absolute frequency of days with cumulated precipitation/24 hrs above significant thresholds in years of major excess rainfall (Table 9).

Tab. 8 - Comparative values of precipitation quantities cumulated over short-time intervals, 1961-2007 (Pătârlagele weather station).

- Valeurs comparatives des quantités de précipitations cumulées pendant des intervalles courts de temps, à la station météorologique Pătârlagele (1961-2007).

Time-intervals	July 1975	September 2005
24 hours	177.8 mm/July 2	54.4 mm/September 20
48 hours	192.9 mm/July 1-2	78.0 mm/ September 20-21
72 hours	203.8 mm/July 1-3	93.3 mm/ September 19-21

Tab. 9 – Absolute frequency of days with precipitation thresholds/24 hrs above significant values in years of major excess rainfall (Pătârlagele weather station).

- Fréquence absolue des jours avec des quantités de précipitations qui dépassent les limites significatives/24 heures, dans les années à excès majeur des précipitations, à la station météorologique Pătârlagele.

Quantitative thresholds/24 hrs.	1975	2005
≥20 mm	6	15
≥30 mm	2	7
≥50 mm	1	1

Individual Angot values in years of significant excess rain reached over 9.00 in July 1975 and more than 2.80 in February and May-September 2005 (5.34 in August). In the Muscel Basin, these values correspond to landslide episodes described by the relationship between the quantities expressed by Angot values and the moment these geomorphological processes occurred (Fig. 10).

The effects of the historical 2005 quantities are evidenced by mapped landslides triggered by successive heavy rainfall intervals, that point out significant thresholds in unleashing and reactivating such movements within this basin (Fig. 9).

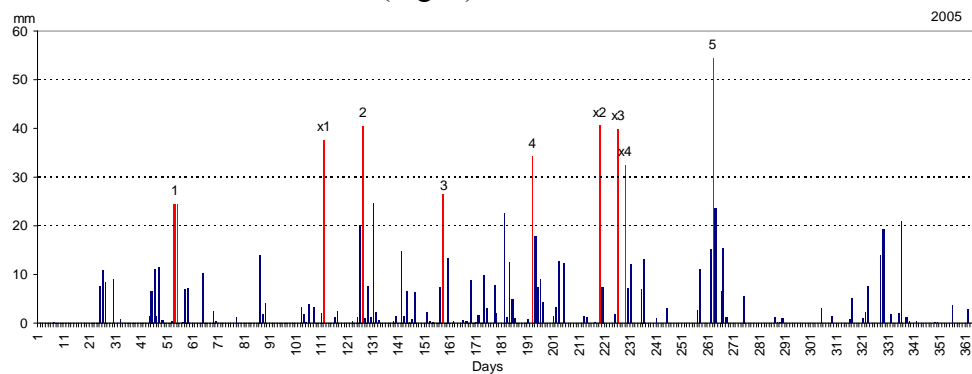


Fig. 9 - Daily variation of precipitation quantities over 2005 (Pătărlagele weather station).

Geomorphological mapping time:

Proximal to landslide-triggered intervals: 1= February 21-23; 2= May 6-12; 3= June 7-08; 4= July 12-16; 5= September 19-21.09;

Post-event landslide-triggered intervals: x₁= April 21; x₂= August 7; x₃= August 14; x₄= August 17.

- Variation des quantités journalières de précipitations pendant l'année 2005 à la station météorologique Pătărlagele.

Le moment de cartographie géomorphologique:

Glissements de terrain aux intervalles proche d'occurrence: 1= 21-23.02; 2= 6-12.05; 3= 7-08.06; 4= 12-16.07; 5= 19-21.09;

Glissements de terrain avec les moments d'occurrence établis après l'événement: x₁= 21.04; x₂= 7.08; x₃= 14.08; x₄= 17.08.

The landslides of February 21-23, May 6-12, July 12-16 and August 19-21 were generally of small-to-medium magnitude (superficial landslides, mostly reactivation, covering 0.3-0.4 ha and 1.2-5 ha), having been triggered by the same cumulated pluvial conditions:

- precipitation quantities/24 hrs ≥ 25 mm;
- precipitation quantities cumulated 1-3 consecutive days, 50-100 mm;
- precipitation quantities in at least three non-consecutive rainfall days, cumulating 32-41 mm, supposedly triggering flood events (Milea, 1976);
- precipitation quantities of 36-122 mm, cumulated within 10 days prior to triggered/reactivated landslides and significant in assessing soil moisture level (Fig. 10).

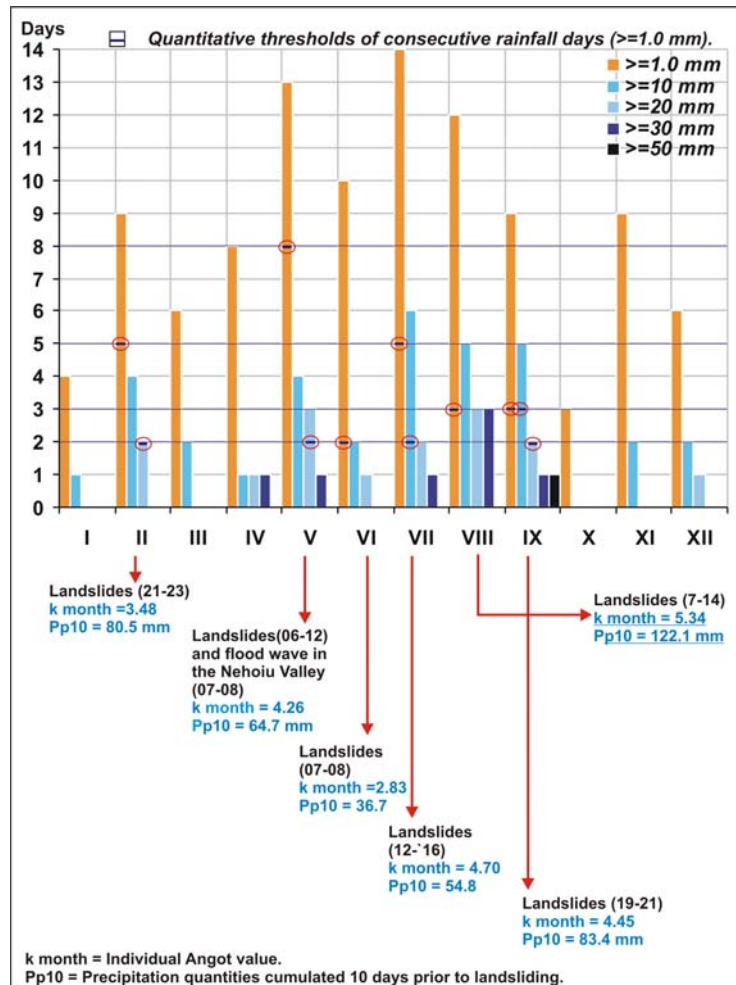


Fig. 10 - Quantitative thresholds of consecutive rainfall days, 2005 (Pâtârlagele weather station) and their landsliding impact in the Muscel Basin.

- Caractère de successivité des jours avec des précipitations sur des différentes limites quantitatives en 2005 (Pâtârlagele) et leurs implications dans l'occurrence des glissements de terrain dans le bassin de Muscel.

4. Conclusions

The annual and especially individual Angot Pluvial Index components represent an objective estimation of the direct relationship between the quantity of precipitation (susceptibility classes) and the terrain response to the pluvial impact materialised in either very dynamic or balanced intervals in the evolution of some modelling processes.

The Angot individual component helps establishing value differences in the monthly variation of precipitation quantities, faithfully indicating the rain excess/deficit peaks involved in landslide dynamics.

The absence of the two extreme susceptibility classes (very dry and very rainy) from the index annual component value indicates a slightly rain-deficient regime in the Curvature Subcarpathians. The exceptional quantities of precipitation evidenced by the index individual component value peaks (July 1975 and February, May-September 2005) represent low frequency limit situations in the length of the observation series analysed by us.

The pluvial interval in which Muscel Basin landslides were likely to be unleashed, or reactivated was May-September, while the impact of excess rain fallen in other periods was quite incidental. Most slide-affected in the above-mentioned interval and in 2005 was the median basin sector underlain by brittle Mio-Piocene molasse formations.

Low precipitation susceptibility in terms of landslide dynamics was characteristic of the December-March winter months (frozen soil and solid precipitation) and of transitional months (October-November and April) marked by very frequent freeze-thaw cycles.

The multitude of practical applications offered by the Angot Index individual and annual components, make it very useful in quantifying the causality relation between climatic and geomorphological events.

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