Application of the Angot (k) pluviometric index to Cotnari Weather Station in the period 1961-2020

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Vol. 32/2022, 29-38

GEOREVIEW

Published:
online first
4 April 2022

ABSTRACT: The paper presents the application of the Angot Rainfall Index (k) to highlight the characteristics of the annual variation of atmospheric precipitation and climatic features of each month in Cotnari. The analysis of precipitation data from 1961-2020 at Cotnari Weather Station, highlights dry monthly intervals every year. January (95% of cases) is the driest, followed by December 88.5%, February 86.7% and March 81.8%. The low values of precipitation are reflected in the reserve of deficient soil moisture and the delays in the beginning of spring agrotechnical practices. The summer months are characterized by an appreciable degree of coverage of the water needs of the soil, the rainiest month being June. It should be mentioned that the summer rains are characterized by short duration (1-2 hours) and are episodes of atmospheric precipitation with a great variability, depending both on the characteristics of the general circulation of the atmosphere at continental level and on the particularities of the active surface.

KEY WORDS: Angot rainfall index (k), rainfall attribute, susceptibility to erosion.

1. Introduction

In evaluating the rainfall surplus or deficit we applied the rainfall index Angot (k), as a mathematical expression of the ratio between average annual and monthly precipitation: supraunitary values indicate monthly rainy intervals (k>1) and subunit values indicate dry monthly intervals (k<1) (Puţuntică, 2007; Satmari, 2010). The name of the Angot coefficient or index comes from the French meteorologist and climatologist Charles Alfred Angot (1848-1924). This index is used to highlight the characteristics of the annual variation of atmospheric precipitation (Dragotă, 2003) and the pluviometric shades of each month. For the period 1961-2020 the annual average amount of precipitation was 547.5 mm. At the annual and intra-annual level, the rainfall is characterized by the alternation of rainy periods and dry periods. This is a representative climatic feature of the rainfall of the researched territory (Mihăilă and Tănasă, 2010).

Index k was used as a landmark in the predisposition for triggering the processes of slope and linear erosion of lands in the analyzed areas (Ghiţă and Dragotă, 2010; Grecu et. al., 2011; Grecu et. al., 2014) and less in assessing the risk of drought (Croitoru, 2003; Larion and Pălimariu, 2006).
The paper aims to determine the susceptibility of the topographic surface to erosion caused by atmospheric precipitation by applying the rainfall index Angot (k).
The objectives of the study are: evaluation and determination of rainfall characteristics for each month, season and year from 1961-2020. Interconnecting the climatic information with the geomorphological one depends on the pluviometric attributes of the different analyzed temporal entities and the susceptibility classes to soil erosion and landslides.

2. Study area

The study area, Cotnari area, is an important vine-growing center, located in the northeast of Romania. Cotnari Weather Station is currently positioned at 47° 22’lat. N and 26° 56’long. E and the altitude of 289 m. Geographically, the station is located on the structural plateau of Hârlău Big Hill – Cătălina Hill subunit. Cotnari is within the continental temperate climate type of transition from the Scandinavian-Baltic influences specific to the Suceava Plateau to the continental influences specific to Eastern Europe, with a pronounced regional atmospheric dynamics in the western and north-western sector, but influenced more than elsewhere, by local topography (Fig. 1). The area of study is characterized by a contrasting annual range and elements of events weather.

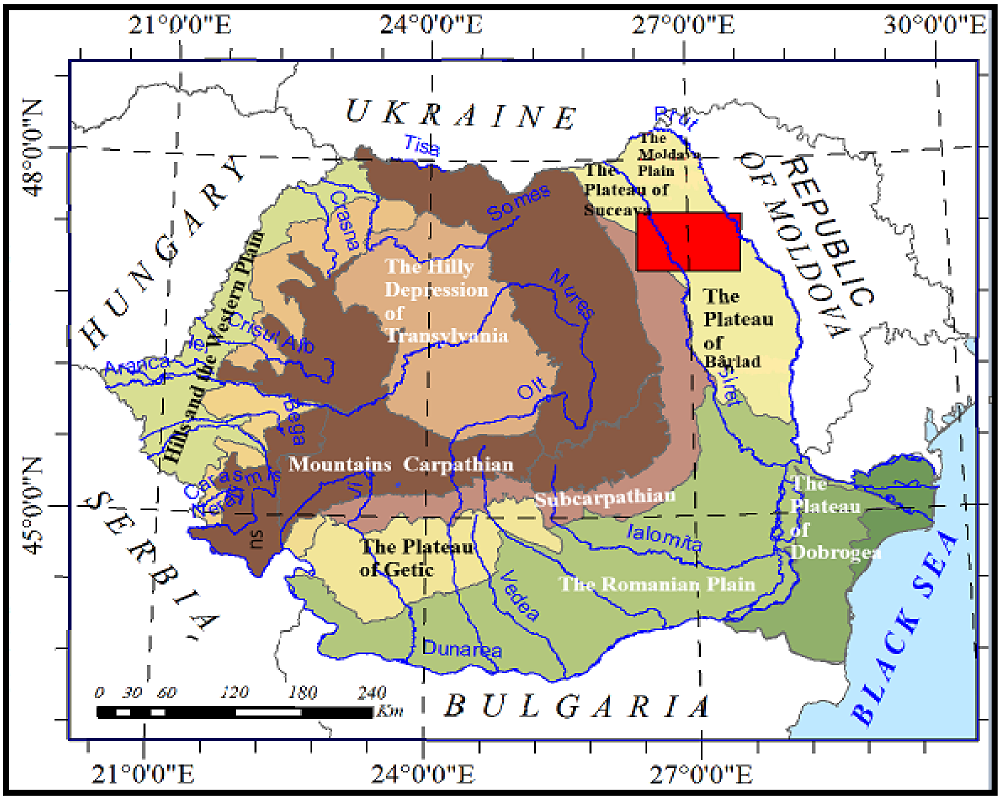


Figure 1 Location of the study area.

3. Methods, data and sources of information used

According to the World Meteorological Organization (W.M.O.), homogeneous climate data strings of at least 30 years are recommended in climate analysis. To achieve the proposed objective, we analyzed the data series of monthly amounts of precipitation at Cotnari Weather Station, for the period 1961-2020 (60 years).

We calculated k based on the number of days in the month, according to the formula [1]:

$$k = p/P, [1]$$

where the parameter was calculated according to the formula [2],

$$p = q/n, [2]$$

and the parameter P according to the formula [3]

$$P=Q/365, [3].$$

where:

q represents the average amount of precipitation in a month;

n represents the number of days in that month;

Q = average annual amount of precipitation;

and 365 is the number of days in a year

Data processing and their representation in the form of tables and graphs was done in Microsoft Excel 2010.

After calculating the monthly and annual values of k, we have linked the climatic information with those from the dynamic geomorphology according to the pluviometric attributes of the different temporal entities analyzed and the classes of susceptibility to soil erosion and landslides (Pelin, 2016). The climatic information obtained has a quantifiable geomorphological output according to Grecu et al. (2014) - Tab. 1.

Table 1 Erosion susceptibility classes and rainfall attribute according to Angot rainfall index values. (Grecu, 2014).

Rainfall attributes	Very dry	Dry	Normal	Rainy	Very rainy
Susceptibility to erosion and landslides	Very low	Low	Moderate	High	Very high
Angot Rainfall Index Value (k)	<0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	>2.50

4. Results and discussion

The long term variability of annual precipitation amount from the period 1961-2020 (Fig. 2) at SMC, according to k, shows 29 dry years with subunit values (k<1), which represents 48.3% of the total number of years analyzed (Fig. 3) and 31 rainy years with supraunitary k values which represents 51.7% of the number of analyzed years of the mentioned period (Fig. 4).

The annual value of k ranges between 0.6 (1967, 1986 - the driest years, having 10 consecutive months in which the value k had subunit values) and 1.6, 2019 being the rainiest year of the studied period. The amount of precipitation in 2019 was 877 mm, of which 265 mm accumulated in June, representing 48.7% of the average multiannual value of 547.5 mm / year at SMC between 1961-2020; the k value for the month in question was 5.9.

The linear trends of the annual values of the Angot rainfall index lead to the rainfall attributes of the "normal", with supraunitary values (Fig. 4) of the rainfall index Angot (k) and "low" and "moderate" sensitivity to the dynamics of slope processes.

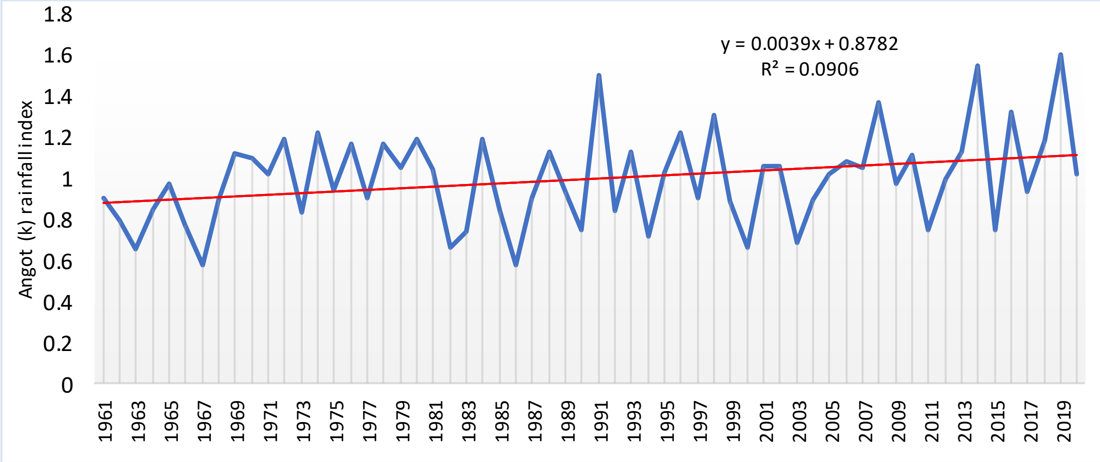


Figure 2 Multiannual variability of the index (k) in Cotnari (1961-2020).

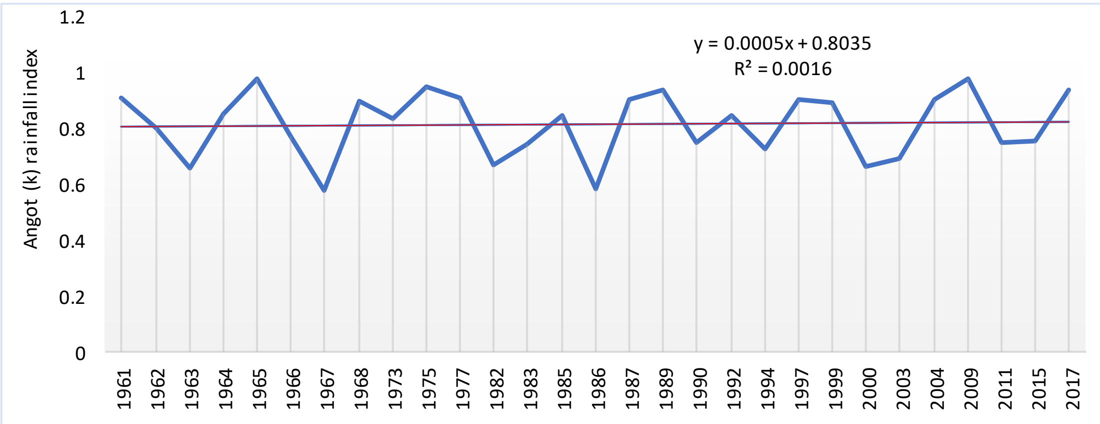


Figure 3 Representation of the multiannual regime of the annual subunit values of k<1 at Cotnari (1961-2020).

Applied to the amount of precipitation from SMC, the index k denotes moderate susceptibility to erosion and landslides at Cotnari, so that these summer processes can be influenced by other factors: petrographic, morphometric, hydrogeological, dominant air circulation or mode of land use, but also the geographical position in northeastern Romania (Mihăilă, 2006).

Cotnari Weather Station is sheltered by the peaks of Dealul Mare-Tudora (587 m), Dealul Cetăţuia (520 m), forested with: common ash (*Fraxinus excelsior*), Mediterranean ash (*Fraxinus angustifolia*), pedunculate oak (*Quercus robur*), European white elm (*Ulmus laevis*) and beech mixed with hornbeam in Asperulo-Fagetum plant formations. The high degree of coverage of the eastern and south-eastern slopes with vine plantations (Tab. 2) can contribute favorably to the moderation of areolar erosion, given that the vegetation diminishes the impact of precipitation on the soil, retaining some of the precipitation and regulating the course of water from the slope and riverbed, thereby mitigating erosion.

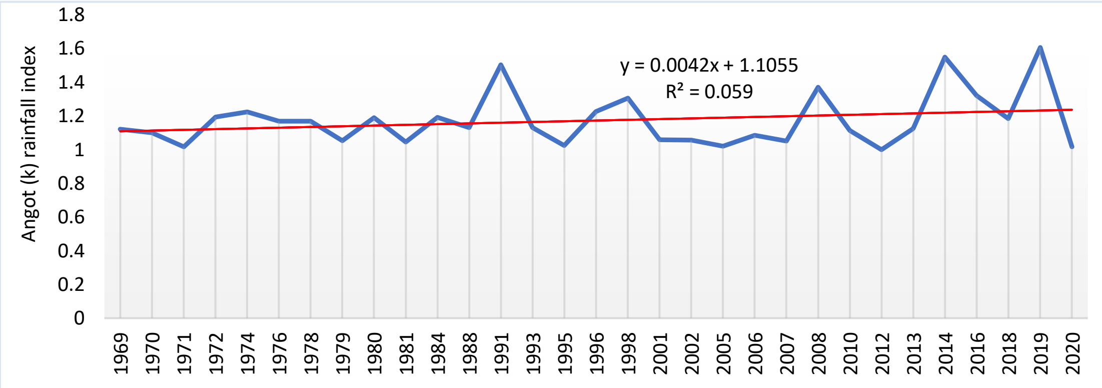


Figure 4 Representation of the multiannual regime of the annual superunit values of k>1 at Cotnari (1961-2020).

Table 2 Annual frequency of erosion and landslide susceptibility classes according to Angot (k) rainfall values at Cotnari between 1961-2020.

Rainfall attributes	Very dry	Dry	Normal	Rainy	Very rainy
Susceptibility to erosion and landslides	Very low	Low	Moderate	High	Very high
Angot Rainfall Index Value (k)	<0.99	1.00 - 1.49	1.50 - 1.99	2.00 - 2.49	>2.50
Absolute frequency (years) Cotnari 1961-2020	29	28	3	0	0
Relative frequency (%)	48.3%	46.7%	5%	0	0

The annual regime configured on the basis of seasonal and seasonal averages highlights the predisposition to soil erosion and landslides, between April and October, when the value of the Angot Rainfall Index was 1.37. The large amounts of precipitation in the hot season (378.4 mm), justify the superunit values of k: summer (k = 1.96), spring (k = 1.02) - these precipitations are generated by intense convective activity and by clouds with high vertical development and growth cyclonic activity at this time of year (Fig. 5). In the cold season there were lower amounts of precipitation. The average multiannual value of atmospheric precipitation between October and March was 169.1mm and k was 0.61.

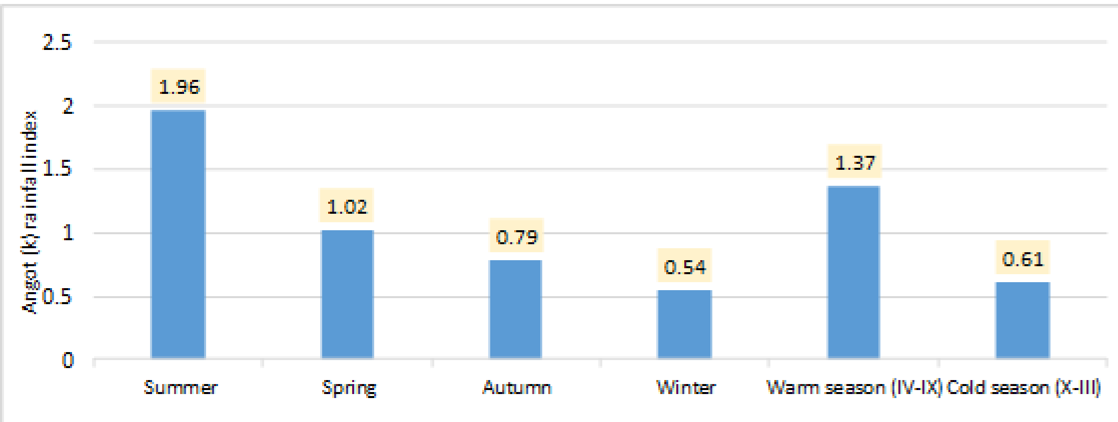
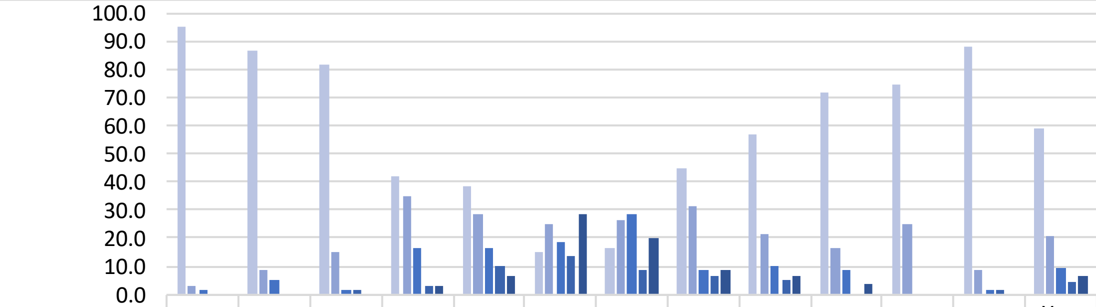


Figure 5 Representation of the seasonal and seasonal values of the k index in Cotnari (1961-2020).

The annual regime configured on the basis of the monthly averages of the index k, in the interval 1961-2020, at SMC, highlights dry monthly intervals every year (Fig. 6). January is the driest month, 57 months out of the 60 of the analyzed period 1961-2020, had the value of the subunit k index, which represents 95%, followed by December 88.5%, February 86.7% and March 81.8%. The low values of precipitation in the mentioned months are reflected in the deficit of soil moisture reserve and the delays in the beginning of spring agrotechnical practices (Strahler, 1952).



	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year avg.
<0.99	95.0	86.7	81.8	41.8	38.3	15.0	16.6	45.0	56.7	71.7	75.0	88.5	59.3
1.00 - 1.49	3.3	8.3	15.0	35.0	28.3	25.0	26.7	31.7	21.7	16.6	25.0	8.3	20.4
1.50 - 1.99	1.7	5.0	1.6	16.6	16.6	18.4	28.3	8.3	10.0	8.3	0.0	1.6	9.7
2.00 - 2.49	0.0	0.0	1.6	3.3	10.0	13.3	8.3	6.7	5.0	0.0	0.0	1.6	4.2
> 2.50	0	0	0	3.3	6.8	28.3	20.1	8.3	6.6	3.4	0	0	6.4

Figure 6 Representation of the average monthly weights of the index k by value categories in Cotnari (1961-2020).

The summer months are characterized by an appreciable degree of coverage of the water needs of the soil. June was the wettest month in the entire study interval, the share of monthly superunit values totalised 85% with rainy and very rainy rainfall attributes and a high susceptibility to erosion and landslides, followed by July (k>1 = 83.4%) and August (k>1 = 55%) (Fig. 6). Atmospheric precipitation in the summer months, can be frequently interrupted by anticyclonic activity, therefore, rainfall deficits can be recorded in any month of the year. The value categories by months of the index k, include Cotnari in the subtype of continental temperate rainfall variation, characterized by a simple oscillation with a maximum in a summer month (June) and a minimum in a winter month (January) (Tab.3). These observations are in agreement with those of Enache (2009). It should be noted that the high values of precipitation amounts in these months have a major statistical importance in economic activities and weather and climate assessments, but summer rains are characterized by short duration (1-2 hours), the amount of water accumulated is directly proportional to the intensity and duration of the rain, there are episodes of precipitation with great variability, depending on the characteristics of the general circulation of the atmosphere over the country and the characteristics of the active surface. Also, the Angot rainfall index (k) does not take into account the regime of air temperature, air humidity, wind or potential evaporation (Stângă and Minea, 2005).

Table 3 Inter-monthly and multiannual regime of rainfall index Angot (k) at Cotnari (1961-2020).

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	**Year avg.**
1961	0.6	0.4	0.2	2.5	2.1	0.9	1.7	1.1	0.1	0.0	0.6	0.5	**0.9**
1962	0.4	0.7	1.4	1.1	0.4	1.0	1.1	0.5	1.1	0.2	1.4	0.3	**0.8**
1963	0.8	0.5	0.7	0.8	0.7	1.0	0.9	1.4	0.2	0.1	0.1	0.7	**0.7**
1964	0.1	0.7	0.9	0.3	0.8	1.1	1.6	1.4	1.2	0.9	0.8	0.4	**0.9**
1965	0.5	0.7	0.3	1.2	1.4	4.5	1.4	0.2	0.5	0.1	0.8	0.2	**1.1**
1966	1.8	0.1	0.9	0.3	0.7	0.6	1.8	1.1	0.1	0.4	1.2	0.4	**0.8**
1967	0.2	0.4	0.5	0.6	0.8	1.2	1.0	0.8	0.3	0.2	0.3	0.4	**0.6**
1968	0.7	0.8	0.5	0.2	0.4	0.6	2.9	1.1	2.0	0.9	0.4	0.2	**0.9**
1969	0.3	1.5	0.8	1.1	0.6	2.5	3.3	1.5	0.3	0.1	0.2	1.3	**1.1**
1970	0.4	0.9	0.5	1.2	3.4	1.0	2.5	1.1	0.4	0.5	0.6	0.6	**1.1**
1971	0.5	0.6	1.1	0.3	1.4	1.8	2.5	1.1	1.2	0.1	0.4	1.4	**1.0**
1972	0.5	0.1	0.4	1.0	1.6	2.1	1.6	3.4	0.9	1.8	0.7	0.1	**1.2**
1973	0.5	1.0	1.2	0.6	1.2	1.3	2.5	0.9	0.1	0.3	0.1	0.3	**0.8**
1974	0.2	0.1	0.1	0.6	1.7	2.7	3.9	1.4	1.6	1.1	1.1	0.5	**1.2**
1975	0.3	0.4	0.0	0.9	1.7	3.7	1.7	0.4	0.4	1.6	0.1	0.1	**0.9**
1976	0.6	0.1	0.4	1.6	1.6	1.0	2.1	2.2	2.0	1.1	0.8	0.6	**1.2**
1977	0.5	0.3	0.2	1.9	1.2	0.9	1.2	2.4	1.3	0.1	0.5	0.3	**0.9**
1978	0.0	1.6	0.5	2.0	2.2	2.5	1.3	0.8	1.8	0.1	0.6	0.6	**1.2**
1979	0.9	0.4	0.4	2.8	0.8	2.1	0.5	2.6	0.2	0.7	0.8	0.5	**1.1**
1980	0.5	0.1	1.2	1.7	1.7	2.3	2.4	0.7	0.5	1.0	1.1	1.1	**1.2**
1981	0.5	0.2	1.0	1.3	2.3	1.7	1.4	0.6	1.4	0.4	1.3	0.5	**1.1**
1982	0.5	0.6	0.7	0.9	0.2	1.9	1.5	0.5	0.1	0.2	0.3	0.5	**0.7**
1983	0.3	0.2	0.2	1.2	2.4	1.3	0.5	1.8	0.2	0.1	0.5	0.2	**0.7**
1984	0.6	1.7	0.9	1.8	2.4	1.2	2.4	1.1	0.4	0.4	0.9	0.5	**1.2**
1985	0.5	0.4	0.1	1.0	0.9	3.6	1.0	0.9	0.7	0.2	0.6	0.3	**0.8**
1986	0.2	0.9	0.2	0.4	0.1	1.8	1.6	0.6	0.2	0.6	0.2	0.3	**0.6**
1987	0.7	0.2	0.2	0.9	1.3	1.4	0.5	2.3	0.3	1.2	1.2	0.7	**0.9**
1988	0.9	0.3	0.9	1.4	1.9	2.9	1.8	0.9	1.6	0.1	0.3	0.6	**1.1**
1989	0.1	0.1	0.4	1.0	1.5	1.5	1.1	1.9	2.9	0.2	0.4	0.1	**0.9**
1990	0.2	0.6	0.1	1.7	1.0	1.3	1.0	0.5	0.1	0.6	0.5	1.3	**0.7**
1991	0.3	0.7	0.4	1.0	3.0	2.0	4.9	3.3	1.1	0.7	0.5	0.2	**1.5**
1992	0.2	0.1	0.6	0.8	0.8	3.7	0.4	0.3	1.5	0.8	0.2	0.6	**0.8**
1993	0.1	0.3	1.7	1.7	1.3	1.2	1.6	0.6	2.2	0.3	1.4	1.1	**1.1**
1994	0.4	0.4	0.2	0.5	0.7	2.4	0.5	0.9	0.2	1.4	0.4	0.6	**0.7**
1995	0.4	0.2	0.5	0.4	2.5	1.8	1.0	1.1	2.7	0.2	0.8	0.6	**1.0**
1996	0.5	0.5	0.6	0.9	1.3	1.1	1.8	1.3	3.5	0.6	1.0	1.6	**1.2**
1997	0.1	0.1	0.1	1.7	0.8	2.3	1.9	1.2	0.7	0.6	0.4	0.8	**0.9**
1998	0.8	0.1	0.7	1.0	2.1	2.5	1.8	0.8	1.9	2.5	1.1	0.3	**1.3**
1999	0.2	0.7	0.3	1.7	0.4	1.3	2.3	1.2	0.2	0.9	1.0	0.5	**0.9**
2000	0.4	0.3	0.4	1.1	0.6	0.9	1.9	0.6	1.0	0.2	0.4	0.3	**0.7**
2001	0.5	0.4	0.3	1.0	1.0	2.3	1.2	0.3	3.0	0.9	1.3	0.4	**1.1**
2002	0.2	0.1	0.9	0.6	0.5	1.5	3.7	2.0	0.8	0.9	1.3	0.2	**1.1**
2003	0.6	0.5	0.2	0.5	0.4	0.6	2.3	1.2	0.4	1.2	0.1	0.3	**0.7**
2004	0.9	0.5	0.5	0.3	0.7	0.3	3.6	1.7	0.9	0.5	0.7	0.2	**0.9**
2005	0.7	1.2	0.4	1.2	1.4	1.5	1.0	3.0	0.6	0.4	0.6	0.5	**1.0**
2006	0.6	0.4	2.1	1.2	1.2	2.6	1.6	2.7	0.3	0.4	0.1	0.0	**1.1**
2007	0.3	0.8	0.8	0.7	0.9	0.9	1.5	1.6	1.1	1.8	1.2	1.1	**1.1**
2008	0.2	0.3	0.5	2.8	1.2	1.9	4.4	1.3	1.3	0.9	0.3	1.3	**1.4**
2009	1.1	0.9	1.1	0.2	1.0	3.0	1.3	0.4	0.3	1.0	0.4	1.2	**1.0**
2010	0.9	0.7	0.5	1.2	1.4	2.2	2.6	0.5	1.0	1.0	0.9	0.5	**1.1**
2011	0.2	0.6	0.3	1.3	0.4	2.5	1.6	0.5	0.4	0.7	0.0	0.4	**0.7**
2012	0.4	1.4	0.3	1.7	1.9	1.1	0.7	0.7	0.4	0.6	0.6	2.1	**1.0**
2013	0.6	0.8	1.3	1.1	1.4	3.5	1.3	1.1	1.1	0.2	1.1	0.1	**1.1**
2014	1.1	0.1	0.8	2.0	4.0	1.5	3.8	1.0	0.6	1.6	1.0	1.1	**1.5**
2015	0.3	0.7	1.0	0.5	0.3	0.7	1.3	1.1	0.7	1.4	0.9	0.1	**0.8**
2016	0.5	0.5	0.7	0.8	1.9	3.4	0.1	0.9	1.2	4.4	1.3	0.2	**1.3**
2017	0.5	0.7	1.4	1.5	0.6	1.8	0.7	0.4	1.2	1.5	0.4	0.6	**0.9**
2018	0.7	1.2	1.3	0.2	1.0	4.4	2.5	0.2	0.5	0.1	1.3	0.9	1.2
2019	1.6	0.6	0.3	1.3	4.1	5.9	1.4	1.3	0.7	0.8	0.6	0.7	1.6
2020	0.2	1.1	0.5	0.1	1.9	3.1	0.9	0.3	1.5	1.4	0.2	1.1	1.0
Average	**0.5**	**0.6**	**0.6**	**1.1**	**1.4**	**2.0**	**1.8**	**1.2**	**0.9**	**0.8**	**0.7**	**0.6**	1.0

Table 4 Monthly frequency of erosion susceptibility classes and pluviometric attribute according to the values of the Angot (k) rainfall index at Cotnari in the period 1961-2020.

Average monthly weight of Angot Rainfall Index (k)			Rainfall attributes	Susceptibility to erosion and landslides
	k=>2.50	6.4%	Very rainy	Very high
	k=2.00-2.49	4.2%	Rainy	High
	k=1.50-1.99	9.7%	Normal	Moderate
	k=1.00-1.49	20.4%	Dry	Low
	k=<0.99	59.3%	Very dry	Very low

The moderate monthly frequency of the classes of susceptibility to soil erosion and landslides is highlighted by the dominance of the subunit values of the k index with deficient rainfall attributes: 20.4% "dry" and 59.3% "very dry" and only 20.3% the share of monthly superunit values of index k with the following rainfall attributes 9.7% “normal” and 10.6% “rainy” and “very rainy” (Tab. 3, Tab. 4).

Against the background of minimum monthly absolute values of k of 0.0-0.1 in over ten months of the analyzed period (Tab. 5), and of the maximum monthly absolute values of 5.9 in June 2019, 4.9 July 1991 or 4.4 October 2016, we can notice the positive trends of the decadal average values of this index, calculated for the periods 1961-1990 and 1991-2020, in almost all months of the year, except April (k = 1.14, 1961-1990 / k = 1.03, 1991-2020) and August (k = 1.23, 1961-1990 / k = 1.12, 1991-2020).

Table 5 Minimum, maximum, decadal and monthly average values of the k index in Cotnari (1961-2020).

The parameter	Jan.	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
The minimum monthly values of the index k (1961-2020)	0.0/ 1978	0.1/ 1966/1972 1974/1976 1980/1989 1992/1997 1998/2002 2014	0.0/ 1975	0.1/ 2020	0.1/ 1986	0.3/ 2004	0.1/ 2016	0.2/ 1965 2018	0.1/ 1961 1966 1973 1982 1990	0.0/ 1961	0.0/ 2011	0.0/ 2006
The maximum monthly values of the index k (1961-2020)	1.8/ 1966	0.7/ 1984	2.1/ 2006	2.8/ 1979 2008	4.1/ 2019	5.9/ 2019	4.9/ 1991	3.4/ 1972	3.5/ 1996	4.4/ 2016	1.4/ 1962 1993	2.1/ 2012
Monthly average values of the k index (1961-1990)	0.50	0.56	0.57	1.14	1.34	1.78	1.69	1.23	0.80	0.51	0.63	0.51
Monthly average values of the k index (1991-2020)	0.51	0.56	0.70	1.03	1.36	2.13	1.84	1.12	1.09	0.99	0.72	0.65
Monthly average values of the k index (1961-2020)	0.5	0.6	0.6	1.1	1.4	2.0	1.8	1.2	0.9	0.7	0.7	0.6

Torrential rains have a high energy materialized by intense erosive processes (Mega and Damian, 2020). Areolar erosion can cause soil washing and linear erosion can deepen ditches, ravines and torrents (Horton, 1945). Hydrologically, their result translates into flooding of valleys or catastrophic floods in small basins (example: Bahlui basin: Oii Valley - July 1991, Bahlui - July 2014, Jijia - June 2019).

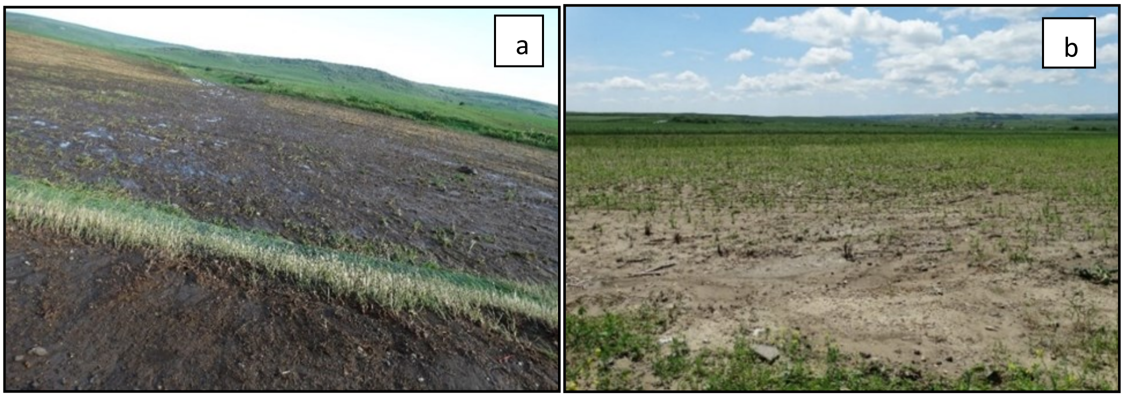


Figure 7 Effects of Movileni (a) – Focuri (b) torrential rainfall, June 1, 2019 (photo by Apopei L.).

Given the agricultural aspect of the area, which focuses on the vine culture and its less demanding moisture needs, depending on the variety, water is needed during the ripening stage of the grapes. In the viticultural specificity of the area, favourable factors are the lithological, pedological substratum and the relief with the exposure of the visitors. Cernozem soils: leached, leavened rendzinic, pseudorendzinic (Cotea, 2006) are the most profitable and occupy over half of the surface of Cotnari followed by forest gray soils and brown soils.
The precipitation deficit, justified by the values of the k index at Cotnari in the period 1961-2020 and the distribution of these values of the k index according to the pluviometric attributes (Grecu, 2014) essential with different frequency and intensity from a spatio-temporal point of view. Knowing the precipitation deficit is of particular practical importance, on the basis of which various measures could be taken to prevent or reduce the negative impact on human activities.

5. Conclusion

Although it is based on a single climatic element, atmospheric precipitation, the practical utility of the k index is evident in the assignment of monthly and annual rainfall ratings. Also, precipitation has a direct impact on the landscape through the processes of rainfall, the appearance of ravines, ditches and torrential organisms. Moreover, as a major and direct impact, we recall the rainfall factor as an active part for the onset of landslides, when analyzing time series older than 30 years.

At Cotnari, the rainfall regime does not offer favorable conditions for triggering the slope geomorphological processes. This situation was underlined by the value of the Angot index, which was less than 0.99 in proportion of 59.3% of the average monthly frequency, with deficient rainfall attributes: 59.3% "very dry" and 20.4% "dry" and only 20.3% the share of monthly superunit values of the k index with the following rainfall attributes 9.7% "normal" and 10.6% "rainy" and "very rainy".

Thus, the type of annual regime can be established on the basis of the index k, up to the level of climatic region.

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