REGIONAL METEOCLIMATIC HAZARDS ASSOCIATED TO CLIMATIC CHANGE IN THE REPUBLIC OF MOLDOVA

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Risques météorologiques régionaux associés au changement climatique en République de Moldova. Le rythme accéléré du changement climatique est associé avec la manifestation des phénomènes extrêmes, devenus plus intensives et fréquents pendant ces dernières années. Malheureusement, nous connaissons que jusqu'à présent, il n'existe pas une conception unanime acceptée à l'égard des caractéristiques des facteurs du risque, il n'existe pas une base d'information scientifique qui permettra à organiser le fonctionnement des systèmes territorials. La mise en œuvre au niveau national des Conventions des Nations Unies concernant la lutte contre la désertification et le changement climatique ainsi que l'accord d'association de la République de Moldavie avec l'Union européenne conditionne la nécessité de la recherche proposée par une série de directives sur la gestion des risques naturels. Le sommet des années les plus chaudes sur le territoire de la République de Moldavie confirme que les dernières années ont été les plus chaudes de la série des observations instrumentales depuis plus d'un siècle. L'évolution des anomalies pluviométriques indique qu'elles alternent de sèches à humides, conditionnées par l'occurrence de sécheresses et d'inondations. Les sécheresses des années 2007 et 2012 ont causé des dommages matériels d'un montant de plus de deux milliards de lei moldaves (MDL). Les excès pluviométriques (2008, 2010) ont provoqué aussi des dommages matériels substantiels. Nous pensons que les résultats obtenus sur l'estimation spatio-temporelle des risques météo-climatiques, des tendances du changement climatique et sur l'impact de ces changements sur les différents domaines pourraient contribuer à leur atténuation au niveau national.

1. INTRODUCTION

The accelerated pace of climate change is associated with the manifestation of extreme phenomena (Apostol, 2000; Bălteanu *et al.*, 2005; Nedealcov 2014), which have become more intense and more frequent in recent years. To our knowledge, there is no scientific information base at regional level that could allow an optimal organization and functioning of the territorial systems (districts). The implementation of the provisions on the Association Agreement of the Republic of Moldova with the European Union – through a series of directives on the management of natural risks, conditions the necessity of the proposed research. In identifying weather-climatic hazards, we have taken into account the unified risk definition developed by the UN Development Program (UNDP) experts that refers to the probability of the negative consequences and predicted losses resulting from the interaction of the natural, anthropogenic, hazardous phenomena and the vulnerability conditions. In this context, we mention that the vulnerability is the conditions determined by the natural, social, economic and ecological factors or processes, which intensifies the exposure of one or another community to the influence of the danger (Reducing Disaster Risk, global report, 2005). Hence, the notion of risk can not be treated isolated by the return time (or period) of an extreme event, their common and logical source, being the probabilities of producing extreme events. The notion of risk can not be treated without a spatial delimitation of vulnerable areas to their manifestation (Bălteanu *et al.*, 2003; Bogdan, 2005; Bogdan *et al.*, 1999; Nedealcov *et al.*, 2018). In the context in which the risk

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means in the quantity or magnitude with which a concrete phenomenon is manifested or may be manifested, namely climate, on a certain temporal and spatial scale (Bogdan *et al.*, 1999; Nedealcov *et al.*, 2018), the knowledge of the spatio-temporal manifestation of climatic risks is extremely important, since this largely depends on the possibilities of mitigating their consequences in different fields of human activity.

Climatic projections for nearest future years, especially in the countries with heightened aridity, reveal a significant increase in temperature even for the next years (Dascălu *et al.*; Bojariu *et al.*, 2015, Climate Change 2018; Chantal *et al.*, 2017). Adaptation to the effects of climate change must be an important element of national policy, because even if greenhouse gas emissions would fall over a near-term horizon, this does not imply the mitigation of the global warming phenomenon. Moreover, long-term climatic changes connected with the changes in precipitation models, precipitations variations and temperatures are most probable to cause an increase of droughts and floods frequency.

In the absence of an effective strategy for adaptation to the effects of climate change, there is a possibility that the Republic of Moldova will face the future adoption of measures to adapt to the effects of climate change with higher implementation costs and without the corresponding effectiveness from economical and social point of view. It is therefore necessary that, in the case of estimated effects with a high degree of certainty, the measures are to be implemented in the shortest possible time.

Analysis of observational data for long periods of time has revealed that global warming is an ongoing phenomenon, which is also accepted by the international scientific community. Simulations using global climatic models have shown the main factors that determine this phenomenon, both natural (variations in solar radiation and volcanic activity) and anthropogenic (changes in atmospheric composition due to human activities). The cumulative effect of the two categories of factors may explain the observed changes in global mean temperature over the past 150 years. The increase in greenhouse gas concentrations in the atmosphere, especially carbon dioxide, was the main cause of heating by 0.13°C in the last 50 years of the 20th century, which is about 2 times the value of the last 100 years, as shown in AR5 of the IPCC [8,15].

Between 1880 and 2012, since there are multiple sets of independent data, the average global air temperature has increased by about 0.85°C (with variations of 0.65 to 1.06), on average by 0.06°C per decade. The overall increase between the average of the 1850–1900's period and the period of 2003–2012 is 0.78°C (0.72–0.85°C) based on the existing only dataset.

Europe's climate recorded a warming of around 1°C in the last century, higher than the global average. All of the 21st century (2001–2013) is among the top 15 warmest, globally, since 1880, according to the 2013 National Oceanic and Atmospheric Administration (NOAA) report. 2013 is the fourth-largest top of the warmest years of the last 133, being the 37th consecutive year with a medium temperature higher than the one of the 20th century. The years 2010, 2005 and 1998 occupy, correspondingly, the top three places in the hottest years since 1880.

Air temperature has increased above the global average and the one recorded in Europe in our country in the last century. Thus, during the period of 1901–2000, the average annual average temperature increase was 0.6°C, in Romania it was below the global average by 0.3°C, and in the Republic of Moldova it consisted 0.9°C, i.e. above the global average by 0.3°C. Another comparative analysis of the regional data with the national ones confirms the accelerated pace for the territory of the Republic of Moldova: during the 1901–2006 period, the mean annual global temperature increase was equal to 0.74°C, while in Romania it was only 0.5°C [8, 14], and in Republic of Moldova – 1.06°C (Fig. 2).

In this context, we consider that knowing the regional particularities of manifestations of the current climate, also taking into account the specifics of the manifestation of weather-climatic hazards caused by the accelerated pace of climate change is extremely important.

Therefore, the objectives proposed in this paper consist of:

1. Identification of weather-climatic hazards according to the international database of information (CRED) and national one (Department of Exceptional Situations);

2. The selection of the climatic indices and their calculation in order to estimate the intensity and duration of the drought manifestation as the most hazardous phenomena for the national economy.

3. Spatial estimation with forecast elements (with a certain return period) for the types of hazards necessary in adjusting the national normative acts in constructions to the European Union Directives.

2. DATA AND STUDY REGION

The Republic of Moldova is located in the south-east of Europe, near the geographical center of this continent, bordering with Romania to the West and Ukraine to the North, East and South. It spreads between 45º28’01” and 48º29’31” N latitude (336.7 km latitude difference in a straight line) and between 26º40’ and 30º6’ E east longitude (approximately 150 km). The country covers an area of 33,843 km², and the relief of the Republic of Moldova is fragmented, represented by a succession of plateaus and relatively low plains. As a whole, it is inclined from the northwest to the southeast (wikipedia.org). The highest regions are those in the northwest and central plateaus (300–400 m), in the south the altitudes are lower (100–200 m). The average altitude is 147 m, the maximum one is 429.5 m, in Balăneşti Hill, and the minimum one – about 2 m, in the lower Dniester River (Fig. 1).

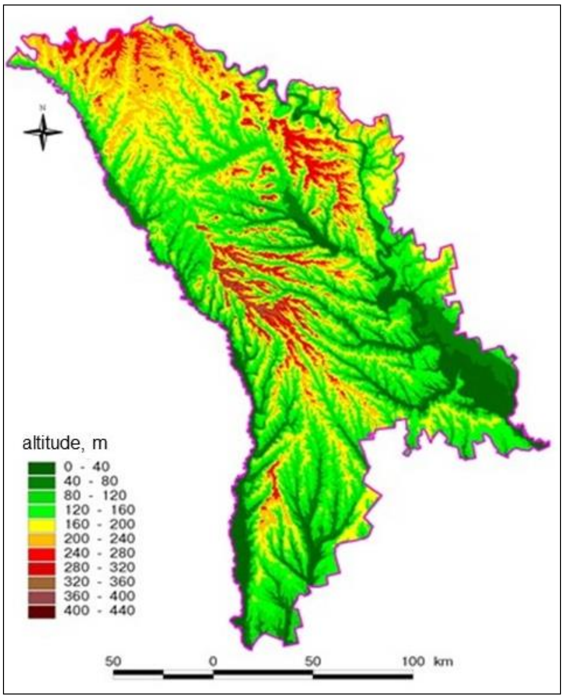


Fig. 1 – Physical map of the Republic of Moldova.

The Republic of Moldova is placed in the temperate-continental climate zone, influenced by the proximity to the Black Sea and the interference of hot-humid air in the Mediterranean area, with insufficient humidity, which determines a high frequency of droughts, which in the last period are intensive and potentially destructive. At the same time, in summer the rains are most often short and abundant, sometimes causing local flooding, leading to substantial material damage (wikipedia.org).

In case of highlighting the national climate change, the trend has been calculated for the time periods 1887–2017. In order to unify the international and national databases, the hazards were identified according to the same criterion (material damage, death toll). The time period of 1961–2015 was selected, a period in which there is a faster rate of climate change and a higher frequency of weather-climatic hazards. The database has served as a pillar for the proposed space-time estimates.

The temporal analysis was performed using the STATGRAPHICS CENTURION XVI software, and the digital maps were developed based on the Radial Basic method of the SURFER software.

3. METHODOLOGY

Monitoring drought and wet periods can be carried out using standardized precipitation index (SPI) and standardized precipitation and evapotranspiration Index (SPEI). SPI was proposed by McKee *et al.*, 1993; SPEI was developed by Serrano, Begueria and Moreno in 2010. Both indices are proposed by WMO which offers data and its calculation for free (Nedealcov *et al.*, 2018).

We mention that the "starting point" in the characterization of the drought serves a certain month in calculating different time scales. For example, for the month of July, the warmest month of the year, the value of the SPI for the 3-month period – will be the calculation of the values of the previous consecutive months, i.e. June, May, April, at the 6-month scale – calculate the previous consecutive months, i.e. June, May, April, March, February, January.

The Standardized Precipitation Index (SPI) is based on the probability of precipitation, and only monthly precipitation for a period of at least 30 years is required for the calculation. Precipitation is normalized using a probability distribution, so that the SPI values are in fact seen as the standard deviations from the median. SPI can be calculated for different time scales. Positive SPI values characterize wet periods, and negative ones – dry periods. SPI Distribution is normal for the whole period, the average is zero and standard deviation – the unit. The drawback of this index is that it only uses atmospheric precipitation, without taking into account the thermal regime and evapotranspiration.

The SPEI index is calculated on the basis of data characterizing the amount of atmospheric precipitation, the thermal regime and the latitude of the site, which also allows potential evapotranspiration to be taken into account. The SPEI is based on the original SPI index calculation procedure and uses the same available time scales. The SPEI calculation is based on the monthly difference between precipitation and potential evapotranspiration, which is a simple water balance methodology and can also be calculated at different time scales. Therefore, in the calculation of the SPEI index, a complete set of serial data characterizing the atmospheric, thermal and potential evapotranspiration is used. In this context, special software has been created to automatically calculate SPEI for a wide range of time scales. The software is available free of charge on the web by the Spanish National Research Council (Nedealcov *et al.*, 2018).

We assessed the climate risk related to precipitation excess (Nedealcov, 2017) using the Fournier Index (IF). This index takes into account the correlation between the amount of rainfall in the month with most precipitations and the annual rainfall and has been used to explain the exposure to terrain erosion processes in the specific wet years.

In regional aspect (Nedealcov, 2017), it is considered that the territory of the Republic of Moldova is in the “very low” erosivity class, registering values below 20. At the same time, this value does not reflect the degree of real erosivity in the years when precipitation intensity is significant.

The Fournier Index (IF) calculation formula is:

$$IF = Pmax.*Pmax/P, \tag{1}$$

where, Pmax.– quantity of precipitations for the month with the highest amount of rainfall, P – annual precipitations sum.

The identification of the degree of pluvial aggression was performed according to the classes included in Table 1, which reflects the degree of climate erosivity of the land.

Table 1

Classes of pluvial aggression determined by Fournier index

Erosivity class	IF
Very low	0–20
Low	20–40
Moderate	40–60
Severe	60–80
Very severe	80–100
Extremely severe	>100

The spatio-temporal estimation of dry/wet periods during the warm season of the year through the above mentioned climatic indexes highlights the magnitude of the vulnerable areas exposed to the weather-related climatic factors during the warm period.

In order to adjust some normative acts in constructions to the directives of the European Union we computed the return periods using the Gumbel distribution for maximum values (Gumbel distribution).

Gumbel distribution for maximums is defined by the probability density function:

$$f(x) = (1/\sigma)*exp(-z-exp(-z)) \quad (2)$$

and cumulative distribution function

$$F(x) = exp(-exp(-z)) \quad (3)$$

where $z = (x-\mu)/\sigma$, μ, şi σ – location and scale (distribution parameters), $f(x) = dF(x)/dx$.

Distribution parameters can be expressed by medium x_{med} and standard deviation σ_1 of the sample:

$\mu = x_{med} - \gamma \sigma$, where $\gamma \approx 0,5772$ –Euler-Mascheroni constant, $\sigma = (\sqrt{6}/Pi)^* \sigma_1$ consequently,

$$\mu = x_{med} – 0,45 \sigma_1 \text{ şi } \sigma = 0,7797 \sigma_1 \quad (4)$$

Quantile function *x(p)* specifies, for a given probability for a probability given in the probability distribution of a random variable, the value at which the probability of the random variable is less than or equal to the given probability. Quantile is the inverse of the cumulative distribution function F (x). Gumbel’s maximum distribution is:

$$x(p) = \mu – \sigma\ln(–\ln(p)) \quad (5)$$

consequently,

$$x(p) = x_{med} – \{0,45 + 0,7797*\ln[\ln(1/p)]\}* \sigma_1 \quad (6)$$

Reference value of soil frost depth would be exceed in an year with a probability *p* equal to:

$$x(1-p) = x_{med} – \{0,45 + 0,7797*\ln[\ln(1/1-p)]\}*\sigma_1 \quad (7)$$

Reference value of soil frost depth would be exceed in an year with a probability *p* equal to 0,02 (mean recurrence interval IMR=50 years) is equal to:

$$x(0,98) = x_{med} + 2.5923*\sigma_1 \quad (8)$$

Exceedance probabilities for the other intervals (period of road construction safety) are shown in Table 2.

Table 2

Exceedance probabilities for recurrence intervals of soil frost depth

Mean recurrence interval, years (IMR)	Exceedance probabilities for a year, p
50	0,02
75	0,01333
100	0,01

We used the Geographical Information Systems (GIS) to process spatio-temporal data and to visualize our results at national scale.

4. RESULTS AND DISCUSSION

The tendency of air temperature's increase (with increase rate of 0.0129^{o}C / year observed in the series of instrumental observations, 1887–2017) in the country allows us to conclude that regional climate change is characterized by a rather accelerated rhythm (Fig. 2).

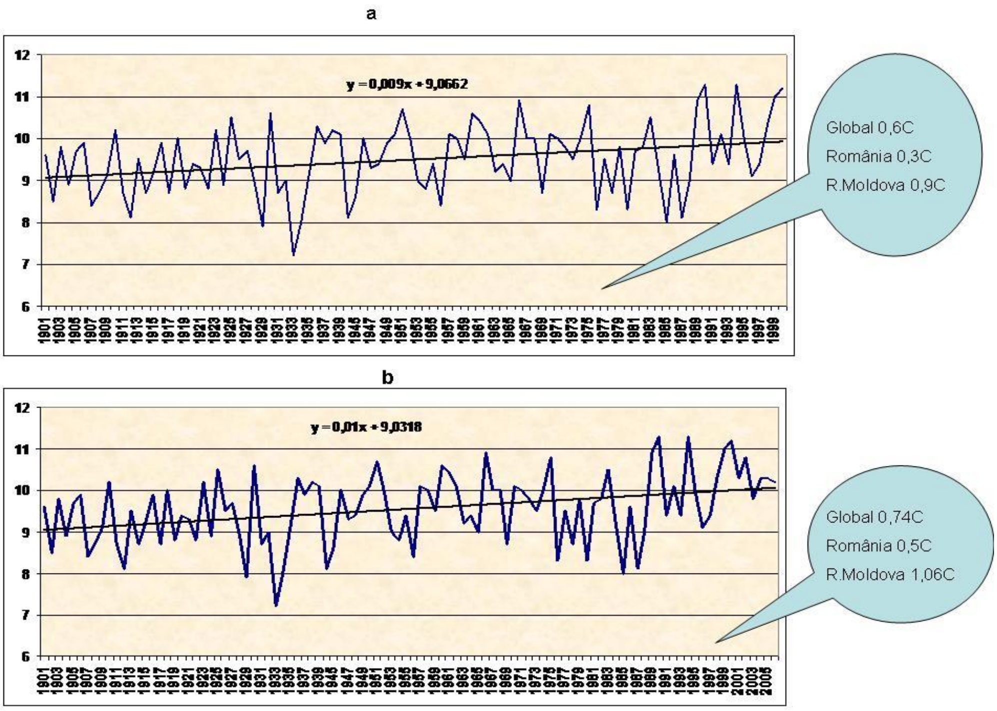


Fig. 2 – Trends in air temperature change in regional and national aspect.

2007 is among the warmest years, and remains the warmest in the last 130 years, after which the years 2015, 2017 and 2016 are set with significant thermal values. So, for the last three years, we have recorded some of the highest values. At the same time, there is an increase in the intensity and frequency of extreme weather events, which in most cases become hazardous phenomena due to the extent of the damage caused.

The database based on the criteria that reflect the material damages and the losses and the death toll using the international data provided by CRED and the national data offered by the Exceptional Situations department was elaborated for the contemporary period 1960–2015 (Fig. 3).

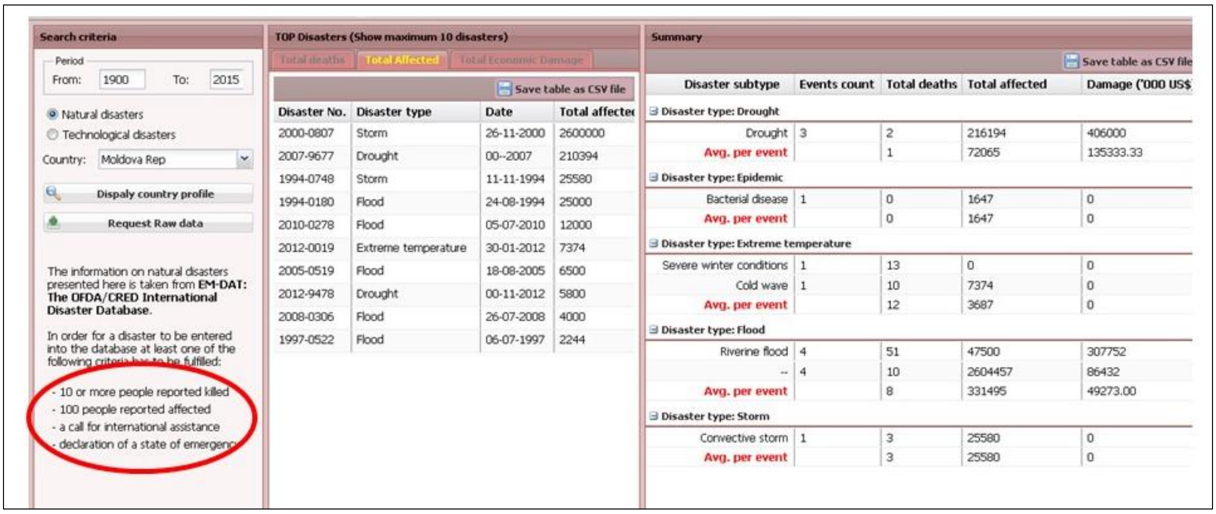


Fig. 3 – Creating of the information database based on the various identification criteria.

Figure 4 is illustrating the weighted estimate of climatic risk that had determined material losses and death toll in the Republic of Moldova, according to CRED data (1960–2015) and the data of the Department of Emergency Situations of Moldova (1960–2015).

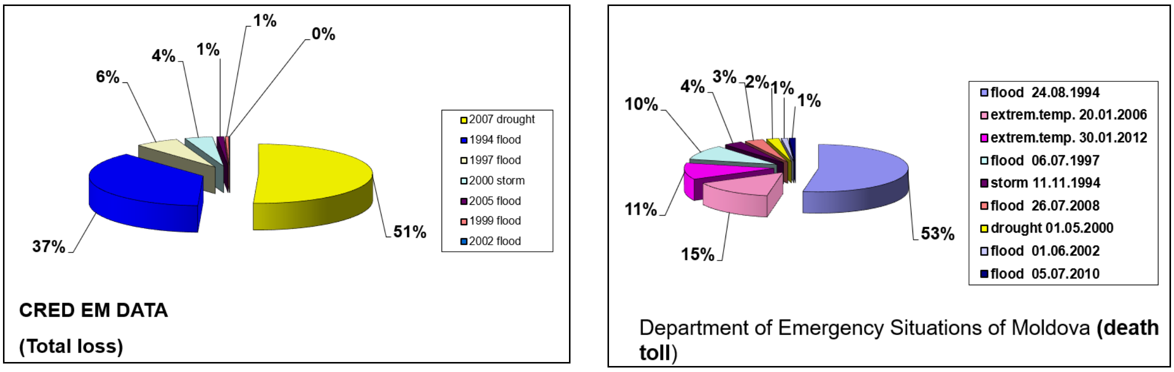


Fig. 4 – The share of climate hazards in the total loss (right) and death toll (left) reported at national scale over the 1960–2015 period in the Republic of Moldova.

The drought of 2007 led to the most significant damage, accounting for about 52% of the losses, while the floods of August 1994 caused at national level about 54% of the total deaths recorded during the period 1960–2015 (Fig. 4).

4.1. Drought and dryness hazards

Thus we obtain not only the intensity of the drought (moderate -1,0 <SPI <-1,49, severe -1,5 <SPI <-1,99 and when SPI <-2,0 drought is extreme), but also of its duration. According to the data presented in Figure 5, in the north of the country, as a duration and intensity we can see the phenomenon of drought that persisted in 1983, 1984, 1985, increasing its degree of severity from -1,0 ie moderate drought for the time scale one month to the extreme drought rating for the 12-month time interval. Over 10 years, the moderate drought phenomenon persists for four years (1993, 1994, 1995, 1996), and in the years 2011, 2012, the drought appeared to be severe.

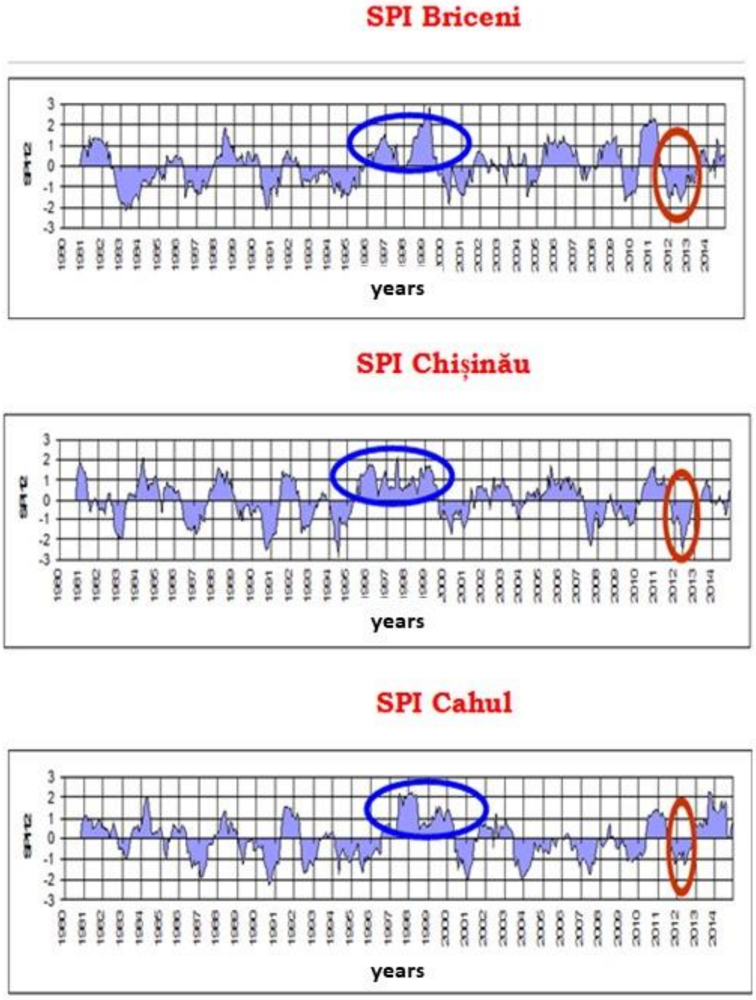


Fig. 5 – Variability of dry and wet periods by SPI at different weather stations in Moldova (1980–2015):
a. Briceni, b. Chişinău, c. Cahul.

For the central part of the country the temporal aspect differs from that in the northern part of the country. Significant values of SPI for the one month period (July) are attested in the years 1991, 1993, 1983, 1987, 2007, 2009. For the time scale of the SPI 12 months the drought qualified as severe and extreme was registered in 1991, 2009, 2012 with prolongation and in subsequent years.

In the country's southern part (Fig. 5), SPI is above the limits of the extremes for one month, which is a feature of the drought, and also it is a phenomenon that has prevailed in this region, especially in recent years. With an increase in the time span of up to 12 months, the frequency of extreme droughts has increased in recent years.

The Standardized Precipitation and Evapotranspiration Index (SPEI) takes into account the multi-annual values for the pluviometric, thermal regime and geographical latitude, thus being able to know the potential evapotranspiration (ETP). The same time scales are used as SPI, so these results come to complement each other.

Graphs showing the dynamics of dry periods in the northern part of the country (Fig. 6), show that the dry years previously highlighted by SPI are preserved, but that the intensity and duration of this phenomenon as widening scale up to 12 months is much more concrete. The same regularity is maintained for the central and southern parts, and droughts event continuity from 3–6 months from 6 to12 months, or recording this phenomenon several years in a row, allow making probabilistic assessments for the years in the nearest future.

Current research shows that the last three years (2015, 2016, 2017) have been recorded as some of the warmest of the series of instrumental observations (Table 3).

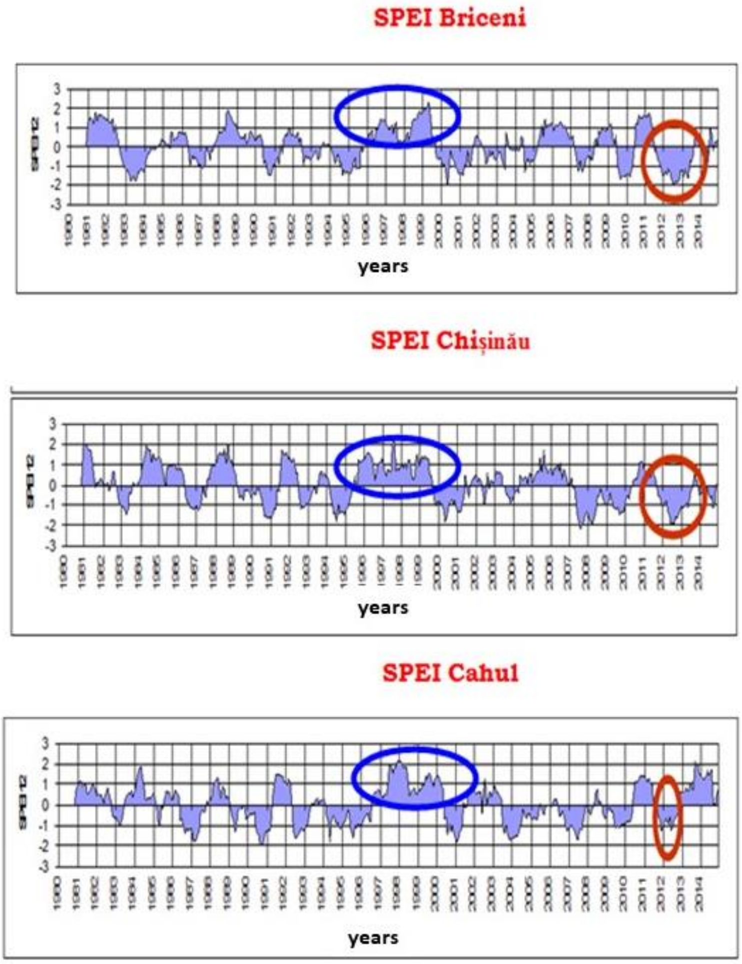


Fig. 6 – Variability of dry and wet periods by SPEI at different weather stations in Moldova (1980–2015): a. Briceni, b. Chişinău, c. Cahul.

Table 3

Top of the coolest and warmest years recorded during the period of 1887–2017

1887–2010 (Nedealcov, 2014)				1887–2017			
very cold		very warm		very cold		very warm	
1933	7,2	**2007**	12,1	1933	7,2	**2007**	**12,1**
1929	7,9	**2009**	11,4	1929	7,9	**2015**	**12,0**
1934	8,0	1990	11,3	1934	8,0	**2016**	**12,0**
1985	8,0	1994	11,3	1985	8,0	**2017**	**12,0**
1912	8,1	**2008**	11,3	1912	8,1	**2009**	**11,4**
1940	8,1	**2000**	11,2	1940	8,1	1990	11,3
1987	8,1	1999	11,0	1987	8,1	1994	11,3
1888	8,3	1966	10,9	1888	8,3	**2008**	**11,3**
1976	8,3	1989	10,9	1976	8,3	**2000**	**11,2**
1980	8,3	**2002**	10,8	1980	8,3	**2012**	**11,2**

If, according to (Nedealcov *et al.*, 2013), during the last two decades the years of the very hot years had a repeatability in 2 years, with the inclusion of the last 7 years, we find that 8 years of the top ten very warm (from the 1887–2017), belong to the period 2000–2017 (2007, 2015, 2016, 2017, 2009, 2008, 2000, 2012). We note the significant share of the last three years in estimating the climate warming trend at regional level. Thus, only with the inclusion of the last year 2017, the trend values increase by 0.00060C, i.e. from 0.01230C / year (1887–2016) to 0.01290C / year (1887–2017), for the whole series of instrumental observations.

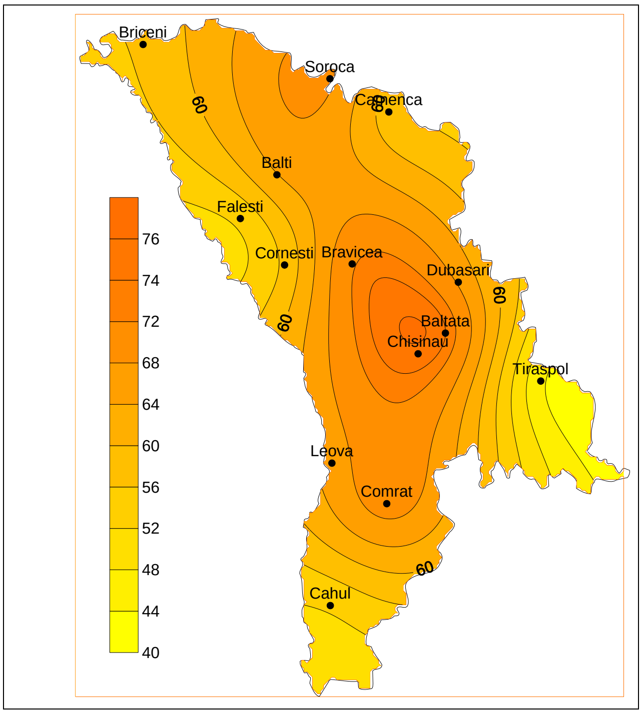


Fig. 7 – Total number of dry days in Moldova (2015).

Those revealed once again demonstrate that climate change persists with a pronounced warming trend. During the above-mentioned years, during the hot season of the year, the days where the daily temperature exceeded 25°C and the relative humidity of the air was below 30% were predominantly considered meteorologically as dry days.

Spatial distribution of the total number of dry days (Fig. 7) on the territory of the Republic of Moldova may reach during certain concrete years (2015) to up to 76 days, sometimes not respecting the principle of the zonality.

4.2. Wetness and pluvial erosion hazards

A specific feature of the regional climate during the warm period of the year is the alternating frequency of dry and rainy periods, and the latter may also be accompanied by material damage, deaths and floods. At the basis of the estimation of rainy periods a standard role is played by standardized indices (SPI and SPEI), used in the identification of periods of drought (Figs. 5, 6). The significant wet period was the consecutive years 1997–1999. So long duration of the falling precipitation with a high intensity can cause the accumulation of large amounts of water that flows on the slopes, in the form of run-off, favouring the production processes of runoff and torrential, that can trigger the process geo-morphological erosion. The analysis of the time series over more than a century (1891–2016) shows that the Fournier Index (IF) on the territory of the Republic of Moldova (Fig. 8), in certain specific years, has significant value leaps. According to the temporal analysis in the Figure 5 we note that in 1952 the pluvial aggression constituted 86.6 units, which is included in the very severe erosivity class, followed by the erosivity class in 1985 and therefore the severe pluvial aggression (67,7).

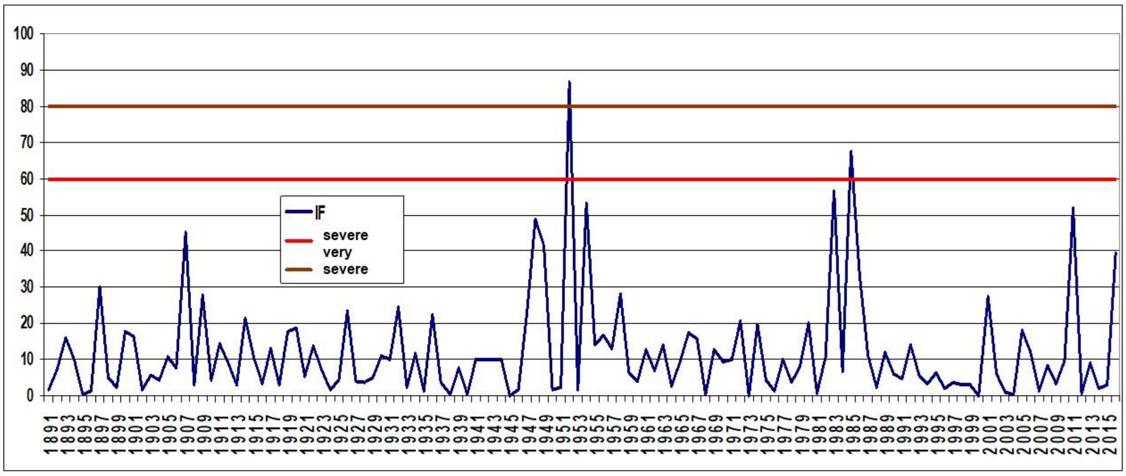
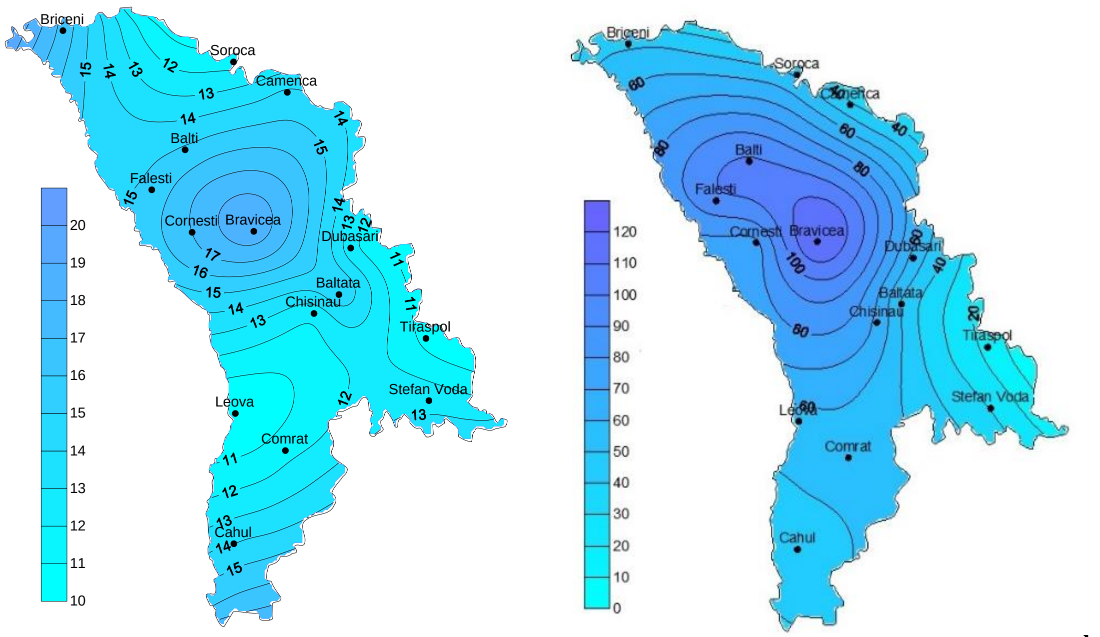


Fig. 8 – Dynamics of the Fournier Index and the estimated pluvial aggressiveness risk at Chișinău weather station over 1891–2016 period.

Cartographic patterns were developed to reveal the multiyear Fournier Index distribution (Fig. 9a), but also for the concrete years apart (Fig. 9b).



a. **b.**

Fig. 9 – The spatial distribution of multi-annual pluvial aggressiveness
(a. 1981–2016) and in specific wet years (b. 1985) in the Republic of Moldova.

Digital map reflecting the multiannual distribution (Fig. 9a) of this index indicates that in multi-annual aspect, according to the IF values distributed in space, the pluvial aggressiveness is very low throughout the Republic of Moldova. If the Fournier Index in multi-year terms is estimated to be below 20 units, in some concrete years IF on extended areas sums severe, very severe and even extremely severe pluvial aggression (Fig. 9b). It should be mentioned that in the case where the pluvial aggressiveness is essential in the fragmented territories, as was the case in 1985, the situation may become even more complicated due to the more pronounced inclination of the slopes in the region

Therefore, the knowledge of the temporal aspect of the manifestation of the pluvial aggressiveness, as well as the highlighting of vulnerable areas, could contribute to the adequate estimations regarding the role of climate erosion in triggering unfavorable geomorphological processes. So there is no doubt that the effect of pluviometric extremes (although they have a rare record in time) in some concrete years can be disastrous.

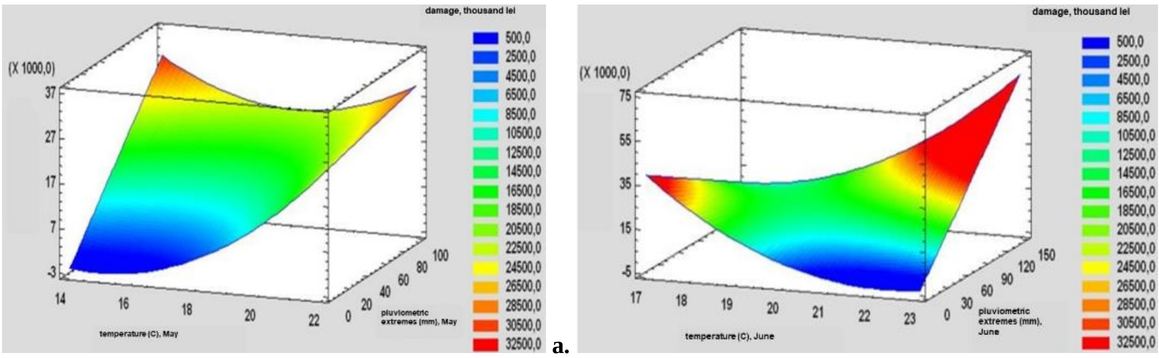


Fig. 10 – The material damage (a. May; b. June) caused by the pluviometric excesses (2000–2014) on the territory of the Republic of Moldova.

Analysis of data on material damage resulting from torrential rain in May (Fig.10a) and June (Fig. 10b) notes that in the years 2000–2014 they varied within the limits of 500–32500 thousand lei. Taking into account the frequent alternations of dry and wet periods, we conclude that the trend of recording material damage will remain in the future.

4.3. Hoar frost and glazed frost risks

From the multitude of climatic risks with manifestations during the cold period of the year, the territory of the Republic of Moldova significantly increased the magnitude of hoar frost and glazed frost manifestation, with the recording of the most essential material damage. In the north there is an increase of days with hoar frost with 0.0269 days / year, and in the central and southern part, due to the peculiarity of the synoptic conditions in the cold period, largely determined by the current climate changes, there is a decrease of -0.0081 days / year in the central part and more pronounced this trend (with - 0.1288 days / year) in the south of the country.

The frequency of hoar frost on the territory of the Republic of Moldova, due to the frequent alternations of the cold and hot periods, has a reversed distribution in regional aspect, compared to the number of days with glazed frost. In the north of the country, in the last years there is a decreasing trend of -0.0093 days / year and an increase of 0.0902 days / year in the central part and 0.0143 days / year in the south of the country (Nedealcov *et al.*, 2018).

At the same time, we note that in the first decade of the 21st century (2000–2010), everywhere was recorded a number of hoar frost days below the trend line, a period of time during which less synoptic conditions of training were certified, after 2010, in the central and the southern part, frequent short-term fluctuations of cold and warm periods contribute to the more frequent occurrence of this unfavorable phenomenon over time.

Within the framework of the proposed researches, the cartographic models of the day and daylight manifestation were obtained in 10 years depending on the physical and geographical factors: geographical latitude and longitude, absolute and relative altitude, slope orientation and slope. The elaboration of the regression models revealed the significant weight of the geographical latitude, the absolute altitude and the orientation of the slopes in the redistribution of the studied climatic elements (Fig. 11). It was found that in colder periods, the number of days with glazed frost may vary geographically from 5 to 12,8 days in the north to 20,8 to 27,1 days in the central and south from the annual average corresponding 9,9 days (north), 10,7 days (center) and 13,9 days (south).

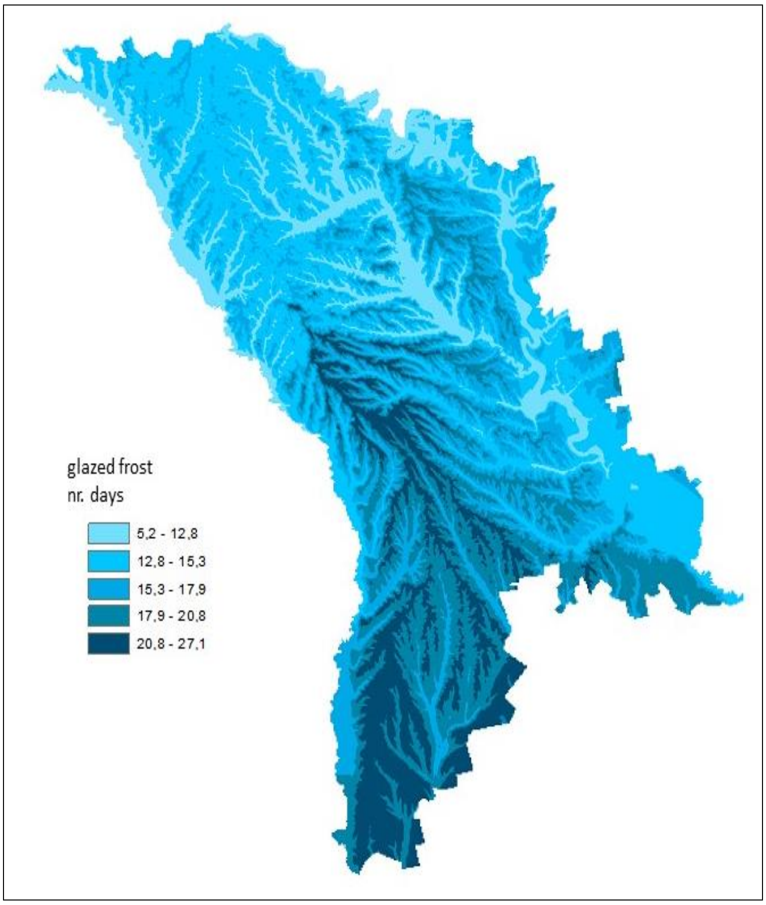


Fig. 11 – Spatial distribution of the number of days with glazed frost in Moldova with a return period of 10 years.

The estimation of the hoar frost days that can occur once in the coldest winters in 10 years reveals the fact that most days are recorded in the north, northeast and at the altitudes in the central and southern part (Fig. 12). Thus, the valleys of large and small rivers in the south and south-east of the country register for 6,5–10,9 days, and in altitude forms they reach values of 19,4–29,0 days. The multiannual values of the chill days on the territory of the Republic of Moldova show a decrease from north to south, namely: from 13,8 days in the north to 8,2 days in the center and 7,9 days in the south. Mapping models highlight the redistribution of this phenomenon in space, and the likelihood of occurrence once in 10 years indicates the possible values that this unfavorable phenomenon can sum up. An important role in the construction of the roads and the edifices is the knowledge of the maximum depth of the frozen soil. We mention that the maximum annual values are obtained from the extreme values observed during five days or decades between November and April.

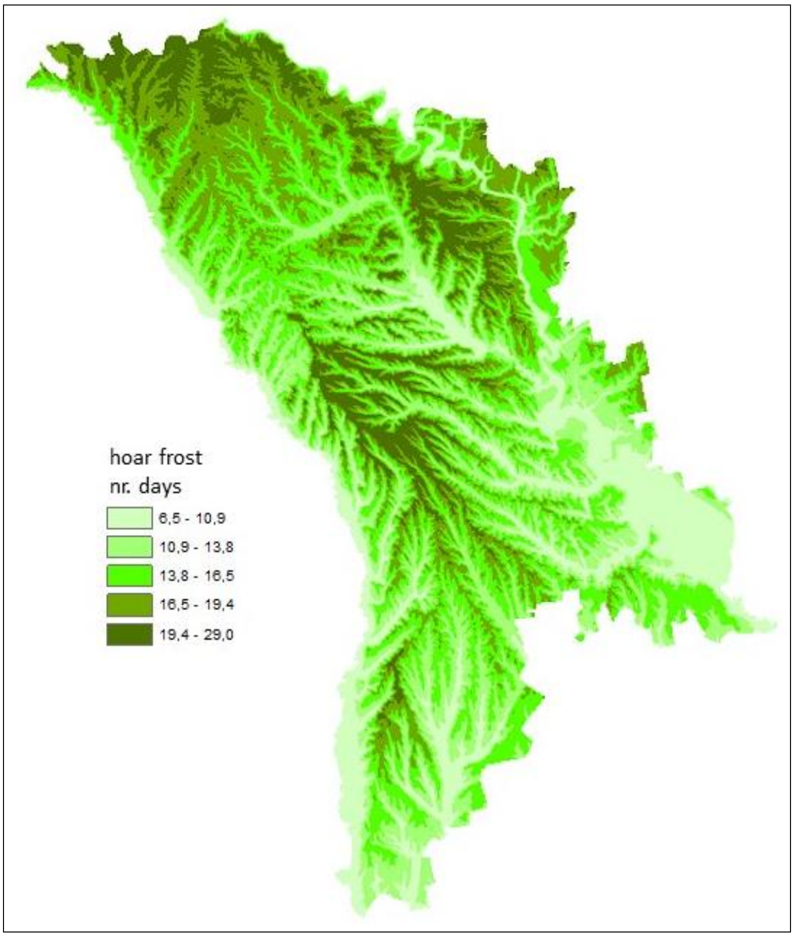


Fig. 12 – Spatial distribution of the number of days with hoar frost in Moldova with a return period of 10 years.

4.4. Soil frost risk

Thus according to Fig. 13 and Fig. 14, depth of frost soil return period once in 50 years may be 90–100 cm in the north of the country, Edinet, Donduseni, Riscani, Ocnita, Glodeni, Soroca and in the east of the country, coinciding with the East Rezina, Dubasari, Grigoriopol. The smallest values that characterize the soil frost depth with the recovery period in 50 years are characteristic of the areas in the south of the Cahul district (under 60 cm). On a large part of the central and northern districts (Falesti, Floresti, Soldanesti, Balti, Hincesti, Ialoveni, etc.), the isothermal zero degrees in the soil will reach the depth of 80–90 cm. The almost null difference between the interpolated data and the observed data confirms the quality of the obtained digital maps.

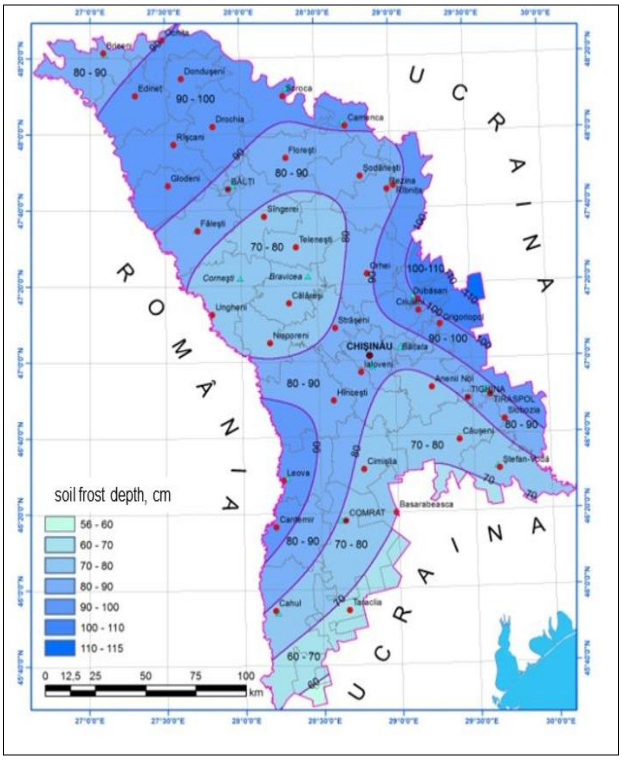


Fig. 13 – Soil frost depth with a return period of 50 years in Moldova (Nedealcov *et al.*, 2018).

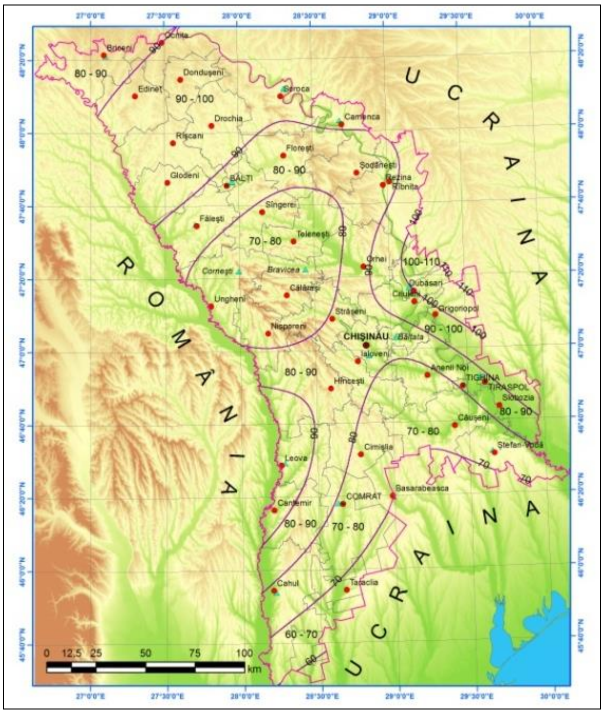


Fig. 14 – Zoning of the return period (IMR = 50 years) of values that characterize the depth of frozen soil (Nedealcov *et al.*, 2018).

5. CONCLUSIONS

Therefore, the great climatic variability conditioned by the climatic changes observed in the last decades leads to the increase of the magnitude and frequency of the climatic risks. These in the most frequent cases take on the appearance on hazardous phenomena being accompanied by substantial material losses and even by human victims. Therefore, the identification of the weather-climatic hazards based on an imposing volume of data stored both internationally and nationally, allowed to highlight the vulnerable areas, and their return periods. The data obtained is extremely necessary when taking measures to adapt to the new climatic conditions, but also to mitigate the impact of hazards by carrying out operational measures, knowing the particularities in time and space of demonstrations. Some of the results already obtained are based on the adjustment of normative acts in constructions to the European Union Directives on natural risks management. Map of spatial distribution of the number of days with glazed frost in Moldova with a return period of 10 years and map of spatial distribution of the number of days with hoar frost in Moldova with a return period of 10 years are used for decision-making process by the local public authorities when mitigating climatic risks. Map of soil frost depth with a return period of 50 years in Moldova and map of zoning of the return period (IMR = 50 years) of values that characterize the depth of frozen soil are already implemented within the Ministry of Agriculture, Construction Development and Environment.

In conclusion we state that the spatial estimations are based on the use of complex and current information, stored on the basis of contemporary research technologies (Geographic Information Systems), which are meant to ensure updating and operative reference of the climatic climatic factors to the real geographical coordinates . Temporal estimates highlight the re-emergence of some weather-climatic factors on the territory of the Republic of Moldova. We believe that the scientific results presented in this paper will be in the future able to provide state bodies and various economic agents with up-to-date climate information in order to mitigate the unfavorable influence of weather-climatic factors on various practical activities.

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