



DE GRUYTER
OPEN

DOI 10.1515/pesd-2015-0021

PESD, VOL. 9, no. 2, 2015

THE CLIMATE CHANGE IMPACT ON GRAPEVINE PRODUCTIVITY

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Key words: grapevine, suitability, coefficient, grapevine

Abstract. The viticulture, a traditional branch of the national economy, is closely related to climatic conditions because the Republic of Moldova territory represents the northern border of its territorial location. Therefore the knowledge of regional particularities of grapevine productivity formation in dependence of current agro-climatic conditions is of particular interest. Along with accelerated climate change in last decades over the Republic of Moldova territory, we find that are essential changes concerning agro-meteorological conditions, at the same time comprehensive researches that would reflect the actual impact of climate change on grapevine are limited. There are known researches, but in the context of changes that occur at regional level it is necessary to supplement permanently the database in order to elaborate an appropriate estimation of current climate conditions. The above reported facts show the importance of parameters influencing the grapevine productivity time and space study in Republic of Moldova.

Introduction

Currently, the accelerating pace of climate change and the agricultural branches inability to adapt to them, determines the climate change impacts estimation for each branch separately, taken into account the climatic requirements necessary for each crop. With accelerated pace of climate changing in the Republic of Moldova during recent decades, we find that there are essential changes concerning agro-meteorological conditions, and complex researches that reflect actual impact of climate change on grapevine are limited. Only microclimatic studies are known that had been conducted in previous periods. In recent years at regional level, following the neglect of cultivation technologies, within the branch has been created an unfavourable ecological situation, as well due to land parceling, grapevine harvest has decreased considerably. That is why, a special role

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in solving the problem of increasing the effectiveness wine-making sector, at present, it may belong to the category of wines with geographical designation of origin. This, no doubt, it is impossible without the current evaluation of agro-climatic potential and without developing new methods of effective use of agro-climatic resources.

According to various climate projections included in the [1] Atlas of Global and Regional Climate Projections (AR5) the outlook for the coming years (2016-2035) in the republic (Fig.1), the average annual temperature shall constitute 11.1-11.6°C referenced to average 10.1°C (1986 to 2005).

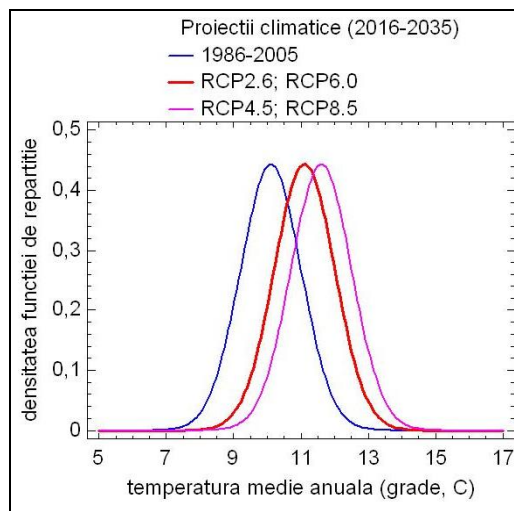


Fig 1. Climate Projections developed in accordance with scenarios

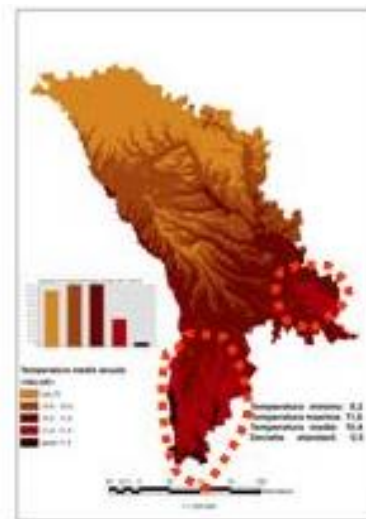


Fig.2. The distribution of current average temperature in the Republic of Moldova (200-2010)

Therefore, the increasing the effectiveness of this sector, it is inconceivable without use of updated climate information that would allow proper planting of grapevines within the limits of the Republic of Moldova.

Cartographic modeling (Fig.2) of annual average temperature -an indicator of the heating process, reveals that in the warmest decade (2000-2010) from series of instrumental observations, the average annual temperature in the country was 10.4°C, while in the south and southeast it is 0.2°C above the temperature projected for the coming decades with the most drastic climate scenarios (2016-2035: RCP8.5; RCP4.5).

1. Materials and methods

As a starting study materials have served the data reflecting phenology and variability of the vine harvest recorded at national level and in different physical-geographical regions. Initial data regarding the average annual, monthly and daytime air temperature, annual and monthly amount and precipitation were collected from 16 states of State Hydrometeorological Service, the years 1963-2012, focusing on the past decades (1980-2012) - a period of time less studied. Besides the above nominees climatic parameters, data characterizing wintering conditions through different agro-climatic indices and the development of vineyards during the warm season were used. Therefore the depth of frozen soil, snow height, number of days with though, wintering conditions for grapevines, the harvest during these years, the evolution of phenological phases of the grapevine - have created a unique informational database with homogeneous time series.

Research methodology is based on the inclusion of complex climatic parameters, including indices, which were used for the first time in the Republic of Moldova; the aim was to appropriate highlight the impact of climate change on grapevine productivity and to estimate spatio-temporal extreme weather events. Thus, in order to align national research to the international one, climates indices were calculated (Heliothermal-Huglin Index and Cold Night Index-September). So, in determining climate favorability of the Republic of Moldova territory for grapevine, these three indices were used as part of the climate system of multi-criterial classification of Geo-Viticulture.

Heliothermal-Huglin Index is a viticultural climate index developed by Huglin (1978), which estimates the heliothermal potential of a specific climatic condition; temperature calculations consider the period of the day in which grapevine metabolism is more active; the index also includes a correction factor for the length of the day in higher latitudes [7, 8, 9].

$$HI = \sum_{i=1}^{183} \frac{[(T_{med} - 10) + (T_{max} - 10)]}{2} * k \quad (1)$$

Cool night Index (CI) was developed to estimate the thermal conditions of nights during the period of maturation of the vine [6,7,8]. Using data concerning minimum temperatures, this index characterizes the region's potential for colour and flavour formation in grapes having the following expression:

$$CI = Tn_g \quad (2)$$

where: T_{n_9} = Minimum average daytime air temperature ($^{\circ}\text{C}$) in September.

In order to determine the intensity and frequency of the climate favourability for grape quality, the coefficient (CNR) of climate suitability, was used, recently developed at national level [6]. The data regarding August month are taken into account for this index, because in conditions of relative humidity of 65-70%, of maximum temperature by $28...30^{\circ}\text{C}$ and the minimum temperature of not less than 14°C , favourable conditions are established in order to obtain quality grapes.

$$CNR_{(VIII)} = \frac{Ur}{T_{\max} + T_{\min}} \quad (3)$$

where CNR- is the climate suitability coefficient for grape quality (August) Nedealcov-Rapcea;

Ur - relative humidity; $T_{\max}$ and $T_{\min}$ are absolute monthly minimum and maximum temperatures.

In the same connection we mention that the calculated coefficient is more than 15.0 – there are established extremely favourable conditions.

2. Results and discussions

Since the Republic of Moldova is at the northern limit of grapevine cultivation, the limiting factor in its location is wintering conditions.

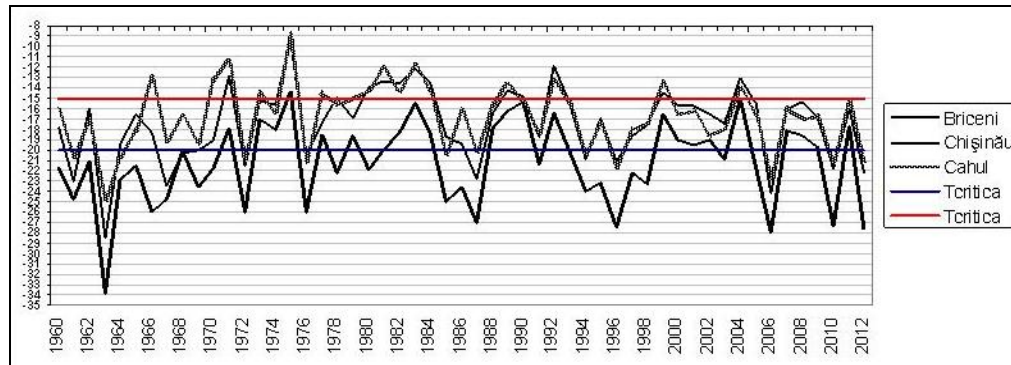


Fig. 3. The manifestation of critical temperatures of injury for unprotected winter buds (-15°C) and the frost resistance limit of annual wood (-20°C)

Dynamic Estimation of critical temperatures event of injury to unprotected buds (-15°C) and the limit of annual wood frost resistance (-20°C), denotes that in the central and south, in some winters in the last period (1996, 2010, 2012) were

achieved both critical thresholds. Meanwhile, in the winters of 1992, 1999, 2004, 2013 was only the absolute minimum values $-12 \dots -13^{\circ}\text{C}$, which demonstrates the significant instability of the thermal regime of the cold season (Fig.3).

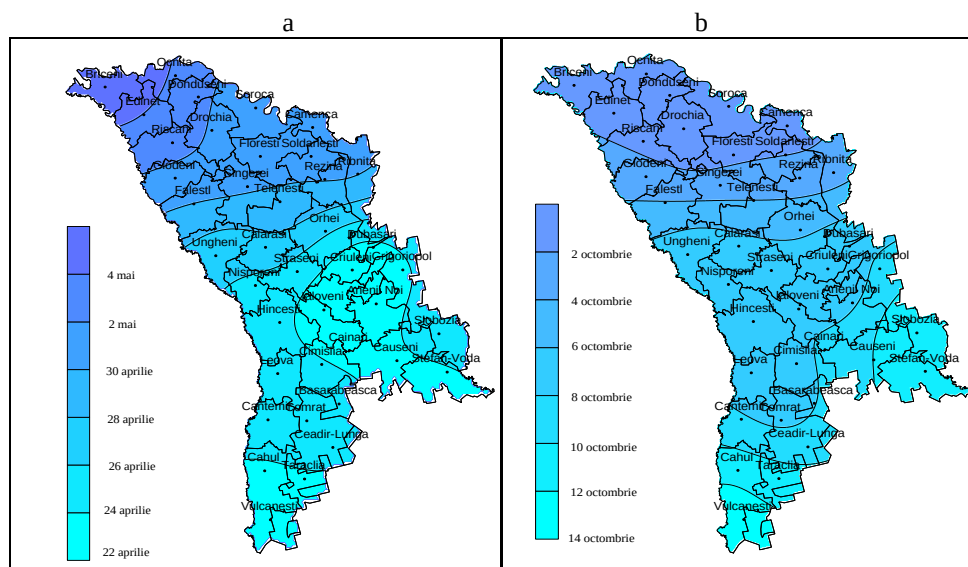


Fig. 4. The last spring frosts (a) and the first autumn frosts (b) at the ground surface - the Republic of Moldova (1951-2012)

Therefore, cartographic modeling of last dangerous spring frosts from the ground surface over the Republic of Moldova overlapping to the administrative districts map highlights the risk areas at districts level (Fig. 4), which is extremely important in the appropriate locations grapevine varieties in order to mitigate or minimize their negative effects.

The dynamic analysis of this parameter shows that in recent years it is recorded an earlier manifestation of spring frosts 0.0742 days/year, which once again confirms the springs heating process. For the first autumn frosts due to the warming trend of this season, it can be noted a late manifestation by 0.136 days/year.

Besides dangerous frost events, thaw periods followed by the sudden low temperatures- can be assessed as unfavourable climatic phenomena during the cold period, which affects the cold resistance of the vine. Over territory of the country the annual average of thaw days (Fig.5) during the cold season (December to February) is about 62 days in the southeast and about 49 in the northern extremity of the country.

Therefore, in the contemporary period (1980-2012), for the most part of the Republic of Moldova (Tab. 1) there is a increased number of days with thaw: 3-4, thus confirmed by warming winters along with high temperature periods, which in our opinion is very important to take into consideration for developing adaptation measures for vines to new climate conditions [4, 5, 6].

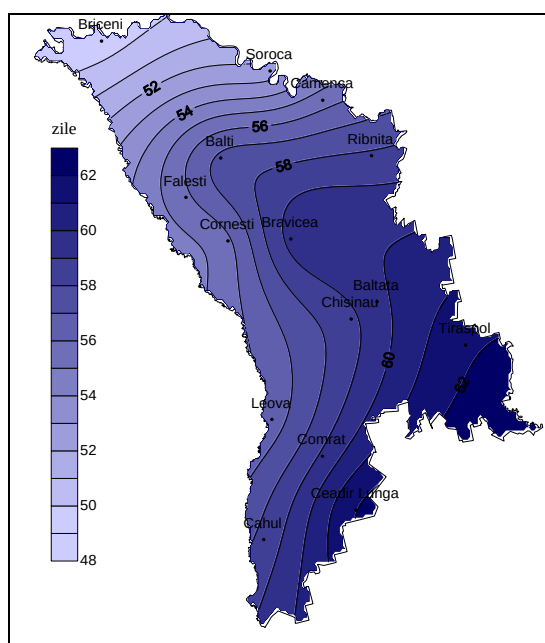


Fig. 5. Average days with thaw during cold period on the Republic of Moldova territory

Table 1. Comparative analysis of the number of days with thaw in different time periods

Physical-geographical regions	The number of days with thaw during the cold period		
	1960-1997 [2,3]	1980-2011	Δ
I.	46	49	+3
II	55	59	+4
III	53	54	+1
IV	58	62	+4
V	56	58	+2

In order to estimate the climate suitability for grapevine cultivation the Huglin's Heliothermal Index was calculated and that the country's territory is entirely favourable to the grapevine cultivation was confirmed.

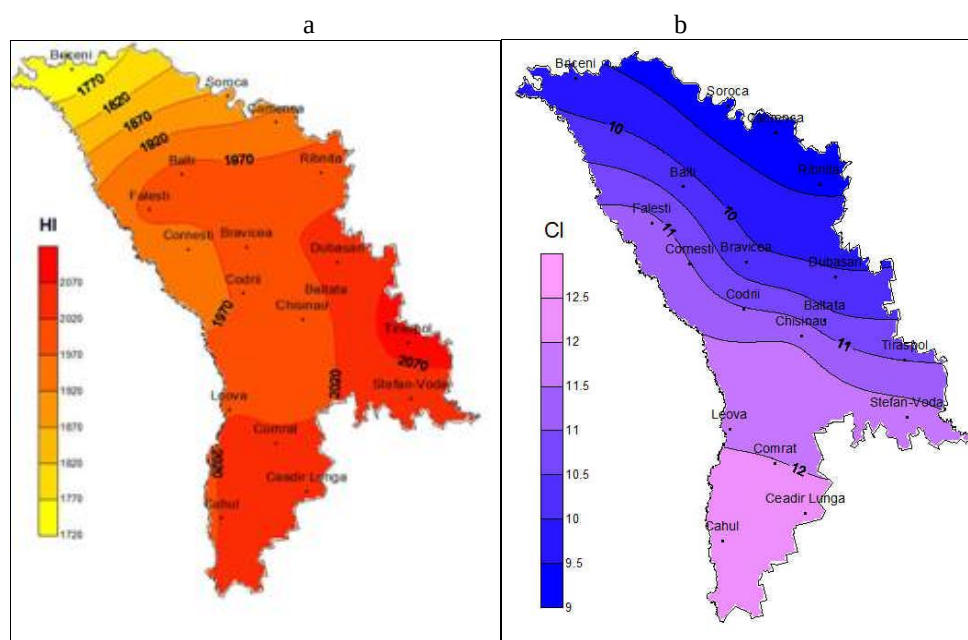


Fig. 6. The values of Huglin Heliothermal Index (a) and Cold Night Index (b) distribution over the Republic of Moldova territory

Thus territories from the northern extremity of the Republic of Moldova are within the range: $1500 < HI \leq 1800$ - quantified as cold; the central part of the country is within $1800 < HI \leq 2100$ (being established optimal conditions for ripening Cabernet and Sauvignon varieties), and, only the southern extremity, reaches $2100 < HI \leq 2400$ - being considered as warm and beneficial for late for varieties cultivation (fig.6).

Also important is the knowledge of climate suitability for grape quality, therefore analysis Climate Suitability Coefficient (Nedealcov-Rapcea) for grape quality was performed in the complex with winter conditions (Tab. 2).

Table 2: The complex analysis of the grapes quality (based on CNR data) and winter conditions in the central part of the Republic of Moldova

The Year	The CNR values	The climate suitability estimation for grape quality	The type of Winter
1980	10,1	favorable	+0,5 σ
1981	8,9	unfavorable	+0,5 σ
1982	15,5	extremely favorable	
1983	13,1	very favorable	+1,5 σ
1984	11,3	favorable	+0,5 σ
1985	12,7	very favorable	-2,0 σ
1986	11,8	favorable	
1987	12,0	favorable	- σ
1988	12,7	very favorable	+ σ
1989	12,3	very favorable	+1,5 σ
1990	12,7	very favorable	+1,5 σ
1991	14,6	very favorable	
1992	17,4	extremely favorable	
1993	10,2	favorable	
1994	14,1	very favorable	σ
1995	11,3	favorable	0,5 σ
1996	14,2	very favorable	-2 σ
1997	13,6	very favorable	
1998	11,0	favorable	0,5 σ
1999	14,9	very favorable	
2000	12,7	favorable	0,5 σ
2001	12,4	favorable	0,5 σ
2002	16,1	extremely favorable	
2003	15,3	very favorable	-1,5 σ
2004	13,5	favorable	
2005	14,1	very favorable	
2006	13,4	favorable	-0,5 σ
2007	15,3	very favorable	1,5 σ
2008	11,6	very favorable	0,5 σ
2009	14,9	very favorable	0,5 σ
2010	13,3	very favorable	-0,5 σ
2011	14,9	very favorable	-0,5 σ
2012	12,4	favorable	-0,5 σ
2013	14,4	very favorable	

It was found that since 2005, for example, in the central part; regardless the type of winter, the quality of the grapes has been high, which demonstrates that warming in August during this period significantly influences the quality of the harvest. This can be confirmed by analysis a concrete year- 1985, when despite the fact that winter conditions were severe, quality of the grapes was due to favorable conditions from August (Fig. 7).

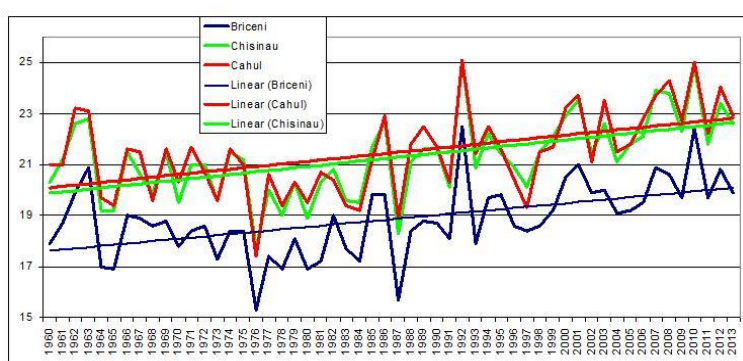


Fig. 7. The evolution of the monthly average temperature in August

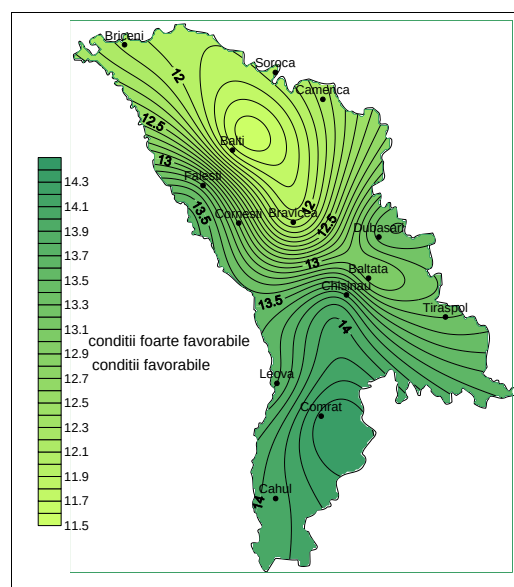


Fig. 8. Cartographic modeling of Climate Suitability Coefficient for grape quality (CNR). Case Study, 2007

It is important to mention the fact that in some years separately taken, when agrometeorological conditions are unfavorable for the growth and development of crops, for vine, in particular for grapes quality, conditions can be very favorable. Thus, in August of 2007 (Fig.8) in the north and northeast, the values CNR (11.5 to 12.9) there were established to ensure favorable conditions for grapevine harvest quality. In the rest of the territory, grape quality was ensured by very favorable climate conditions (CNR values ranging within 11.5 to 12.9).

The obtained results (Table 2), explain the important role of current climatic conditions from August in ensuring the quality of grapes on the Republic of Moldova territory.

Therefore, we believe that the elaboration Climate Suitability Coefficient for grape quality, adequately contributes in estimation the current climate for grapevine harvest quality at regional level.

Conclusions

Analysis of grapevine varieties over a long period of time confirms their dependence to climate resources, including the adverse weather conditions. The obtained results have allowed to conclude that the thermal, such as cold waves, determine the grapevine wintering, which in recent years have essentially influenced the harvest. Analysis of periods with thaw and the calculated data for the previous period, indicates a growth of up to 4 days in some physical - geographical regions, supporting the idea of warming winters process and the significant variability of the thermal regime during this period. The specific indicators (HI, CI) calculation, at regional level, indicate that most of the territory of the republic, especially the south, it is conducive to the grapevine cultivation. CNR (Nedealcov-Rapcea) analysis in correlated to wintering conditions highlights the complexity of favorable conditions for grape quality in the Republic of Moldova. Cartographic modeling all these indices highlight areas favorable and unfavorable in terms of climate suitability for grape quality. We note that the results are necessary within the elaboration of adapting measures to new climate conditions of this crop.

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