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CHARACTERISTICS OF THE BASELINE CLIMATE OF THE COTNARI (ROMANIA) WINE GROWING REGION

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ABSTRACT. The paper presents the baseline climate of the Cotnari wine growing region, the climate under whose influence were set up the wine grape varieties, wine types and grapevine training systems of this vineyard. It is also presented the baseline climate suitability for wine grape growing and its spatial variation in the vineyard area. The study is based on the climate data for the 1961 to 1980 time period, previous to the beginning of the climate warming and, therefore, considered to be representative for the baseline climate time period. According to study results, the baseline climate of the Cotnari wine growing region was cool, with annual average temperatures by 8.5…10.0°C, with a sum of the effective temperatures by 1081…1382°C, with freezing phenomena at the beginning and towards the end of the growing season, and with very cool nights during the month of September (CI+2). Elements that generate the baseline climate suitability for wine grape growing were: high average temperatures for the month of July (19…21.1°C); long growing season up to 190 days, and high values for the global radiation, up to 93 kcal/cm^2/April 1st - September 30th on the sunny slopes within the vineyard area. According to the multicriteria evaluation of the suitability for wine grape growing, 87.9% (1792 ha) of the vineyard surface was characterized by a baseline climate suitable for white quality wines and 11.9% (241.0 ha) by a baseline climate suitable for white table wines, sparkling wines and wines for distillates.

Key words: Cotnari wine growing region; Grapevine; Wine types; Climatic factors; Climate warming.

REZUMAT. Caracteristici ale climatului de bază al regiunii viticole Cotnari. Lucrarea prezintă climatul de bază al podgoriei Cotnari, cel care a generat sortimentele de soiuri, tipurile de vin şi sistemele de conducere a viţei de vie reprezentative pentru această podgorie. De asemenea, este prezentată favorabilitatea climatului de bază pentru cultura soiurilor de vin şi distribuţia sa spaţială în arealul podgoriei. Studiul se bazează pe datele climatice din perioada 1961-1980, anterioară încălzirii climatice şi, din acest motiv, considerată reprezentativă pentru

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climatul de bază. Conform rezultatelor acestui studiu, climatul de bază al podgoriei Cotnari a fost unul rece, cu temperaturi medii anuale de 8.5…10.0°C, bilanţ termic util de 1081…1382 °C, brume în timpul perioadei de vegetaţie şi nopţi foarte reci în cursul lunii septembrie (CI+2). Elementele care au conferit climatului de bază favorabilitate pentru cultura soiurilor de vinau fost: valorile mari ale temperaturii lunii iulie (19…21.1°C); perioada lungă de vegetaţie, de până la 190 zile, şi valorile mari ale radiaţiei solare, de până la 93 kcal/cm^2/1 aprile-30 septembrie, pe versanţii însoriţi din arealul podgoriei. Conform evaluării multicriteriale a favorabilităţii climatului de bază pentru cultura soiurilor de vin, 87.9% (1792 ha) din suprafaţa podgoriei a beneficiat de un climat de bază favorabil producţiei vinurilor albe de calitate, iar 11.9% (241.0 ha) de un climat de bază favorabil producţiei vinurilor albe de masă, spumantelor şi vinurilor pentru distilate.

Cuvinte cheie: podgoria Cotnari; viţă de vie; tip de vin; factori climatici; încălzire climatică.

INTRODUCTION

The baseline climate of vineyards is the climate under whose influence were established their representative wine grape varieties, wine types and grapevine training systems. The knowledge of baseline climate is required to have a comparison term for the current climatic conditions of vineyards and to identify the modifications caused to their "viticultural potential" (Irimia *et al.,* 2014) by the climate warming (IPCC, 2007). The baseline climate varies mainly depending on climate zone within which vineyards are located, and determines viticultural features depending on its suitability for grapevine growing. As example, is possible to differentiate vineyards in Mediterranean climate, producing mainly red and sweet wines; vineyards in temperate climate, producing mainly both white and red quality wines; and vineyards in cool climate, producing mainly white wines and sparkling wines. While the key factor which determines these differentiations is temperature, they can be also found within each climatic zone with mountainous and hilly relief, where the altitudinal differentiation of temperatures, determines altitudinal differentiation of topoclimates and as a consequence, the altitudinal differentiation of vineyards viticultural potential.

The baseline climate of vineyards maintained rather constant during the centuries, being modified significantly only by severe global climate changes. Such changes, occurring as temperature increases or decreases, determined shifts in vine growing area on globe and also changes in grapevine phenology. From the middle of the XIX century, the climate of European vineyards' remained quite stable (Jones *et al.,* 2005) which led to the establishment of their specific wine grape varieties, wine types and vineyard training systems.

Recent studies indicate however that, since the beginning of '80, the baseline climate of vineyards is affected by global warming (Kenny and Harrison, 1992; Bonnardot, 1996;

Schultz, 2000). During the XX century, the global temperature increased by 0.6 to 0.7°C (IPCC, 2007), which determined changes in the values of specific climatic parameters of vineyards, in grapevine phenology and yield characteristics (Duchene and Schneider, 2005; Ramos *et al.,* 2008). These changes are prone to produce also in the future (Malheiro *et al.,* 2010; Santos *et al.,* 2012; Moriondo *et al.,* 2013), with benefits or challenges for vine cultivation from one wine growing region to another, depending on its geographical location (Jones and Webb, 2010). The magnitude of changes caused to baseline climate of vineyards depends on climate zone, the most affected currently being vineyards in Mediterranean climate (Jones *et al.,* 2006).

The climatic changes also concern the temperate climate zone and, with this, the baseline climate of vineyards in these region. For the Moldavia region in Romania, Quénol *et al.* (2014) reported an increase in January mean temperature by 1.1°C for the 1971 to 2000 time period (-2.6°C) as compared to the 1961 to 1990 time period (-3.7°C). For the same region, our analysis (Irimia, Patriche and Quénol, unpublished data) reveal: an increase by 0.55°C of the average annual temperature for 1981 to 2007 time period (9.51°C) as compared to 1961 to 1980 time period (8.96°C), and an increase by 1.02°C of the average temperature of the month of July during the 1981 to 2007 time period (20.8°C) as compared to 1961 to 1980 time period (19.78°C). These changes affected the baseline climate of vineyards in the area, observable as an increases by 0.49°C of the average temperature of the growing season (Jones, 2006) within the Cotnari area during the 1981 to 2007 time period (16.37°C), as compared to 1961 to 1980 time period. It also influenced its specificity, while during the last decade this vineyard started to grow wine grape varieties for red wines, despite of its traditional specialization in white wine production.

As a consequence, a study regarding changes affecting the baseline climate of the Cotnari wine growing region and its viticultural potential is required, in order to establish the adaptation measures of local viticulture to a new climatic context. This paper present the results of the first approach, regarding characterization of the baseline climate of the Cotnari wine growing region and its suitability for wine grape growing.

MATERIALS AND METHODS

The Cotnari wine growing region is located in the north eastern part of Romania, at 47°20' N lat. and 27°00' E long. (*Fig. 1*). It has 2,037 ha, and comprises ten lands, placed mostly on the eastern slope of the Dealul Mare - Hârlău Hill, between 106 and 290 m above sea level (asl.). The local climate is temperate continental, Dfb in Köppen climate classification (Peel *et al.,* 2007), with minima during the winter down to -30°C (Irimia *et al.,* 2012a; Planchon *et al.,*

2014). Severity and high frequency of frosts led to practice a grapevine training system which permits to protect the vine stocks from freezing by covering them with soil. In the Cotnari wine growing region are grown four local *V. vinifera* L. wine grape varieties (Fetească albă, Frâncuşă, Tămâioasă românească and Grasă de Cotnari) and are produced exclusively white wines. The four wine grape varieties represent the established assortment of the Cotnari vineyard, which is unchanged before the phyloxera crisis in XIX century (Oşlobeanu *et al.,* 1991). During the last decade, within the Cotnari area started to grow the *V. vinifera* L. Fetească neagră, the best Romanian wine grape variety for red quality wines.

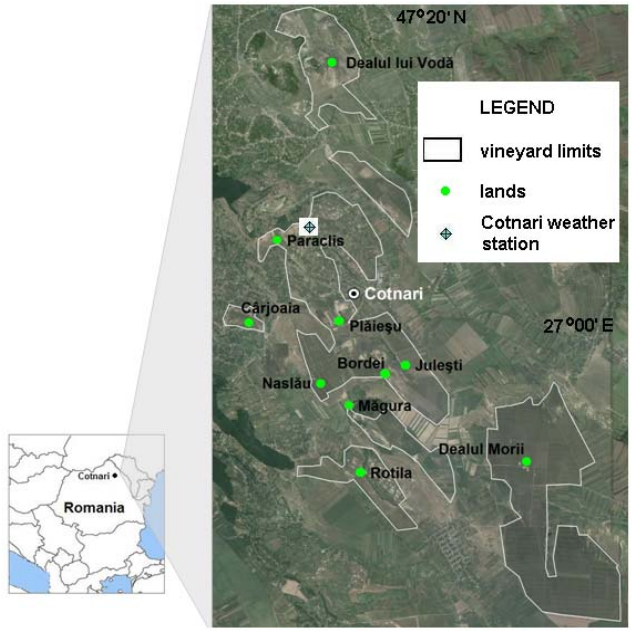

Figure 1 - Geographical location and the structure of the Cotnari wine growing region

To characterize the baseline climate of the Cotnari wine growing region 10 climatic parameters were analyzed: average annual temperature (AAT,ºC), average temperature of the warmest month (TWM,ºC), global radiation (GR, kcal/cm^2/1.04-30.09), actual sunshine duration (ASD, hours/1.04-30.09), precipitation in the growing season (PP, mm/1.04-30.09), sum of effective temperatures (Σt_u,°C/1.04-30.09), actual heliothermal index (IHa/1.04-30.09), bioclimatic index (Ibcv/1.04-30.09) and oenoclimate aptitude index (IAOe/1.04-30.09). These parameters characterize the climate suitability for wine production in temperate climate of Romania (Irimia *et al.,* 2014). To represent the baseline climate of the Cotnari wine growing region, the 10 climatic parameters were computed based on temperature and precipitation recorded during the 1961 to 1980 by the Cotnari Weather Station (290 m asl.). As we did not disposed by data characterizing an earlier time period, we considered that climate data before 1980, when global warming started to appear (Morice *et al.*, 2012), are the most

representative for the Cotnari baseline climate. The spatial distribution of temperature and precipitation was achieved in GIS environment, based on DEM; solar radiation and sunshine duration were computed in SAGA GIS-based on DEM (30 x 30m).

The baseline climate suitability for wine grape growing and wine production was computed by using the GIS-based methodology for vineyard viticultural potential assessment in temperate continental climate conditions of Romania (Irimia *et al.,* 2014). Climatic parameters characterizing the baseline climate were classified and ranked depending on wine type production they determines (*Table 1*). The baseline climate suitability was expressed as the spatial distribution of wine types which can be obtain in the area.

Table 1 - Climatic parameters classified and ranked depending on their suitability for different types of wine production in temperate climate of Romania (Irimia *et al.,* 2014)

Climatic parameters	Suitability interval for grapevine growing	Unsuitable	Suitability classes/ranking points*		
		IV/0	III/5	II/8	I/10
			Type of wine production		
		Restrictive for grapevine growing	white table wines, sparkling wines, wines for distillates	quality white wines, red table wines	quality red and white wines
AAT (°C)	8.5-11.2	< 8.5	8.5-9.3	9.4-10.0	10.1-11.2
TWM (°C)	18.0-22.0	< 18.0	18.1-19.7	19.8-21.0	21.1-22.0
GR (kcal/cm^2)	80.0-92.0	< 80.0	80-83.9	84.0-86.9	87.0-92.0
ASD (hours)	1280-1610	< 1280	1280-1450	1451-1550	1551-1610
PP (mm)	250-390	-	> 390	< 250	251-390
Σt_u (°C)	1045-1675	< 1045	1045-1200	1201-1400	1401-1675
LGS (days)	160-210	< 160	160-175	176-190	> 190
IHa	1.36-2.66	< 1.36	1.36-1.70	1.71-2.20	2.21-2.66
Ibcv	3.9-13.0	< 3.9	3.9-5.0	5.1-8.0	8.1-13.0
IAOe	3793-4600	< 3793	3793-4300	4301-4600	> 4600

*Suitability classes of climatic factors for different wine type productions. Values were graded using a 10 point scale, as follows: 10, 8 and 5 points for class I, II and III, respectively; unsuitable values (class IV) were given 0 points (Irimia *et al.,* 2014).

RESULTS AND DISCUSSION

Characterization of climatic parameters for the 1961 to 1980 time period. The climatic parameters characterizing the Cotnari area during the 1961 to 1980 time period reveal a cool climate, poor in heliothermal resources and low to moderate suitable for wine grape growing.

The minimum of the AAT (8.5°C) (*Fig. 2a*) is below the lower threshold of suitability for grapevine growing (9.0°C), while its maximum (10.0°C) correspond to the lower threshold of suitability for quality

wines (Ţârdea and Dejeu, 1993). The Σt_u (°C) ranges between 1081 and 1382°C (*Fig. 2b*), values characterizing cooler vineyards producing white table wines. More suitable proves to be TWM (*Fig. 2c*) with values by 19.1 to 21.1°C, characterizing vineyards specialized in quality white wines production.

Data regarding temperature parameters characterizing the baseline climate match to those previously reported by Patriche (2012), which mention for the Cotnari area an AAT by 9.0°C for the 1886 to 1955 time period, and by 9.1°C for the 1956 to 1993 time period. The same author reported a TWM by 20.3°C for the 1886 to 1955 time period, and by 20.0°C for the 1956 to 1993 time period. An additional analyze to this study revealed that the *night cold index* (CI; Tonietto and Carbonneau, 2004) for the 1961 to 1980 time period was 11.59 (*very cool nights;* CI +2), with four years in ten having averages below 10°C. Also, the number of days with freezing phenomena during the growing season (April 1st to September 30) was by 0.9 for the month of April, 0.1 for May, and 0.2 for September; and the average of monthly minima for the growing season was by 12.1°C. All these data also confirm the harshness of the Cotnari baseline climate, to which the frost severity during the winter season can be added.

A limiting factor for the suitability of the baseline climate is also the ASD (*Fig. 2d*): its minimum (1061.5 hours) fall below the threshold of suitability for grapevine growing, while its maximum (1399 hours) is lower compared to maximum (1610 hours) characterizing Romanian vineyards. Regarding the GR, its values are very contrasting (*Fig. 2e*): while the minimum (62.34 kcal/cm^2) is unsuitable for the grapevine growing, the maximum (93 kcal/cm^2) exceeds the upper level characterizing Romanian vineyards. This reveal the existence within the Cotnari area of plots with very suitable GR conditions. The values of these parameters match with those previously reported by Neacşa and Popovici (1967) for the 1956 to 1965 time period: a GR by 87.06 kcal/cm^2 and an ASD by 1482 hours.

The scarcity of heliothermal resources of the baseline climate of the Cotnari area is also revealed by the IHa and IAOe values (*Fig. 2f; Fig. 2g*), whose minima are under the lower threshold of suitability for grapevine growing, while the maxima characterizes the quality white wine production.

A gain in the suitability of the baseline climate was brought by the PP (*Fig. 2h*), optimum for quality wine production (326 to 395 mm), and also by LGS (*Fig. 2i*) (175 to 190 days), which assured grapes maturation for middle ripening wine grape varieties and over ripening at the early grapevine varieties. Actually, the Cotnari wine growing region is renowned by its sweet wines obtained from over ripen and botrytized grapes of Grasă de Cotnari (Amerine and Joslyn, 1970).

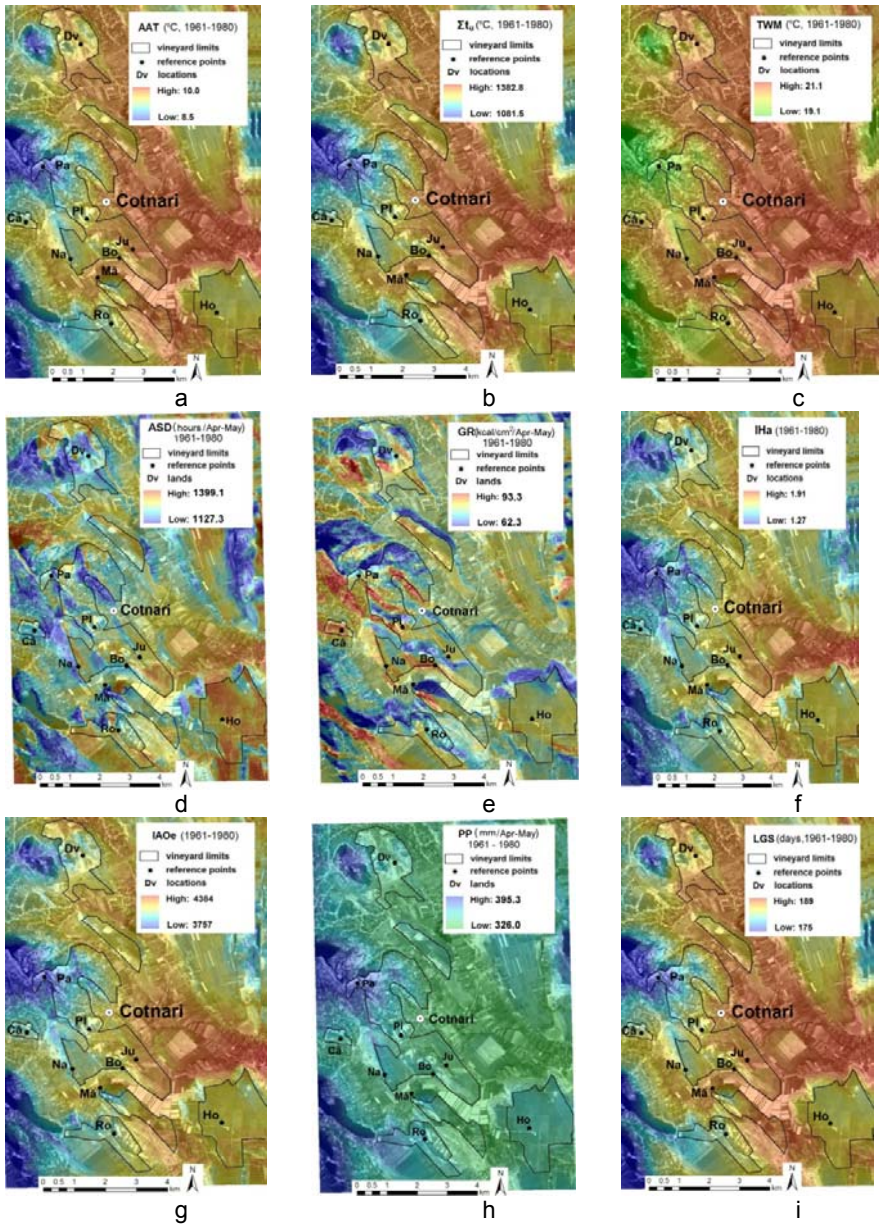

Figure 2 - Spatial distribution of some climatic parameters characterizing the baseline climate of the Cotnari wine growing region (based on 1961-1980 averages): a - average annual temperature; b - sum of effective temperatures; c - average temperature of the warmest month; d - sunshine duration; e - global radiation; f. - actual heliothermal index; g - oenoclimate aptitude index; h - precipitation in the growing season; i - lenght of the growing season.

Table 3 - The suitability of climatic parameters characterizing the baseline climate of the Cotnari wine growing region

Climate parameters	Suitability		Structure of suitability of climate parameters	
	ranges	classes*	ha	%
AAT (°C)	< 8.5	IV	0	0
	8.5-9.3	III	90.6	4.4
	9.4-10	II	1946.7	95.5
	10.1-11.2	I	0	0
TWM (°C)	< 18.0	IV	0	0
	18.1-19.0	III	0	0
	19.8-21	II	2037.4	100
	21-22	I	0	0
Σt_u (°C)	< 1045	IV	0	0
	1045-1200	III	42.5	2.1
	1201-1400	II	1994.8	97.9
	1401-1675	I	0	0
GR (kcal/cm^2)	< 80	IV	140.4	6.8
	80-83.9	III	571.5	28.0
	84-86.9	II	1064.6	52.2
	87-92	I	260.8	12.8
ASD (hours)	< 1280	IV	108.6	5.3
	1280-1450	III	1928.7	94.6
	1451-1550	II	0	0
	1551-1610	I	0	0
LGS (days)	< 160	IV	0	0
	160-175	III	0	0
	176-190	II	2037.4	100
	> 190	I	0	0
PP (mm)	> 390	III	0	0
	< 250	II	0	0
	251-390	I	2037.4	100
Ibcv	< 3.9	IV	0	0
	3.9-5.0	III	0	0
	5.1-8.0	II	2037.4	100
	8.1-13.0	I	0	0
IHa	< 1.36	IV	0	0
	1.36-1.70	III	529.4	25.9
	1.71-2.20	II	1507.9	74.0
	2.21-2.66	I	0	0
IAOe	< 3793	IV	0	0
	3793-4300	III	1868.3	91.7
	4301-4600	II	169.1	8.3
	> 4600	I	0	0

*class I, quality red and white wines; class II, quality white wines, red table wines; class III, white table wines, sparkling wines, wines for distillates; class IV, restrictive for grapevine growing

Regarding the spatial variability of the climatic parameters (*Fig. 2*), it is observable that temperatures (represented by AAT, TWM and Σtu), and also the parameters including temperature as component (IHa, Ibcv, IAOe), or computed based on temperatures (e.g. LGS), diminishes on altitude, from under 116 m asl., where Juleşti and Măgura lands are located, towards above 290 m asl. where Paraclis land is located.

The suitability of climatic parameters characterizing the baseline climate. By classifying the climatic parameters according to the methodology for vineyard viticultural potential assessment in temperate climate of Romania (Irimia *et al.,* 2014) it appear that, during the baseline climate time period, they felt mainly in the classes II and III of suitability. Class II indicates the suitability to produce white quality wines and red table wines; class III indicates the suitability to produce white table wines, sparkling wines and wines for distillates (*Table 3*).

The structure of suitability of the baseline climate of the Cotnari wine growing region. The suitability for wine production of the baseline climate is characterized by 5, 6 and 7 ranking points (*Table 4*). Representative for the baseline climate of the Cotnari wine growing region is the average of 7 ranking points, indicating the suitability for quality white wines, which characterize 87.9% of the area (1792 ha); 11.9% of the area (241.0 ha) is characterized by averages of 5 and 6 ranking points, which indicates the suitability to produce white table wines, sparkling wines and wines for distillates. In the structure of suitability of the baseline climate of the Cotnari wine growing region, do not appear the averages by 8, 9 or 10 points, which would reveal the suitability to produce red wines.

Table 4 - The structure of the suitability for wine grape growing of the baseline climate of the Cotnari wine growing region

Suitability	Average of ranking points	The structure of the suitability of the baseline climate		
		ha	%	
Class I	10	0	0	0
	9	0	0	
Class II	8	0	0	87.9
	7	1792	87.9	
Class III	6	241.0	11.8	11.9
	5	4.0	0.17	
Class IV	0	0	0	0
Total	-	2037.4	100	100

10 - quality red wines; 9 - quality red wines and quality white wines; 8 - quality white wines and red table wines; 7 - quality white wines; 6 - white table wines, sparkling wines, and wines for distillates, as well as for quality white wines in very suitable years, in terms of climate; 5 - suitability for white table wines, sparkling wines, and wines for distillates; 0 - unsuitable for grape growing.

The suitability of the baseline climate of the Cotnari wine growing region comes to support the observation regarding the latitudinal differentiation of the climatic suitability for wine grape growing: the Cotnari wine growing region, the most northern between the Romanian wine growing regions assessed by the GIS-based evaluation system of viticultural potential (Irimia *et al.,* 2014), has also the least suitable climate for wine production. Advancing from south to north, the climate suitability diminishes: the climate of Urlaţi vineyard, the most southern one (45°00' N lat.) is suitable for red quality wines (Irimia *et al.,* 2013); the climate of Huşi vineyard (46°60' N lat.) is suitable for quality white wines and in a small extent for red table wines (Irimia *et al.,* 2011); the climate of the Bucium vineyard (47°10' N lat.) is suitable for quality white wines and white table wines (Irimia *et al.,* 2012b); the climate of Cotnari wine growing region (47°20' N lat.) is also suitable for quality white wines and white table wines, but is characterized by severe frosts during the winter and freezing phenomena during the growing season.

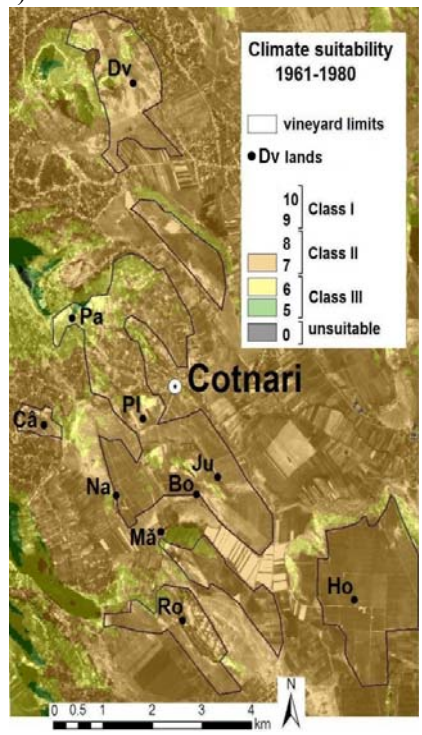

Figure 3 - The spatial variation of the suitability for wine production of the baseline climate of the Cotnari wine growing region

The spatial variation of the baseline climate suitability (*Fig. 3*) reveal that area suitable for white quality wines (average by 7 ranking points) covers nine of the ten lands of the Cotnari wine growing region. The least suitable land, characterized by averages of 6 and 5 ranking points is the Paraclis land (Pa), located at highest altitude (290 m).

CONCLUSIONS

The baseline climate of the Cotnari wine growing region determined a particular viticultural profile characterized by: growing four local *V. vinifera* L. wine grape varieties (Grasă de Cotnari, Fetească română, Frâncuşă and Tămâioasă românească); producing exclusively white quality wines and white table wines, and practicing a grapevine training system which permit to cover the vine stocks with soil during the winter, in order to protect them by freezing.

The baseline climate of the Cotnari wine growing region was cool, with annual average temperatures by 8.5…10.0°C, with a sum of the effective temperatures by 1081…1382 °C, with freezing phenomena at the beginning and towards the end of the growing season, and with very cool nights during the month of September (CI +2). Its suitability for wine grape growing was improved by a high average temperature of the month of July; a rather long growing season, assuring over ripening of grapes to local wine grape varieties; high values of the global radiation on some sunny slopes within the vineyard area.

According to study results, 87.9% (1792 ha) of the Cotnari wine growing area was characterized by a baseline climate suitable for quality white wines, and 11.9% (241.0 ha) by a baseline climate suitable for white table wines, sparkling wines and wines for distillates. The structure of baseline climate suitability revealed by this study match to the structure of traditional types of wine production of the Cotnari wine growing region.

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