COTNARI VINEYARD - A GIFT OF HYDRAULIC FOEHN?

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Abstract

Cotnari vineyard is the northernmost wine-growing vineyard of our country, located close enough to the northern limit of the expanding region of the grape vine. Within this study, we analyse one of the climatic factors that, in our view, contributes to the climatic favorability of this region for the vine plantations: the foehn. More precisely, the hydraulic foehn, which is not mentioned in the Romanian climatology literature, although the mechanism associated with the development of this type of foehn wind, is described for more than 40 years in the international climatological literature. We bring arguments for the manifestation of the hydraulic foehn during winter 2013-2014 in the related region of Cotnary vineyard on the basis of measurements accomplished at Paşcani climatologic station and at other 11 points of hourly monitoring temperature of Dealu Mare-Hârlău region. Additionally, radio-sounding data, synoptic maps and other synoptic data of some of the meteorological indicators of foehn development are used. Local generating mechanism, periods of occurrence, synoptic conditions associated to its generation, the intensity of temperature difference recorded within the region and the possible effect of its development in the increase of the region's favourability for the vine-growing, are analysed in our study.

Key words: Vineyard Cotnari, hidraulic foehn, climate favorability.

In the Romanian climatological literature, foehn is defined solely through the classic theory, thermodynamic, being a warm and dry wind, as a result of the transfer of latent heat form the slopes exposed to the advection of moist air - where the condensation accompanied by precipitation is produced - on the leeward slopes (Drăghici I., 1988; Bogdan O., 1990 etc.). The classic theory of foehn explains the temperature difference between a slope and another of an orographic obstacle by the cooling air after moist adiabatic lapse rate on the slope exposed to advection, as the air ascends, while the air descends over the top of the mountain at a dry adiabatic lapse rate. This type of foehn has a valuable indicator: precipitations on the slope exposed to advection (Hann J., 1866).

The region promoted as emblematic for the manifestation of foehn in Romania remains the north slope of Făgăraş Mountains, where this type of wind is known as "snow eater". In this region the thermodynamic mechanism of foehn has the most similarity features with the foehn from Alpes (southerly flow, orographic obstacle with east-west orientation). Nevertheless, the regions in our country where the foehn has enough frequency as a visual amenity mark reflected in the high favorability it generates for vineyards and orchards are Mures Corridor in the lee of the Apuseni Mountains and in the Buzău and Vrancea Subcarpathians at the Carpathian arc, regions in which balance these type of land usage is quite high.

However, the manifestation of foehn cannot include only these regions. Hereinafter we reason with a second type of foehn produces on the territory of Romania, named hydraulic foehn, with a higher incidence than that of classic foehn, with spectacular temperature differences as the classic one.

One of the areas with particular action of the hydraulic foehn is the region corresponding to hilly Massif Dealu Mare-Hârlău. The results of the analysis support the climatic favorability for the vine-growing within the region of Cotnari Vineyard as a sole result of the hydraulic foehn manifestation.

MATERIAL AND METHOD

In order to complete this analysis, we used data resulted from the monitoring of temperature and humidity of air of cold semester 2013-2014, hourly, in Dealu Mare-Hârlău region in 12 monitoring points located in Siret Valley (Pascani and Tudora), on interfluve (Deleni), but also on the eastern slope from Moldova Plain, most of the observation points being concentrated in Cotnari Vineyard (*figure 1*). The monitoring points are located at altitudes that allow the identification of temperature distribution typical for the development of foehn. The monitoring is made

with temperature and humidity data loggers under lee conditions standard for the making of representative meteorological observations. The analysis of daily synoptic maps of Deutsche Wetterdienst and also radio-sounding observations available from Cernăuţi, Ucraina, in the closest point with observations of this type of the analysed area, results in the identification of synoptic situations leading to the occurrence and development of hydraulic foehn in Dealu Mare-Hârlău region.

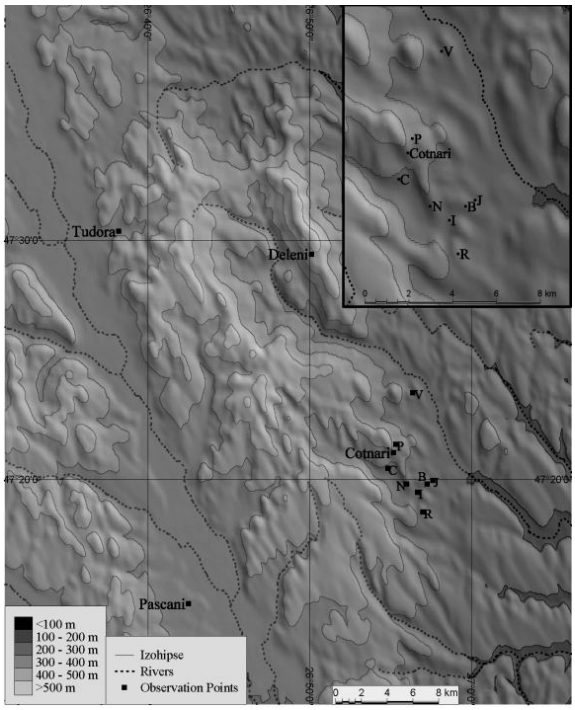

Figure 1 **Observation network**

In addition, the foehn development was identified with the help of products of forecast model WRF/România (relative humidity, air temperature, heat flux, air directions etc.).

Graphic and cartographic materials are carried out using Excel 2007 soft and TNTMips 6.9.

RESULTS AND DISCUSSIONS

The region associated with Dealu Mare-Hârlău Vineyard is known on the distribution of air temperature maps at the level of Moldova, as a strong positive temperatures anomalies region (Patriche C.-V., 2009; Mihăilă D., 2004). These foehn phenomena of westerly flow produced on the east slope of Dealu Mare-Hârlău Massif support the explanation for these situations (Erhan E., 2004, Mihăilă D., 2004, Hohan D.S., 2001).

Mostly, though, the high temperatures of Cotnari are not accompanied by precipitation on the west slope of Dealu Mare-Hârlău Massif. In this context a second type of foehn is concerned, named hydraulic (Schweizer H., 1953) or dry (Carrega P. And Napoli A., 2002), in which one of the slopes in the lee of the massif is situated in a cold-air pool, inert, resulting from the previous synoptic period, and as the air makes a discharge on the other slope over the ridge limit of warm air originated from a developing warm advection (*figure 2*). This „discharge" leads to an additional heating of warm air through adiabatic compression (1°C/100 m) caused by a downdraft.

Within the monitoring of meteorological conditions of 2013-2014 winter in the region, we bring arguments in favour of this type of foehn development.

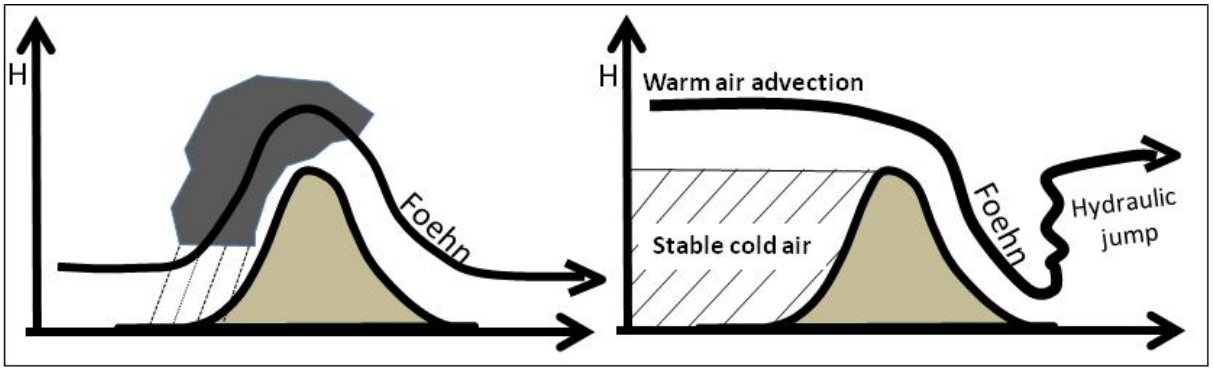

Figure 2 **Classical development of foehn (left) versus hydraulic foehn (right)**

Dealu Mare-Hârlău region experienced during 2013-2014 winter a very warm weather, with a single extreme cold weather episode at the end of January and at the beginning of February, when the minimum temperatures dropped down up to -20, -24°C on the whole region.

Low temperatures throughout winter were recorded in Siret Valley (-1.3°C in Pascani or -0,7°C in Tudora) compared to the higher region (-0,1°C) of Dealu Mare-Hârlău Massif, which indicates primarily a high frequency of temperature inversions within the region, reflecting the fact that prolonged periods of lower clouds and fog persist in Siret Valley, while the higher regions are under

warm air advection conditions. This distribution of temperatures marks too, the high frequency of thermal inversions over the whole winter, but very often distribution of air temperature within the region indicates warming the air on the east slope of Dealu Mare-Hârlău Massif, pointing out the hydraulic foehn development.

This is the case of situation occurred during the interval 22.12.2013, 5:00 p.m., 23.12.2013, 9:00 a.m., when under westerly flow above Romania, the mean temperature of air was -3.9°C in Pascani, +4.9°C in Deleni and +6.2°C in Paraclis-Cotnari (observation point in close proximity to ANM weather station).

The analysis of synoptic-scale weather patterns of that period gives us information about the hydraulic foehn manifestation on the eastern slope of Dealu Mare-Hârlău Massif and we further present a specific scenery for the production of hydraulic foehn within this region:

a. The baric conditions on the continent indicate a westerly warm advection between the anticiclonic system of the south-east of the continent and the depressionary area of the north of the continent, in a classical example of westerly flow in a continent-wide but also regionally (fig. 3). We have observed this airflow parameters (westerly wind, increased temperature and low relative humidity) on our region (fig. 4) through the mean of the runs of the RoMetEx/WRF forecast model of West University of Timisoara.

b. Temperature in Cotnari-Paraclis is +6.2°C and relative humidity 50%. During all this time, according to the prognostic material WRF Romania, the wind blows from the west with variation from WSV to WNW with speeds between 20-30 km/h. Moreover, Cotnari temperature is higher than that of the interfluve level, showing in relation to western direction of wind and low relative humidity, a foehn of hydraulic nature of air during descent.

c. The air temperature is very high in relatively isolated points, east of certain orographic massifs (Cotnari), but also Târgu Neamţ or Târgu Ocna according to meteoromania.ro data at that time, along with the synoptic conditions of that period, characterized through a persistent westerly flow, pointing out that there is a possibility of hydraulic foehn development at a larger scale on the eastern slopes of the Oriental Carpathians and in the Moldavian Sub Carpathians and the Sub Carpathians of Curvature, given the fact that all this time in Transilvania Basin was present a cold-air pool from a previous synoptic period, and above this, warm westward air rises. Hydraulic foehn would represent in this case, a secondary foehn, developed on the east slope of Siret Hill, the main hydraulic foehn phase taking place in the Sub Carpathian region adjoining the Oriental Carpathians.

d. Between the two points (Paşcani and Contnari), precipitation were not produced, revealing the absence of the particular mechanism of classic foehn.

e. Temperature in Siret Valley drops way below 0°C, (-3.5°C at 9:00 p.m.), cold air being inert and under atmospheric calm with relative humidity over 90%.

This episode of hydraulic foehn characterized a prolonged period of positive thermal anomalies set in the hilly Dealu Mare-Hârlău Massif region. Based on the hourly values of air temperature and of wind and relative humidity maps, we were able to estimate the frequency of situations that indicates the generation of hydraulic foehn. This situations involve the existence of lower temperatures in Siret Valley, situated in a cold-air pool, supplied during the night by the descent of cold air on the slopes, the highest of which in Cotnari-Paraclis, reflex of adiabatic warming of air transported by westerly flow with increase in altitude and intermediate values at the interfluves level.

Table 1

Mean air temperature in Dealu Mare-Hârlău for 2013-2014 winter

	Altitude (m)	Mean air temperature	
		Whole 2013-2014 winter	During hidraulic foehn conditions
Julesti (J)	114	-0,6	+1,6
Iaz (I)	128	-0,6	+1,7
Bordei (B)	144	-0,3	+2,6
Vodă (V)	144	-0,6	+2,1
Cârjoaia (C)	171	-0,3	+2,9
Naslău (N)	185	-0,4	+3,0
Rotila (R)	194	-0,5	+3,2
Pascani	242	-1,3	-0,1
Tudora	265	-0,7	+1,7
Cotnari	265	-0,6	+3,0
Paraclis (P)	274	-0,4	+4,3
Deleni	484	-0,1	+3,7

Based on this identification, our assessments reveal that, during 2013-2014 winter, the frequency of situations showing the production of hydraulic foehn, was of about 20% of the total number of hourly observations. This were the situations in which the highest temperatures were recorded on the east slope of the hilly massif (fig. 6), more precisely in Cătălina Hill, symbolic hill for Cotnari Vineyard.

Analysing the hourly distribution of temperatures only for the intervals we estimate that the hydraulic foehn developed, we can reach to a clearer image of such situations. Thus, Siret Valley is located in a strong thermal inversion with

increasing intensity during the nights. This is the reason why the temperatures in Tudora and Paşcani are the lowest within the region. The hydraulic foehn theory suggests that this sector would represent the so called „dead air“ (Welzenbach, 2008) supporting the lapse rate of warm air with increasing altitude.

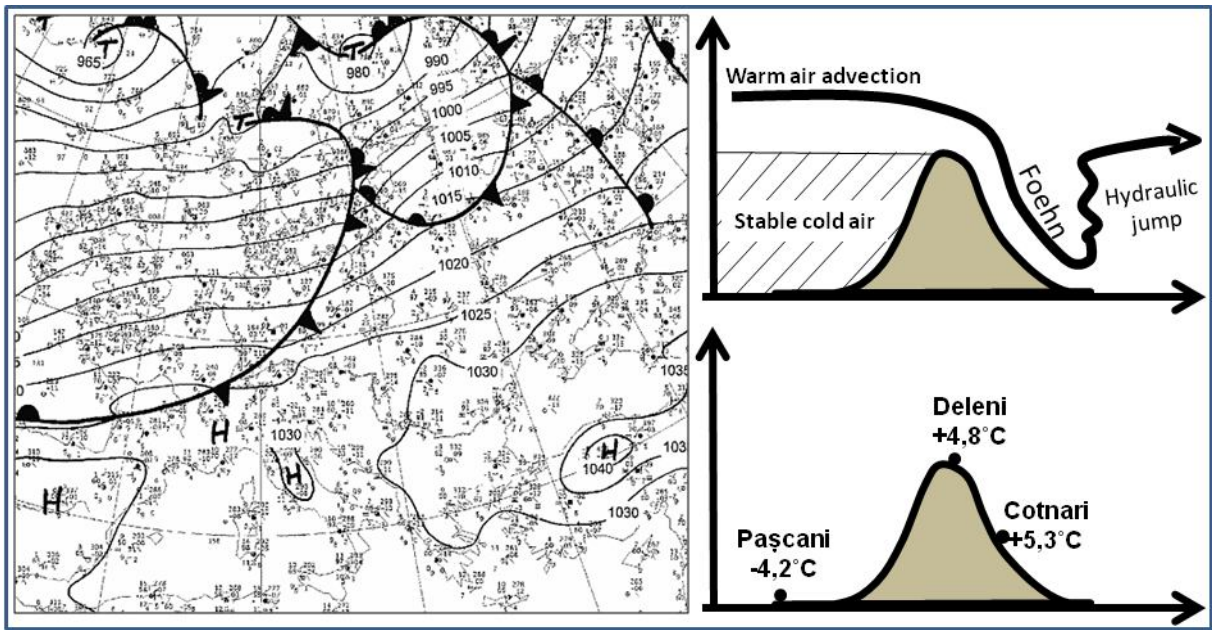

Figure 3 **Synoptic conditions favorizing the westerly flow over Romania (left) and the temperature distribution in the Dealu Mare-Hârlău Hill associated with the hidraulic foehn (right) on 23.XII.2014**

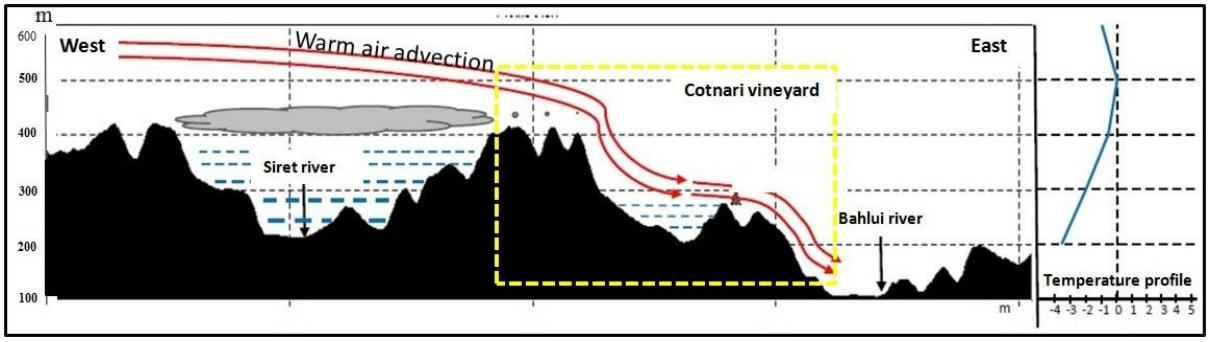

Figure 4 **Regional pattern of hydraulic foehn in Dealu Mare hill and Siret valle**

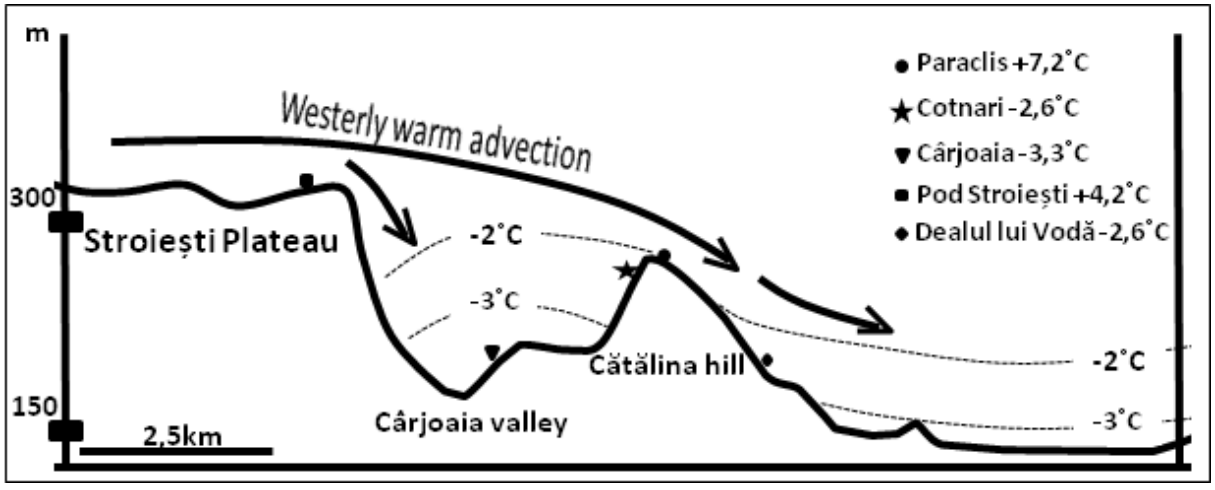

Figure 5 **Temperature distribution along a SV-NE profiel through Cotnari region on 22 December 2012, 23GMT**

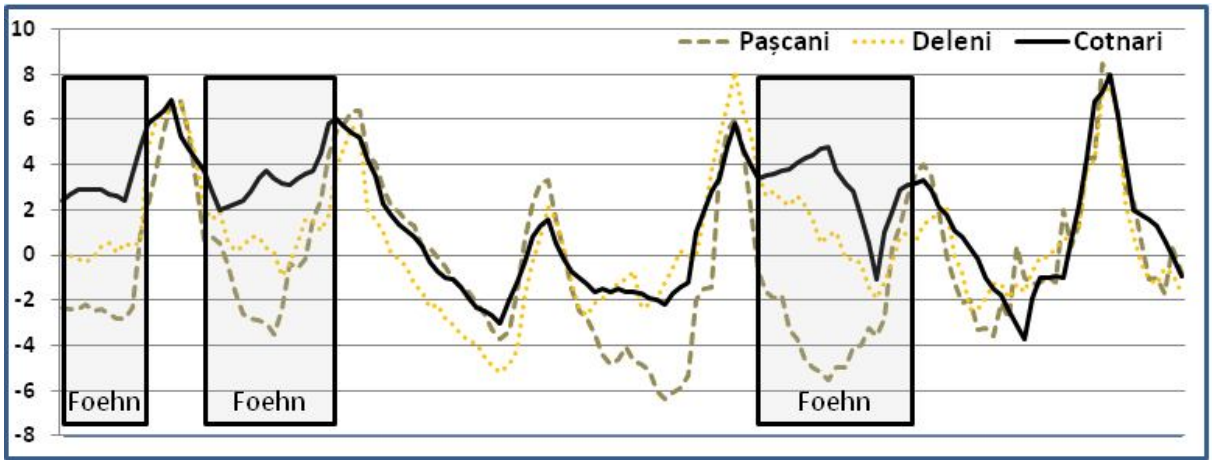

Figure 6 **Foehn type distribution of the temperature in the region of Dealu Mare-Hârlău Hill (1-6 of December 2013)**

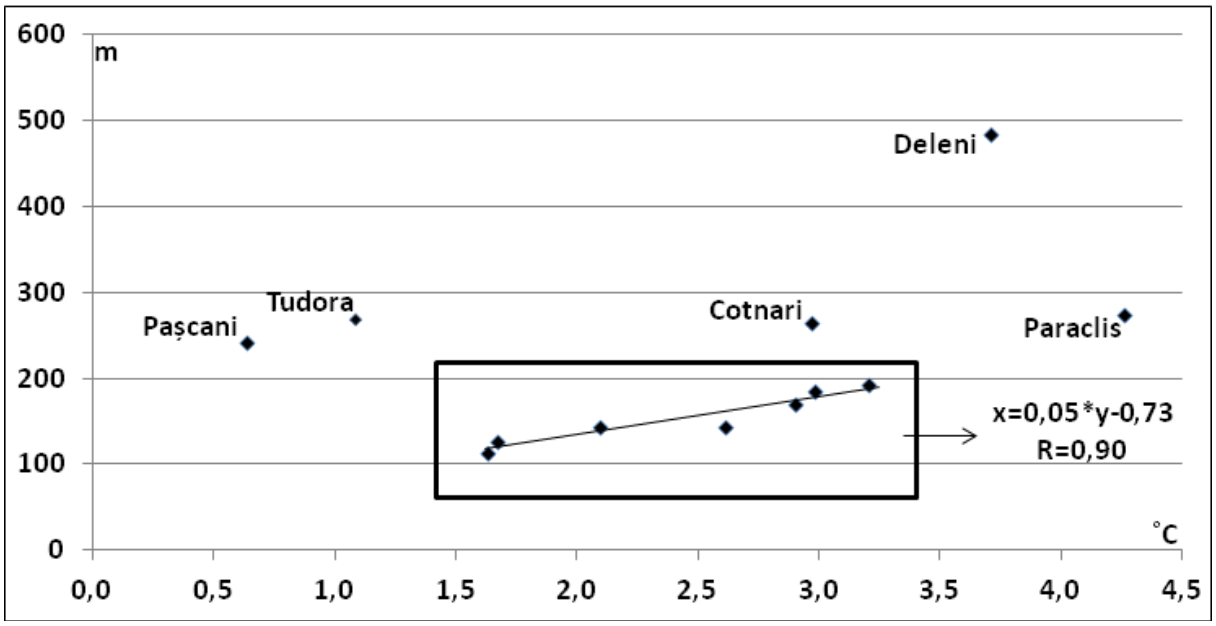

Figure 7 **Temperature distribution during hidraulic foehn condition in the region of Dealu Mare-Hârlău hill**

At the same time, on the eastern slope of the hilly massif, until 200 m of altitude, another inversion layer is well represented having a reduced intensity (*figure 7*).

Higher temperatures occur in higher altitude due to westerly warmer air, specific for all these periods, identified based on synoptic materials. Mean values in Deleni for these intervals are +3.7°C, up to 2°C higher than the lower regions, provided that for the whole winter temperatures in the higher region are almost similar with those from the lower regions, over the whole being between 0 and -0.36°C (*table 1*).

However, the highest values are those registered in Cotnari-Paraclis point of observation, located in Cătălina Hill, the mean temperature for all types of hydraulic foehn being of 4.3°C, the highest from the region.

Moreover, Cătălina Hill region coincides to an isolated thermal anomaly region, which in our view arises directly as a result of local mechanism of hydraulic foehn development in the region. Under the conditions of westerly flow the warm air circulates over Stroieşti plateau composed of a downside cuesta, which facilitates the laminar motion of air (*figure 5*), plunges over Cârjoaiei Valley that stagnates the pre-existent air and enters in a descending motion, characteristic to rising over the orographic obstacle (Durran D.R., 1986). Adiabatic warming of downward moving air by 1°C/100 m level difference is specific to hydraulic foehn (Schweizer H., 1953). Therefore, at the

intersection of warm advection with Cătălina Hill in Paraclis point of observation, 100 m below the altitude of Stroieşti plateau, temperatures registered in this point are higher due to hydraulic foehn phenomena. A distinctive feature of the hydraulic foehn is that the downward air carries a hydraulic jump, limiting its warming on the third superior level of the slope.

Furthermore, this thing is experienced in the exploitation of land, vine climbs in Cotnari Vineyard at high altitudes on the slope and avoiding the third inferior level of the slope where the foehn warming is more diminished, and the thermal inversions generate low temperatures and more frequent frosts.

Occasionally, only the higher region of Cătălina Hill experiences warm advection with characteristics and synoptic conditions of foehn, leading to high thermal contrasts on extremely small-scale regions. For example, on 22.12.2013, at 10:00 p.m, in Cotnari point of observation a temperature up to -2,6°C was recorded and +7,2°C at only 700 m distance and at 10 m level difference in Paraclis point of observation.

CONCLUSION

As we mentioned in the beginning, foehn, would partially justify the thermal anomaly Cotnari symbolises at Moldavian level, particularly in the cold season, but not exclusively. The incidence of foehn, classical, but particularly hydraulic, results in fewer cases of early and late frosts that can affect the vine-growing yields.

Furthermore, hydraulic foehn, can contribute to the attenuation of frosts during winter season, phenomena that is directly reflected through agricultural productivity growth measured for the next year or for longer periods of time.

We can take into account in this manner the fact that the distinctive climatic favourability of Dealu Mare-Hârlău region for the vine-growing is a cumulated result of the convergent action of four factors: eastern exposition ensures a long-term sunlight exposure, in the inversion layer the temperature increases with height and the amounts of precipitations are moderate, and last but not least, foehn, predominantly hydraulic, protects the higher regions against frost and determine milder overwintering conditions.

Therefore, the incidence of hydraulic foehn within this region contributes to the climatic favourability of the region for the vine-growing and in this way Cotnari wine can be considered, at least partially, a result of this type of foehn.

We could equally anticipate that this is the dominant condition of foehn across Romania, but it has to be demonstrated in research and through monitoring temperature conditions using topoclimatic modeling in other known regions by means of significant incidence of foehn (same as Bisoca in Sub Carpathians of Curvature).

The ideas presented in this study would be consolidated in the years to come by monitoring the meteorological conditions within the region, many more observations on a local scale being required throughout the development of this phenomenon in order to elaborate its mechanism of manifestation.

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