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GIS APPLICATIONS IN VITICULTURE: THE SPATIAL DISTRIBUTION ANALYSIS OF SLOPE INCLINATION AND SLOPE EXPOSURE IN HUŞI VINE GROWING CENTRE – HUŞI VINEYARD

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ABSTRACT - The paper presents the results of a study regarding the spatial distribution of slope exposure and slope inclination in Husi vine growing centre, Husi vineyard. These factors determine the ecological suitability of an area for vine growing and influence, to a large extent, both directions of wine production and grape quality. The knowledge in their share and variation in vine growing areas, allows to establish the proper grapevine varieties, to place each variety in the optimum location (microzoning), to choose the optimal training system and the appropriate maintenance techniques for the vineyard area. The technology that allows such analysis and the elaboration of maps with spatial distribution of the ecological factors is GIS (Geographic Information Systems), an instrument of information technologies introduced in the last years in viticulture too. The research presents a case study in which GIS is used to determine the geomorphological features of Husi vine growing center, the local variation of the slopes and the spatial distribution of ecological suitability in the vineyard, depending on these factors. The results show that, in relation to suitability of slope inclination and slope exposure, Husi center includes four areas with different suitability for vine growing. Of the total vineyard area, 42.2% (903.2 ha) has south and predominantly south exposure, the most favorable for vines, and 37.98% (814.58 ha) northern exposure, bad or limiting for vines. The slope analysis shows that 29.19% (624.2 ha) is suitable for high production varieties, and 70.81% (1515.6 ha) for quality wines varieties. According to the suitability of slope inclination and slope exposure, the most favorable for vine cultivation is SD4 area, that includes *Recea* and *Galbena* lands, while the worst for the vines is SD1 unit that includes *Rusca, Schit* and *Ochi* lands.

Key words: Grapevine, Vineyard, Geographic Information Systems, Climate maps, Slope, Sope exposure.

REZUMAT - În lucrare sunt prezentate rezultatele unui studiu privind distribuția spațială a *expoziției versanților* şi *pantei*

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terenului în centrul viticol Huşi-podgoria Huşi. Aceşti factori determină favorabilitatea ecologică a unui areal pentru cultura viţei de vie şi influenţează, în mare măsură, atât direcţiile de producţie, cât şi calitatea strugurilor. Cunoaşterea ponderii şi a variaţiei lor în arealele viticole permite alegerea sortimentelor de soiuri, microzonarea soiurilor şi alegerea sistemelor de conducere optime. Tehnologia care permite efectuarea unor astfel de analize ecoclimatice şi elaborarea de hărţi cu distribuţia spaţială a factorilor ecologici este reprezentată de *Sistemele Informaţionale Geografice* (GIS), instrument al tehnologiilor informaţionale, implementat în ultimii ani şi în viticultură. Cercetarea de faţă reprezintă un studiu de caz, în care GIS este utilizat pentru determinarea particularităţilor geomorfologice ale centrului viticol Huşi şi a distribuţiei spaţiale a potenţialului viticol în cadrul acestuia, în funcţie de panta şi expoziţia terenului. Rezultatele evidenţiază faptul că, în raport cu favorabilitatea pantei şi expoziţiei terenului, în centrul viticol Huşi pot fi delimitate patru microareale cu favorabilitate distinctă pentru cultura viţei de vie. Din totalul suprafeţei viticole 42.2% (903.2 ha) prezintă expoziţie sudică şi predominant sudică, cea mai favorabilă pentru viţa de vie, iar 37.98% (814.58 ha) expoziţie nordică, nefavorabilă sau limitativă pentru viţa de vie. Din analiza pantei terenului rezultă că 29.19% din suprafaţă (624.2 ha) este favorabilă pentru cultura soiurilor de mare producţie, iar 70.81% (1515.6 ha) pentru cultura soiurilor de calitate. Din punct de vedere al favorabilităţii *pantei* şi *expoziţiei terenului*, cel mai favorabil pentru cultura viţei de vie este arealul SD4, care include plaiurile *Recea* şi *Galbena,* iar cel mai puţin favorabil arealul SD1, care include plaiurile *Rusca, Schit* şi *Ochi*.

Cuvinte cheie: viţă de vie, podgorie, Sisteme Informaţionale Geografice, hărţi climatice, pantă, expoziţie.

INTRODUCTION

Huşi vineyard is one of the oldest and most famous vineyards of Romania, situated in the Central Moldavian Plateau, at 46 °67’ latitude N and 28°05’ longitude E. Its development has followed an upward trend over the centuries, vines representing, for the local population, the most efficient way to exploit the sloping, eroded and poorly fertile terrains from this area. During the “classical” period of the vineyard, up to the Second World War, the vine growers identified and exploited by vine culture the isolated lands (*Ochi, Saca, Pleşu, Ograda, Rusca, Coţoi, Şara*), located among the bumps of the uneven slopes that surround the Husi city like a natural amfiteatre. These lands have acquired fame through the quality of the wines produced and transmitted it to the entire vineyard in time. Modernization of the vineyard, which began during the centralized economy (1965), brought together with the benefit of mechanization, the loss the identity and ecological suitability of the old famous lands. Terracing the slopes has changed the landscape morphology and uniformed the ecological suitability of the vine growing centre, making “lost” the old famous lands with their real *terroir* characteristics. Plantations are currently being rejuvenated, but the vine growers do not have detailed scientific information regarding the spatial distribution of the vine

growing suitability so there is the risk of replanting the terrains unfavorable for vine or exposed to frosts.

The results of this research are part of a larger study, whose goal is to realize the map with spatial distribution of ecological suitability for vine growing in Huşi vineyard. The research uses a modern methodology, based on GIS (Geographic Information Systems), tools that have been experimented in the last years for similar research (Jordan *et al*. 1980; Jones, 2004; Pythoud, 2006; Patriche, 2006). The analysis of Avereşti vine growing centre, a part of Huşi vineyard, shows that GIS offers a detailed image of the spatial distribution of the ecological factors in a vineyard area, and more than that, allows to achieve the map of vineyard suitability (Irimia and Patriche, 2010; Irimia and Rotaru, 2009).

MATERIALS AND METHODS

For this study we used satellite images representing the Huşi region and the adjacent sloping coasts where the vine plantations are located. By using these images a digital elevation model (DEM) was created (USGS, 2004), that was resampled from the original 90 m resolution to 10 m resolution, through bilinear interpolation, for an accurate reproduction of the land surface. The DEM was used to derive the slopes and their exposure (Patriche, 2006). The slope inclination and slope exposure were analyzed according to their influence on the vine biological potential, as in the similar analysis which we had made previously for this vineyard (Irimia and Patriche, 2009). Huşi vine growing area has 2139 ha and includes a few *lands, such as Rusca, Schit, Ochi, Dobrina, Lohan, Corni, Dric, Recea* and *Galbena* with specific ecological characteristics (*Fig. 1*).

Figure 1 - Huşi vine growing centre (satellite image)

RESULTS AND DISCUSSION

Spatial distribution analysis of the geomorphological factors. The relief is represented by hills with an average altitude of 80 - 400 m and inclined slopes (16-39%), affected by erosion and stabilized landslides. Vine plantations are placed on the slopes of a natural amphitheatre that surround the Huşi city to the north, west and south, and on the eastern hills that make the transition from the amphitheatre opening to the Prut river valley. The arrangement of the hills that form the natural amphitheatre (*Lohan* to north, north-east and north-west; *Dobrina* to west; *Schit* to south) and their uneven surfaces cause an important local variation of the *slopes exposure* and of the *slopes inclination*. Using GIS we studied the spatial distribution of these two ecological factors and we analysed their suitability for vine growing.

The slopes exposure. In relation to the climatic characteristics of this region, placed near the northern limit of the vine growing, the exposure range from very suitable (S, SE, SW) up to unfavourable (NW, NE) and even restrictive (N) for vine (*Fig.* 2).

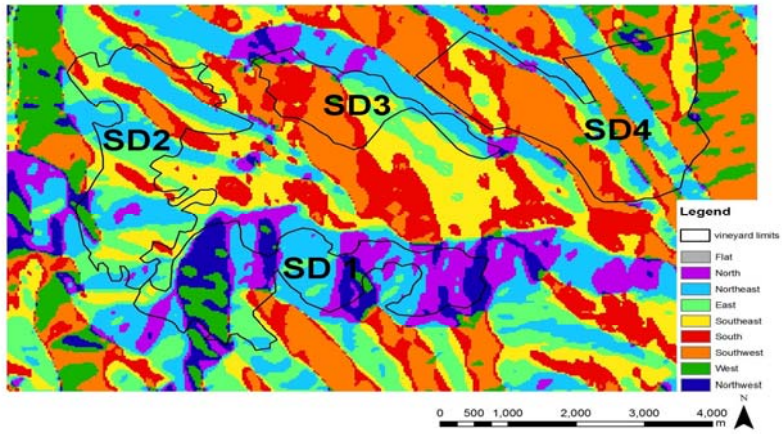

Figure 2 - Spatial distribution of the slopes exposure in Huşi vine growing centre

Spatial distribution of the slopes exposure is mainly determined by the orientation of the *Lohan*, *Dobrina* and *Schit* hills and then by the unevenness of their surfaces, which, in some places (northern slope of the *Schit* Hill) has a sharp gradient. In relation with the hills orientation and the slopes exposure suitability we delimited four different areas with distinct ecological characteristics *(Table 1):*

- **SD1** area, of 554.3 hectares, including *Rusca*, *Schit* and *Ochi* lands. Predominant (77.74%) exposure of the slopes is N, NE and NV, considered improper or even restrictive for the vine culture. The most suitable exposure for the vine (S, SE, SV) has in this area an

insignificant representation, by only 2.87%;

- **SD2** area, that includes *Dobrina, Lohan* and *Corni* lands, totalize 570.69 hectares. Here, the spatial distribution of slope exposure is more balanced, although the northern, north-eastern and north-western slopes have a higher percentage of about 37.77%; S, SE and SW exposure, the most suitable for the vine, account 34.33%; E and W exposure, medium suitable, represents 27.48%;

- **SD3** area, which includes *Dric* land, located in the NE part of the Huşi amphitheater and account 264.42 hectares. S, SE, SW exposure represent 62.10%; V and E exposure, middle favourable for vine growing, has only 16.16% *(Table 1)*. Unfavourable N, NE and NW exposures hold 19.38% share, being the mostly represented by NE slopes;

- **SD4** area contains *Recea* and *Galbena* lands, located in the eastern part of the vine growing centre, in the hilly area that make the transition to east, from the opening of the natural amphitheatre to Prut river valley. This is the largest vineyard area in the wine growing centre, totalizing about 749.7 ha. SD4 has the most favourable slope exposure, parameter that provide superior heliothermic conditions, that assure qualitative grapes. S, SE and SW slope exposure represents 70.27% of the total, and the V exposure, rather suitable, is 15.24% *(Table 1)*. Unfavourable NE, NW and N slope exposure is reduced, by only14.10% and does not influence the suitability of this area for vines.

Table 1 - Slopes exposure (%) local variation in Huşi vine growing centre

Exposure	SD1	SD2	SD3	SD4
	% in total surface of Husi vine growing centre			
N	24.93	2.176313	2.3145	0.540216
NE	29.22552	34.74215	16.09939	12.7611
E	9.806787	25.84766	14.19333	10.52821
SE	1.493749	17.75745	12.01498	12.96519
S	0.746874	11.08658	21.95371	14.21369
SW	0.649456	5.503864	28.1484	43.10924
V	9.530768	1.64012	1.974132	4.729892
NW	23.60773	0.867371	0.987066	0.888355

Expression in *hectares* shows that the most suitable for vine growing, in terms of slopes exposure, is the SD4 area, where 526.95 ha (70.27%) are S, SE and SW oriented, and the least favourable is SD1 area with 430.90 ha (77.74%) having N, NE and NW exposure. In SD2 area the very suitable slopes have rare disposition, totalizing 196 ha (34.33%); in SD3 area the most suitable exposure is on the southern

slope of a secondary branch of Lohan Hill that totalzing 164.25 ha (62.1% of SD3 surface).

The slopes inclination. As an environmental factor the slope does not exercise a direct influence on grapes quality. But it influences it indirectly, through its fertility, and the lower edaphic volume of the soils, the temperature and the water drainage better than in the case of flat terrains, and through larger values of heliothermic factors when the slope has a favourable exposure. The most suitable for the vine growing are the slopes with 10-15% inclination. Flat lands with slope inclination less than 5% are generally more fertile and more exposed to the frosts, while the slopes over 15% are more difficult to set up vine plantations and more exposed to erosion.

The slopes inclination in Huşi vine growing centre vary between 0 and 39 degrees *(Fig. 3)*. The majority (43.57%) of the vine plantations are located on medium slopes, with a 5-15% inclination, the most favourable for grape growing; 29.0% of the surface is represented by the flat terrains, favourable for very productive wine varieties cultivation and for table grape varieties cultivation; 27% are represented by slopes with more than 15% inclination.

Very large spatial distribution of the slopes inclination *(Table 2)* is due, on the one hand, to the orientation of the hills that form the amphitheatre and, on the other hand, to the unevenness of their surfaces affected by erosion and stabilized landslides, which have radically changed the morphology of the land.

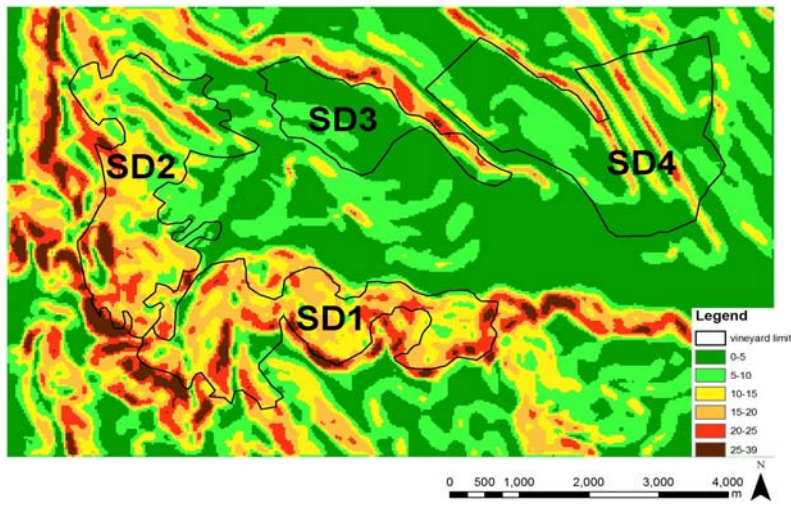

Figure 3 - Spatial distribution of the slopes in Huși vine growing centre

Table 2 - The slope inclination (%) in Huși vine growing centre

Slope (%)	SD1	SD2	SD3	SD4	Total
	% in total surface of vine growing centre				
0 - 5	4.17	10.70	60.34	50.76	29.19
5 - 10	9.43	22.15	30.22	32.11	23.34
10 - 15	29.77	31.63	4.49	10.58	20.42
15 - 20	36.32	24.30	3.19	5.39	18.17
20 - 25	16.36	8.48	1.63	1.14	7.10
25 - 39	3.92	2.71	0.10	0	1.75

Thus, in **SD1** more than half of the area (56.60%) is represented by slopes with 15 to 39% inclination, concentrated in some small natural amphitheatres formed by stabilized landslides *(Fig. 4)*. The character of natural shelter of these geomorphologic formations is cancelled by their northern, north-eastern and north-western exposure, which diminishes significantly the values of heliothermic factors and reduces their suitability for vine growing.

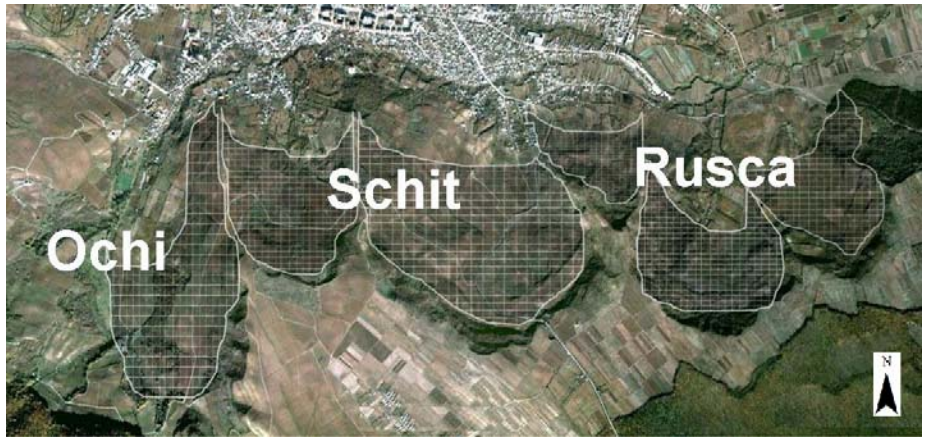

Figure 4 - The small natural amphiteatres formed by landslides on the eastern slopes of the Schit Hill, Huși vine growing centre

In the **SD2** area that includes *Dobrina*, *Lohan* and *Corni lands*, the most favourable slopes, with 5-15% inclination, sum 53.78%. The slopes with sharp inclination have a significant share, of 35.49%, but their southern and eastern exposure creates very favourable conditions for grape growing, especially for wine varieties.

The **SD3** area that includes the *Dric* land has slopes with a 5-15% inclination at a rate of 34.71% and

southern exposure, very favourable for wine varieties. A high proportion (60.34%) is owned by flat terrains with less than 5% inclination, suitable for productive grape varieties both for wine and table grapes.

In the **SD4** area which includes *Recea* and *Galbena* lands, the flat terrain represents 50.76% and the middle slopes terrains represent 42.69% of the surface. In Recea land the flat terrains predominate, giving it the ecological potential for growing table grapes varieties and wine varieties with high yield potential. The slopes of 5-15% are located mostly within the perimeter of *Galbena* land that can be considered in terms of geomorphology very suitable for qualitative wine varieties.

The expression in *hectares* shows that mid-slope terrains (5-15%) and terrains with sharp slope (>15%), very suitable for growing quality wine varieties, sum approximately 1515.6 ha, while the flat terrains suitable for growing table grapes varieties and table wines varieties with high yield potential, sum about 624.42 ha *(Table 3)*.

Table 3 - The slopes inclination (ha) in Huşi vine growing centre

Slope (%)	SD1	SD2	SD3	SD4	Total (ha)
	ha				
0-5	23.13	61.11	159.57	380.61	624.42
5-10	52.29	126.45	79.92	240.75	499.41
10-15	165.06	180.54	11.88	79.38	436.86
15-20	201.33	138.69	8.46	40.41	388.89
20-25	90.72	48.42	4.32	8.55	152.01
25-39	21.78	15.48	0.27	0.00	37.53

CONCLUSIONS

Regarding the suitability of the terrain exposure, in Husi vine growing centre there are four different areas with distinct geomorphologic characteristics that were delimited as follows: SD1 area that includes *Rusca*, *Schit* and *Ochi* lands; SD2 area with *Dobrina*, *Lohan* and *Corni* lands; SD3 area with *Dric* land; SD4 area which includes *Recea* and *Galbena* lands.

When it comes to the slopes exposure suitability, the most favorable area for vine is SD4 with 70.27 % of surface (526,95 ha) in S, SE and SV exposure; the least suitable is SD1 area, with 77.74% (430.90 ha) in N, NE and NV exposure.

The slope in Husi vine growing centre varies between 0 and 39%: 43.57% of surface is represented by slopes with middle inclination, 5-15%; 29.0% are flat terrains; 27% is represented by sharp slopes, with 15-25% inclination, arranged as terraces.

Mid-slope terrains (5-15%) and sharp slopes terrains, arranged in terraces suitable for growing quality

wine varieties sum about 1515.6 ha, while the varieties for table grapes and table wine varieties with high yield potential totalise 624.42 ha.

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