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LAND CAPABILITY AND SUITABILITY ANALYSIS FOR VINEYARDS IN SĂLAJ COUNTY, ROMANIA

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Abstract

Land capability classification (LCC) for soils ranking is used to link the peculiarities of an area to the productions and the applied management. Terroir has a great influence on viticultural activities and wine quality. The aim of this study was to analyze and compare the components of Carastelec and Camăr vineyards' terroirs and determine the influence of the soil and land characteristics on the suitability and capability of these lands for vine culture. Data on soil and climate were gathered. Soil samples were collected, analyzed, and modelled to establish their capability and suitability for vine use followed by land capability improvement approaches and grape varieties recommendation. The results reveal that the studied areas consist of different soil types and ecologically homogenous territories which ranks them into different capability and suitability classes suggesting that they have a moderate capability for table grapes production and a higher one for wine grapes production. By applying works to reduce or cancel the identified limitations, the ranking was higher for both vineyards and recommendations of the moist suitable grape varieties to be cultivated were made.

***Key words**: land capability, soil, grapes, wine, classification.*

INTRODUCTION

Land capability classifies land based on the potential for different uses, e.g., agriculture, forestry, grazing, depending on the environmental and soil characteristics. Many kinds of land capability classification systems have been developed (FAO, 1976; Gizachew & Ndao, 2008; Hall, 2008; USDA, 1997; Klingebiel & Montgomery, 1976; Lynn et al., 2009; Rowe et al., 1981; Tesfay et al., 2017) using different principles and parameters. Land capability classification is a useful instrument to evaluate the terroir conditions.

Regarding vineyards and wine making, it is well known that all wine brands owe their specific characteristics and qualities to such terroirs (Brillante et al., 2020).

Developed in France and adopted globally, mostly in the wine industry, the concept became more precise: from a largely descriptive regional science to a technical research field with the main focus on the variation of biophysical characteristics of a vineyard site and their interaction with vine performance (Bramley, 2020). Concerning soil-vine interaction, most of the research studies involve precision agriculture methodologies used to better elucidate the contribution of both ecological and pedological factors (geology, lithology, climate, groundwater, vegetation, and fauna) to the formation of vineyard soils and their influence on different grape varieties and rootstocks. Currently, zoning, constitutes the first step in site selection and has a crucial role in the optimization of vineyard management. Similarly, they increase production efficiency and enhance the site-specific peculiarities of the product (Bramley, 2020; Vaudour et al., 2015).

Soil types also play an important role in vineyard performance and grapes composition (Echeverría et al., 2017). Interactions between vine and climate-soil system were studied by several authors. The results suggest that the effects of climate, soil and variety on vine behavior were highly significant. Furthermore, it has been reported that the anthocyanin concentration of the grapes was mostly influenced by the climate and the soil than by the vine variety (Jones, 2015; Van Leeuwen et al., 2004). Other studies suggest that soil temperature has a crucial role and a great effect on vine phenology and roots affecting their size and function (Lanyon et al., 2004; van Leeuwen et al., 2018).

Soil quality is another important parameter with an essential role in vine development and performance, exhibiting a strong linear association between soil and yield quality (Coipel et al., 2006).

Geological features of the terroir were investigated by various authors who consider that climate change has a sensitive impact on grapevine cultivation, affecting phenological stages in different terroirs increasing vulnerabilities in the future. They also suggest that more studies of both the terroir and the wine industry are needed to reduce this vulnerability (Bargmann, 2003; Bonnardot, 2002; Conradie et al., 2002; Hancock, 1999; Haynes, 1999; Holand & Smith, 2010; Maltman, 2008; Morlat, 2001).

In the capability system, soils are generally grouped in different levels, in accordance with the used system. Most of the systems consider climatic conditions, soil, and terrain conditions as being the most important, having different influences depending on the crop type, level of inputs and management.

The selection of attributes, data sets and indicators also need to be relevant for the standardization of soil quality attributes and their analyses (Mueller et al., 2010). Some indicator sets and thresholds have been developed for typical regions or countries (Barrios et al., 2006; Govaerts et al., 2006; Sparling et al., 2008; Teaci, 1980). Also, some systems take into consideration the improvement capabilities (Dalal-Clayton & Dent, 1993; Teaci, 1980). Land attributes can be related to either the direct use of the land or the possibilities of a major improvement of the land conditions if it's possible (Bennema, 1978). According to Vlad (2001) a land evaluation method is characterized by (1) the set of primary data used, (2) the set of evaluation criteria and land suitabilities used and (3) the evaluation models used for determining the evaluation criteria and land suitabilities.

Some research results reveal that Romanian vineyard terroirs could be classified by ecosystems: North, South and East Carpathian, Banatic, Dobrogea and Danubian. According to Toti & Ignat (2011), critical ecopedological factors that determine the architectonics of the vine root system are the edaphic factors which subserve or set back the development and functioning of the root system in terms of shape, length, thickness, and efficiency. In this context, the need for more specific studies to reveal the variables of other terroirs from Romania. Therefore, the main aim of this research was to i) identify the types of soils and analyze their properties ii) to assess land suitability and capability for wine and grapes in both natural and improved conditions, in two vineyards (Carastelec and Camăr) from Sălaj County, Romania.

MATERIALS AND METHODS

In order to assess LCC various land qualities and characteristics were analyzed in both Carastelec and Camăr vineyards. The most important land characteristics which should be included in any LCC are topography, soil, and climate. All of these, but especially topography and soil, are significant components in the determination of land units.

Location and site description

Carastelec and Camăr vineyards belong to the Wine Center of Sylvania which is situated in the North-Western part of Romania, in Sălaj County.

The plantations are located on low hills, between 220 and 320 m above sea level in Camăr, and between 200-230 m in Carastelec, on a moderately inclined slope (5-15%) in Camăr, and with 10-15% inclination in Carastelec, mostly with southern and south-western exposure.

In Camăr, the areas intended for the establishment of the vineyard are located on a slightly uneven slope, with favorable exposure and a soil with medium fertility. The plantations in Carastelec are located on a slightly uniform slope, with favorable exposure, highly fertile soil and unterraced surfaces. The predominance of southern and south-western exposure of the lands favors successful vine cultivation. Depending on the slope, it might not be necessary to carry out specific correction works in order to set up the

plantation. All these features guarantee obtaining high-quality grapes (Genoiu, 2015).
From geomorphological point of view, the territory of Carastelec commune is part of the Someș Plateau, whose external or north-western side includes the Sylvania Hills or the Salaj Platform, gradually leaning towards the Tisa Plain. The relief, rather than the microrelief, caused changes in the soil formation process, thus the soils evolved differently, according to the geomorphological unit to which they belong.
It is worth mentioning that the whole area comprises hills and elevated land, mostly with Northwest-facing slopes with hills ranging between 881 m (Plopiș) and 151 m (near the Barcău River). As a result of the geological evolution, the generated soil types by the parent rock found in this area are: carbonate clay minerals (typically light green or purplish), carbonate-cemented sandstones alternating with carbonate clay and colluvium. This area is currently serving as a wine processing center and a sparkling wine factory. Thus, Vinum Partium Winery was established in Carastelec commune and Fort Silvan 47 Winery in Camăr commune. The vineyards are surrounded by the forest in the vicinity.
Carastelec vineyard covers an area of 22.4 hectares. The land was split into 8 vine plots, each consisting of several sub-plots. The Camăr vineyard is slightly bigger, covering an area of 36.08 hectares, and is divided into 14 lots of grapevines, with their sub-plots.

Climate

Sălaj County is under the direct influence of western air masses. Atmospheric circulation, as well as relief, by its appearance and altitude, create climatic differences, on one hand between the West and East of the county, and on the other hand, between the main geomorphological units. The climate of Carastelec and Camăr region are characterized by moderate temperate-continental climate, with Sub-Mediterranean oceanic influences, with the characteristic climate of low-elevation regions. The annual average rainfall is 626 mm, although unevenly distributed, sufficient for most agricultural crops during years considered as normal. The highest average quantities of rainfall/month have been recorded in June (94.5 mm) and July (80.3 mm) while the lowest values have been registered in January (34.1 mm) and February (30.2 mm). Concerning the mean annual values of the climatic water balance, the studied land areas fall into the class of low precipitation surplus and are characterized by moderate erosion (code 0127) (according to data provided by the National Meteorological Administration, Regional Northern Transylvanian Meteorological Centre, 1982-2011).
The average annual temperature exceeds 9°C while the temperature amplitude ranges from 19.3 and 27.6°C. From a pedo-geoclimatic point of view, Carastelec and Camăr communes fall into a moderate cool-humid climate, with moderately rugged relief, and Luvisol as the predominant soil, identified with 78/13aIIID-BP in the climatic microzone class (Florea et al., 1999).

Soil description and characteristics

In order to identify soil types and describe their characteristics for both territories (Carastelec and Camăr) three soil profiles were opened for each territory to depict all the horizons. The soil profiles were opened at the minimum depth of 125 cm and soil layers were observed and described to classify and interpret the soil for various uses. Field observations were followed by the collection of 34 soil samples taken from each horizon which were then transferred to the laboratory to determine the physical and chemical characteristics of the soils. The soil samples were dried first at 30°C, then grinded and filtered to prepare them for further analyses.

Land suitability and capability evaluation

Land evaluation is a very complex process based on the land characteristics and its resources which are matched with a specific use of the land according to scientifically standardized techniques. In this regard, land suitability and capability could be assessed for present (current) land conditions without applying any input, or for future conditions which could be reached after land improvement (potential land suitability). To define current land suitability, soil characteristics and environmental data related to growth requirements of a specific crop need to be evaluated. Potential land suitability refers to a future state, after land improvements have been applied and the productivity of the land was enhanced, thus creating more suitable conditions for the crop (Ritung et al., 2007). In Romania, the LCC system is called Databases of agricultural soil-land units in Romania and the support system of expertise on soil-land-BDUST, developed by The National Institute for Pedology and Agrochemistry (ICPA Bucureşti), which was used for the current study. Data processing and mapping of the soil units (US), the ecologically homogeneous territories (TEO) and favorability and suitability maps were performed using Global Mapper program (ICPA, 2016).

The main parameters scored and used in order to establish suitability and capability classes for the vineyards under study were: the average annual temperatures, the average annual rainfall, the degree of glazing and stagnation, texture, salinization/alkalization, slope, erosion hazard, total porosity, carbonate content, groundwater depth, soil pH, useful soil volume, and organic matter content. In order to obtain the suitability scores, parameters matching system between land quality and land characteristics with plant's requirements was used according to the evaluation flow presented in Figure 1.

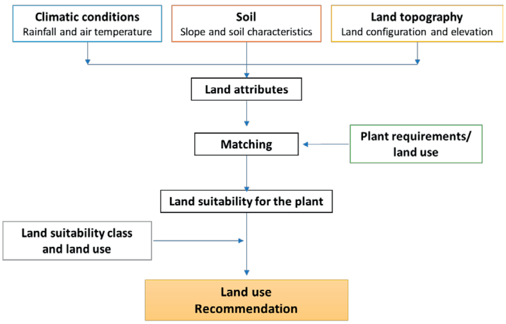

Figure 1. General framework for land evaluation

Florea et al. (1986) suggests that based on land evaluation scores, lands can be listed in five different classes: the first one with the highest scores being considered the most suitable: Class 1-81-100, followed by Class 2-61-81, Class 3-41-60, Class 4-21-40 and Class 5-0-20. Suitability classification according to the guidelines of FAO (1976) is divided into Order, Class, Sub Class, and Unit. The Order is the global land suitability group. Furthermore, Land suitability Order is divided into S (Suitable) and N (Not Suitable). Class is the land suitability group within the Order level which defines six soil quality classes based on the data obtained due to soil evaluation as follows:

- Class 1 - high-quality soils;
- Class 2 - good quality soils;
- Class 3 - medium quality soils;
- Class 4 - low-quality soils;
- Class 5 - very low-quality soils;
- Class 6 - unsuitable soils for the crop chosen.

In addition to the evaluation and soil quality classes, lands are also evaluated according to their capability. As described by the global Land Capability Classification (LCC) System, the capability of a land is determined by its potential to be suitable for certain uses and to assess if there are any risks of degradation. In this regard, it must be mentioned that some land restrictions could be ameliorable (by choice) and due to the improvement, they could fall into higher classes of suitability and capability, while other restrictions of an absolute nature could not be improved (climate, edaphic volume, etc.). The description of these classes are as follows: Class 1 - land with very good suitability for crops, without any restrictions; can be grown without applying measures to prevent degradation or improve the soil (ensures very good yields); Class 2 - land with good suitability, with low limitations, the risk of soil degradation or existing deficiencies can be improved by current practices or ameliorative measures (provides good yield); Class 3 - land with medium suitability, with moderate limitations, which limits the use of agricultural crops and requires improvement measures to prevent degradation (provides medium yield); Class 4 - land with low suitability, with severe limitations, which leads to significant decrease in crop yields and requires intensive planning and/or improvement measures in order to ensure yield safety; Class 5 - land with very severe limitations, unsuitable for agricultural crops, orchards or vineyards without special, complex and intensive land improvement measures. However, after improvement, these lands could be reconsidered and proposed for: arable land if the weather conditions are suitable for the prioritized agricultural crops (AL); orchards (OR) or vineyards (VY). Class 6-land with extremely severe limitations which cannot be used for agricultural crops nor for orchards or vineyards even after improvement measures.

For the establishment of a vineyard, besides the results of the soil analyses, it is very important to take into consideration the ecological factor as well, which can influence the growth and the production of the vine. Depending on the characteristics of the land associated with the eco-pedological factors (relief, hydrology, etc.), the suitability of the land can be established.

Every parameter analyzed in this study was associated with a coefficient from 0-1, where 1 represents maximum suitability and 0 means completely unsuitable. The final score was then calculated based on the coefficients and multiplied by 100 (Teaci, 1980).

While for the land suitability classes the evaluation scores are used. The grouping of land units in relation to capability for field crops and other uses is done in classes, subclasses, groups, and subgroups, in relation to the nature and the intensity of the limiting factors of production (relief, climate, soil). The subclass is marked with capital letters corresponding to the limiting factors, and Arabic numbers (2 to 6) added to the symbols of the limiting factors (Table 1) are used to mark the groups (Figure 2).

Table 1. The restrictions used for the establishment of the capability classes

Symbol	Restrictions
S	Salinization
A	Acidity
M	Reserve of humus
K	$CaCO_3$ content
N	Coarse texture
C	Fine texture
T	Compactness
V	Low edaphic volume
O	Reduced bearing capacity
P	Slope
E	Surface erosion
R	Deep erosion
F	Slides and falls
Z	Land cover with stones and rocks
U	Unevenness of the terrain
Q	Excess of water table
W	Excess of stagnant water
H	Flooding
L	Excess of moisture on slopes
G	Anthropical degradation
B	Low temperatures
Δ	Moisture deficit

The higher the value, the higher the intensity of the limiting factor. One and the same terrain can have restrictions of different intensities (Q4, W2, etc.) or several restrictions of the same intensity (Q4, W4, etc.). The placement in the class is done by considering the restriction or restrictions of the highest intensity.

Land capacity classes can change to higher classes if the existing limitations can be permanently removed or reduced to some extent by economically feasible rehabilitation measures.

These can happen by providing irrigation, ensuring adequate drainage, damming, or stabilizing the land, terracing. The application of these measures allows a new assessment of the land, namely potentiated regime, by using new coefficients for the new state of the corrected indicator/limitation.

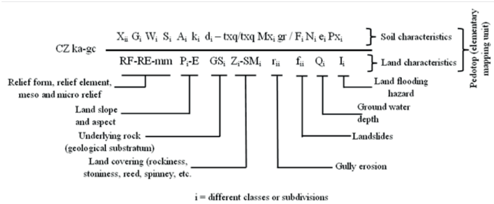

Figure 2. Capability formula/Soil-land unit, completing information on soil (upper part) with information on environmental (underlined part)

RESULTS AND DISCUSSIONS

Soil conditions

In contrast to other crops, vines are able to add value and perform successfully even on lands with low agricultural values. They only need sunshine, warmth, a little water, a low amount of soil volume and a low dose of nutrients in the soil to thrive. However, soil characteristics are essential for vine growing. In general, soil layers are destroyed and relocated due to terracing or deep plowing right before vine planting which poses a negative effect on both physical and chemical characteristics of the soil. Carastelec and Camăr communes are located in the north-western part of Sălaj County, north-western part of the country, overlapping almost entirely with the connection area between the Apuseni Mountains and the Eastern Carpathians, known as the Someşana Platform. From geomorphological point of view, the territory of Carastelec commune is part of the Someșan Plateau. During this research it has been observed that the relief had an important impact on the soil formation process in this area. It should be noted that the whole area is dominated by hills with their slopes oriented to the north-west. The maximum elevation recorded is 881 m (Plopiș), while the lowest is 151 m. This difference of 730 m elevation must be considered when distributing the production across the territory. The hills are fragmented and both surface and deep soil erosion were observed in this area. Soil analyses revealed that in Carastelec area, in the Vinum Partium Vineyard covering 22.4 hectares the only soil type identified was Anthrosol (Florea & Munteanu, 2012) according to RSST (Anthrosols in WRB), with three subtypes (US1, US2 and US3) as presented in Figure 3.

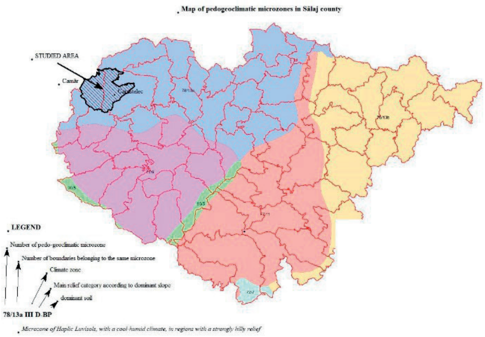

Figure 3. Map of pedogeoclimatic microzones in Sălaj county (adapted from Florea et al., 1999)

In this area, three soil profiles were opened as follows: Profile 1. Anthrosol aric preluvic-stagnic Ao1d-Ao2-ABd-Bt1w-Bt2w-Cn, deep, developed on mezobasics hard rocks; Profile 2. Antrosol aric preluvic Ao1d-Ao2d-ABd-Bt1-Bt2-Cn, developed ob mezobasics hard rocks and Profile 3. Antrosol aric cernic Am1d-Am2d-ABd-Bt1-Bt2-Cn, developed ob mezobasics hard rocks.

All analyzed profiles present a Bt horizon richer in clay (about 60 cm depth), which could cause compaction at the level of the roots correlated with a much slower percolation of water. But these conditions can be readily reversed through deep loosening, which was the main improvement measure for potentiated evaluation.

At Camăr, within the plots in Podgoria Fort Silvan 47 on 33.58 hectares the predominant soil type identified was Phaeozem, with the three subtypes as follow:

- Profile 1. Haplic Phaeozems Am1-Am2-AC-Ck, well developed on carbonatic clays (US1)
- Profile 2. Vertic Stagnic Phaeozems Am1y-Am2y-ABy-Bt1yw-Bt2yw-Ck., well developed on carbonatic clays (US2).
- Profile 3. Luvic Stagnic Phaeozems Am1-Am2-AB-Bt1w-Bt2w-Cn, well developed on clays (non-carbonatic) (US3).

The parent material represented by clays stimulates the accumulation of organic matter in larger quantities and ensures a larger reserve of humus, but the presence of swelling clays also determines the appearance of the vertical character (US2) which prevents the normal development of the roots. Also, lower porosity values than in the case of anthrosol also determine the appearance of stagnant character (US1 and US3). Grapevines are tolerant to waterlogging but only during the inactive phase, not during the growing period (Campbell-Clause & Moore, 1991). As a result, in addition to deep loosening, works to remove excess stagnant water are also recommended.

In both areas, the slope is slight to moderate which is desirable in vineyard sites since it accelerates the drainage of cold air from the vineyard. Cold air is denser than warm air and will drain downhill and therefore there is no need for protection during cold periods of the year (Bufu, 2014; Genoiu, 2015).

Climate

The studied lands fall into the class of low surplus annual average hydroclimatic balance and into the middle erosion class (code 0127) according to the National Meteorological Administration, Regional Meteorological Center Transilvania-Nord, 1982–2011.

From pedological and geoclimatic point of view, Carastelec and Camăr communes are characterized by a moderately cool-humid climate, with moderately rugged relief, with whitish Luvosol as the predominat soil, which allows this land to be classified by the climatic microzone with the symbol 78/13aIIID-BP (Florea et al., 1999) as presented in Figure 3. From pedological and geoclimatic point of view, Carastelec and Camăr communes are characterized by a moderately cool-humid climate, with moderately rugged relief, with Albic Luvosol as the predominant soil, which allows this land to be classified by the climatic microzone with the symbol 78/13aIIID-BP (Florea et al., 1999) as presented in Figure 3.

The annual rainfall of 626 mm is evenly distributed, with a slight surplus in May–June and with the least precipitations in December–March. The significant decrease in rainfall in August, September and October has a positive impact on soil temperature and fruit ripening and provides good phytosanitary status for the grapes. The significant decrease of the average air temperature by 3-4°C, in September, helps the preservation of chemical components in fruits sensitive to higher temperatures-flavors, acids-in grapes (ONVPV, 2014). The number of foggy days with high humidity level is very low which enhances the helio-thermal availability for vineyards in this area and guarantees the production of high-quality. aromatic white and red wines. The De Martonne annual aridity index (IaDM) is 36.9 and the monthly index varies between 58.8 in January and 26.1 in September, values which indicate no month with moisture deficiency in the studied areas (Genoiu, 2014) (National Meteorological Administration, Regional Meteorological Center Transilvania-Nord, 1982-2011).

The natural shelter of the Meseș Mountains makes the extreme minimum temperature one of the least harsh in Romania. In the studied area, the frequency of the absolute minimum temperature in winter, unfavorable for vines, is low (Oșlobeanu et al., 2014). Due to the southern exposition of Carastelec and the Southwestern orientation of Camăr the slopes benefit from extra light and warmth.

Based on the climatic parameters recorded, it can be claimed that from climatic point of view the investigated sites, namely, Carastelec and Camăr are suitable for vineyard establishment (Genoiu, 2015).

Land suitability and capability

Land suitability and capability are often confused or even considered identical; however, they define two different and very important characteristics of a certain land. Thus, suitability is evaluated based on the positive features of the land which can facilitate successful production, whereas land capability is defined mostly focusing on the features (limitations or restrictions) which can prevent the land to be used for certain agricultural land categories, e.g.,vines, arable, orchards or pastures (Blaga et al., 2008).

Similar to this study a number of LCC researches have been used as a valid tool in helping land managers and land use planners to manage land considering soil proprieties and potentialities, identifying areas with physical constraints for a range of land uses (Girmay et al., 2018; Scopesi et al., 2020).

Following data analysis and processing, the evaluation scores were assessed, and then quality classes, suitability and land capability classes were defined for the wine-producing vineyard and for grapes production in both natural and improved conditions, for Carastelec (Table 2) and Camăr (Table 3) vineyard as well.

Ecologically Homogeneous Territories (TEO) represent “a distinct portion of land on which all natural factors, or in the case of improved and anthropogenic surfaces, manifest themselves uniformly, the portion of territory cannot be further divided according to any of the criteria used” (Teaci, 1980). Therefore, the same type of soil could be divided into multiple TEOs based on the changes of the land characteristics (different slope, different orientation, etc). In total, seven TEOs were separated, three in the Carastelec plantation and four in the Camăr plantation. The separation of TEOs was achieved by overlapping soil and the topographic maps based on the following data: orientation, slope, hydrographic basin, main relief, meso- and micro-relief form, risk of surface erosion, deep erosion and landslides, corrected annual average air temperature, corrected annual cumulative average precipitation, groundwater depth, reed cover, stands, mounds or ridges, degree of land cover with stones, degree of reed bed land cover, feasibility for land improvement and agropedoameliorative works, earthworks land terracing and anti-erosion works (Vlad, 2015).

a. Carastelec vineyard. The results suggest that, in natural conditions, regarding the wine producing sector, no differences have been recorded between US 1 and US 2, both sharing the same evaluation score (58) indicating medium suitability with medium quality soils with moderate limitations, which limits the use of agricultural crops and requires improvement measures to prevent degradation. US 3 was slightly different, falling into the 2nd quality class with low quality soils, but with medium suitability associated with moderate limitations. The final scores of land suitability and capability indicate that in Carastelec US 3 and TEO 3 had the highest evaluation scores defining good and medium quality soils but low land suitability and capability for both wine and grape production (Table 2).

These results show that the land is more suitable for cultivating wine grapes varieties than table grapes varieties. Similar results were obtained in Ankara province (Uyan et al., 2023), assuming a relative match between LCC systems used in the evaluation.

Table 2. Evaluation scores, suitability, and land capability classes for Carastelec vineyard

		Natural conditions											
		wine				grapes				average			
No. US	No. TEO	Evaluation score	Quality classes	Suitability classes	Land capability classes	Evaluation score	Quality classes	Suitability classes	Land capability classes	Evaluation score	Quality classes	Suitability classes	Land capability classes
1	1	58	III	V	III	52	III	V	III	55	III	V	III
2	2	58	III	V	III	46	III	VI	III	52	III	V	III
3	3	65	II	IV	III	58	III	VI	III	62	II	IV	III
		Potential conditions											
		wine				grapes				average			
No. US	No. TEO	Evaluation mark	Quality classes	Suitability classes	Land capability classes	Evaluation mark	Quality classes	Suitability classes	capability	Evaluation mark	Quality classes	Suitability classes	Land capability classes
1	1	71	II	III	III	63	II	IV	III	67	II	IV	III
2	2	87	I	II	III	84	I	II	III	86	I	II	III
3	3	79	II	III	III	70	II	IV	III	75	II	III	III

Regarding the potential suitability evaluation, the results show that after improvement, US 2 became the most suitable and capable area for wine and grapes production out of the three areas under study, followed by US 3.

Based on the eco-pedological data, maps were generated to represent the soil unit, together with the ecologically homogenous territorial units (TEOs) for Carastelec (Figure 4).

For Carastelec vineyard, TEO 1 and 2 fall into the 3rd quality class, and TEO 3 into 2nd quality class, according to the value of scores in natural conditions (Figure 5). The implementation of improvement measures changes the classification of quality classes of territorial-homogeneous units, up to one class, 2nd and 1st respectively (Figure 6). This new state of the land assures better conditions for vine growth and presumably more production.

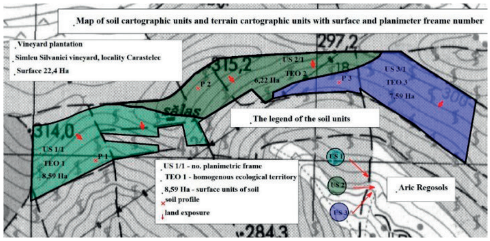

Figure 4. Mapping of soil units (US) and ecologically homogenous territorial units (TEO), plots and surfaces, Carastelec vineyard

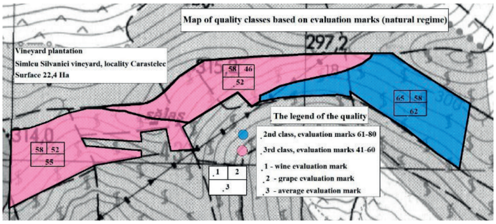

Figure 5. Map of quality classes per TEO units, Carastelec vineyard (natural conditions)

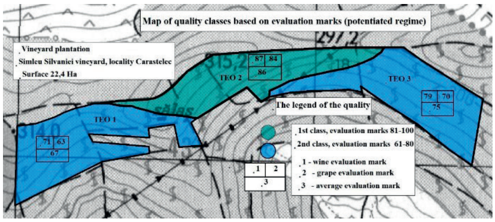

Figure 6. Map of quality classes per TEO units, Carastelec vineyard (improvement conditions)

For vine cultivation, the suitability maps for the Carastelec plantation showed an average suitability, the best degree of suitability being registered in the case of TEO-3, as part of the 4th class, with favorability grades between 65–58 points. TEO 1 and 2 fall into the 5th suitability class, with an average of 55 and 52 points, respectively (Figure 7). After improvements, the suitability degree increases (Figure 8), reaching the 2nd suitability class for TEO 2 and the 2nd suitability class for TEO 1 and 3, with 75 suitability points and 67 points, respectively, for grape vines.

Based on the identified limits (indicators with coefficients below 0.7), reduced porosity and compaction respectively, the recommended improvement work was deep loosening. The lands used for horticultural activities, in particular for the vine culture, fall into the 1st to 3rd capability classes (Campbell-Clause & Moore, 1991). As a result, the lands in the Carastelec vineyard fall into the optimal category both under natural and potentiated conditions (Figure 9).

b. Camăr vineyard evaluation marks in natural conditions (Figure 10) are lower, leading to classification into the 3rd quality class for TEO 1, 3 and 4 and into the 4th class for TEO 2 (Figure 11). In the potential regime (Figure 12), a higher classification is observed for TEO 2, with an average of 99 favorability points and is classified into the 1st quality class, while TEO 1, 3 and 4 reach the 2nd favorability class.

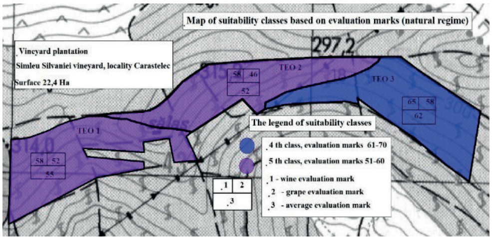

Figure 7. Map of suitability classes per TEO units, Carastelec vineyard (natural conditions)

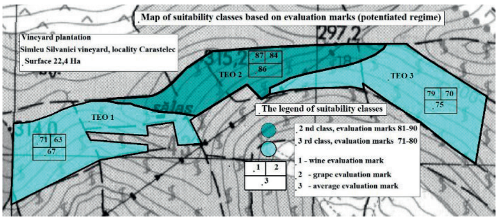

Figure 8. Map of suitability classes per TEO units, Carastelec vineyard (improvement conditions)

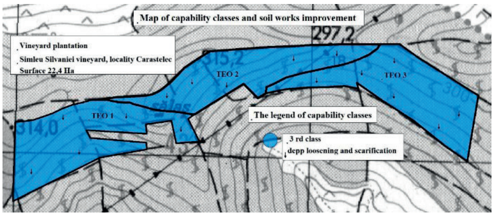

Figure 9. Map of capability classes per TEO units, Carastelec vineyard (improvement conditions)

The final scores of land suitability and capability indicate that in Camăr US 3 and TEO 4 had the highest evaluation scores defining medium and low-quality soils and also low land suitability and medium capability for wine production and, low land quality, suitability and capability for grapes production on the other hand (Table 3).

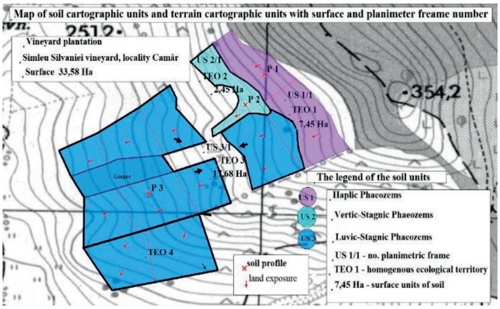

Figure 10. Map of soil units (US) and ecologically homogenous territorial units (TEO), plots and surfaces, Camăr vineyard

Table 3. Evaluation scores, suitability, and land capability classes for Camăr vineyard

No. US	No. TEO	wine: Evaluation score	wine: Quality classes	wine: Suitability classes	wine: Land capability classes	grapes: Evaluation score	grapes: Quality classes	grapes: Suitability classes	grapes: Land capability classes	Average: Evaluation score	Average: Quality classes	Average: Suitability classes	Average: Land capability classes
Natural conditions													
1	1	52	III	V	III	41	III	VI	III	47	III	VI	III
2	2	38	IV	VII	IV	26	IV	VIII	IV	32	IV	VII	IV
3	3	47	IV	VI	III	36	IV	VII	III	42	III	VI	III
	4	47	III	VI	III	36	IV	VII	III	42	III	VI	III
Potential conditions													
No. US	**No. TEO**	**wine: Evaluation mark**	**wine: Quality class**	**wine: Suitability classes**	**wine: Land capability classes**	**Grapes: Evaluation mark**	**Grapes: Quality class**	**Grapes: Suitability classes**	**Grapes: Land capability classes**	**Average: Evaluation mark**	**Average: Quality class**	**Average: Suitability classes**	**Average: Land capability classes**
1	1	78	II	III	III	76	II	III	III	77	II	III	III
2	2	105	I+	XI	IV	92	I	I	IV	99	I	I	IV
3	3	78	II	III	III	76	II	III	III	77	II	III	III
	4	78	II	III	III	76	II	III	III	77	II	III	III

In Camăr vineyard, the lower evaluation scores in natural conditions led to the classification into the 5th suitability class for TEO 1, 6th class for TEO 3 and 4, and 7th class for TEO 2 (Figure 13).

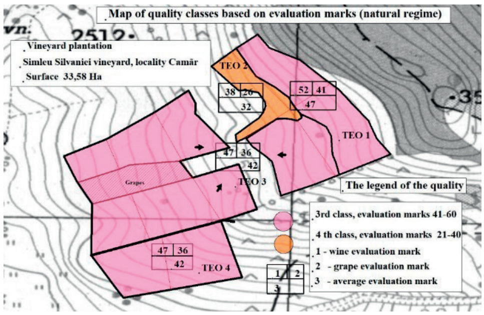

Figure 11. Map of quality classes per TEO units, Camăr vineyard (natural conditions)

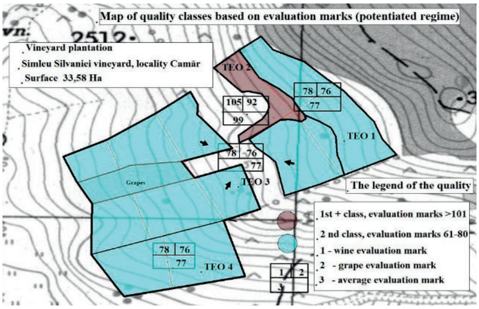

Figure 12. Map of quality classes per TEO units, Camăr vineyard (potential conditions)

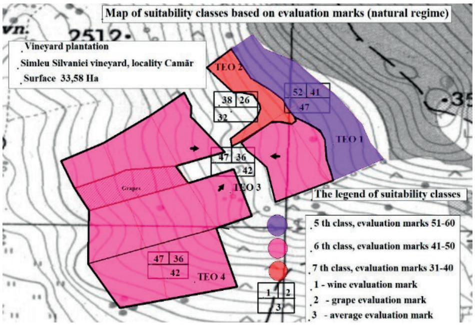

Figure 13. Map of suitability classes per TEO units, Camăr vineyard (natural conditions)

The enhanced favorability scores allow the classification into higher suitability classes; class 11 with over 100 favorability points for TEO 2 and the 3rd suitability class for the rest of TEOs with 77 favorability points (Figure 14).

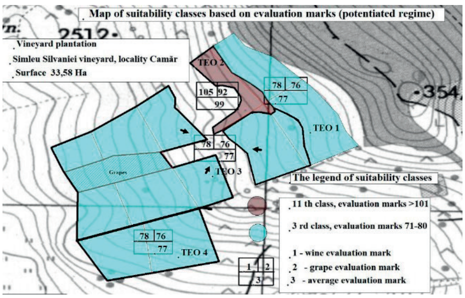

Figure 14. Map of suitability classes per TEO units, Camăr vineyard (potentiated regime)

The suitability for grape vine cultivation, as well as for the application of improvement works, shows a higher suitability of the Carastelec vineyard as compared to Camar vineyard, all TEOs being classified into the 3rd suitability class, while the recommended improvement work is deep soil loosening (Figure 15). Instead, the TEOs from the Camăr plantation fall into the 3rd and 4th suitability classes, and along with deep soil loosening, drainage works are also recommended to remove the excess of groundwater moisture (Figure 15).

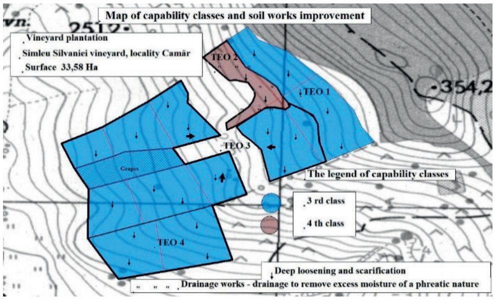

Figure 15. Map of capability classes per TEO units, Camăr vineyard

The lands in Camar vineyard, because of more limitations (stagnant water, compactness, low porosity) in natural conditions, fall into the 4th class and their suitability for vines is dependable on the improvements of limitations. LCC can be used to make recommendations about grapes varieties (Wanyama et al., 2014; Parker et al., 2020). The grape varieties indicated to be grown in the terroir conditions of Carastelec are those used to produce sparkling wine such as Royal Maiden, Italian Riesling, Pinot Noir, and Pinot Gris, and the recommended varieties for the Camăr vineyard are Traminer, Muscat Ottonel, Merlot, Black Maiden and Cadarca.

CONCLUSIONS

The application of LCC in the vineyards of Carastelec and Camăr allowed the identification of suitability and capability for vine culture, for both wine grape varieties and table grape varieties. By highlighting the suitability and capability categories in the natural regime, it was possible to pick out the improvement works specific to each restriction/limitation, so that through the evaluation in the potentiated regime, the assessment of favorability and suitability was increased. For each vineyard, depending on the climate, soil and terrain conditions, suitable wine grape varieties were identified for successful cultivation.

The identification of terroir elements gives the decision makers (from farmers to government agencies) a sense of prediction concerning the potential of the land, either for current or proposed uses.

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