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Darko D. JAKŠIĆ[1], Veljko S. PEROVIĆ[2], Dragan T. NIKOLIĆ[3], Dragoslav M. IVANIŠEVIĆ[4], Bratislav M. ĆIRKOVIĆ[5], Vojkan D. STOJANOVIĆ[6], Ivan Z. BRADIĆ[7]*

[1] Institute for Science Application in Agriculture,
Bulevar Despota Stefana 68b, Belgrade 11108, Serbia
[2] University of Belgrade, National Institute of the Republic of Serbia,
Institute for Biological Research "Siniša Stanković",
Bulevar Despota Stefana 142, Belgrade 11060, Serbia
[3] University of Belgrade, Faculty of Agriculture,
Nemanjina 6, Belgrade 11080, Serbia
[4] University of Novi Sad, Faculty of Agriculture,
Trg Dositeja Obradovića 8, Novi Sad 21000, Serbia
[5] University of Priština, Faculty of Agriculture Lešak,
Lešak bb, Lešak 38219, Serbia
[6] Ministry of Agriculture, Forestry and Water Management,
Nemanjina 22–26, Belgrade 11000, Serbia
[7] Centre for Viticulture and Oenology Niš,
Kolonija EI 6, Niš 18116 (Office in Trstenik), Serbia

CLASSIFICATION OF SUSTAINABILITY POTENTIAL OF GENETIC RESOURCES OF LOCAL GRAPEVINE VARIETIES IN SERBIA

ABSTRACT: The starting point for every viticultural and wine-producing country with respect to local grapevine varieties is their identification, inventory, preservation and development of genetic resources of those varieties. There are currently 224 grapevine varieties cultivated in Serbia for the purpose of commercial production of grapes and wine. Out of that number, 31 wine varieties are local. Vineyards under those varieties can be differentiated by their importance for production of grapes and wine, and by the level of their endangerment, that is, sustainability in conditions caused by climate changes. This paper presents the creation, that is, the modeling of the Method for Vineyard Sustainability Clas-

* Corresponding author. E-mail: darkojaksic@yahoo.com.au

sification (MVSC). The purpose of MVSC classification is: to valorize vineyards with local wine grapevine varieties on grounds of their endangerment and sustainability, based on 20 examined and categorized individual vineyard sustainability parameters; to carry out comprehensive classification into one of the four established vineyard sustainability classes (Class A – very endangered vineyards, Class B – endangered vineyards, Class C – sustainable vineyards and Class D – very sustainable vineyards); spatial identification and presentation of vineyards based on determined vineyard sustainability class through application of GIS technology; and finally, application of Network Analysis (NA), prioritization of examined parameters and, therefore, vineyards. A total of 10,402 vineyards under local grapevine wine varieties were used for modeling, and it was determined that 29 vineyards with the total surface of 1.2 hectares should be classified in Class A, while 2,883 vineyards with the total surface of 158.2 hectares should be classified in Class B. With respect to the strength of 20 individual vineyard sustainability parameters, it was determined that the parameter Structure of the vine rootstock (SVR) has the greatest impact, and priority in selection of vineyards in different sustainability classes should be given to vineyards without rootstocks. In accordance with the scientific justification of obtained results, the MVSC enables comprehensive classification of the potential for sustainability of genetic resources of local grapevine varieties in Serbia, and it can be applied in other countries and wine-growing areas, as well as to other groups of grapevine varieties.

KEYWORDS: grapevine genetic resources, local grapevine varieties, MVSC classification

INTRODUCTION

The process of differentiation and valorization of local grapevine varieties, as well as getting wine-growing areas recognition for these varieties is time-consuming and hard work. Some of the reasons are reflected in a huge number of different grapevine varieties worldwide and globalization of viticulture and wine production, where a few well-known grapevine varieties prevail. It is believed that there are between 5,000 and 8,000 grapevine varieties worldwide, grown under 14,000–24,000 different synonyms (Schneider et al., 2019). The Vitis International Variety Catalogue (VIVC) encyclopedic database list 23,529 names of cultivars, breeding lines and *Vitis* species that exist in grapevine repositories and/or described in bibliography (www.vivc.de). This number includes over 12,000 *V. vinifera*, but also a considerable number of synonyms and homonyms (Maul and Topfer, 2015). The actual number of vine varieties for the *V. vinifera* species in the world is estimated to be about 6,000 (Lacombe, 2012), while the VIVC database presents 6,355 genetic profiles of cultivars. Nevertheless, only 300 to 400 of these have commercial importance in global production (Nikolić et al., 2021). According to the International Organization of Vine and Wine (OIV), 13 grapevine varieties are grown in more than 1/3, and 33 varieties in 50% of all vineyards in the world (OIV, 2017). In such global circumstances, the starting point for each wine-growing country is to identify and make an inventory of its local grapevine varieties, and preserve and develop genetic resources of these varieties.

Serbia, as a country with long-lasting tradition of viticulture and wine-making, is characterized by different *terroir* conditions, according to which comprehensive wine-growing area (Wine-growing Serbia) is divided into three

big wine-growing units, 22 regions and 77 subregions (districts) (Jakšić et al., 2015). Such abundance of agroecological conditions enables cultivation of different grapevine varieties. Currently, there are 224 grapevine varieties in Serbia that are used for commercial viticulture and wine production. Within that number of varieties, 13.84% (31 wine varieties) are local, commonly referred to as autochthonous and regional varieties (Jakšić et al., 2019.). Instead of going into a literal analysis of individual terms that explain their name and origin, or giving the official terms for domesticated varieties, all these varieties as well as old ones (grown in Serbia for a long time) are referred to in this paper as local grapevine varieties. The following is a list of those grapevine wine varieties, presented in descending order according to the size of the surface on which they are grown: *Grašac* (colour of berry skin: Blanc/B), *Frankovka* (colour of berry skin: Noir/N), *Prokupac* (N), *Tamjanika Bela* (group of genotypes/subvarieties) (B), *Smederevka* (B), *Vranac* (N), *Slankamenka Crvena* (group of genotypes/subvarieties) (color of berry skin: Rouge/R), *Muskat Krokan* (B), *Tamjanika Crna* (black genotype) (N), *Kreaca* (B), *Skadarka* (N), *Žametovka/Kavčina* (N), *Portugizer* (N), *Ružica* (R), *Bagrina* (R), *Furmint* (B), *Žilavka* (B), *Začinak* (N), *Kratošija* (N), *Kujunđuša* (B), *Buvije* (B), *Medenac Beli* (B), *Sremska Zelenika* (B), *Bakator Beli* (B), *Lipolist* (B), *Seduša* (N), *Ezerjo* (B), *Slankamenka Bela* (B), *Blatina* (B), *Bela Dinka* (B) and *Bela Skadarka* (B).

The main problems for viticulture and winemaking in Serbia are the result of massive grubbing up of vineyards that occurred in the previous period and deterioration of vineyards with local varieties, together with a lack of special programmmes to save those vineyards and select the best genetic material beforehand. Due to these circumstances, Serbia has lost considerably large areas with local varieties, which is a permanent loss of its genetic grapevine potential (Jakšić et al., 2019). However, neither are all local varieties equally important for viticulture and wine production, nor are their vineyards equally endangered/sustainable, especially in the new conditions caused by climate change. Namely, some local varieties are experiencing an expansion in production, while other local varieties are on the verge of disappearing and are present only in old or neglected vineyards on small plots or in mixed varietal vineyards. Due to this, it was necessary to classify vineyards with local varieties based on the level of their endangerment or sustainability as a starting point for scientific and vocational research, as well as for drafting strategic documents or planning specific activities with the aim of preserving, developing and valorizing local varieties.

The main objective of this paper is exactly as follows: to use a large number of parameters that primarily affect the longevity and health of vineyards and to classify vineyards with local varieties according to their endangerment, i.e. sustainability according to individual vineyard sustainability parameters. Furthermore, it is essential to establish a comprehensive classification based on the four vineyard sustainability classes and then to make spatial identification

and representation of vineyards based on established vineyard sustainability classes. Finally, there has to be prioritization and then selection of vineyards where urgent measures are needed to conserve genetic resources and select positive genotypes for further scientific research. All of the four applied methodologies represent innovative modeling, i.e., classification of vineyards with local (primarily wine) grapevine varieties called the Method for Vineyard Sustainability Classification (acronym: MVSC).

MATERIALS AND METHODS

Valorization of analyzed vineyard sustainability parameters by sustainability categories of local grapevine varieties

In order to valorize the vineyards with local grapevine varieties, within the first phase of the MVSC classification, 20 parameters were analyzed and categorized that affect the sustainability, i.e. the longevity and health of the vineyards. These included:

– General factors (which affect sustainability of vineyards and viticulture and wine production);

– *Terroir* factors (which primarily affect vineyard health and longevity, such as: climate, topography, soil, and anthropogenic *terroir* factors).

The valorization of 10 analyzed parameters (with an individual minimum score of one and maximum scores of five, ten or 20, in several categories) that affect sustainability, i.e., longevity and health of vineyards was done by using existing classifications of *terroir* factors – the Conceptual Multifactorial Spatial *Terroir* Model (CMST model) (Jakšić, 2021; Jakšić et al., 2023). Other analyzed parameters that are not part of the CMST model are valorized in a specific way adapted to this modeling. The valorization, i.e., categorization of individual vineyard sustainability parameters by sustainability categories was carried out as shown in Appendix 1.

Classification of vineyard sustainability

Given that each vineyard was individually assessed (valorized) for each of the 20 classification parameters, receiving with a minimum of one point for each parameter, the minimum score was 20. Therefore, the scores are distributed from 21 to the maximum of 140 points. The interval between each of the four MVSC classification classes (Class A, B, C and D) was 30 points, where a lower total score implies that a vineyard is endangered and higher score that a vineyard is more sustainable (Table 1).

Table 1. Classification of vineyards in the MVSC based on analyzed vineyard sustainability parameters

Minimum (mandatory) score	20			
Total score	21–50	51–80	81–110	111–140
General sustainability classes	Endangered vineyards		Sustainable vineyards	
Vineyard sustainability classes	Class A (very endangered vineyards)	Class B (endangered vineyards)	Class C (sustainable vineyards)	Class D (very sustainable vineyards)

Spatial identification and representation of vineyards within the MVSC

For spatial identification and representation of vineyards, the GIS (Geographic Information System) technology was applied through use of GIS software packages: Global Mapper 13 (https://www.bluemarblegeo.com/global-mapper/), QGIS v2.18 (https://qgis.org/en/site/index.html), ArcGIS, and Google Earth Pro.

Methodology applied to prioritize the importance of vineyard sustainability parameters and vineyards with local grapevine varieties

In the end, in order to prioritize and single out analyzed vineyard sustainability parameters, determine their mutual dependence and prioritize vineyards where field research must be conducted first, the evaluation, start of genetic resources conservation and selection of potentially valuable genetic material, i.e., genotypes of local varieties were carried out using Network Analysis (NA). The evaluation of NA was examined using the Extended Bayesian Information Criterion (EBIC) glasso. As a result, for easier interpretation, a graph was created in which green edges indicate positive relationships and red edges indicate negative relationships. The relationships between factors function as a large multiple regression. In addition, the edge weights are represented in terms of different thickness and colour density of the edge connecting the nodes, where thicker lines with denser colour indicate stronger relationships. The Expected Influence (EI) (Robinaugh et al., 2016) was used in interpretation of obtained results, to evaluate the centrality of each node in the network. The centrality is calculated as the sum of absolute weights of edges that they share with other nodes in the network. Thus, the EI of a given node is the sum of weights of edges it shares with the rest of the nodes in the network, taking into account negative associations as well, unlike other criteria (Robinaugh et al., 2016). Therefore, EI helped us determine the influence of analyzed parameters within the network for selection of vineyards within the appropriate class for scientific research and implementation of professional activities.

Vineyards with local grapevine varieties modeled in accordance within the MVSC

Out of the total of 7,033 ha or 31,667 vineyards divided by grapevine varieties, out of which 6,636 ha or 27,339 vineyards are under wine varieties, modeling (valorization and categorization, classification, mapping and prioritization) was carried out on 2,142.5 ha, or 10,402 vineyards with 31 local grapevine wine varieties.

RESULTS AND DISCUSSION

INDIVIDUAL VALORIZATION OF VINEYARDS BY SUSTAINABILITY CATEGORIES

Based on the individual valorization of 10,402 vineyards divided by local wine varieties according to the sustainability categories of local grapevine varieties, a valorization (categorization) was made for each of the 20 analyzed parameters. The valorization and later distribution were carried out based on the number of vineyards and their surface given in percentage points. This paper only presents data on the most disadvantaged category of vineyards (score 1) given for each parameter in question.

Valorization of General factors

Regarding General factors, namely the analyzed parameter Structure of grapevine varieties (SGVV), it can be seen that 13.83% of all vineyards divided by varieties have the lowest score – 1 (the most disadvantaged category for this parameter – minor varieties both in Serbia and in the region), and that they comprise 6.27% of the total area under local grapevine varieties.

The research results indicate that the distribution of the Age structure of grape producers (ASGP) was rather unfavourable. Namely, grape producers in 55.71% of all vineyards (persons that cultivate these vineyards) were over 60 years old (the most disadvantaged category in this parameter, score 1), which was the case for 27.93% of vineyard surfaces under local grapevine varieties.

As for the Structure of the development of wine production by municipality (SDWPM), this parameter was well distributed, with only 6.15% of vineyards in the lowest category (score 1) according to this parameter, in municipalities with no registered wineries, which make up only 2.99% of the total analyzed vineyard surface under local varieties in municipalities without wineries.

Out of the total number of vineyards studied and analyzed, 18.73% of the analyzed vineyards are located in areas with difficult production conditions in agriculture (parameter class with a score of 1). As for this parameter (Vineyards from the area with difficult production conditions in agriculture/VADPC), 17.01% of vineyard surface belonged to this category.

Regarding the Structure of the vine rootstock (SVR) parameter, it was determined that most of the vineyards used grapevine rootstock, with only 0.54% of vineyards not using rootstock (minimum score: 1) these represent 0.57% of total vineyard surfaces planted with local grapevine varieties.

Valorization of Climatic *terroir* factors

Valorization of Factors that primarily affect the health of vineyards

Analysis of the parameter Average number of days with daily minimum temperature below 0°C for the standard growing season (NTN0) show that this parameter was poorly distributed by category. Namely, 60.29% of the vineyards divided by varieties were classified in the most disadvantaged category (score 1) with more than 3 days of frost, which represents 73.06% of the total surface of the analyzed vineyards.

The parameter Average number of days with daily minimum temperature bellow -15 °C for the dormant period (NTN15) had a more favourable distribution. Namely, 5.43% of the vineyards classified in the lowest category (score 1), representing 10.6% of vineyards surface with over 2 frosty days.

As for the distribution of the parameter Average number of days with daily maximum temperature higher than 35 °C for the standard growing season (NTX35), it can be seen that 17.31% of the vineyards scored 1, being classified into the disadvantaged category, with more than 6.5 days with air temperature higher than 35 °C. This is 22.87% of the total surface under analyzed vineyards.

Valorization of Factors that primarily affect the longevity of vineyards

Based on the analysis, it is concluded that the Drought Index (DI) parameter was favourable for analyzed vineyards with local grapevine varieties. None of the vineyards was categorized in the lowest category, with DI over 200.

The Sunshine/Shading (S/S) parameter was also favourable. Namely, only 0.55% of the vineyards was categorized in the most disadvantaged category (score 1), with S/S of 1,000 and less. In terms of area, vineyards from the most disadvantaged category made up only 0.28% of the total vineyard surfaces under local grapevine varieties.

Valorization of Topographic *terroir* factors

Valorization of Factors that primarily affect the health of vineyards

With respect to the Topographic forms (TF) parameter, 10.76% of the vineyards were categorized in the most disadvantaged category (score 1), having the following topographic forms: hollows (valleys, coves, depressions) and ridges,

making up 6.26% of the total surface under vineyards with local grapevine varieties.

Valorization of Factors that primarily affect the longevity of vineyards

Regarding the Slope of the terrain (STe) parameter, the structure is somewhat more favourable. In fact, only 6.02% of all vineyards, i.e. 2.11% of the total surface under vineyards were categorized in the most disadvantaged category (slope over 12º) with the minimal score of 1.

As for the Elevation (E) parameter, 11.43% of the vineyards were categorized in the most disadvantaged category (low elevation of up to 150 m where negative frosts can occur), scoring 1, which makes up 17.99% of the total surfaces under vineyards.

The Terrain exposure (TE) parameter was evenly distributed, as 10.04% of the vineyards were categorized in the most disadvantaged category, with north-facing exposure (minimal score 1), representing 12.31% of the total surface under vineyards.

Valorization of Soil *terroir* factors

Valorization of Factors that primarily affect the health of vineyards

According to the Soil types (STy) parameter, 7.1% of the analyzed vineyards had the most disadvantaged category of soil types (minimal score 1), which represents 5.32% of the total surface under vineyards with local grapevine varieties.

Valorization of Anthropogenic *terroir* factors

Valorization of Factors that primarily affect the longevity of vineyards

The Age of the vineyard (AV) parameter has a relatively good structure, since only 7.08% of analyzed vineyards was over 70 years old or older (score 1), making up 2.77% of the total surface under vineyards with local grapevine varieties. However, one should note that very old vineyards should be the subject of research on clonal selection of local grapevine varieties.

The Surface of the vineyard (SV) parameter was quite unfavourable when observed in mixed varietal vineyards. Namely, 62.41% of the vineyards had the average surface below 0.1 ha, thus being categorized in the most disadvantaged category (score 1). Having analyzed this parameter by surface, it can be seen that the situation is better, with only 12.08% of the area categorized in the most disadvantaged category.

Having analyzed the Thinning of the vineyards (TV) parameter, it can be concluded that 16.36% of the total number of vineyards was categorized in the most disadvantaged category (minimal score 1), with over 12% of thinning. Area-wise, 32.18% of the total surface under vineyards with local varieties was classified into the most disadvantaged category.

Valorization of Factors that primarily affect the longevity of vineyards

With respect to the Condition of the vineyard (CV) parameter, only 1.94% of the total number of vineyards was categorized in the most disadvantaged category, implying an unsatisfactory condition of vineyards (score 1), making up 8.88% of the total surface under vineyards with local grapevine varieties.

Finally, the parameter Monovarietal/mixed varietal vineyard (M/MVV) has a rather unfavorable structure in terms of the number of vineyards, namely, 40.17% of analyzed vineyards were mixed varietal vineyards (having two or more different grapevine varieties) (score 1). Nevertheless, those vineyards are mostly on small areas and make up 9.64% of the total surface under vineyards with local grapevine varieties.

Classification of vineyards with local grapevine varieties based on vineyard sustainability classes

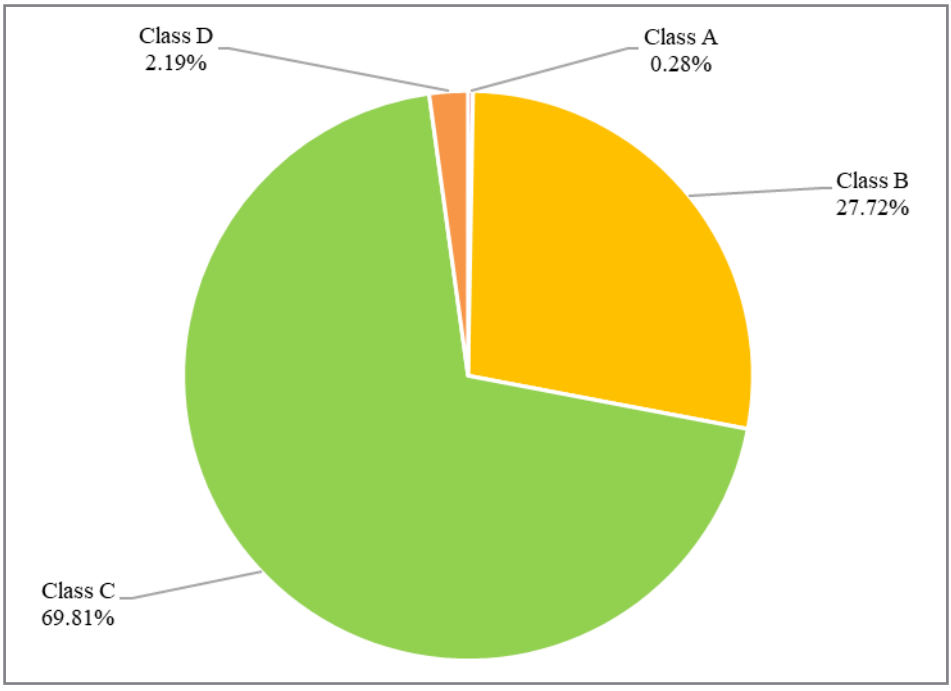
After analyzing individual scores and sublimating all values/scores for each vineyard, broken down by grapevine varieties, vineyards were classified into four vineyard sustainability classes (Table 2). Most of the vineyards from Class A (very endangered vineyards) are situated in the municipalities of Pirot, Vlasotince and Bujanovac. Most of the vineyards from Class B (endangered vineyards) are situated in the municipalities of Aleksandrovac, Pirot and Vlasotince.

When analyzing the distribution of classes based on surface, it appears that the largest areas of Class A vineyards are located in the municipalities of Pirot, Bujanovac and Vlasotince. As for Class B vineyards, the largest vineyards in terms of surface are located in the municipalities of Aleksandrovac, Trstenik and Pirot.

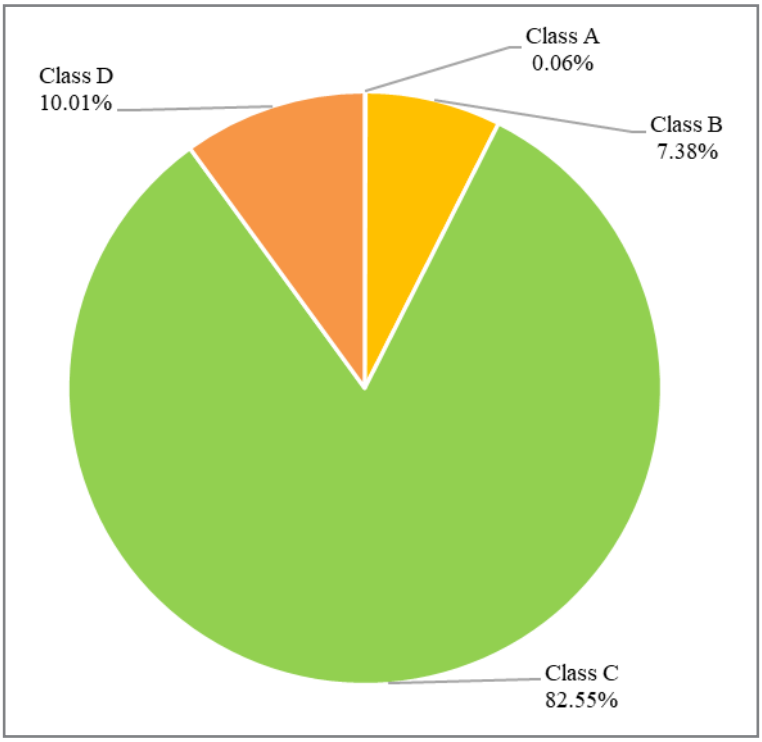
Table 2. Vineyards classified according to their sustainability of the MVSC, given by the number and the surface of vineyards with local grapevine varieties

Vineyard sustainability class	Number of vineyards	Surfaces of the vineyards (ha)
Class A (very endangered vineyards)	29	1.2
Class B (endangered vineyards)	2,883	158.2
Class C (sustainable vineyards)	7,262	1,768.6
Class D (very sustainable vineyards)	228	214.46

The structure of sustainability classes based on the number of vineyards is such that the vineyards classified in Class C (sustainable vineyards) predominate. The classes of endangered vineyards have a significant share in the total number of examined vineyards (2,912 vineyards). Class A vineyards (very endangered vineyards) have a share of 0.28% and Class B vineyards (endangered vineyards) have a share of 27.72% in the total number of all examined vineyards with local grapevine varieties (Graph 1). Analyzing the structure of sustainability classes for vineyards based on surface, we concluded that sustainable vineyards account for the largest share (Graph 2). The total surface of endangered vineyards (Class A and Class B) is 159.4 ha, which nevertheless represents a significant vineyard area that must be the subject of scientific and professional work in the near future in order to preserve and develop the genetic resources of local grapevine varieties.



Graph 1. Structure of vineyard sustainability classes (A, B, C and D) based on the number of vineyards

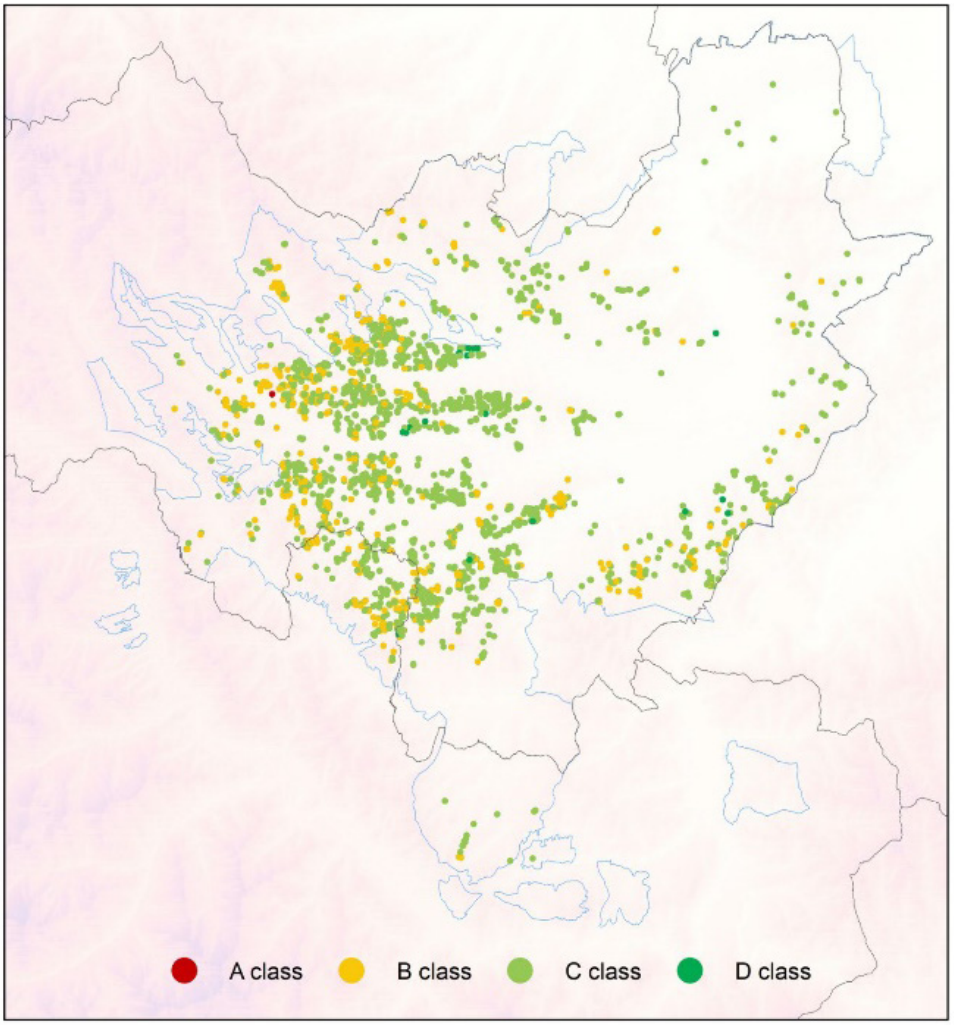


Graph 2. Structure of vineyard sustainability classes (A, B, C and D) based on vineyard surface

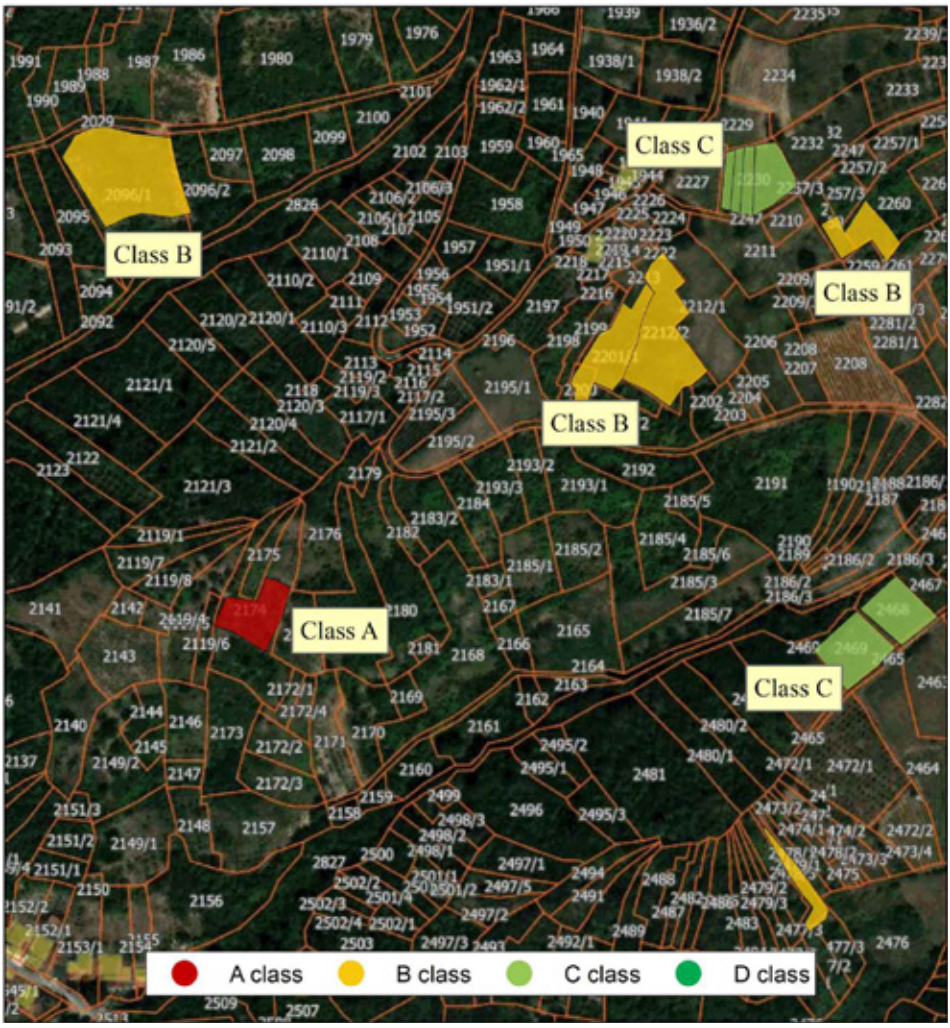
Based on the presented results of the research of vineyards with local grapevine varieties, it can be concluded that there is a significant proportion of endangered vineyards in the number of vineyards.

Spatial identification and representation of vineyards

Through the application of GIS technology and techniques, spatial identification and representation of vineyards with local grapevine varieties was carried out for all four vineyard sustainability classes of the MVSC classification. The spatial representation, i.e., mapping of vineyards of local grapevine varieties within the MVSC classification is presented on the example of the Župa wine-growing district (Map 1) and the Puhovac cadastral municipality in the Aleksandrovac municipality (Map 2).



Map 1. Mapped vineyards of local grapevine varieties classified according to the vineyard sustainability classes of the MVSC in the Župa wine-growing district



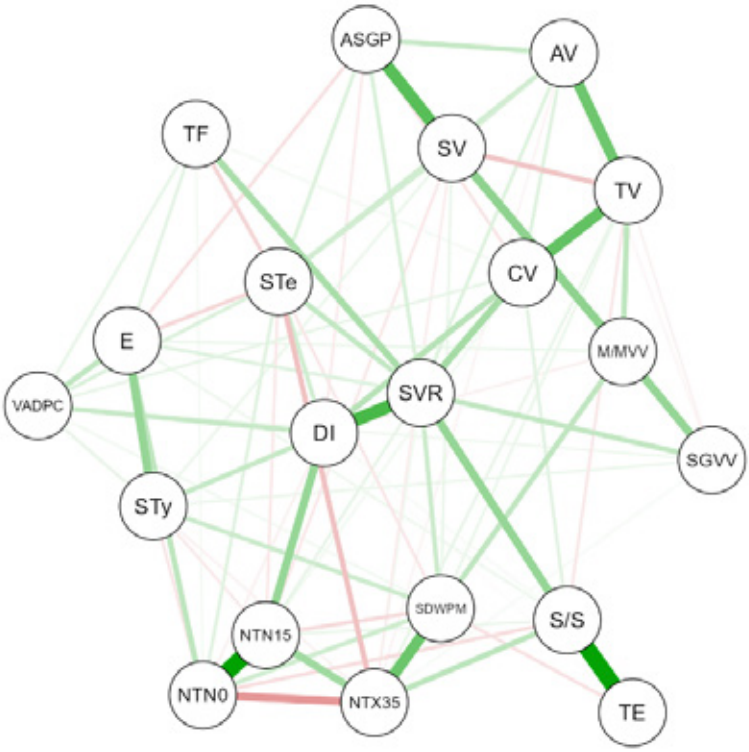
Map 2. Example of mapped vineyards of local grapevine varieties according to the vineyard sustainability classes of the MVSC in the Puhovac C. M.

The established spatial basis will facilitate future scientific and professional research, as well as implementation of measures for protection and development of genetic resources of local grapevine varieties in Serbia.

Results of prioritization of importance of parameters and vineyards

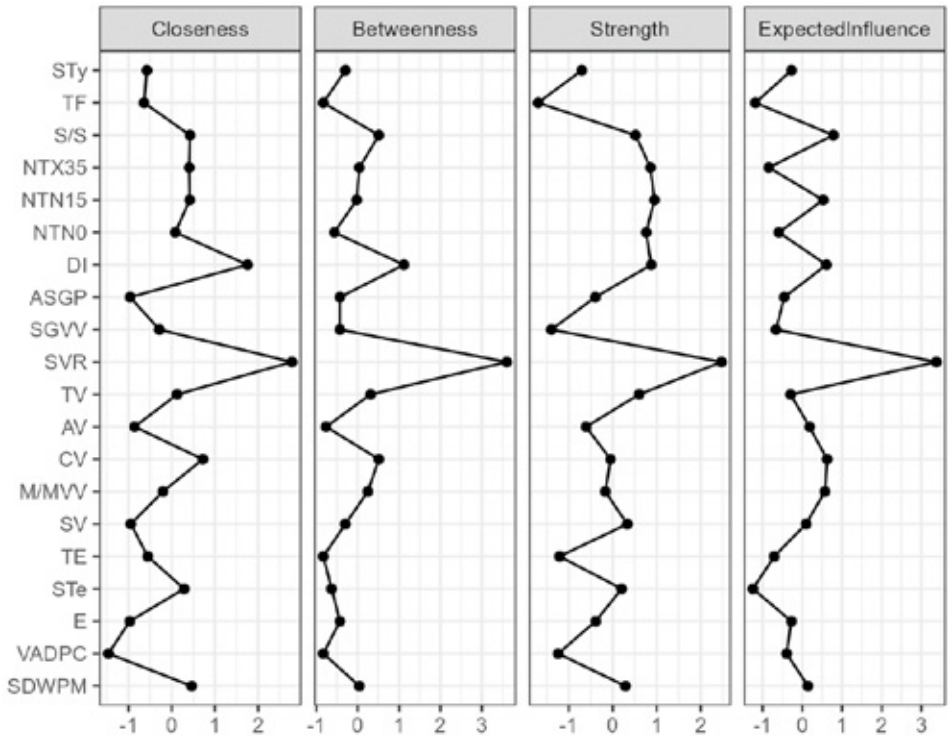
Using Network Analysis (NA), it was found that the strongest positive network nodes exist between vineyard sustainability parameters TE and S/S,

NTN0 and NTN15, DI and SVR, etc. (Graph 3). The obtained results have a scientific justification, considering that solar radiation depends on terrain exposure, that in areas where low winter temperatures prevail, late spring frosts also occur, and that vine rootstocks are directly dependent on the Drought index, etc. The most significant negative nodes in the network are represented by pairwise relations between parameters NTX35 and NTN0, TV and SV, etc., which is also scientifically justified. Namely, in areas, i.e., vineyards where high summer temperatures occur, the number of frost days during the growing season is lower, thinning is lower in vineyards with larger surfaces, etc. NA has shown that the SVR parameter for sustainability of vineyards has the highest centrality in the network.



Graph 3. Representation of mutual interactions of different strengths of positive and negative relations of vineyard sustainability parameters

NA has shown that the Structure of the vine rootstock (SVR) parameter has by far the greatest closeness, betweenness, strength, and expected influence within all vineyard sustainability parameters (Graph 4).



Graph 4. Distribution of closeness, betweenness, strength and expected influence of vineyard sustainability parameters

Analyzing the strength of vineyard sustainability parameters according to their EI, it was concluded that the parameter Structure of the vine rootstocks (SVR) has the greatest impact. This leads us to the conclusion that when choosing very endangered (Class A), endangered (Class B), or vineyards from other classes of the MVSC classification, priority should be given to vineyards classified in the most disadvantaged class of this parameter (score 1), i.e., vineyards without rootstocks (Table 3). Vineyards rated with lower scores of the parameter Sunshine/Shading (S/S), i.e., vineyards that are most shaded follow in order of priority. After that, priority should be given to vineyards that have poor scores for the parameter Condition of the vineyard (CV), and so on.

Table 3. Vineyard sustainability parameters in the order of strength of the expected influence

Variable (examined parameter)	Expected influence	Variable (examined parameter)	Expected influence
SVR	3.378	STe	-1.244
S/S	0.784	STy	-0.272
CV	0.627	E	-0.275
DI	0.610	TV	-0.295
M/MVV	0.572	VADPC	-0.394
NTN15	0.529	ASGP	-0.453
AV	0.182	NTN0	-0.592
SDWPM	0.143	SGVV	-0.663
SV	0.094	TE	-0.704
TF	-1.180	NTX35	-0.846

The above results and analysis indicate that this prioritization of vineyard sustainability parameters according to the importance of EI influence facilitates correct selection of the priority and important vineyards within the same vineyard sustainability class within the MVSC classification.

CONCLUSION

With the innovative Method for Classification of Vineyard Sustainability (MVSC), it was found that of the 10,402 modeled vineyards with local wine varieties, 29 vineyards belong to class A (very endangered vineyards), and 2,883 vineyards belong to class B (endangered vineyards). The MVSC classification used to classify the sustainability of vineyards of local grapevine wine varieties in Serbia can be successfully applied to other countries or wine-growing areas, as well as to other groups of grapevine varieties. First and foremost, the modeled MVSC classification enables efficient identification of vineyards with local grapevine varieties classified in Class A (very endangered vineyards), which are the highest priority for scientific and professional research and implementation of urgent actions for conservation of genetic resources, especially in the current conditions of climate change. Moreover, the modeled MVSC classification allows an appropriate selection of the most important vineyards with the aim of identifying potentially valuable genetic material, i.e., genotypes, as well as future clonal selection of local grapevine varieties. In this way, the basis and possibility are created for all scientific institutions, relevant ministries, public and private organizations, as well as associations of grape and wine producers to use the data of MVSC classification to initiate systematic measures for conservation and development of genetic resources of local grapevine varieties in Serbia.

Annex 1. VALORIZATION OF INDIVIDUAL VINEYARD SUSTAINABILITY PARAMETERS BY SUSTAINABILITY CATEGORIES OF LOCAL GRAPEVINE VARIETIES WITHIN THE FIRST PHASE OF MVSC

1. General factors (affecting the sustainability of vineyards and viticulture-wine production)

1.1. The Structure of grapevine varieties (SGVV) was categorized into nine categories, with values ranging from 10 (most favourable for sustainability of genetic resources of local varieties) to 1 (least favorable) (Table 4). Some data were used from the OIV publication Distribution of the world's grapevine varieties (OIV, 2017).

Table 4. Categorization of the Structure of grapevine varieties (SGVV) parameter

Prevalence in Serbia – Prevalence in the region	Acronyms for prevalence	Valorization
Leading variety (Le) – Leading variety (Le)	Le – Le	10
Leading variety (Le) – Local variety (Lo)	Le – Lo	9
Leading variety (Le) – Minor variety (Mi)	Le – Mi	8
Local variety (Lo) – Leading variety (Le)	Lo – Le	7
Local variety (Lo) – Local variety (Lo)	Lo – Lo	6
Local variety (Lo) – Minor variety (Lo)	Lo – Mi	5
Minor variety (Mi) – Leading variety (Le)	Mi – Le	3
Minor variety (Mi) – Local variety (Lo)	Mi – Lo	2
Minor variety (Mi) – Minor variety (Mi)	Mi – Mi	1

1.2. Age structure of grape producers (ASGP) was categorized in five categories, with values ranging from 10 (highest value) to 1 (lowest value) (Table 5).

Table 5. Categorization of the parameter Age structure of grape producers (ASGP)

Age structure of grape producers	Valorization
Company	10
Entrepreneur	8
Grape producer under 40 years of age	6
Grape producer (40 to 60 years of age)	3
Grape producer above 60 years of age	1

1.3. Based on the number of commercial wineries, the Structure of the development of wine production by municipality (SDWPM) was categorized into five categories, with values ranging from 5 (largest number of wineries in the municipality) to 1 (no wineries in the municipality in question) (Table 6).

Table 6. Categorization of the parameter Structure of the development of wine production by municipality (SDWPM)

Number of vineries in the municipality	Valorization
Over 20	5
11–20	4
4–10	3
Up to 3	2
No wineries	1

1.4. Vineyards from areas with difficult production conditions in agriculture (VADPC) were categorized in two categories, as follows: vineyards in developed municipalities – value 5 and vineyards in municipalities with difficult production conditions – value 1.

1.5. The Structure of the vine rootstock (SVR) was also categorized in two categories, as follows: vineyards with grapevines grafted on rootstocks – value 5 and vineyards with grapevines grown on their own rootstock – value 1.

2. Climatic *terroir* factors

Factors that primarily affect the health of vineyards

2.1. Average number of days with daily minimum temperature bellow 0 °C for the standard growing season (NTN0) was categorized into five categories defined within the CMST model (Jakšić, 2019; Jakšić et al., 2023);

2.2. Average number of days with daily minimum temperature bellow -15 °C for the dormant period (NTN15) was categorized into five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023);

2.3. Average number of days with daily maximum temperature higher than 35 °C for the standard growing season (NTX35) was also categorized into five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023).

Factors that primarily affect the longevity of vineyards

2.4. Drought Index (DI) categorized within five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023);

2.5. Sunshine/Shading (S/S) was categorized into five categories defined within the CMST model (Jakšić, 2019; Jakšić et al., 2023).

3. Topographic *terroir* factors

Factors that primarily affect the health of vineyards

3.1. Terrain exposure (TE) was categorized into five categories defined within the CMST model (Jakšić, 2019; Jakšić et al., 2023);

3.2. The Topographic forms parameter was also categorized into five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023).

Factors that primarily affect the longevity of vineyards

3.3. Slope of the terrain (º) (STe) parameter was categorized into five categories defined within the CMST model (Jakšić, 2019; Jakšić et al., 2023) with values ranging from 10 (highest value, slope 0–3º), 8 (> 3–5º), 5 (> 5–8º), 2 (> 8–12º) to 1 (lowest value, > 12º);

3.4. Elevation (m) was also categorized into five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023).

4. Soil *terroir* factors

Factors that primarily affect the longevity of the vineyards

4.1. Soil types (STy) was categorized into five categories within the CMST model (Jakšić, 2019; Jakšić et al., 2023).

5. Anthropogenic *terroir* factors

Factors that primarily affect the health of vineyards

5.1. Age of the vineyard (AV) was categorized into five categories, with values ranging from highest to lowest, where 20 stands for very young vineyards, and 1 for very old vineyards (Table 7).

Table 7. Categorization of the parameter Age of the vineyard (AV)

Age of the vineyard	Valorization
0–3	20
4–29	16
30–49	10
50–69	4
70 years and over	1

5.2. Surface of the vineyard (SV) was categorized into five categories, with values ranging from 10 (large surface) to 1 (very small surface) (Table 8).

Table 8. Categorization of the Surface of the vineyard (SV) parameter

Surface of the vineyard (ha)	Valorization
> 1	10
> 0.5–1	8
> 0.3–0.5	5
> 0.1–0.3	3
Up to 0.3	1

5.3. Thinning of the vineyard (TV) was categorized into five categories with values ranging from 10 (less thinned) to 1 (very thinned vineyards) (Table 10).

Table 10. Categorization of the Thinning of the vineyard (TV) parameter

Thinning (%)	Valorization
Up to 3	10
> 3–6	8
> 6–9	6
> 9–12	3
> 12	1

Factors that primarily affect the longevity of vineyards

5.4. Condition (status) of the vineyard (CV) was categorized into three categories, such as: good (value 5), satisfactory (value 3) and unsatisfactory (value 1).

5.5. Monovarietal/mixed varietal vineyard (M/MVV) had only two categories: monovarietal vineyards (value 5) and mixed varietal vineyards with two or more grapevine varieties (value 1).

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КЛАСИФИКАЦИЈА ПОТЕНЦИЈАЛА ОДРЖИВОСТИ ГЕНЕТИЧКИХ РЕСУРСА ЛОКАЛНИХ СОРТИ ВИНОВЕ ЛОЗЕ У СРБИЈИ

Дарко Д. ЈАКШИЋ[1], Вељко С. ПЕРОВИЋ[2], Драган Т. НИКОЛИЋ[3], Драгослав М. ИВАНИШЕВИЋ[4], Братислав М. ЋИРКОВИЋ[5], Војкан Д. СТОЈАНОВИЋ[6], Иван З. БРАДИЋ[7]

[1] Институт за примену науке у пољопривреди Београд, Булевар деспота Стефана 68б, Београд 11108, Србија
[2] Универзитет у Београду, Институт од националног значаја за Републику Србију, Институт за биолошка истраживања „Синиша Станковић”, Булевар деспота Стефана 142, Београд 11060, Србија
[3] Универзитет у Београду, Пољопривредни факултет, Немањина 6, Београд 11080, Србија
[4] Универзитет у Новом Саду, Пољопривредни факултет, Трг Доситеја Обрадовића 8, Нови Сад 21000, Србија
[5] Универзитет у Приштини, Пољопривредни факултет Лешак, Лешак бб, Лешак 38219, Србија
[6] Министарство пољопривреде, шумарства и водопривреде, Немањина 22–26, Београд 11000, Србија
[7] Центар за виноградарство и винарство Ниш, Колонија ЕИ 6, Ниш (Трстеник) 18116, Србија

РЕЗИМЕ: Полазна основа сваке виноградарско-винарске земље када су локалне сорте винове лозе у питању је њихова идентификација, инвентаризација, очување и развој генетичких ресурса тих сорти. Тренутно се у Србији гаји 224 сорте винове лозе са наменом комерцијалне производње грожђа, односно вина. Од тог броја, 31 сорта су локалне винске сорте. Њихови виногради се разликују по важности за производњу грожђа и вина, али се разликују и по угрожености, односно одрживости у условима изазваним климатским променама. У овом раду је израђена, односно моделована Метода класификације одрживости винограда (*Method for Vineyard Sustainability Classification*; акроним: *MVSC*). Намена *MVSC* јесте: валоризација винограда са локалним винским сортама по основу њихове угрожености, односно одрживости на основу 20 појединачних испитиваних и категорисаних параметара одрживости; затим свеобухватна класификација на основу успостављене четири класе одрживости винограда (класа *A* – веома угрожени виногради, класа *B* – угрожени виногради, класа *C* – одрживи виногради и класа *D* – веома одрживи виногради); просторна идентификација и представљање винограда на основу утврђених класа одрживости применом *GIS* технологије; као и на крају, применом *Network* анализе (*NA*), приоритизација испитиваних параметара, а тиме и винограда. За моделовање је коришћено 10.402 винограда локалних винских сорти винове лозе, при чему је утврђено да се 29 винограда, односно 1,2 хектара, класификује у класу *A*, док се 2.883 винограда, односно 158,2 хектара класификују у класу *B*. По питању јачине појединачних 20 параметара одрживости, утврђено је да параметар *Структура подлога винове лозе* (*SVR*) има

највећи утицај, па приоритет при избору винограда у оквиру различитих класа одрживости треба да буду виногради који су на сопственом корену. У складу са научном оправданошћу добијених резултата, *MVSC* класификација омогућава свеобухватну класификацију потенцијала одрживости генетичких ресурса локалних сорти винове лозе у Србији, а може се применити и у другим земљама или виноградарским подручјима, као и за друге групе сорти винове лозе.

КЉУЧНЕ РЕЧИ: генетички ресурси винове лозе, локалне сорте винове лозе, *MVSC* класификација