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EXAMINATION OF TOPOGRAPHICAL PARAMETERS IN VINEYARD AREAS – CHANGES IN THE SZEKSZÁRD WINE REGION

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Abstract: The Szekszárd Wine Region holds prominent importance among the Hungarian wine regions, as literature confirms that the Romans had already cultivated grapes in the area as early as the 3rd century AD. The eastern part of the Szekszárd hills provides favorable topographical, soil, and climatic conditions, enabling the cultivation of characteristic grape varieties. Our research examined the changes in the location of vineyard areas within the wine region. We also investigated whether there have been any changes in the preferred topographical characteristics (aspect, slope steepness) during different time periods in vineyard cultivation.

Keywords: *Szekszárd Wine Region, Morphology, Land use, Landcover*

1. Introduction

The Szekszárd Wine Region is of outstanding significance among the Hungarian Wine Regions since literature indicate that grape cultivation was already taking place in the area as early as the 3rd century [1, 2]. The Eastern part of the Szekszárd Hills has favorable topographical, soil, and climatic conditions that enable grape cultivation [1, 3, 4]. According to the CORINE 2018 land cover database, the region has 3848.87 hectares of vineyards. Almost 84% of the vineyards consist of red grape varieties, with the most typical ones being Kékfrankos, Kadarka, Merlot, and Cabernet Franc, Cabernet Sauvignon [4]. Our research aimed examined vineyard area changes using historical maps, topographic data, and land cover databases. Subsequently, we investigate whether there are any differences in the topography between the different time periods during the cultivation season.

2. Materials and Methods

Our research used a digital elevation model (DEM) with a spatial resolution of 25 m. The DEM was created from 1 : 10,000 scale topographic maps' contour lines, elevation points, and drainage network. This was done by applying the Topo to Raster interpolation in ArcGIS 10.2. From the DEM, we derived the examined surface parameters like slope and aspect maps, respectively.

The vineyard areas were digitized from the historical First, Second, Third, and Fourth Military Surveys [5, 6, 7] and from the topographic maps. Additionally, we utilized data from the CORINE (1990, 2000, 2006, 2012, 2018) land cover databases [8] to identify the location of the vineyards in each period. Subsequently, we depicted the morphometric values of each period using a boxplot diagram.

3. Study Area

The Szerkszárd Wine Region is situated at the convergence of four regions. The northern part of the wine region is located on the Mezőföld, encompassing the Sárvíz microregion, and on the Tolna Hills, which include the Tolnai-hegyhát and the Szekszárd Hills. The southern part is situated on the Mecsek-Baranya Hills region, encompassing the Baranya Hills microregion. Finally, it is situated east of the Danubian Plain, which includes the Tolnai-Sárköz microregion *(Figure 1)* [9].

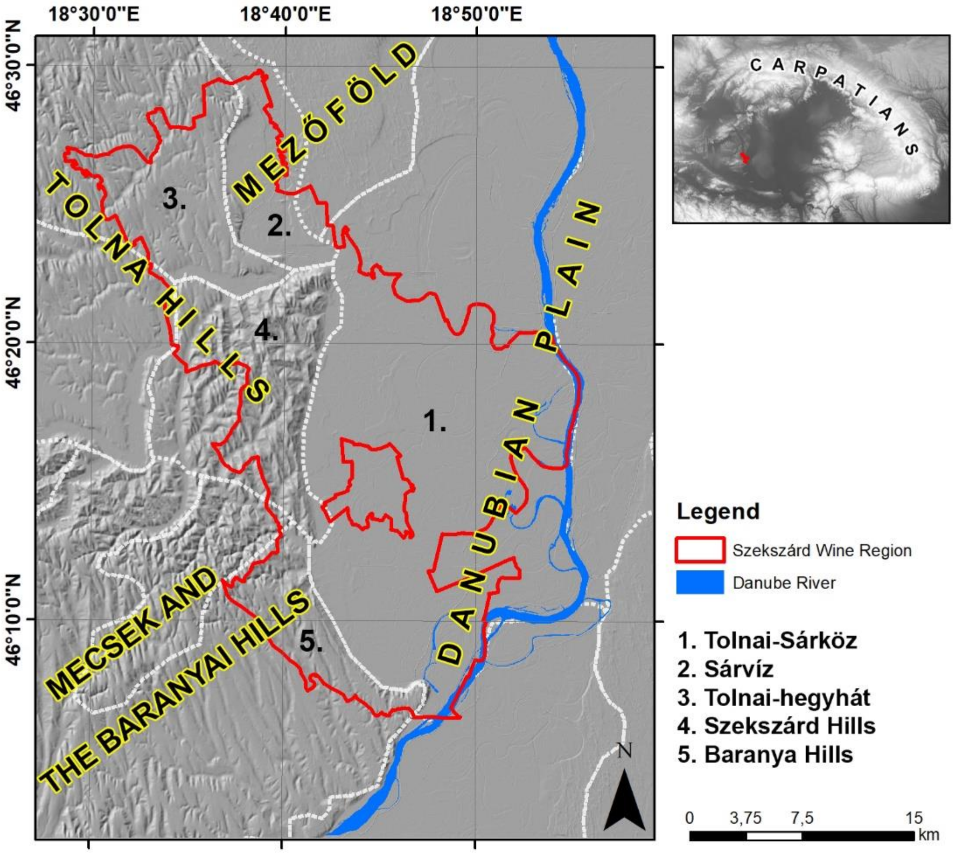

Figure 1
The location map of the Szekszárd Wine Region

The area is mainly covered by fluvial sediments formed during the Quaternary period, along with loess and alluvium. In some places, due to erosion and structural movements, Pannonian period sediments (Kállai Gravel Formation, Somló Formation) and even older Carboniferous monzonite, granite, and granodiorite rocks (Mórágy Granite Formation) also emerge to the surface [1, 10]. On the mentioned bedrocks, in the low-lying floodplain areas, raw and humic alluvial soils, meadow and alluvial meadow soils have formed, while in the higher elevated terrains, brown forest soils and chernozems have developed [11].

According to the Péczely-climate classification, the area falls into the warm-moderately warm, warm-moderately dry, and warm-dray climatic zones, from west to east. The sub-Mediterranean influence strongly manifests in this part of the Carpathian Basin. The average annual temperature hovers around 10.3 °C, and the annual precipitation reaches 680 mm. There are approximately 2055 hours of annual sunshine duration per year, while the number of frost-free days amounts to 206 days [4, 12].

4. RESULTS AND DISCUSSION

4.1. The change in the spatial extent of vineyard areas in the Szekszárd Wine Region

Based on the utilized maps, it can be stated that the largest extent of vineyard areas was during the Fourth Military Surveying period (1888–1902) with 5732.12 hectares, while the smallest was during the First Military Surveying period (1782–1785) with 3184.56 hectares. The spatial extent has been quite fluctuating over the centuries *(Figure 2)*. In the past 30 years, a significant decrease in growth in the area has not been observed.

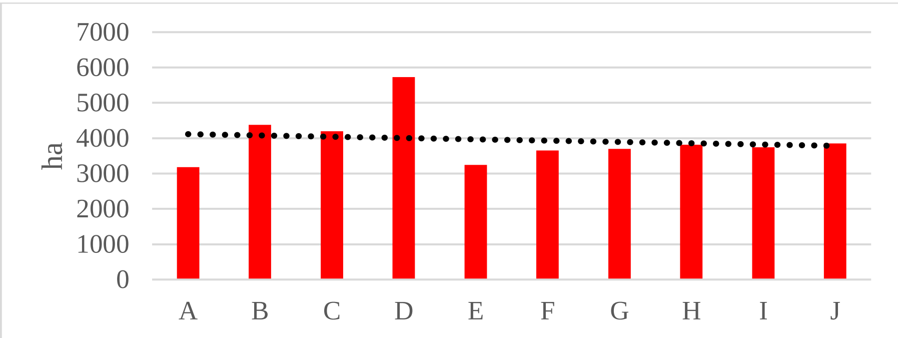

Figure 2

The changes in vineyard areas during the different time periods (A: First Military Survey (1782-1785); B: Second Military Survey (1806-1869); C: Third Military Survey (1869-1887); D: Fourth Military Survey (1888-1902); E: topographic maps; F: CORINE 1990; G: CORINE 2000; H: CORINE 2006; I: CORINE 2012; J: CORINE 2018

Between the period of the Second Military Survey *(Figure 2, D)* and the topographical maps of EOTR *(Figure 2, E)*, the size of the areas decreased by 43.40%. The devastating phylloxera epidemic *(Phylloxera vastatrix)* in the 19th century, the loss of markets after World War I, and the economic crisis between World Wars II, as well as overproduction and difficulties in wine sales, later compounded by state-imposed vineyard planting restrictions, led to the deterioration of the condition of the plantations and a significant decrease in grapevine areas [4].

4.2. The morphometric indicators of vineyard areas in different periods

Over the past 300 years, the average elevation of the vineyard areas has continuously increased from 142 m to 165 m. The median values varied between 137 m and 160 m. The significant difference in elevation above mean sea level was only observed during the First Military Survey, where the median (137 m) and mean (142 m) values were the lowest. The vineyard areas digitized from topographic maps had the highest variation (42.53 m), but similar levels of variability were observed for the First Military Survey (42.52 m) and the Corine databases for 1990 (42.29 m) and 2000 (42.36 m) *(Figure 3)*. The lowest variation was observed during the Fourth Military Survey period (36.88 m) *(Figure 3)*.

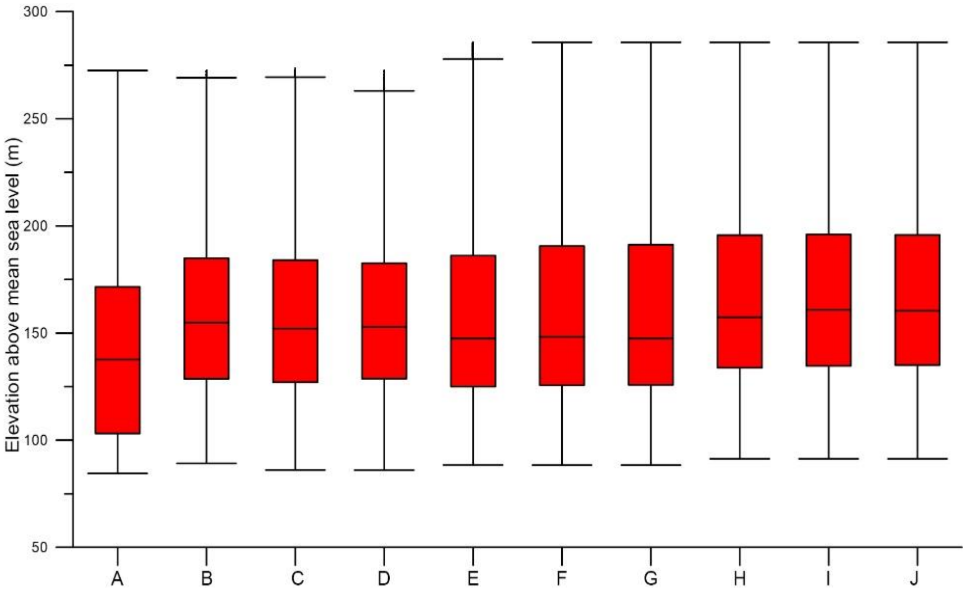

Figure 3
Elevation above mean sea level of vineyard areas during the different time periods (Legend as in the case of Figure 2)

Regarding slope steepness, the average values for different periods ranged from 12.47% to 16.59%, with similar standard deviations (~7.5%), except for the First

Military Survey period, which had a slightly higher deviation of 8.65%. The vineyard areas listed in the CORINE 2006 database had the lowest average slope steepness (12.18%) *(Figure 4)*.

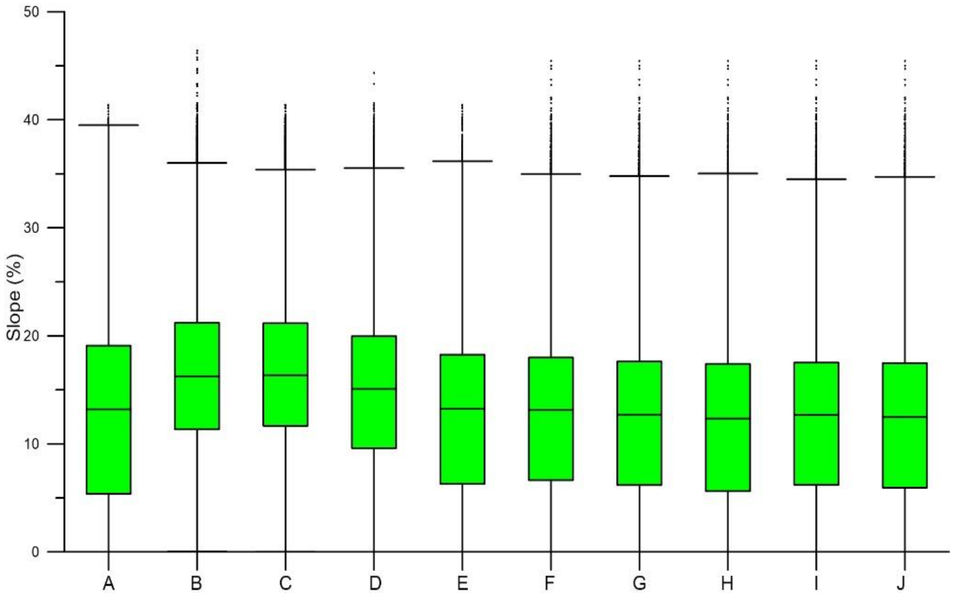

Figure 4

Slope steepness of vineyard areas during the different time periods (Legend as in the case of Figure 2)

It is evident that during the period of the Fourth Military Survey, the average elevation above mean sea level and slope steepness of the vineyard areas were higher than during the time of the EOTR maps. The reason for this can be partly attributed to the phylloxera epidemic and subsequent economic changes. The vineyards were situated at lower elevations, typically remaining on the hillside [4]. According to Máté [4], the vineyard reconstruction took place in three phases. Initially, during the phylloxera crisis (1880–1915), the vineyards moved to the lower levels of the hillsides. In the second phase (1960–1975), they expanded onto the hilltops and terraces. In the third phase, the reclamation of favorable vineyard areas began. Our own findings also partially support this.

Analyzing the aspect of vineyard areas in examined 10 periods (see *Figure 2*), it is evident that eastern slopes dominate, but the ratio of southwestern exposed slopes is also high *(Figure 5)*. There is a good correlation between the aspects of different periods, with only minor changes observed during the First Military Survey, where southwestern slopes occupy a smaller proportion.

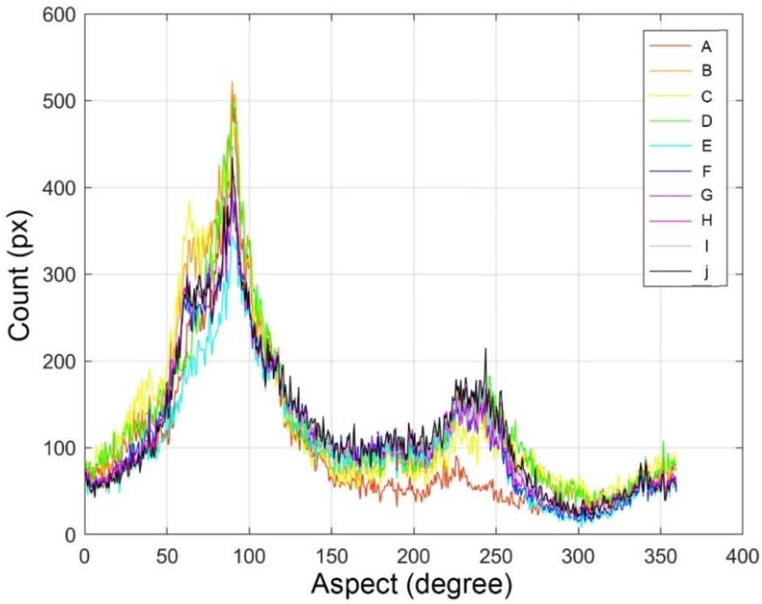

Figure 5
The aspect of vineyard areas during the different time periods
(Legend as in the case of Figure 2)

One reason for the dominance of eastern exposed slopes is that the area is structurally tilted along fault lines in an eastward direction, creating a chessboard-like pattern, which fundamentally determines the overall slope direction (87°) [1, 13]. The microclimatic influence of the Danube River likely compensates for temperature differences resulting from eastern exposure.

4.3. Spatial stability of vineyard land use category

We examined the spatial stability in vineyard areas in the Szekszárd Wine Region over 10 periods (as mentioned above). Over nearly 300 years, some areas remained under cultivation in all 10 periods, while others were only vineyards during a single period.

First, we created rasters of the vineyard areas from digitized maps and databases. Then, we summed up the vineyard areas for each period, obtaining a relative value. We referred to this value as "land use stability". A pixel with a value of 1 indicates an area that was a vineyard in only one period (any period), while those with a value of 10 represent locations that were vineyards throughout all periods (Class 1–10). The latter (Class 10) can be interpreted as potential core vineyard areas for viticulture *(Figure 6)*. This represents 10.26% of all vineyard areas.

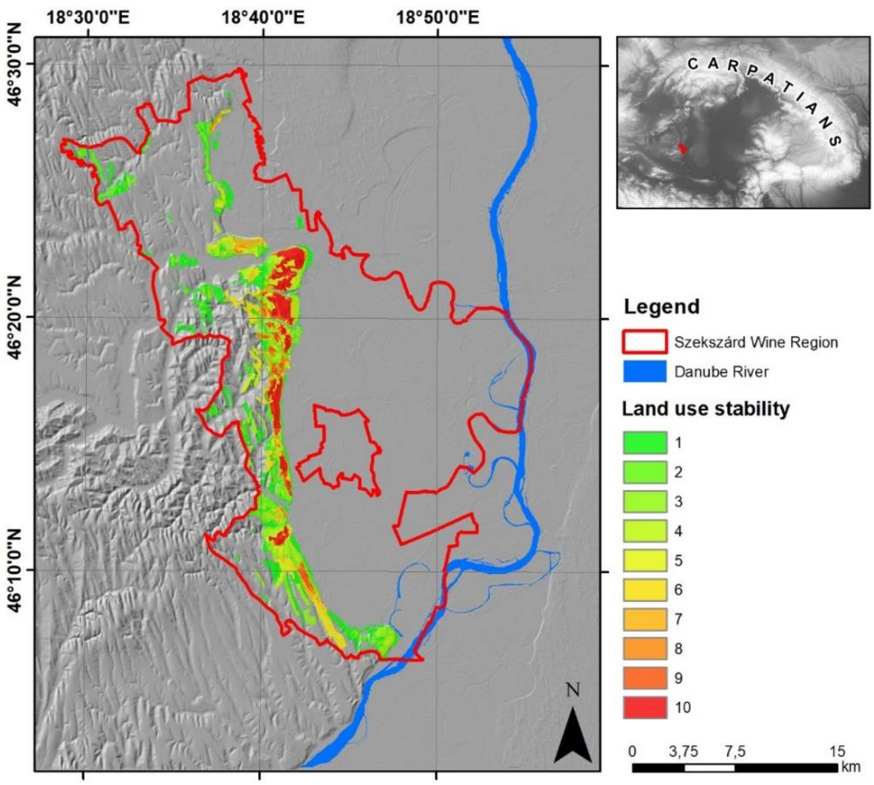

Figure 6
Map of vineyard areas' land use stability

Subsequently, we also examined the morphology of each stability class to identify if there were any differences in the topographical parameters (elevation above sea level, slope steepness, aspect) among the classes. Analyzing each stability class's elevation above sea level, the median values ranged from 136 to 172 meters, and the average values varied between 145 and 170 meters. The class with the highest average elevation is Class 5, while the lowest is Class 1. For potential core vineyard areas, represented by Class 10, the average elevation above sea level is 163 meters, and the median is 160 meters *(Figure 7)*. Regarding slope steepness, the average values for each stability class ranged from 11.6% to 16.4%, while the median values varied between 9.9% and 16.3%. The class with the highest average slope steepness is Class 10, representing potential core vineyard areas, while the lowest is Class 6 *(Figure 8)*. When examining aspect, a significant difference is observed between Class 1 and the other classes. In Class 1, both eastern and western exposed slopes appear relatively dominant, while in the other classes, the eastern exposed slopes are more predominant *(Figure 9)*.

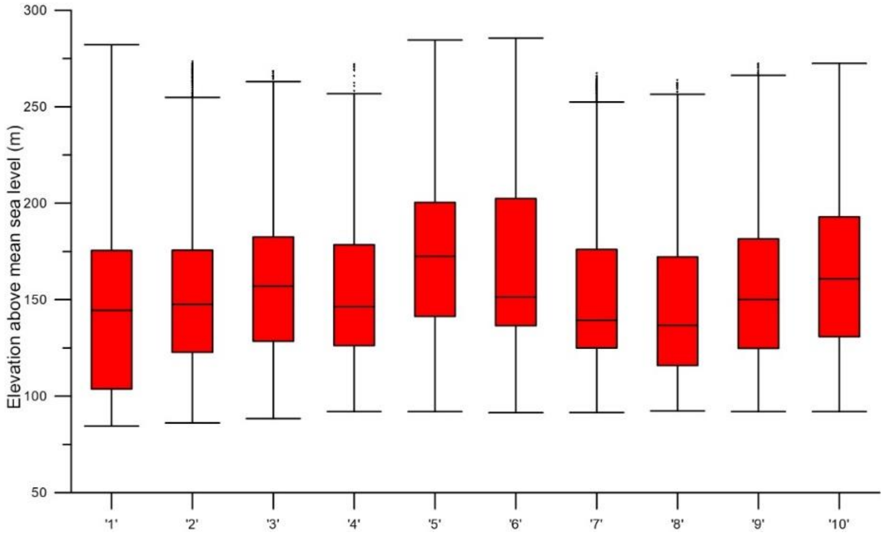

Figure 7

Elevation above sea level of the identified potential core vineyard areas (Class 1–10)

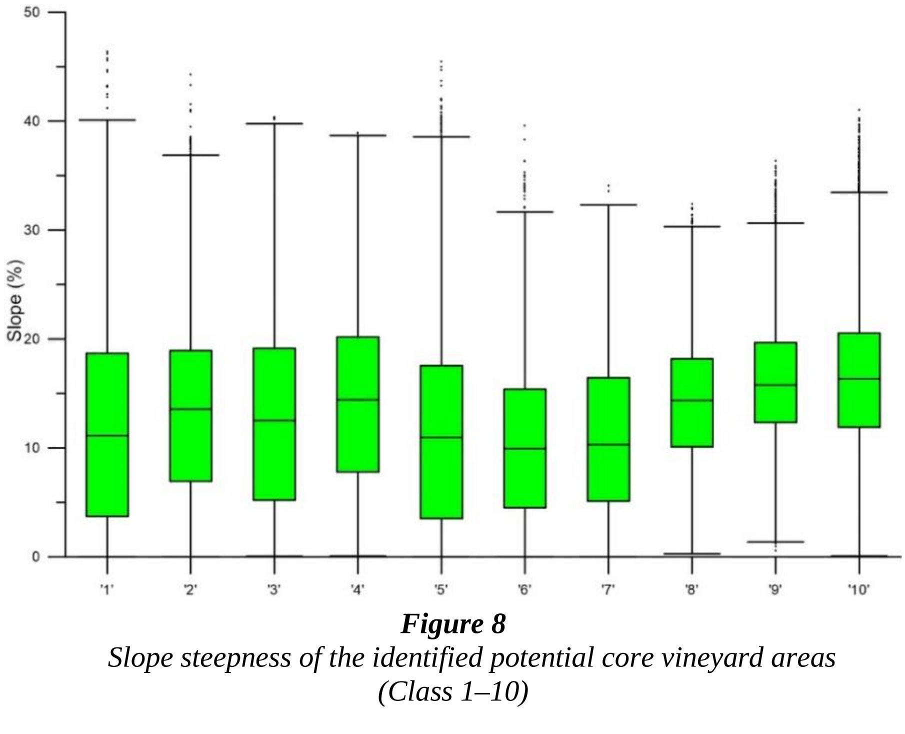

Figure 8

Slope steepness of the identified potential core vineyard areas (Class 1–10)

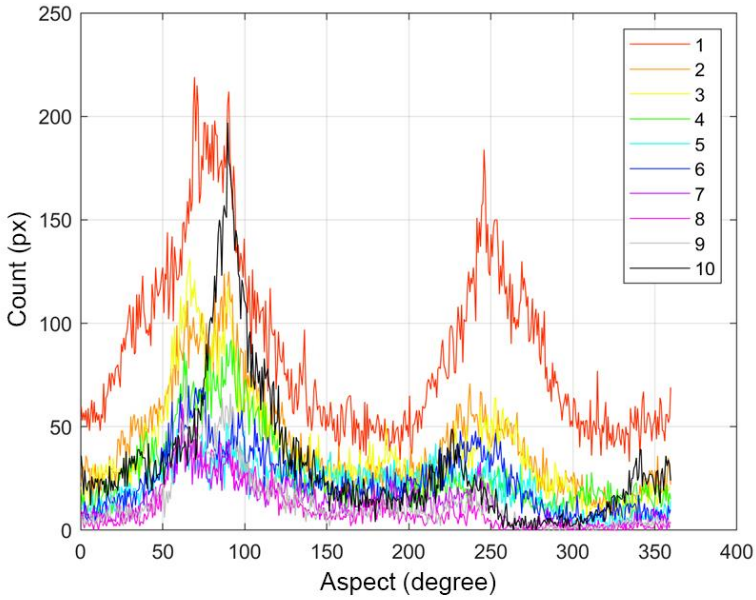

Figure 9
The aspect of the identified potential core vineyard areas
(Class 1–10)

5. CONCLUSION

In our study, we investigated the changing patterns of vineyard areas within the Szekszárd Wine Region. We found that there has been no alteration in the extent of these areas in recent times (1990–2018). However, when considering a time span of more than 230 years, a notable decrease becomes apparent. Across various time periods, there has been an increase in the average elevation above sea level of vineyard areas, accompanied by a reduction in slope steepness. These transformations can be partly attributed to the outbreak of phylloxera and shifts in social and economic dynamics.

In terms of exposure, the prevailing direction has consistently been eastward throughout each period. This alignment reflects the structural geological characteristics of the region and the microclimate impact of the Danube River [1, 4, 13].

We also made a classification of the vineyards, examining their spatial stability. The highest value (10) shows the location of most consistent vineyard sites across all 10 time periods. We designate these as core areas. These core areas constitute 10.26% of the entire territory. The average elevation above sea level for these regions is 163.53 meters, with an average slope steepness of 16.43%. Regarding the aspect, the eastward direction is predominant.

The classes considered as potential core areas (8-9-10) boast an average elevation above sea level of 158.25 meters and a slope steepness of 15.91%. Exposure-wise, the dominant direction remains eastward in this case as well.

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