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TERROIR-BASED SPATIAL STRUCTURAL ANALYSIS  
OF HUNGARY, WITH SPECIAL REGARD TO THE  
DANUBE WINE REGION

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## **1. BACKGROUND AND OBJECTIVES OF THE RESEARCH**

The grape and wine sector is one of Hungary's historically decisive agricultural branches. Beyond its economic role, it also performs major spatial-organising, social and cultural functions. However, the spatial structure, plantation morphology and renewal capacity of Hungarian wine districts have become increasingly differentiated over recent decades. These processes cannot be interpreted exclusively from sectoral or agronomic perspectives, as they are closely linked to regional inequalities, the evolution of centre–periphery relations and the structural issues of rural development.

The relevance of the research is explained, first, by the structural transformation of global and European wine production, which has created a new competitive environment for Hungarian wine districts. Second, the support system of the European Union's Common Agricultural Policy is a decisive factor, as its instruments targeting restructuring, investment and crisis management exert a significant influence on the spatial processes of wine districts. Third, the intensifying impacts of climate change – the rearrangement of temperature and precipitation patterns and the growing frequency of extreme events – affect viticulture in spatially differentiated ways, thereby increasing the importance of terroir conditions, plantation structure and adaptive capacity. The theoretical and analytical framework of the dissertation is provided by the terroir approach, which interprets terroir not as a static site category but as an internally differentiated and dynamically changing spatial structure. In this approach, terroir-based characteristics, plantation-morphological features and support-policy interventions jointly shape the spatial patterns and renewal trajectories of wine districts. As

an analytical logic, the terroir approach makes it possible to examine how these factors create stable or transforming centre–periphery structures within and between wine districts. The central empirical field of the research is the Danube Wine Region, Hungary’s largest and most heterogeneous wine region. The area is characterised by a structural duality: large-scale plantations typically linked to quantity-oriented production coexist with small-scale, fragmented forms of production. The spatial-structural characteristics, age structure of plantations and support patterns of the Danube Wine Region are particularly suitable for the empirical examination of trajectories of renewal and decline.

The general aim of the dissertation is to reveal how the spatial-structural, plantation-morphological and terroir-based characteristics of Hungarian wine districts, together with the intensity and structure of wine-sector supports, shape regional differences and centre–periphery patterns. The research is based on the assumption that the spatial and age-structural features of plantations, as well as the geographical distribution of supports, interact to determine the renewal potential of wine districts. The research is organised around three interconnected goals: first, to explore the spatial-structural, plantation-morphological and terroir-based differences of Hungarian wine districts and to examine whether stable centre–periphery patterns can be identified on this basis; second, to analyse the spatial distribution and structure of wine-sector supports and to assess whether they follow the differing terroir and spatial-structural endowments of wine districts or rather reproduce existing regional disparities; third, to identify the trajectories of renewal and lagging behind in the Danube Wine Region, with special regard to the relationship between plantation age structure, structural duality and support patterns. The research is built on an empirically testable system of research questions and hypotheses, which examines the spatial-structural and

support-policy differences of wine districts by means of GIS and spatial-statistical methods (Table 1).

Table 1: Overview of the system of research goals, questions and hypotheses (RGQH)

Research objective (C)	Research question (RQ)	Research hypothesis (H)
C1 – Exploration of the spatial-structural, plantation-morphological and terroir-based characteristics of Hungarian wine districts.	RQ1 – What spatial-structural and terroir-based differences characterise Hungarian wine districts, and do stable centre-periphery patterns emerge on this basis?	H1 – The plantation structure and terroir characteristics of Hungarian wine districts jointly create strongly polarised, stable centre-periphery patterns.
C2 – Spatial examination of the intensity and structure of wine-sector supports.	RQ2 – How are wine-sector supports distributed spatially and structurally, and to what extent do they follow the terroir and spatial-structural differences of wine districts?	H2 – The spatial distribution of wine-sector supports is not neutral but partly reproduces existing regional disparities.
C3 – Identification of the trajectories of renewal and decline in the Danube Wine Region.	RQ3 – How is the structural duality of the Danube Wine Region linked to support patterns and plantation age structure?	H3 – Renewal in the Danube Wine Region is mosaic-like and is closely related to plantation age structure and support intensity.

*Source: author's own compilation*

The analytical framework thus developed makes it possible to interpret the regional differentiation of Hungarian wine districts quantitatively, while giving a central role to the exploration of the specific spatial-structural challenges of the Danube Wine Region.

## 2. MATERIALS AND METHODS

The methodological starting point of the research is that the terroir approach can be operationalised not only as a conceptual framework but also as a spatial-structural analytical logic. The aim was to develop an integrated methodological system capable of empirically examining the agro-ecological, spatial-structural, support-policy and socio-discursive differences of Hungarian wine districts. The study was conducted at three spatial scales: vineyard level, municipal level and wine-district level. The vineyard level made it possible to analyse soils, relief, bioclimate and parcel structure; the municipal level served as the basic unit for structural and renewal indicators as well as regression analyses; and the wine-district level provided the framework for typological and comparative analyses. In order to mitigate the Modifiable Areal Unit Problem, indicators interpreted at multiple scales, as well as specific and proportional measures, were applied. The methodological logic consisted of three consecutive analytical levels (Figure 1).

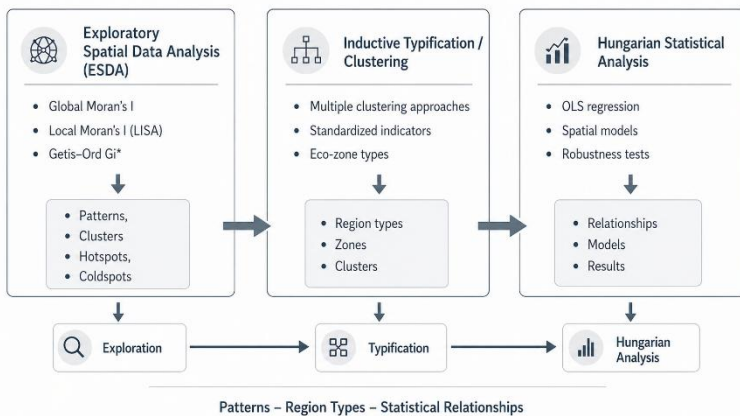


Figure 1: The logic linking spatial-statistical exploration (ESDA), inductive typology and explanatory statistical analyses.

*Source: author's own calculations and editing*

The first level was diagnostic spatial-statistical exploration based on ESDA procedures. Within this framework, global and local Moran's I as well as Getis–Ord  $G_i^*$  indicators were applied to identify spatial autocorrelation, clustering, hotspots, coldspots and peripheral zones. These served the exploration of spatial patterns.

The second analytical level was typology. The typology of vineyards was based on the integrated interpretation of parcel structure, relief, soil suitability and the bioclimatic background. Fragmentation was measured by the number of vineyard polygons, average and median patch size, shape index and edge density. Relief analysis, based on EU-DEM v1.1, examined elevation above sea level, slope and aspect. Soil analysis was built on the AGROTOPO database, with special regard to texture, water management, humus content, rooting depth, pH and clay mineral composition.

One methodological innovation of the dissertation was the development of the Vine-Specific Soil Suitability Index (SSI). The SSI categorises and scores AGROTOPO soil parameters according to the ecological requirements of grapevine and then assigns sites to favourable, medium and unfavourable categories. To analyse the bioclimatic background, the ANUCLIM BIO1–BIO19 variables were used, with special attention to annual mean temperature, annual thermal amplitude, the maximum temperature of the warmest month, the minimum temperature of the coldest month, annual precipitation and precipitation in the warmest quarter. Principal component analysis was used to reduce redundancy among variables, while Getis–Ord  $G_i^*$  hotspot analysis served to examine spatial concentrations.

The final typology of vineyards was produced by k-means cluster analysis. The main input variables were the SSI score, elevation above sea level, slope and aspect. The analysis

distinguished three vineyard types: lowland large-scale, hilly optimal and mountainous terroir types. The bioclimatic differences among the clusters were checked by descriptive statistics, ANOVA and Tukey post hoc tests.

The typology of wine districts was based on two complementary approaches. The deductive agro-ecological–statistical typology distinguished homogeneous large-scale, homogeneous terroir, transitional and heterogeneous wine-district categories. Its basis was provided by the SSI median, cluster shares, Shannon entropy and a quality score. In contrast, the inductive ecological–statistical cluster typology identified empirical eco-zones at municipal level in a data-driven way. The eco-index was constructed as a standardised and normalised combination of SSI, relief indicators, bioclimatic principal components and parcel-structure characteristics.

The third analytical level was relationship analysis. Vineyard renewal was expressed by the renewal index, which measured the relative ratio of younger and ageing vineyards on the basis of age structure. In the regression models, the explanatory variables included SSI, mean elevation, slope and aspect, parcel number, shape index, edge density and bioclimatic principal components. Municipality size and wine-district affiliation were included as control variables. The basic model was estimated using pooled OLS, complemented by VIF indicators, HC3 robust standard errors and spatial sensitivity checks. The examination of winery supports was based on NAV and MÁK data. For the period 2011–2024, a wine-district-by-year panel database was built integrating production and support data. The main production variables were vineyard area for wine grapes, planted area, quantity of harvested grapes and wine production volume. The support analysis included, among others, restructuring support, winery investment support, machinery acquisition, promotion, crisis distillation, green harvesting and crisis-management supports.

The study applied intensity indicators such as support per hectare, support per hectolitre and support per winery, as well as the Hoover index, Gini coefficient, Pearson correlation, and the Moran's I and Getis–Ord  $G_i^*$  spatial-statistical indicators. The qualitative stage examined the “soft” dimension of the terroir approach. Structured interviews based on open questions were conducted with six actors from five wineries in the Danube Wine Region. The analysis was carried out through thematic qualitative content analysis with open and axial coding. Four sub-dimensions were distinguished: interpretive framework of terroir, intensity of regional identity, narrative attachment to place and perception of cohesion. Overall, the methodological framework connects GIS, spatial-statistical, regression, support-policy and qualitative discourse-analytical approaches as a multi-scale mixed-method system, directly serving the empirical testing of hypotheses H1–H3.

### **3. RESULTS AND DISCUSSION**

#### **3.1. Wine-District Typology and Renewal**

The study confirmed that the renewal capacity of Hungarian wine districts is jointly determined by site conditions, plantation structure and local social processes. The aim of the typology was not merely delimitation but to demonstrate how ecological, economic and demographic factors are interlinked in the development patterns of wine districts.

##### ***3.1.1. Fragmentation and Environmental Characteristics of Vineyards***

The examination of the fragmentation and environmental characteristics of vineyards provides one of the foundations of the agro-ecological typology of wine districts. The aim of the analysis was to reveal the spatial differences in the parcel structure, topographic position, soil conditions and bioclimatic environment of Hungarian vineyards, and how these contribute to the formation of the differing character of wine districts.

The shape and fragmentation analyses show that the structure of Hungarian vineyards is highly differentiated. Nationwide, an average of 3.6 vineyard patches can be found within a municipality, while the median is only 2, indicating the importance of a small-parcel, scattered structure. The average municipal vineyard area is about 150 ha, but the standard deviation is very high. Average patch size is 37 ha, and the national average shape index is 3.6, indicating a predominance of more irregular and elongated parcels. One of the most important indicators of fragmentation is edge density, whose national average is 446 m/km<sup>2</sup>, although the values vary over a very wide range. High ED values indicate a mosaic-like, small-parcel structure, while low values indicate large-block,

homogeneous vineyard structures.

Differences between wine districts are marked. The Badacsony and Balatonfüred–Csopak wine districts are characterised by exceptionally high edge-density values, with averages above 1400–1500 m/km<sup>2</sup>. These are highly fragmented, topographically dissected areas with a mosaic structure. In contrast, the Kunság, Hajós–Baja and Csongrád wine districts of the Danube Wine Region show lower fragmentation values, typically around 200–300 m/km<sup>2</sup>. This is the spatial imprint of large-block, large-scale cultivation on flat terrain. The Felső-Pannon and Pannon wine regions represent a transitional situation.

Relief analysis shows that most Hungarian vineyards are located under favourable elevation, slope and aspect conditions. Of the vineyards, 63.8% are situated at 100–200 m above sea level, while another 24.3% lie between 200 and 400 m. The share of areas below 100 m is 11.8%, mainly associated with the large-scale lowland areas. In terms of slope, 38.2% of vineyards are located on 3–10% slopes, 35.3% on 0–3% slopes, and 25.0% on 10–20% slopes. The share of very steep slopes above 20% is low, 1.6%, but these areas carry considerable terroir potential. Regarding aspect, 66.6% of vineyards are south-facing, which ensures favourable light and heat conditions.

The Vine-Specific Soil Suitability Index (SSI) developed for soil analysis is an assessment system tailored to grapevine needs. The index evaluates texture, water management, organic matter content, rooting depth, pH and clay mineral composition. Most Hungarian vineyards are located on brown forest soils, humic sandy soils, shifting sands, chernozem brown forest soils and clay-illuviated brown forest soils. The morphological analyses show that the size and shape of vineyard blocks are closely related to the historical development of wine districts and to the evolution of landholding structure. Natural endowments – especially relief

and climate – fundamentally influence the possibilities of viticulture. Based on the eco-index and SSI values of vineyards, mountainous areas clearly possess more favourable site conditions. The average SSI value of the Danube Wine Region is 0.47, significantly below the 0.66 average of the Transdanubian wine districts (Figure 2).

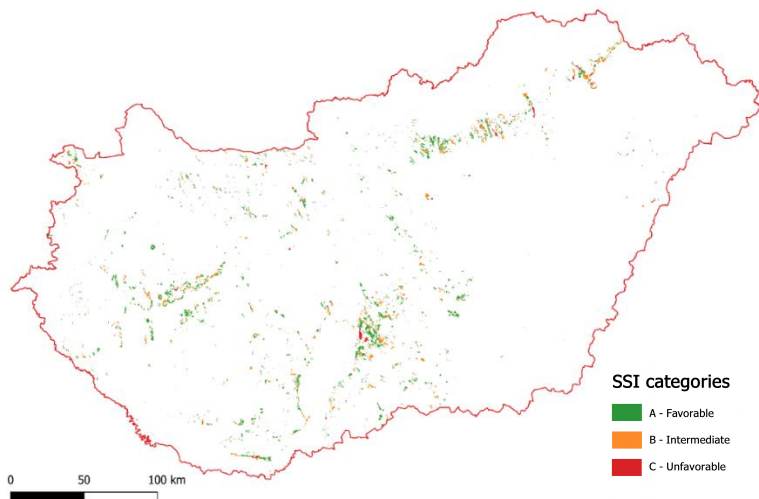


Figure 2: Distribution of SSI categories  
*Source: author's own calculations and editing*

According to the soil-physical analysis, 42.7% of vineyards are located on loose soils, 34.9% on medium-textured soils and 17.2% on heavy soils. In terms of humus content, 57.7% are on soils with high organic matter, 30.4% on medium, and 11.9% on low organic matter reserves. The distribution of water management is balanced: good 36.2%, medium 31.4%, weak 32.4%.

Cross-tabulation analyses confirmed significant relationships among soil properties. The relationship between texture and humus content is significant,  $\chi^2 = 15432$ ,  $p < 0.001$ ; the

relationship between texture and water management is even stronger,  $\chi^2 = 28765$ ,  $p < 0.001$ ; and the relationship between humus content and water management is also significant,  $\chi^2 = 4820$ ,  $p < 0.01$ . Thus, the strongest association was found between soil texture and water management.

The bioclimatic analysis was based on six main variables: BIO1, BIO5, BIO6, BIO7, BIO12 and BIO18. ANOVA showed significant cluster differences for all variables ( $p < 0.001$ ). The lowland large-scale cluster is warmer, drier and characterised by greater thermal amplitude; the hilly optimal cluster is more balanced; and the mountainous terroir cluster is cooler and wetter. Annual precipitation is 531.5 mm in the lowland cluster, 573.5 mm in the hilly cluster, and 586.5 mm in the mountainous terroir type.

Cluster analysis distinguished three major vineyard types (Figure 3). The lowland large-scale cluster includes 1,184 vineyards and 67,041 ha, at an average elevation of 118 m, with 2% slope and an SSI median of 15. The hilly optimal cluster consists of 634 vineyards and 35,988 ha, with an average elevation of 189 m, 9% slope and an SSI median of 14. The mountainous terroir cluster represents 659 vineyards and 36,325 ha, with an average elevation of 208 m, 11% slope, southern exposure and an SSI median of 14. These results show the dual structure of Hungarian vineyards: the Great Plain forms the quantitative large-scale base, while hilly and mountainous areas carry the potential for quality terroir production.

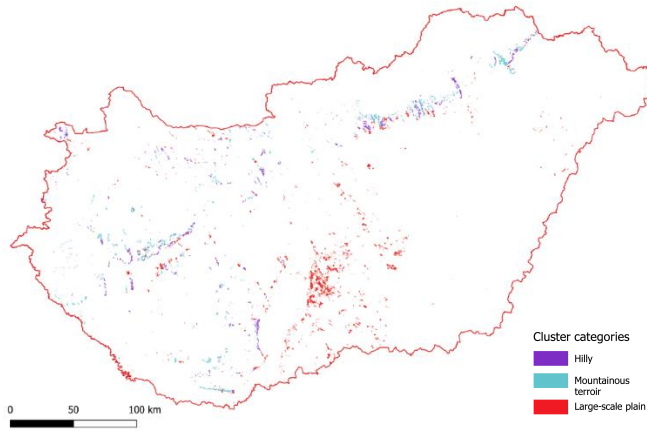


Figure 3: Vineyard clusters

*Source: author's own calculations and editing*

### **3.1.3. Renewal Index**

Based on 2020 data on Hungary's vineyard stock, most plantations are middle-aged (36%) or old (43%). The share of young vineyards aged 0–3 years is only 4.5% on average, while those in the 3–9 year category account for only 16.7%. Median values indicate the concentration even more strongly: in more than half of the municipalities there are no vineyards at all in the 0–3 year category, and the share of the 3–9 year age group barely exceeds 5% (Figure 4).

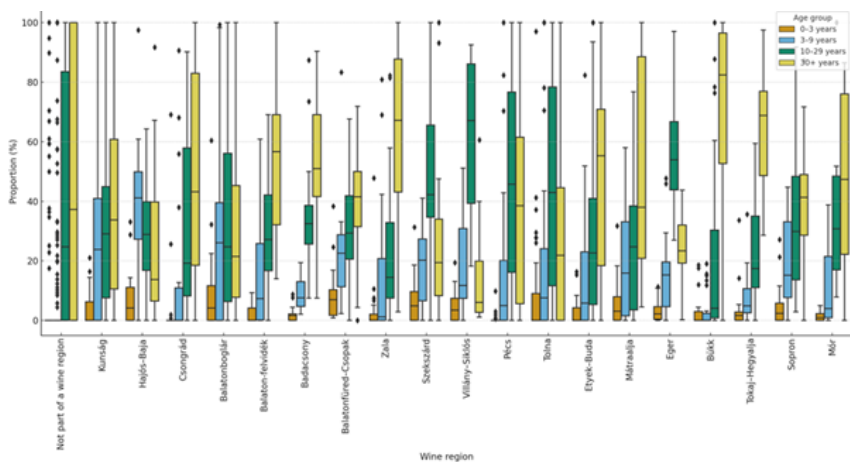


Figure 4: Spatial distribution of vineyards by age group in Hungarian municipalities (2020)

*Source: National Council of Wine Communities (HNT), Vineyard Register (2020), author's own calculations and editing*

These data clearly indicate that the structure of Hungarian vineyards is ageing, while the emergence of young vineyards is spatially limited and concentrated in only a few wine districts. From the perspective of long-term sustainability, this represents a serious risk, as vineyard renewal is progressing at an adequate pace in only a few areas. In most of the country's wine districts, vineyards older than 30 years dominate, while the rate of rejuvenation differs significantly between municipalities and wine districts.

To measure renewal, the research developed a municipal-level Renewal Index (RI), interpreted as the ratio of young (0–9 years) to old (over 30 years) vineyards. With the help of the index, it became possible to identify those areas where the vineyard stock is becoming younger and where ageing is characteristic (Figure 5).

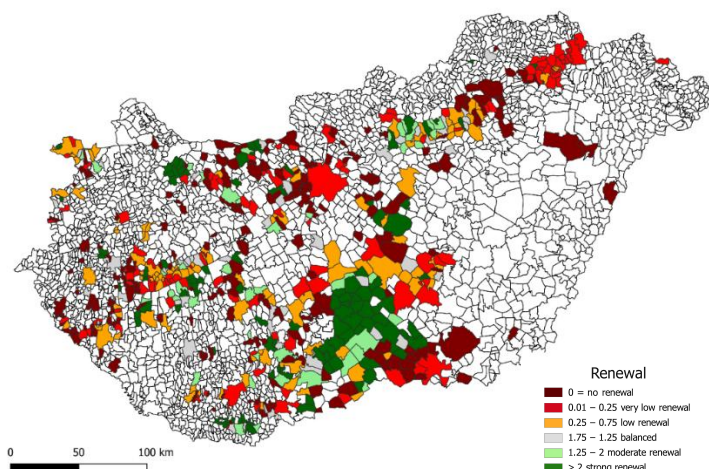


Figure 5: Renewal index of vineyards at municipal level (2020)

*Source: author's own calculations and editing*

The results show that in most wine districts the dominance of old vineyards is characteristic, while rejuvenation processes show meaningful intensity only in a few regions. The spatial distribution is strongly differentiated: whereas ageing dominates in several wine districts of the North Hungarian Mountains and Transdanubia, distinctly active renewal processes can be observed in the municipalities of the Danube Wine Region.

The national picture is bipolar: in some areas almost exclusively old vineyards are found, while in others dynamic planting activity is typical. A balanced age structure is rare, which shows that Hungarian viticulture is strongly territorially polarised. This deserves attention also from a development-policy perspective, since the lack of rejuvenation in several wine districts threatens production security.

In this respect, the wine districts of the Danube Wine Region

are in a more favourable position than, for example, Tokaj or Eger, where the index is close to zero in many municipalities. This suggests that wine districts operating with mountainous, small-parcel structures adapt more difficultly to age-structure challenges, while the large-scale systems of the Danube Wine Region respond more flexibly to economic and technological change.

The spatial centres of renewal in the Danube Wine Region are clearly visible. The most active municipalities include Jakabszállás, Bócsa, Szank, Tompa and Dávod, while Fülöljakab, Jászszentlászló and Hajós belong among the lagging areas. These focal points are of particular importance from a support-policy perspective, because renewal is a process to be interpreted at regional level, in which the integration of the weaker-performing municipalities is also indispensable.

The statistical analyses confirmed that the renewal index is influenced primarily by ecological and territorial factors (soil conditions, precipitation patterns, parcel structure) and less by wine-district affiliation. This finding supports the view that revising wine-district boundaries may be justified if the aim is a more precise spatial determination of sustainability potential.

Further results of the age-structure models show that in the case of younger vineyards in the AGE\_3\_9 category, wine-district affiliation plays a somewhat greater role, while for middle-aged and old vineyards ecological and territorial factors are more decisive. This difference suggests that the spatial distribution of young vineyards may become a key aspect in the future development of wine districts and in the targeting of support policies.

The analysis of the renewal index and age-structure shares confirmed the hypothesis: vineyard renewal is determined primarily by environmental conditions and territorial structure rather than by administrative wine-district classification. The

results can be used both for strategic planning aimed at the sustainable renewal of the vineyard stock and for the fine-tuning of wine-district development policy.

### ***3.1.4. Municipalities Proposed for Inclusion***

One aim of the study was to identify non-wine-district municipalities whose natural conditions and spatial location make them suitable for inclusion in an already existing wine district. According to the eco-index, these municipalities were mainly classified into the high or very high categories, indicating favourable agro-ecological conditions for viticulture.

The map analyses showed that the municipalities proposed for inclusion are not scattered but located in clearly delimited regional clusters (Figure 6).

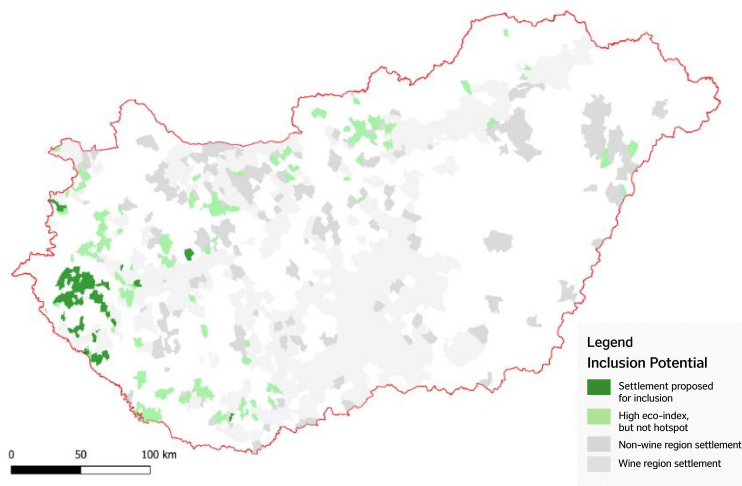


Figure 6: Inclusion potential of non-wine-district municipalities based on the eco-index and hotspot analysis.  
*Source: author's own calculations and editing*

Villages on the fringes of the Balaton Highlands are particularly prominent, as their relief and climatic conditions integrate organically into the wine-district structure of the area. A similar pattern can be observed at the border of Tokaj–Hegyalja, where several settlements currently outside the wine district show high eco-index values and significant hotspot status, supporting the territorial homogeneity and expansion potential of the area. Several municipalities around the Sopron wine district can also be identified which, based on their site potential, could make a meaningful contribution to the ecological and economic expansion of the district.

By contrast, on the Great Plain there are far fewer municipalities that would fit meaningfully into the surrounding wine districts. Although a few settlements show high eco-index values, they rarely form significant spatial clusters, and their typological features – flat terrain, large-block farming and homogeneous parcel structures – are less favourable for terroir-based wine-district integration. It may therefore be concluded that wine-district expansion is primarily realistic where topography, microclimate and land-use structure support the spread of quality-oriented wine production.

The study identified more than fifty municipalities that currently lie outside wine districts but whose ecological potential and spatial cluster position may justify their future incorporation into an existing wine district. Their distribution is not random: they are concentrated in Western Hungary, especially in Zala County and the West Transdanubian region (Figures 7 and 8).

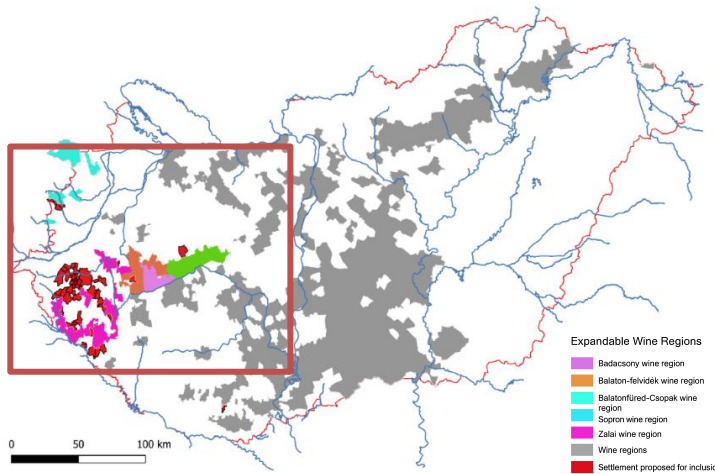


Figure 7: Location of municipalities proposed for inclusion in Western Hungary, in the context of existing wine districts.  
*Source: author's own calculations and editing*

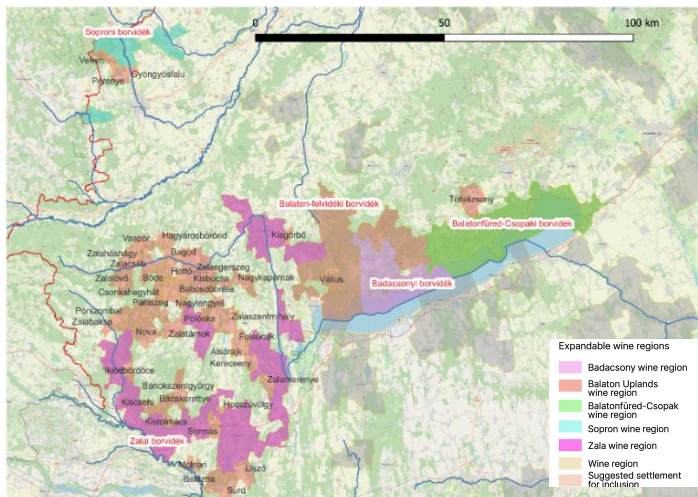


Figure 8: Detailed map of the surroundings of the Zala wine district.

*Source: author's own calculations and editing*

Based on the filtering criteria, the municipalities proposed for inclusion are linked primarily to the Zala wine district, while a smaller part of them shows similar potential on the fringe of the Sopron wine district. The results suggest that territorial enlargement of wine districts is not a nationwide but a regionally limited phenomenon, and can be scientifically justified primarily in Western Transdanubia. The second category of the study comprises municipalities with a high eco-index but without hotspot status. On their own, they do not justify inclusion, but they may be considered potential reserve areas. Their agro-ecological endowments are favourable, but their spatial position does not form a coherent cluster. If local wine culture, economic needs or wine-tourism potential also reinforce their connection, their inclusion may be considered in the future. The spatial concentration of municipalities proposed for inclusion thus clearly emerges around the Zala wine district. This pattern confirms that reviewing wine-district delimitations should not be carried out at national scale but in a targeted way at regional level. In the case of Western Transdanubia, the proposals for inclusion expand the development options of wine production and may also contribute to the practical implementation of sustainable land use and the eco-wine-district concept.

## **3.2. Supports and Territorial Processes**

### ***3.2.1. Spatial Structure of Wineries and Supports***

The spatial-statistical analysis of the municipal distribution of wineries clearly proved that the spatial pattern of winemaking is not random but follows a well-defined cluster structure. The results of the Local Moran's I autocorrelation analysis (Figure 9) showed that wineries are primarily concentrated around historical wine-district centres, around which stable, high-density clusters have formed.

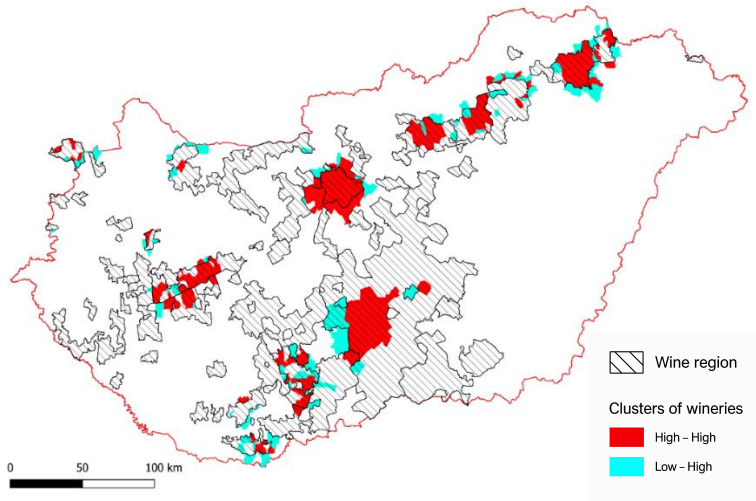


Figure 9: Clusters of wineries based on the Local Moran’s I analysis.

*Source: based on NAV excise database data (2025), author’s own calculations and editing*

By contrast, in peripheral areas, especially in certain parts of the Great Plain, winery activity is sparser and less diversified. This spatial duality suggests that the economic gravitational pull of wine districts remains significant: proximity to more developed centres is a decisive factor of winery activity. The temporal evolution of the support system likewise clearly shows the cyclical nature of the sector. The volume of payments peaked in the period 2020–2022, when investment schemes linked to the last years of the Rural Development Programme (VP) – such as vineyard restructuring and development of processing plants – operated at full intensity (Figure 10).

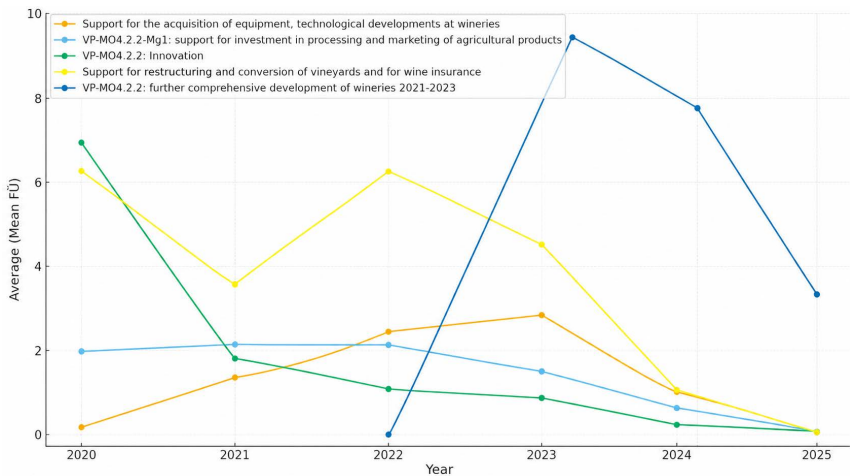


Figure 10: Evolution of payments under the largest winery support titles between 2020 and 2025 (billion HUF)  
*Source: based on MÁK 2025 data, author's own calculations and editing*

After this, the new schemes launched in 2023 under the CAP Strategic Plan did not yet reach the volume of the previous resources, so a temporary decline in winery investments can be observed. The 2020–2025 period can therefore be interpreted as a structural shift: after the earlier large-volume investment programmes, a smaller-scale, more differentiated support structure emerged. This trend is also consistent with the findings of agricultural governance bodies, according to which the emphasis is gradually shifting towards sustainability and quality-oriented development.

The ratio indicators derived from support data make the differences in resource allocation interpretable at municipal level.

Three main indicators were developed: the Average Transaction Indicator (ÜÁT), the Normalised Support per Beneficiary (KNT), and the Activity Intensity Indicator (AIM), making it possible to assess not only the amount of resources but also their distributional character and

concentration. High ÜÁT values indicate few but large-volume transactions, whereas low values point to broader participation in smaller support amounts. KNT approximates the actual support effect because it also considers the number of beneficiaries, while AIM describes participation intensity by showing how many support transactions a beneficiary participated in on average.

Map-based analysis of these indicators revealed that support patterns closely follow the structural and ecological characteristics of wineries. In the homogeneous, large-block lowland wine districts, resources tend to be more concentrated – in the form of fewer but larger developments – whereas in mosaic-like, small-parcel mountainous regions the resources are distributed more widely among several smaller beneficiaries.

This picture fits well with the previous results of the dissertation: fragmentation, soil conditions and age-structure analyses all confirm that the spatial expression of support-policy effects depends strongly on the ecological structure of wine districts. The dynamics of resource allocation, being shaped by economic, spatial-structural and natural factors alike, provides a sound basis for interpreting the Complex Support Intensity Index (KTII) introduced in the study.

### ***3.2.2. Wine-District Trends 2011–2024***

The vineyard area of Hungarian wine districts showed significant regional differences between 2011 and 2024. While in some areas vineyard size remained relatively stable – for example in the Badacsony, Balatonfüred–Csopak and Kunság wine districts – in others dramatic decline occurred. The largest decrease affected the Csongrád wine district (–42.7%), where almost half of the vineyards disappeared during the period examined. A considerable decline also took place in the Balaton Highlands (–30.6%), while in a few areas,

such as the Eger (+7.1%) and Balatonboglár (+13.8%) wine districts, vineyard area increased. These latter processes were largely the result of restructuring supports and new plantings. The largest Kunság wine district maintained its dominant position during the period, with its area fluctuating between 15,700 and 23,800 hectares, indicating stability in production volume.

The trends indicate that while several wine districts struggle with shrinking vineyard area, others have been able to move towards renewal and expansion. The reasons can be traced back both to ecological endowments and to the differing effectiveness of support-policy and investment structures.

Harvest quantities between 2011 and 2023 also evolved in strongly differentiated ways. In the Kunság (+92.2%) and Hajós–Baja (+88.7%) wine districts, the harvested quantity of grapes nearly doubled, indicating the strengthening of large-scale production forms. By contrast, the harvested quantity fell by half in the Badacsony (−52.1%), Balaton Highlands (−49.3%), Bükk (−59.7%) and Csongrád (−51.0%) wine districts. The decline in the Eger wine district was more moderate (−26.9%), while the Etyek–Buda wine district moved in the opposite direction, achieving 25.6% growth.

These results indicate intensifying polarisation among wine districts: volume-based production growth in some regions occurred at the expense of quality orientation, while in other areas structural change and parcel fragmentation caused a decline in production.

Wine production volume showed similar spatial disparities: the Kunság wine district recorded 127.1% growth and Hajós–Baja 31%, while positive trends were also observed in Etyek–Buda (+20.8%) and Badacsony (+66.3%). By contrast, the Csongrád wine district virtually collapsed (−93.3%), while the Balaton Highlands (−78.9%) and Balatonboglár (−60.3%) districts also suffered major decline. The Eger wine district remained relatively stable, with a moderate decrease of −22%,

which can be regarded as favourable compared to the national average.

The analysis of specific yields (hl/ha) illustrates particularly well the performance differences between wine districts. In the Kunság wine district, yield more than doubled (+122.3%), reflecting more favourable weather cycles, intensive use of supports and technological modernisation. Yield also increased in Hajós–Baja (+37.2%) and Badacsony (+64.9%), while in several areas drastic decline occurred: in the Balaton Highlands (−70.4%), Balatonboglár (−65.1%) and Csongrád (−89.0%) specific yields fell to very low levels. The −29.1% decline of the Eger wine district is considered moderate, while Etyek–Buda and a few smaller wine districts showed relative stability.

Minimum–maximum yield values differed three- to fourfold in several wine districts, clearly reflecting the climatic and market volatility of the period. In unfavourable years, drought and market disturbances shaped yields, while in favourable years climatic optimum and supportive price structures were decisive.

The joint examination of the main indicators of the grape and wine sector – vineyard area, harvested quantity and average yield – clearly reveals the spatial polarisation of wine districts (Figure 11).

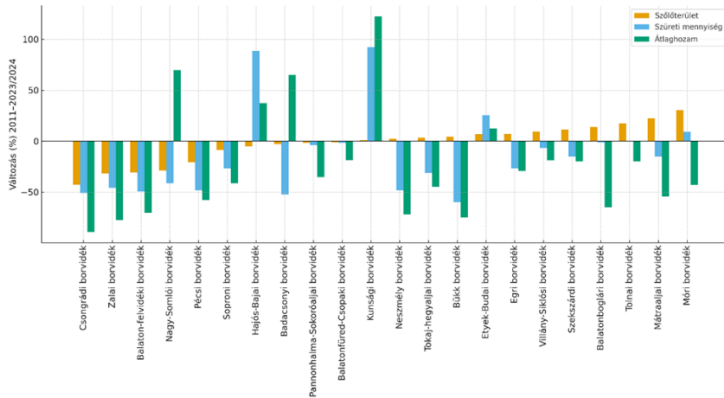
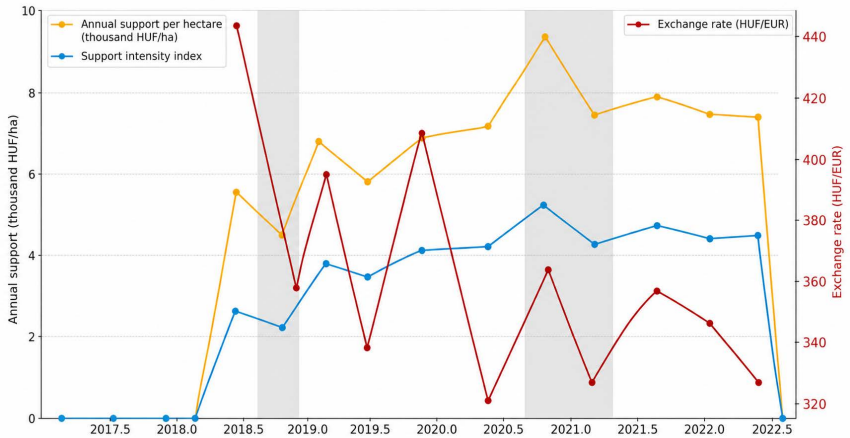


Figure 11: Percentage change in vineyard area, harvested quantity and average yield by wine district (2011–2023/2024).

*Source: based on data from the National Council of Wine Communities (2025), author’s own calculations and editing.*

Some areas, such as the Kunság and Hajós–Baja wine districts, followed a development path oriented towards volume and yield, while others – for example Csongrád and the Balaton Highlands – moved into a position of territorial loss due to declining area, yields and production capacity. In the case of the Badacsonyi and Eger wine districts, a dual trend can be observed: although area and quantity decreased, yield efficiency or specific production improved in certain years. Overall, the period examined shows that differences between Hungarian wine districts did not diminish but intensified. While a few export-oriented and capital-strong regions were able to expand production, smaller wine districts based on family farms moved into structural and market disadvantage. This process also justifies further analysis of the territorial effectiveness of support policies. Several “crisis years” can be identified in the 2011–2024 time series (Figure 12). The drought years 2012 and 2022 caused drastic declines in harvested quantities, especially on the Great Plain.



2024. The grey bands mark the outstanding crisis years (2012 and 2022 drought, 2020–2021 COVID–19).

*Source: based on data from the National Council of Wine Communities (2025), author’s own calculations and editing.*

During the COVID–19 pandemic (2020–2021), declining demand and the shutdown of hospitality caused temporary market losses, which were partly mitigated by crisis-management supports such as crisis distillation and green harvesting. By contrast, 2013 and 2018 were exceptionally good vintages, when favourable climatic conditions led to record yields.

In some wine districts opposite trends also emerged: for example, the Badacsony wine district achieved yield growth despite decreasing area, while in the Csongrád wine district both yields and wine production practically collapsed after 2020. These examples highlight that, alongside long-term structural trends, short-term climatic and market shocks also decisively influence the performance and sustainability of wine districts.

### ***3.2.3. Complex Support Intensity Index (KTII) and Wine-District Trends***

Three basic indicators were included to assess the support intensity of wine districts:

- support amount per hectare (HUF/ha),
- support amount per litre (HUF/hl),
- and average support amount per transaction (HUF/transaction).

The joint examination of these three indicators provides a comprehensive picture of the support processes between 2011 and 2024 and of the internal logic of resource allocation.

The results of the analysis show clear spatial and structural polarisation. Smaller, quality-oriented wine districts – such as Szekszárd, Pannonhalma, Villány and Pécs – received much higher support intensity per unit than the larger, volume-oriented wine districts geared to mass production. By contrast, the Kunság and Eger wine districts – although they account for a substantial share of national winery output – received lower specific support. Peripheral wine districts such as Csongrád, Zala and the Balaton Highlands were situated in the lower band of the support hierarchy both in absolute and relative terms.

This differentiation clearly reflects that support policy shifted its centre of gravity towards quality- and premium-oriented production areas, while large-volume but lower value-added production received less targeted support (Figure 13).

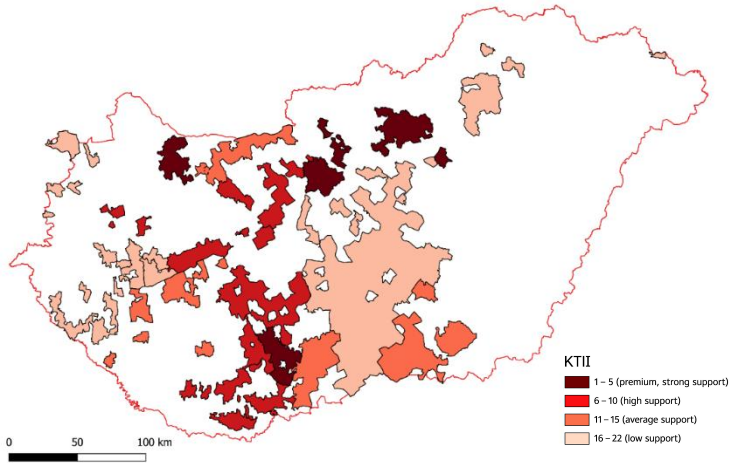


Figure 13: Distribution of the Complex Support Intensity Index (KTII) by wine district, based on 2011–2024 averages.  
*Source: based on data from the Hungarian State Treasury (2025), author’s own calculations and editing*

The Complex Support Intensity Index (KTII) is built from the normalised values of the three basic indicators (HUF/ha, HUF/hl, HUF/transaction) and expresses the support performance of wine districts in an integrated way. A low KTII value is characteristic of support-intensive wine districts, where above-average resource absorption occurred in all three dimensions (for example in the Szekszárd, Pannonhalma and Mátraalja wine districts). By contrast, a high KTII value indicates lower support activity per hectare, per litre and per transaction – including, among others, the Balaton Highlands, Zala and Csongrád areas.

Thus, the KTII serves simultaneously as a composite indicator and as a territorial diagnostic tool: it shows which wine districts benefited most from the support cycles of 2011–2024

and where the intensity of resource absorption lagged behind. The spatial distribution clearly demonstrates regional fragmentation: the wine districts of Southern and Central Transdanubia are in the most favourable position, while the Danube Wine Region and peripheral areas represent lower support weight.

The results also confirm that the Hungarian winery support system did not strengthen wine districts evenly. Smaller wine districts with high quality potential received disproportionately greater support intensity, while large, volume-oriented areas obtained fewer resources per unit. This structural polarisation is expected to persist in the long run and may even deepen further unless support policy specifically addresses the financing lag of disadvantaged peripheral wine districts.

The KTII analysis made it possible to uncover the spatial patterns of past resource allocation and thus to lay the foundations for a fairer and more differentiated future support system that would serve not only quality development but also territorial equalisation.

### ***3.2.4. The Relationship Between Production and Support***

The aim of the examination was to determine whether a statistically significant relationship could be detected between the intensity of winery supports and the production performance of wine districts. During the 2011–2024 period, supports were implemented under several titles – for example restructuring, crisis distillation, promotional and investment programmes, and HORECA measures – but the central question of the research was whether their specific magnitude showed any relationship with the economic performance of wine districts.

The relationship was examined in two main dimensions. First,

the relationship between support intensity per hectare (HUF/ha) and average wine yield (hl/ha) was analysed in order to reveal any yield-increasing effect of supports; second, the relationship between support per litre (HUF/hl) and the size of vineyard area (ha) was examined to identify how the specific level of support changes in the case of wine districts with larger areas.

At national level, the analysis revealed a strong negative relationship between support intensity and production indicators. In both dimensions – per hectare and per litre – significant, moderately strong or very strong negative correlations were obtained. This means that in wine districts where the specific value of support was higher, the level of production (yield or area) generally remained lower.

Analyses at the wine-district level confirm that the relationship between supports and production indicators appears in a heterogeneous way across areas.

Analyses broken down by wine district further confirmed that the relationship between supports and production indicators is not homogeneous.

In premium-oriented wine districts, supports played more of a stabilising and crisis-management role, whereas in areas based on large-volume production (such as the Danube Wine Region) resources served to maintain production capacity. Supports therefore often went where production was weaker or where market protection and income stabilisation were the goal. By contrast, large wine districts with stable production – such as Kunság and Hajós–Baja – received less support per unit.

The typology also confirms that support intensity and production performance are not linearly related. In quality-oriented, terroir-based wine districts, supports served structural renewal and market resilience, while in lowland, volume-oriented areas the main goal was the stabilisation of production. This differentiated effect contributes to the

persistence of structural polarisation among wine districts. A specific feature of support policy is that it did not aim to expand production but rather to preserve the viability of more vulnerable wine districts.

Our results are consistent with the earlier literature, which pointed out that crisis-management and restructuring programmes (e.g. crisis distillation and green harvesting) are primarily tools of market stabilisation rather than mechanisms of increasing output.

After the correlation analyses, the research also examined the relationship between supports and production using a regression model. The dependent variable of the model was wine production (hl), expressing the annual aggregated performance of wine districts. Three explanatory variables were included in the model:

1. Support/ha (HUF/ha) – support intensity per hectare,
2. Support/hl (HUF/hl) – support intensity per litre,
3. Support/transaction (HUF/transaction) – average transaction value, indicating the concentration of supports.

The national-level regression results showed low explanatory power ( $R^2 = 0.083$ ), suggesting that the volume of wine production was influenced primarily not by the magnitude of supports but by other factors such as weather conditions, market circumstances and production structures. Supports therefore did not directly increase production performance but rather stabilised it.

Differences between wine districts further reduced the overall explanatory power of the model: in some areas (e.g. Kunság, Badacsony) a slight positive relationship could be detected, while in others (e.g. Balaton region, Hajós–Baja) a negative association prevailed. Winery supports had spatially differentiated effects and were primarily equalising rather than growth-promoting in character.

### ***3.2.5. Polarisation and Centre–Periphery Patterns***

The territorial distribution of supports between 2011 and 2024 was consistently more unequal than the distribution of production volumes, indicating that the differences between wine districts did not decline but became fixed. During the period examined, wine-district polarisation not only persisted but, according to some indicators, even strengthened further. The large-volume lowland wine districts – although they produced a substantial share of total output – received lower specific support levels, while smaller premium-oriented areas benefited from the resources to an outstanding degree. This support-policy distortion reinforces the stabilising, crisis-management character of the system, while also contributing to the conservation of structural differences.

The results of spatial autocorrelation and hotspot analyses made it possible to reveal the spatial-structural patterns of wine production and supports. These statistical methods show whether the distribution of indicators is random, clustered or dispersed, and in which wine districts significantly outstanding values can be observed. The study interpreted separately the absolute indicators – which represent the economic weight of wine districts and the magnitude of resources – and the intensity indicators, which describe the territorial characteristics of specific support levels and efficiency concentrations. On the basis of the absolute indicators, it became clear that wine districts with larger production volumes (such as Kunság or Hajós–Baja) tied up a substantial share of the resources, but in these areas the specific efficiency of supports was lower. By contrast, the intensity indicators – for example support per hectare or per litre – revealed the outstanding position of smaller, quality-oriented wine districts (such as Szekszárd, Villány and Pannonhalma). This duality clearly represents centre–periphery relations: central, premium-oriented wine districts

stand at the top of the support hierarchy, while peripheral mass-production areas – especially on the Great Plain – are pushed into the background from the point of view of resource allocation. The joint analysis of absolute and intensity indicators made it possible to assess the strategic priorities followed by support policy. The results show that resource allocation did not prefer large-volume production but rather placed greater emphasis on supporting quality-oriented, terroir-based wine districts. While this approach served to strengthen high value-added wineries, it also made the developmental differences between wine districts more persistent. Thus, supports reinforced not convergence but rather the persistence of spatial divergence.

The examination therefore proved that the differences between wine districts are spatially structured and that support policy followed a centre–periphery logic: it further strengthened stable quality centres while the lack of resources in peripheral areas remained. In this way, the support system – although it stabilised the sector in the short run – contributed in the longer term to preserving the territorial polarisation of Hungarian winemaking.

### **3.3. Discursive Patterns of the Terroir Approach and Regional Identity**

The analysis of the qualitative interviews examined the social, identity-related and cohesion-related dimensions of the terroir approach in the Danube Wine Region. The analysis was organised around four main dimensions: the interpretive framework of terroir, the intensity of regional identity, place-bound narratives and the perception of cohesion. The aim was to reveal what meanings the region’s winemakers attach to terroir, on what spatial scale they identify with their own producer environment, and how they interpret the possibilities of cooperation within the region.

According to the interviews, terroir appears within several discursive fields of meaning. One interpretation considers terroir an ecological and economic optimum in which soil, climate, varietal choice and market rationality are linked together. In this understanding, terroir is not a mystical endowment but rather a system of decision-making. Another interpretation treats the concept as a form of socio-economic embeddedness: here terroir is the interrelationship of livelihood, generational change, rural retention capacity and local economic stability. An agronomic-realist framework also appears, interpreting terroir through measurable parameters such as soil composition, aspect and water balance. The fourth interpretation is based on experience and life perspective: terroir is tied to one's own vineyard area, estate, use of place and personal presence. In this discourse, terroir is a way of life.

One of the most important findings of the interviews is the narrowing of identity in relation to spatial scale. The strongest identification appears at the level of the estate, the specific site and the local variety. For winemakers, "our own soil," Arany Sárfehér, Ezerjő or another local specificity functions as a strong carrier of identity. At the level of the wine district, identity intensity is also perceptible, especially in the case of Kunság, which appears in several interviews as a strengthening territory receiving positive feedback. At the level of the Danube Wine Region, however, identity thins out. The region appears too large, heterogeneous and difficult to communicate; it is interpreted more as an administrative, application-related or internal management framework than as a consumer-facing or collective identity core. The structure of spatial scale can thus be described as follows: estate – local variety – wine district – weak wine region.

Attachment to place appears in three main narratives. The first is variety-based distinction, where unique grape varieties function as means of communicating local difference and

independent character. The second is the narrative of technological authenticity, in which the extent of winery intervention becomes the central issue; a cleaner expression of both variety and site is associated with the authentic manifestation of terroir. The third is the experience narrative, which interprets the estate as a living space, a tourism experience and a personal locality.

Perception of cohesion is ambivalent. Professional consultation, informal knowledge sharing and joint event participation do exist, yet the protection of one's own market and brand is strong. The system can therefore be described as decentralised autonomy: there is cooperation, but no strong common regional brand or unified varietal concept emerges.

The qualitative analysis identified four discursive actor types: integrated rationalist, social-strategic rural developer, agronomic realist and experience-based localist. The main conclusion is that the terroir approach becomes stronger at the wine-district level, while at the level of the Danube Wine Region it does not become the primary identity framework. The region functions more as a formal institutional space than as an internally built collective identity. This pattern suggests that terroir, as an agro-ecological category, is simultaneously a multi-level social process of lived space, representation and institutionalisation.

## **4. CONCLUSIONS AND RECOMMENDATIONS**

The overall aim of the research was to reveal the conditions of structural, ecological and social renewal in Hungarian wine districts – especially in the Danube Wine Region. The results clearly proved that the spatial structure of the wine sector, site endowments and social dynamics are closely interrelated, and that these three dimensions jointly shape the development trajectories of wine districts. The novelty of the dissertation lies in examining these relationships with integrated GIS-based, statistical and social-geographical methods, treating wine districts as an ecological–economic–demographic system.

### **4.1. Main Findings of the Research**

The research revealed the agro-ecological, spatial-structural, support-policy and social characteristics of Hungarian wine districts, with special regard to renewal processes and the situation of the Danube Wine Region. The results show that vineyard renewal is linked primarily not to administrative wine-district categories but to ecological and spatial-structural endowments. Soil suitability, climatic conditions – especially precipitation patterns – and parcel structure jointly determine the spatial probability of renewal.

Regression and spatial-statistical analyses showed that official wine-district delimitations explain the spatial differences of the renewal index only to a limited extent. Renewal is not an isolated municipal phenomenon but a process organised at regional scale: the spatial coexistence of renewal hotspots and lagging areas indicates the importance of the ecological and economic context of surrounding territories.

The differing historical development trajectories of Hungarian wine districts also determine present-day patterns. In particular, strong path dependence can be observed in

lowland, volume-oriented wine districts, appearing in landholding and parcel structure, weaker renewal dynamics and lower regional resilience.

Based on the agro-ecological typology, the development of wine districts can be effective only with a differentiated policy logic. In homogeneous large-scale wine districts, climate adaptation and water-management adaptation should be central; in homogeneous terroir districts, strengthening quality potential and terroir character; in transitional districts, internal differentiation; and in heterogeneous districts, the conscious management of diversity.

The research also identified non-wine-district municipalities whose ecological endowments and hotspot status align them with neighbouring wine districts. This confirms that current wine-district delimitations do not always reflect agro-ecological realities, and that designating internal eco-zones or fine-tuning boundaries may therefore be justified.

The research confirmed that the differences between Hungarian wine districts are structural in nature. The renewal index, agro-ecological typology and spatial-statistical analyses are jointly suitable for identifying vulnerable areas, especially the Danube Wine Region, and for underpinning a territorially differentiated, ecologically based reconsideration of support policy.

## **4.2. General Policy Lessons**

Based on the empirical results, it can be stated that the support system of the wine sector does not convey a uniform development logic but fulfils different functions across territories. In some wine districts, supports serve to strengthen quality concentration and terroir-based competitiveness, while in other areas – especially in the Danube Wine Region – the stabilisation of structural survival and operational viability becomes dominant. This duality stems not from inconsistency

in the system but from the differing agro-ecological and spatial-structural positions of the wine districts.

(1) The wine-related measures of the Common Agricultural Policy played an effective stabilising role in the short run, but they did not generate meaningful growth in performance or productivity. Crisis-management programmes – especially during COVID–19 and drought years – were indispensable for the survival of wineries, but they did not contribute to long-term structural renewal.

(2) The differences between wine districts did not diminish during the period examined; rather, they increased. Premium-oriented wine districts received higher levels of support and development resources per unit, while lowland volume-oriented regions operated at lower support levels per unit. The unified support logic thus had not an equalising but a polarising effect.

(3) Crisis-management instruments and long-term development instruments are not functionally interchangeable. Crisis distillation and market stabilisation measures are indispensable in the short run, but they are not suitable for handling problems of overproduction, quality and landholding structure. A conscious separation of restructuring-oriented interventions is therefore justified from the perspective of policy design.

(4) Strategic investment and innovation programmes supported primarily the development of quality-oriented wine districts, while the relative disadvantage of the lowland volume regions increased. This trend carries the long-term risk of a split within the Hungarian wine sector. On the basis of these lessons, the Danube Wine Region requires special policy attention. Due to its size, production volume and market weight, it plays a decisive role in the structure of the domestic wine market, yet its large-block, homogeneous, quantity-oriented structure is highly vulnerable to climate and market shocks. The support analysis showed that specific

support amounts in the region are low and resources are fragmented, which does not favour a turn towards quality and innovation. All this justifies a targeted, complex intervention programme for the Danube Wine Region aimed at correcting the production structure, encouraging a quality transition and improving adaptive capacity. In this sense, the support space may be interpreted not merely as a resource-allocation mechanism but as an active shaper of rural spatial structure.

### **4.3. Proposal Package for the Danube Wine Region**

The empirical results of Chapter 6 together with the discursive analysis of Chapter 5.3 show that the Danube Wine Region requires a specific development logic. The problem of the area is not simply a low level of specific support, not exclusively climate vulnerability, and not merely a lag in quality, but a structural and identity-related duality in which renewal is local and patchy, while cohesion and coordination at regional level are weak. The current functioning of the region is a network of decentralised autonomies in which cooperation among actors is pragmatic but does not follow an integrated development path. Consequently, rather than a single isolated policy instrument, a three-level intervention logic built upon one another may offer a solution for the Danube Wine Region. First, ecological adaptive capacity must be strengthened, with special regard to water-management and climate-adaptation challenges. Second, the incentives of the support system need recalibration so that quality transition rather than quantitative stabilisation becomes the dominant development direction. Third, it is indispensable to create the minimum institutional conditions for regional-level coordination and cooperation, capable of linking local initiatives and transforming the mosaic structure into a more structured development trajectory. The recommendations presented below are formulated along these three strategic pillars. My objective is

the gradual correction of the Danube Wine Region and its shift towards a quality-oriented path, in line with the long-term competitiveness and sustainability goals of the Hungarian wine sector. The results of the research highlighted that in the Danube Wine Region – especially in the Kunság wine district – the production structure is predominantly based on mass production, characterised by low unit costs, high yields and a high degree of mechanisation. This model secures quantity-oriented production in the short run, but in the longer term it may jeopardise the quality ambitions of the Hungarian wine sector and damage the international perception of Hungarian wines. The intervention directions below designate policy instruments that are in line with the results of the dissertation: they aim, on the one hand, to mitigate polarisation and, on the other, to encourage a quality-oriented transition.

1. Introduction of mandatory yield limits. According to the analysis, the currently voluntary yield-limiting instruments (e.g. green harvesting) have not proven effective in the Danube Wine Region. Overproduction may lead to market distortions, therefore the introduction of mandatory upper yield limits may be justified in certain areas. This could be complemented by a compensation mechanism (income support and investment support) that encourages producers to switch to quality-oriented varieties.
2. Regulation of grape and wine transfers between wine regions. The research showed that the winery operations of the Danube Wine Region process significant amounts of grapes and wine originating from other wine regions, which may distort the economic and market image of the region. From a policy perspective, it may be justified to introduce stricter regulation similar to that of the Tokaj wine district: separate labelling, accounting and control of transferred products. This would increase consumer trust and strengthen the system of origin protection.

3. Creation of a differentiated support system for quality-oriented producers. The current support system differentiates only to a limited extent between quality-oriented and volume-oriented producers. According to the results of the dissertation, premium-oriented wine districts (e.g. Szekszárd, Villány, Pannonhalma) received much higher support intensity per unit, while resource use remained lower in lowland areas. It would be justified to create a new support tier for those who demonstrably produce premium wines with lower yields, environmentally friendly technology and protected designation of origin. The Hajós–Baja wine district may serve as a good example, where quality orientation is already stronger in production.
4. Reconsideration of the status of the Csongrád wine district. According to several indicators (territorial shrinkage, high share of unprocessed grapes, peripheral position), the Csongrád wine district is moving on a path of marginalisation. Rethinking its status is possible in several ways: integration into the Kunság wine district, the creation of a special functional category, or the launching of a targeted intervention programme to expand processing capacity and strengthen producer integration. The necessity of this step is underpinned by the fact that supports have so far not proven sufficient to mitigate decline in peripheral areas.
5. Training, awareness-building and innovation programmes. A key to the more sustainable functioning of the Danube Wine Region is the strengthening of a quality-conscious mindset. Based on the findings, targeted training programmes (courses on varieties, sustainable winemaking) and the promotion of innovation in precision viticulture and quality assurance are justified. Agricultural higher-education institutions (University of Szeged, MATE) can play a key role in this process.

These interventions may have significant effects not only at regional level but also nationwide, since because of the weight of the Danube Wine Region the competitiveness and structural balance of the Hungarian wine sector as a whole depend on it.

#### **4.4. Scientific and Methodological Recommendations**

1. The applied GIS and statistical models (SSI, Eco-index, KTII, RI) could in the future be developed into a nationwide decision-support system that could assist the evaluation of CAP programmes.
2. The methodology is also suitable for international comparisons, especially in the context of the Carpathian Basin and Mediterranean wine districts.
3. Annual updating and open-access publication of spatial-temporal datasets would strengthen the transparency and researchability of the sector.

#### **4.5. Summary Scientific Theses**

As a summary of the research, the following scientific theses can be formulated:

1. T1: The structural and ecological characteristics of wine districts determine the conditions of economic and social renewal – the low ecological potential and high degree of fragmentation of the Danube Wine Region are key factors behind its development lag.
2. T2: The Complex Support Intensity Index (KTII) is a new integrated indicator suitable for the spatial comparison of the effectiveness of winery supports.
3. T3: The Renewal Index (RI) is demonstrably suitable for measuring demographic and social regeneration and correlates with the innovation performance of wine districts.
4. T4: In the Hungarian wine sector, support-policy and

social processes have temporally differentiated effects – development shows lasting impact only where the human and community conditions are in place.

5. T5: The sustainability of wine districts can only be ensured in the long term through an integrated territorial approach that combines agro-ecological, economic and social-development dimensions.

## **5. NEW SCIENTIFIC RESULTS**

New Scientific Results (summary – thesis booklet)

Through the complex – ecological, economic and social – examination of the municipalities of the Danube Wine Region, the research produced several interrelated methodological and substantive innovations.

1. Eco-index (indicator of ecological potential)  
One of the most important results of the dissertation is the development of a new multidimensional eco-index built on the integrated assessment of soil conditions, water balance, relief and bioclimatic factors. The index is operationalised at municipal level and scaled between 0 and 1, enabling a comparable ecological ranking of territories (low-to-high potential categories). Its application creates a new empirical basis for examining the spatial structure of wine districts.
2. Complex Territorial Innovation Index (KTII)  
A new methodological contribution of the research is the KTII, which serves the integrated measurement of support intensity, innovation potential and economic performance. At municipal level the indicator can reveal centre–periphery differences and the spatial concentration of supports. The KTII system of indicators is suitable for targeting development-policy interventions and for the typification of territories.
3. Systematic application of spatial-statistical methods

The dissertation was the first to consistently apply global Moran's I, local Moran's I (LISA) and Getis-Ord  $G_i^*$  indicators in the municipal-level analysis of the wine region. These procedures make it possible to identify hotspot (HH), coldspot (LL) and transitional (HL, LH) areas, showing the spatial organisation of renewal, ecological and support patterns.

4. Integration of ecological and economic indicators  
The combined application of the eco-index and the KTII opened a new analytical dimension: it became possible to show that the spatial distribution of support resources does not always coincide with favourable ecological conditions. This discrepancy points to the limits of the spatial rationality of the support system and provides a basis for its recalibration.
5. New municipal typology: The research created an integrated regional typology by combining the eco-index, the KTII and spatial-statistical clusters. The typology is both analytical and decision-supporting, because it positions municipalities according to ecological potential, economic strength and support level. This enables targeted, differentiated development policy.
6. International adaptability: The methodological framework – especially the composite indices (eco-index, KTII), the spatial-statistical tools and the typology-building procedure – can also be applied in other regions. Given an appropriate database, the model is exportable to other wine areas, especially in Central and Eastern Europe, and thus has international relevance.
7. Mixed-method integration (quantitative + qualitative)  
The research integrates GIS and spatial-statistical analyses with qualitative discourse analysis. This approach makes it possible to interpret structural patterns (e.g. hotspots and clusters) and actor-based meaning constructions (interpretations of terroir, identity, cohesion) in relation to

one another.

One of the key statements of the dissertation is that terroir is not merely an agro-ecological category but also a social and institutional construction. Space is simultaneously a lived, represented and institutionalised reality. If this is ignored, development policy is unable to grasp the true logic of the spatial functioning of the wine sector.

## 6. PUBLICATIONS OF THE AUTHOR RELATED TO THE TOPIC OF THE DISSERTATION

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2. Járdány, K. (2021b). Territorial distribution of winery development supports in Hungary between 2014 and 2020. *ÉSZAK-MAGYARORSZÁGI STRATÉGIAI FÜZETEK*, 18(1), 58–71. <http://doi.org/10.32976/stratfuz.2021.20>
3. Járdány, K. (2021c). Spatial analysis of certain population processes in the Danube wine region. *STUDIA MUNDI - ECONOMICA*, 8(3), 143–155. <http://doi.org/10.18531/Studia.Mundi.2021.08.03.143-155>
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5. Járdány, K. (2021a). Analysis of the viticultural and winery situation of the Danube Wine Region within the Hungarian grape and wine sector. *STUDIA MUNDI - ECONOMICA*, 8(1), 49–64. <http://doi.org/10.18531/Studia.Mundi.2021.08.01.49-64>
6. Járdány, K., & Duray, B. (2021). The impact of the COVID-19 pandemic on the Hungarian wine sector in the light of temporary support for wineries. *A FALU*, 26(4), 5–21.
7. Hajdú, D., & Járdány, K. (2020). TERRITORIAL DISTRIBUTION OF ADULT EDUCATION IN HUNGARY. In *CHANCES AND CHALLENGES FOR THE EUROPEAN RURAL DEVELOPMENT (2021–2027)* Peer-reviewed Scientific Conference

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