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Research paper

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Assessment of geological and geomorphological conditions for viticulture and enotourism development and landscape transformation: A case study of a rural municipality in the Silesia region, Poland

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Summary

This study assesses the impact of geological and soil conditions on viticulture and enotourism development amidst a changing Central European climate, using the rural commune of Hazlach, southern Poland, as a case study. Our aim was to determine how environmental parameters contribute to productive terroir and what role they play in the spatial and landscape transformation of rural areas. Presented methodological approach integrated a literature analysis, a comparative analysis of established wine regions in Austria, Germany, and the Czech Republic, and a detailed case study of Hazlach. This allowed for a standardized evaluation of soil and terrain characteristics, as well as climatic data. Results underscore the critical role of loose, well-drained, moderately fertile soils with specific mineral compositions in supporting vine growth, particularly in marginal climatic zones. Climate warming has become a key enabling factor, expanding viticultural potential into previously unsuitable areas. Furthermore, soil structure and microtopography significantly impact root development, crop quality, and yield consistency. The study demonstrates that the synergy of soil quality, terrain, and local climate is paramount for viticultural viability. These findings not only support the targeted expansion of vineyards in nascent regions but also emphasize how natural conditions shape a region's physical and socio-cultural landscape and land use, ultimately solidifying its identity as an emerging enotouristic destination.

Keywords

viticulture • terroir • soil conditions • climate change • landscape transformation

1. Introduction

Global climate change is contributing to the growing popularity of viticulture in areas previously unsuitable for it, including Poland in Central Europe, since the 17th century. Notably, favourable climatic conditions enabled wine production in Poland during the Middle Ages and the Renaissance, roughly from the 14th to the late 16th century. Currently, rising average temperatures are once again extending the growing season, allowing fruit to ripen to the required quality whilst milder winters reduce the risk of vines frosting [Olewnicki 2018, Brodnicka 2019, Galin 2023, Fraga et al. 2012].

Winemaking and related enotourism is experiencing a revival in Poland, and its development is attracting a growing number of supporters. Poland can be divided into six major wine regions: the Małopolska region, the Małopolska Vistula Gorge, the Podkarpackie region, the Lubelszczyzna region, the Lower Silesia region, and the Świętokrzyskie region [Winnice…, n.d., Olewnicki 2018, Brodnicka 2019, Kapczyński 2021]. In addition to this, some wineries are not located in the listed areas.

The rural municipality of Hazlach in Cieszyn County in the Silesian Voivodeship is noteworthy as it does not have a wine region within its borders yet. The commune lies within the Moravian Gate area of influence – a land depression between the Carpathian and the Sudeten mountains that acts as a natural air corridor. The Moravian Gate causes periodic increases in air temperature [Motłoch, n.d., Tudzierz 2021], influencing the region's climate, resulting in milder winters, smaller temperature amplitudes and increased circulation of air masses.

The municipality of Hazlach was chosen as the study area due to its favourable environmental conditions and growing potential for the development of winemaking and enotourism. The dynamic growth of the number of vineyards, the grassroots initiatives of winemakers, and the involvement of the local government in this sector of the municipality's development create good conditions for the further expansion of the wine industry. Taken together, these are factors that are currently influencing and will in the future significantly affect the rural structure and landscape of the commune [Buława and Nagel 2022, Stowarzyszenie Cieszyński Szlak Wina 2024].

A key term when assessing the impact of the environment on the landscape is the French term 'terroir'. The term refers to the unique set of climatic and habitat characteristics that together influence the nature of grapes and wine. Climatic conditions include temperature, sunlight and precipitation, while habitat characteristics include soil type, texture, mineral composition, and moisture retention [Bosak 2015, Rekowski 2023, Santorufo 2025]. The research aimed to identify the potential for viticulture and related ecotourism in the municipality of Hazlach in terms of soil conditions as a part of the terroir. This study investigates the relationship between geological and soil conditions in Hazlach for the potential expansion of winemaking and enotourism. Furthermore, it examines how these factors, in conjunction with climate change, create a new terroir in the municipality, also transforming its landscape. The objective was to highlight soil conditions, which are among the key factors determining vine cultivation in a given area. Although they have a limited impact on the quality parameters – (taste) of wine [Robinson et al. 2023], they contribute to significant changes in the landscape transformation of the commune.

In this context, the following research questions were formulated:

- What type of soil and soil conditions have the greatest impact on vine cultivation?
- Which of these soil and ground types play a key role in shaping the quality and abundance of crops?
- How do environmental conditions (especially soil), affect the possibility of viticulture and enotourism development in the rural municipality of Hazlach in Poland, and in consequence how do they influence its landscape transformation?

2. Methods of evaluation

The study was based on three methods that enabled a comprehensive assessment of soil and geological conditions affecting viticulture in the municipality of Hazlach: analysis of scientific sources, comparative analysis, and case study.

2.1. Literature analysis

The research process began with a literature analysis that covered the latest publications on the impact of soil conditions on viticulture, works dealing with current climate change, and specialist monographs on viticulture.

Sources describing the influence of climate, soil, and terrain on grapevine development were analyzed. The purpose of the analyse was to systematise knowledge about the environmental conditions necessary for successful cultivation and to compare them with the results of the comparative analysis and case study. An examination of the literature concerning the impact of climatic and habitat conditions on grapevine development in Poland highlights their interconnectedness and importance for crop optimisation. Most existing studies concentrate on the southern regions, particularly Małopolska and Podkarpacie, where the revival of winemaking in Poland originated. The Hazlach municipality is situated in Silesia, which lies west of these areas. Consequently, we have incorporated studies from the Małopolska and Podkarpacie wine regions in our analysis to deepen our understanding.

2.2. Comparative analysis as a tool of evaluation

The second method involved a comparative analysis of three selected wine regions in Europe: Rosalia in Austria, Saxony in Germany, and the Mikulov region in Czech Republic (Fig. 1, Table 1). These regions were selected based on two criteria:

- location is within a humid continental climate with a warm summer subtype climate (according to Köppen's classification: Dfb),
- similar terrain conditions, including solar exposure and optimal thermal and water conditions.

The Köppen climate classification, topographic maps, and maps of the locations of wine regions in Europe were used to select the three regions [Kottek and Rubel 2023]. For this method, the materials included basic thematic studies, academic textbooks, scientific monographs, publications from peer-reviewed scientific journals, and topographic, geological, and soil maps. The World Reference Base for Soil Resources system was utilised to standardize data, facilitating comparisons as each country employs its own classification method.

Source: Authors' own study based on Google Maps 2025.

Fig. 1. The location of the analysed cases and Hazlach

Table 1. The summary of climate and terrain features of the analysed cases

	Climate features			Terrain features		
Wine region / country	**Avg. annual temperature [°C]**	**Annual rainfall [mm]**	**Sunlight annually [h]**	**Approx. area [km²]**	**Terrain altitude above sea level (a.s.l.) [m]**	**Water resources**
1	**2**	**3**	**4**	**5**	**6**	**7**
Rosalia / Austria	11.00	726.4	2142	238	from 120 to 700 m most vineyards at 220 m	Wulka river
Saxony / Germany	9.3	819	1570	120	from 89 to 96 m, flat terrain in the Elbe valley	Elbe river
Mikulov / Czech Republic	9.5	662	1726	481	average altitude 175 m, valleys 144 m, hills up to 400 m	Dyje river with water dam Nove Mlýny; Ipoly and Sucha rivers
Hazlach municipality / Poland	about 10	about 900	1568	49	lowland, elevations from 250 to 300 m, relatively flat terrain	Olza river and its streams

Source: Authors' own study based on: Austrian Wine [2024], German Wine Institute [2025], Provozovatel [2025], VDP.Team [2025], Wine-Searcher [2025], World Wide Travel Organization [2025b, 2025a]

2.3. Case study – Hazlach municipality

The last method was a case study of the Hazlach municipality in Poland (Fig. 1, Table 1). It was based on documents discussing the local soil environment and state cartographic studies, and it involved an analysis of soil-agricultural maps, land and soil types, as well as data from the international portal topographic-map.com [topographic-map, n.d.], which allows topographic analysis of the study area. The analyses of the geological development of the region, the types of rocks, and the rock formations were also carried out.

This method has considered geographical, geological and climatic parameters, and landscape of Hazlach found in literature, municipality's urban planning documents, photo documentation, and area of interest mapping in the years 2022–2024. The contextual information about the municipality of Hazlach is presented below:

- location,
- settlement characteristics,
- landscape characteristics,
- socio-economic characteristics,
- climate.

2.3.1. Territory of Hazlach municipality

Hazlach is located in southern Poland, in a region bordered by the Czech Republic to the west (the Olza River), the municipality of Cieszyn to the south, Zebrzydowice rural municipality to the north, and the Dębowiec rural municipality to the east. The municipality's area is 49 km², of which about 67% is agricultural land. It is inhabited by about 10,800 inhabitants.

The municipality consists of six villages: Brzezówka, Kończyce Wielkie, Hazlach, Pogwizdów, Rudnik, and Zamarski (Fig. 2). The village of Hazlach dominates as the seat of the rural municipality. Advanced rural sprawl is visible across the municipality. Villages have a dispersed structure; only the village of Zamarski has a distinct centre. There are notable historical churches on the Wooden Architecture Trail (Szlak Architektury Drewnianej).

Source: Google Maps

Fig. 2. Overview of the municipality of Hazlach

The municipality is characterised by fragmented small-scale agricultural and vernacular landscapes. Varied land use is visible (cropland, farming, forest, water bodies) with medium forest cover. The topography of the municipality is slightly hilly with the web of ponds in the eastern part as a special landscape feature (Fig. 3).

The municipality is undergoing significant economic and demographic development. Between 2017 and 2019, municipality saw an increase in both income and expenses in terms of municipality agriculture. In the village of Kończyce Wielkie, the Chateau Kończyce Wielkie Vineyard – the first winery in the municipality – was established in 2020 as part of the planned development under the Cieszyn Wine Route Association (Fig. 4) [Stowarzyszenie Cieszyński Szlak Wina, 2024].

Photo: B. Buława, 2024.

Fig. 3. View of Hazlach municipality's landscape

Photo: B. Buława, 2024.

Fig. 4. The Chateau Kończyce Wielkie Vineyard

2.3.2. Climate conditions

The Hazlach municipality is located in a region with a warm temperate transitional climate, according to the Köppen system. This climate is characterised by warm and high-precipitation summers, along with cool and relatively dry winters, detailed in Table 1. The variability in weather conditions can be attributed to the influence of air masses from both northern and southern directions, which penetrate the municipality through the Moravian Gate (a regionally significant atmospheric corridor). An examination of meteorological data from institutions such as IMGW-PIB and meteoblue by Windy.com reveals notable alterations in the local microclimate. The average annual temperature in the municipality increased from 7.6°C in 2010 to 10.9°C in 2024, indicating a pronounced warming trend. Furthermore, data from meteoblue indicate that all monthly temperature readings have surpassed their respective long-term averages since mid-2023 [meteoblue, n.d.]. Concurrently, there has been a gradual reduction in total precipitation levels. In 2024, the annual precipitation figure aligned with the long-term average, suggesting a potential stabilisation of precipitation at a lower threshold. Regarding insolation, the Hazlach municipality was identified as one of the least insolated regions in Poland during the summer months of 2010, with an average of approximately 550 to 600 hours of sunlight. However, as a consequence of the ongoing climate change, the average number of hours of sunlight during the summer has risen to between 750 and 800. The average number of hours of sunlight in summer recorded from 1991 to 2020 ranged between 700 and 750 hours, further substantiating the upward trend observed in recent years [IMGW-PIB, n.d.].

3. Results

3.1. Literature analysis

3.1.1. Geomorphology and soil types

According to existing literature, optimal soil and topographical conditions are essential in the selection and development of vine crops. Numerous studies indicate that factors such as soil type, slope orientation, and water availability significantly influence the quality and attributes of the wine produced.

Habitat characteristics, such as soil quality and land exposure, are an important element in balancing climatic difficulties. Olewnicki [2018] pointed out that suitable soils with a permeable, nutrient-rich structure can compensate for thermal and moisture deficiencies during fruit ripening. In turn, Bachowski et al. [2010] stated the importance of soils with good water holding capacity in regions with large climatic fluctuations, stressing that compact loamy-sandy soils can protect vines from frosts and droughts. In the context of Małopolska, Kruczek [2018] noted that the landscape and geological diversity of the region offer locations with soils that meet the standards of good vineyard habitat, further enhancing the climatic potential of the region. The substrate for grapevines should have specific properties that allow both water retention and rapid drainage. Poor and dry soils that are unsuitable for growing other crops can be suitable for vineyards, provided they are permeable, airy, loose, and moderately moist [Mysliwiec 2008]. Another important aspect is their ability to heat up quickly, which promotes plant growth. Grapevines badly tolerate compact and dense soils in which water stagnates close to the surface, as well as soils with a shallow depth, exposed to frost in winter. The optimal groundwater level should be at a depth of 2 to 3 m [Kruczek 2009, Włodarczyk 2010, Rzeszotarska-Pałka 2012, Gembara 2021]. Soil pH, ranging from 6.0 to 7.2 pH, is another parameter affecting grapevine cultivation. Neutral or slightly acidic soils, formed from suitable bedrock, such as carbonate or some volcanic rock, provide good chemical conditions. The alkalinity or acidity of the soil is directly related to the type of rock it was formed on, which should also be considered when choosing a location for a vineyard [Myśliwiec 2008, Bosak 2010, 2013]. The terrain is yet another important aspect, which affects insolation and air circulation, as noted by Bokwa and Klimek [2009]. Their study of the Wieliczka Foothills indicated that sunny slopes, especially those with southern and southwestern exposures, improve microclimatic conditions and thus support vine development. Similar conclusions were made by Kruczek [2018], who highlighted that the lofty slopes of Małopolska allow the fruit to ripen longer on the vines, resulting in higher quality. However, Galin [2023] warned that in regions with high altitude differences, precipitation and temperature can significantly hamper crop efficiency [Bokwa and Klimek 2009, Kruczek 2018, Galin 2023].

The stony and gravelly fraction of soil comprises particles larger than 2 mm, predominantly derived from the weathering of bedrock. This fraction is characterised by large grain size and inherent voids, resulting in high permeability and substantial aeration. However, these soils exhibit poor capacity for water and nutrient retention [Soil Survey Staff 1999, Chohura 2021, Juras 2021]. Furthermore, the presence of larger particles may impede the mechanisation of agricultural practices and the development of root systems [Chohura 2021]. Sands, defined as particles ranging from 0.063 to 2.0 mm, are primarily composed of quartz and silica. Their incorporation into the soil matrix is associated with elevated permeability, diminished water retention, and an acidic pH, particularly in the case of aeolian sands [Chohura 2021]. While sandy soil exhibit rapid warming, they are typically nutrient-deficient and thus necessitate extensive fertilisation in order to optimise agricultural production [Soil Survey Staff 1999]. Dust grains, with diameters ranging from 0.002 to 0.063 mm, play a significant role in improving water retention and facilitating capillary rise. They contribute to the formation of soil aggregates and enhance overall soil structure. However, when present in excessive quantities, they can exacerbate erosion processes [Chohura 2021]. The influence of dust on soil characteristics is indirect - while it improves certain physical properties, its sorptive capacity remains moderate [Soil Survey Staff 1999, Ryżak et al. 2009]. The finest soil particles, defined as those less than 0.002 mm in size and rich in clayey minerals (kaolinite, illite, montmorillonite, smectite, etc.), are fundamental to soil compactness, viscosity, and plasticity. This fraction is particularly effective in enhancing water retention and contributing to the soil's sorption complex. However, an overabundance of clay can adversely affect air-water relations and overall permeability [Soil Survey Staff 1999, Soil Science Division Staff Agriculture 2017]. Despite this potential drawback, the presence of clay is crucial for maintaining soil fertility and its capacity to retain cations, thereby supporting plant growth and ecosystem health [Chohura 2021].

Structure (…) [2019] states that vines can extend their roots up to 30 m deep into the soil (an extreme, rare value). Normally, maximum root depth for grapevines is up to 6m, making it possible for a small fraction of roots to reach 20 m. That highlights that robust root development is crucial for attaining high-quality fruit. The vine's root system has a bundle-like structure, enabling the roots to grow both horizontally and vertically in pursuit of nutrients [Rijal and Bergh 2016, Structure… 2019]. This adaptability allows the vine to flourish in a wide range of growing conditions. The root system's development depends greatly on the soil profile. In fertile soils with proper irrigation and aeration, vines typically do not need to delve deep, with most roots found at depths of up to 1 m. However, individual roots can reach depths of up to 10 m when growing in less favourable soil conditions. In instances of poorer soil quality, particularly when the soil is highly permeable and of average fertility, the roots tend to grow deeper in search of water [Hellman 2003, Rijal and Bergh 2016, Structure… 2019].

3.1.2. Influence of global warming

Kruczek (2018) emphasised that the continental climate of the Małopolska Wine Route region, with harsh winters and a shorter growing season, can pose challenges for grapevine production. Nonetheless, thanks to their specific microclimates, the best sunlit hills and slopes create favourable conditions for vine development. In a similar vein, Galin [2023] noted that late spring frosts and short growing seasons are a major constraint in northern wine regions in Poland, but properly selected habitats can effectively limit their negative impact. Climate warming, as discussed by Olewnicki [2018] and Galin [2023], is leading to a northward shift of grape growing zones, increasing production opportunities in Poland [Olewnicki 2018]. Galin stated that rising average annual temperatures and milder winters favour grape growing, even in regions previously considered too cold [Galin 2023]. However, extreme weather phenomena that occur in Poland are also a determinant factor for vineyards' survival. Olewnicki stressed that mitigating climatic difficulties requires synergy with soil quality and microclimate. In particular, Bachowski et al. [2010] emphasised the importance of soil as an element that stabilises growing conditions, especially in regions exposed to variable weather conditions [Bachowski et al. 2010, Kruczek 2018, Olewnicki 2018, Galin 2023].

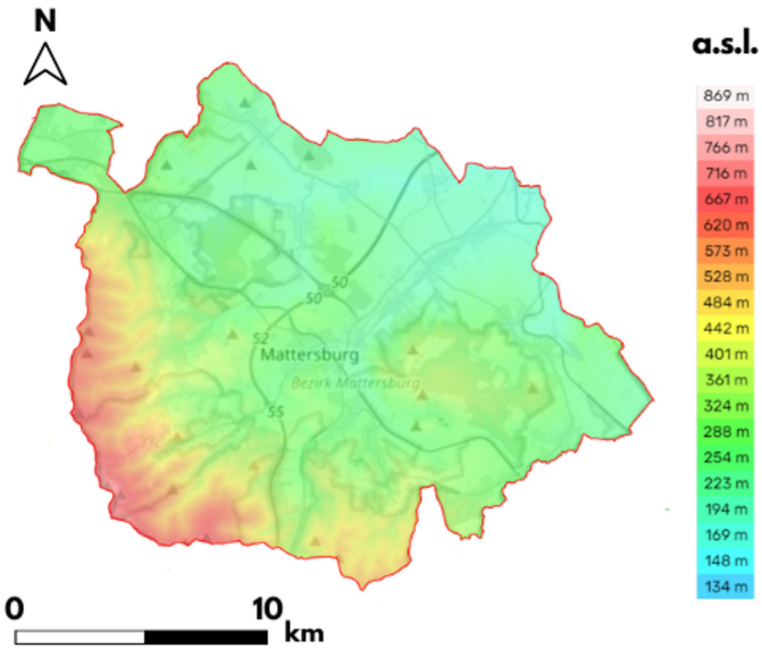
In conclusion, the consulted references indicate that both climate and habitat are both crucial for viticulture. Climatic conditions form the basis for establishing a vineyard, while soil quality and microclimate can effectively promote plant growth even under less favourable conditions. The interaction of these factors, coupled with the right terrain and the use of modern agricultural technologies, makes it possible to achieve optimal production results. Another, no less important benefit is the future transformation of the landscape of Hazlach.

3.2. Comparative analysis of selected well-recognised wine regions

A comparative analysis involved three prominent European wine regions: Rosalia in Austria, Saxony in Germany, and Mikulov in Moravia in the Czech Republic (Fig. 1, Table 1). The objective of this analysis was to explore how soil conditions and terrain influence viticulture across varying climatic contexts, utilizing environmental and geographical data.

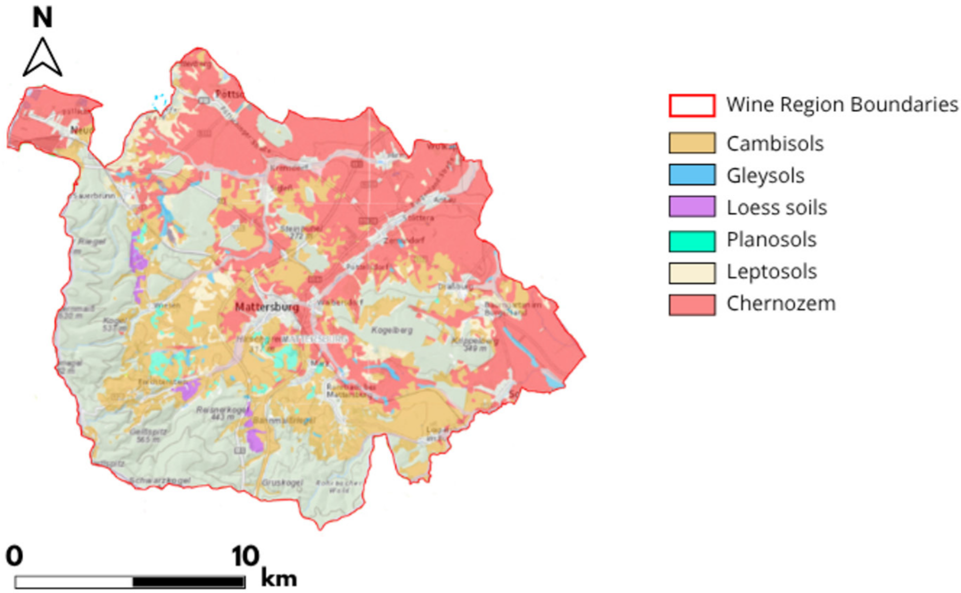
3.2.1. Rosalia region in Burgenland

The **Rosalia region**, situated in the Austrian province of Burgenland, is characterised by its gentle topography, with elevations ranging from 120 to 700 meters above sea level (a.s.l.). Most vineyards are positioned at height around 220 m a.s.l. (Fig. 5). Although the availability of water resources is limited, primarily provided by the Vulka River, the soils within this region exhibit exceptional fertility. The dominant soil types include chernozem, brown soils, and rendzina (Fig. 6). These soil factors, combined with a temperate climate (average annual temperature of 11°C) and the highest recorded annual sunlight hours among considered the regions (2,142.6 hours), create optimal conditions for viticulture, particularly for red varietals. The region receives an average annual precipitation of 726.4 mm, which maintains a favourable water balance without presenting the risk of excessive moisture [Austrian Wine 2024].



Source: Authors' own study based on: topographic-map [n.d.]

Fig. 5. Topographic map of Rosalia wine region (Austria)

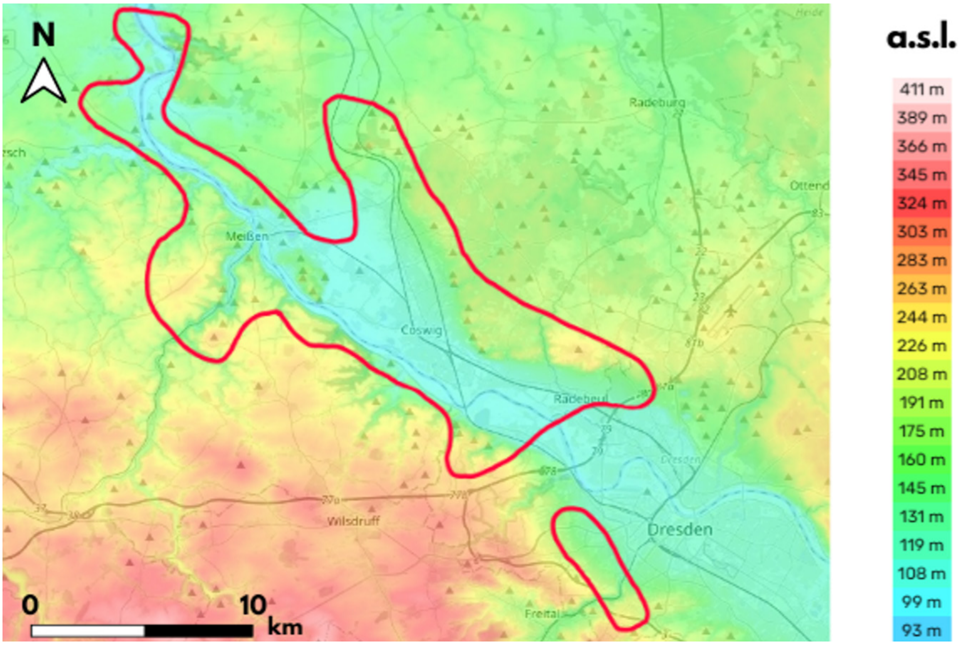


Source: Authors' own study based on: Austrian Wine Marketing Board [n.d.], Federal Research and Training Centre for Forests [2023]

Fig. 6. Soil map of the Rosalia wine region (Austria)

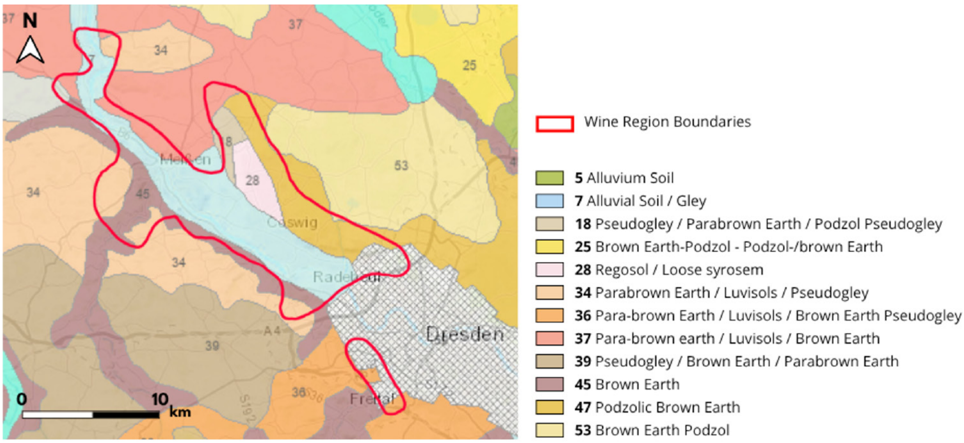
3.2.2. Saxony region in East Germany

The **Saxony region**, located along the Elbe Valley in Germany, represents one of the country's smallest wine regions, characterised by low elevations of 89 to 96 m and predominantly flat terrain (Fig. 7). Despite the region's less advantageous climatic conditions, including an average temperature of 9.3°C, 1,570 hours of sunlight per year, and the highest rainfall at 819 mm, Saxony benefits from diverse soil types. These soils include alluvial soils (noted for their high fertility), regosols (which are poor and not typically used for agriculture), and brown soils (Fig. 8). The proximity to the Elbe River serves as a vital irrigation source, mitigating the challenges posed by comparatively reduced sunlight exposure. This interplay of soil quality and water access facilitates local viticulture, although the limitation in sunlight may influence the quality and selection of grape varieties cultivated [German Wine Institute 2025, VDP.Team 2025, Wine-Searcher 2025, World Wide Travel Organization 2025a].



Source: Authors' own study based on: topographic-map [n.d.]

Fig. 7. Topographic map of Saxony wine region (Germany)

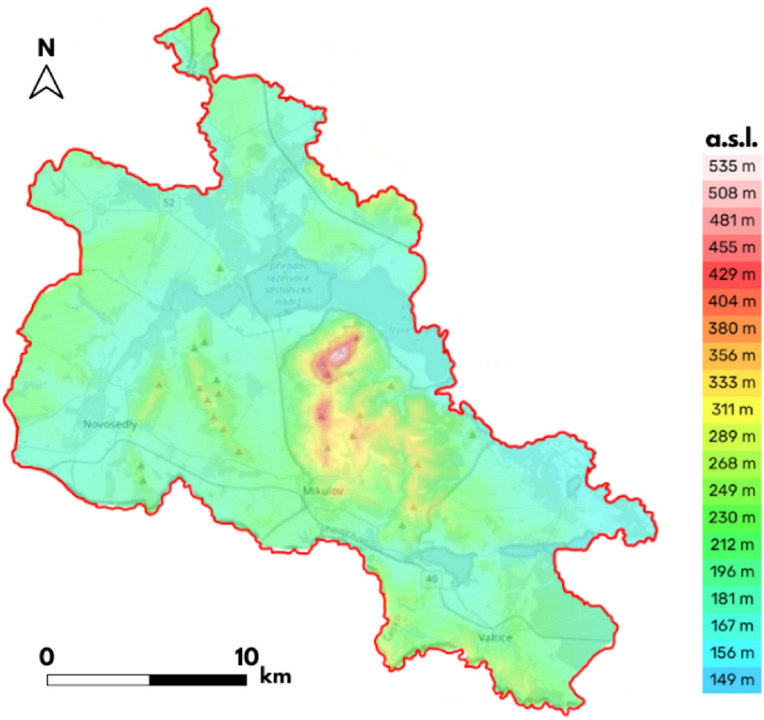


Source: Authors' own study based on: Geoportal of the Federal Institute for Geosciences and Natural Resources [n.d.]

Fig. 8. Soil map of the Saxony wine region (Germany)

3.2.3. Mikulov region in South Moravia

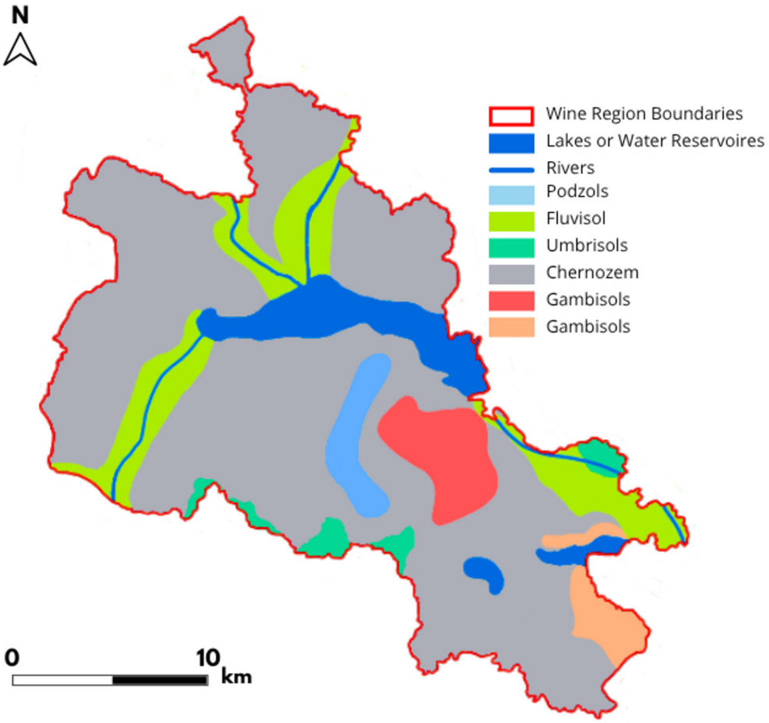
The **Mikulov region**, located in the southeastern part of Moravia in the Czech Republic, presents the most varied terrain among the examined regions, with altitudes ranging from river valleys at 149 m a.s.l. to hills exceeding 500 m, including Devin Hill (Fig. 9). This region averages annual temperature of 9.5°C, with the lowest annual rainfall recorded in this analysis at 662 mm. Dominated by chernozem – an exceptionally fertile soil – the Mikulov's region is further enriched by fluvial alluvium and fluvisols, providing essential minerals (Fig. 10). The region also benefits from a relatively high annual number of sunshine hours (1,726 hours) and – due to the presence of the Dyje, Ipoly, and Sucha rivers, along with Nové Mlýny Lake – provides favourable irrigation conditions. The varying altitudes and diverse soil composition contribute to the production of wines with distinct characters and rich flavour profiles [Provozovatel 2025].



Source: Authors' own study based on: topographic-map [n.d.]

Fig. 9. Topographic map of the Mikulov wine region (Czech Republic)

Each of the wine analysed regions – Rosalia, Saxony, and Mikulov – exhibit unique environmental characteristics that significantly influence the resultant wine profiles. Rosalia is distinguished by its climate, the wormest and sunniest among the compared regions. This is coupled with exceptionally fertile soils which promote intensive production of red wines. Meanwhile, despite its cooler climate and higher rainfall, Saxony harnesses its proximity to the Elbe River and fertile alluvial soils to cultivate more delicate grape varieties. Mikulov, with its temperate climate and diverse soil landscapes, presents an environment conducive to the production of wines with pronounced character and complexity.



Source: Authors' own study based on: Ministry of Environment of Czechia [n.d.]

Fig. 10. Soil map of the Mikulov wine region (Czech Republic)

3.3. Hazlach municipality in Silesia – case study

Drawing on field observations along with soil and topographical data, an analysis was conducted to evaluate the potential for viticulture in the rural municipality of Hazlach. This selected area exemplifies how an assessment of natural conditions can effectively serve as a foundation for planning new vine plantings.

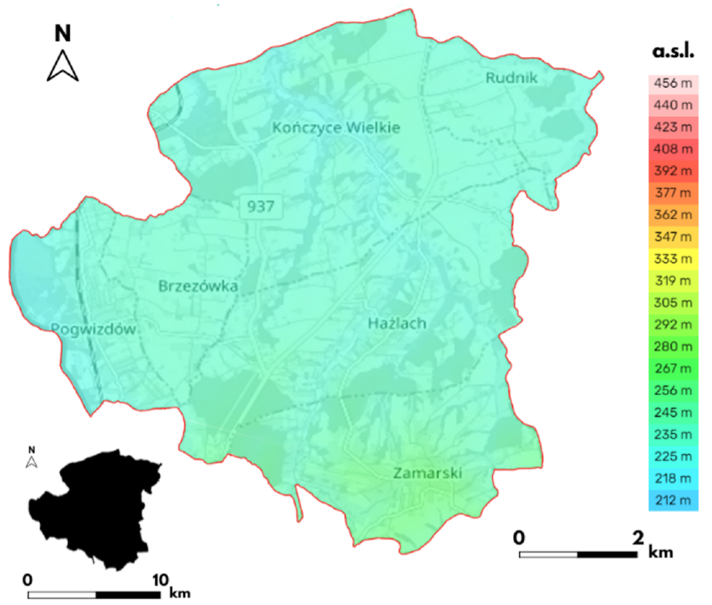
The area of Hazlach is situated within the Kończyce Plateau, and the southern part of the municipality belongs to the Silesian Foothills. In accordance with the physical-geographical classification of Poland, the Hazlach municipality belongs to the Carpathian Mountains, a megaregion that was formed through the processes of overthrust and uplift during the Alpine orogeny. The Western Carpathian Mountains within Poland are categorised into the Outer Carpathians, formed predominantly by flysch formations, and the Nipple zone of West Carpathians, which contain limestone in the enveloping series of crystalline mountains, including granitoids and crystalline schists. Adjacent to the Carpathians lies a subsiding region known as the Subcarpathian region or Podkarpacie, which is rich in deposits of sulphur, gypsum, rock salt, oil, and natural gas [Mizerski 2015, Stupnicka and Stempień-Sałek 2016].

The Subcarpathian region, also known as the Outer Subcarpathia, is further subdivided into smaller areas – provinces. The municipality of Hazlach is located within the province of the Western Carpathians, which encompasses both Western and Northern Subcarpathia. The Northern Subcarpathia, recognised as a physical-geographical subprovince, extends from the Czech Republic through Poland to Ukraine, lying between the Western Carpathians and the Lesser Poland Uplands. Due to its extensive area, this subprovince is classified into several smaller regions: the Ostrava Basin in the west, the Oświęcim Basin to the east, followed by the Krakow–Częstochowa Upland, which includes both the Carpathians and the Krakow Gate [Bachowski et al. 2010, Mizerski 2014].

The municipality of Hazlach occupies the only portion of the Ostrava Basin located in Poland, specifically the Kończyce Plateau. This mesoregion lies between the Olza and Vistula valleys, and it features undulating peaks that rise to a maximum elevation of 300 m a.s.l. The landscape comprises a series of hillocks and isolated elevations that ascend 35–70 m above the river valleys (Fig. 11). These hills are predominantly formed from Miocene sediments, upon which deposits related to the South Polish glaciation (Nida glaciation), occurring between 730,000 and 430,000 years ago, have been laid down. The upland is characterised by the accumulation of moraine sediments, resulting in the highest peaks being capped by a substantial layer of loess and loess-like clays [Mizerski 2014, Stupnicka and Stempień-Sałek 2016].

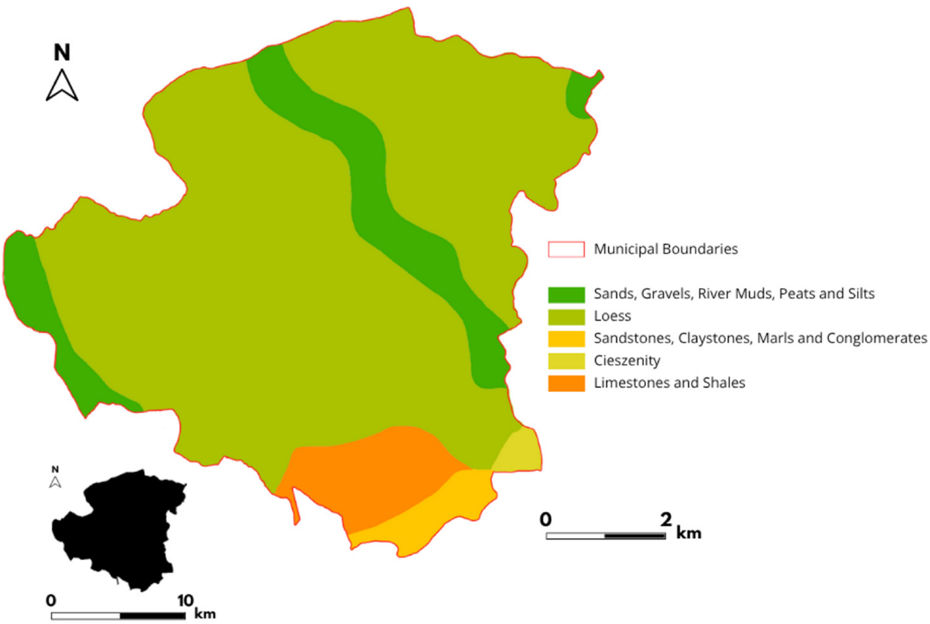
The Hazlach municipality is situated within the Silesian Plateau, which is part of the Carpathian Flysch. This plateau exhibits a complex geological structure, which is a consequence of sedimentary folding and overthrusting. Such geological processes gave rise to numerous faults that traverse the Silesian Plateau and lead to the stratification of overlying rocks. One of the most significant faults is the Skawa, which bisects the plateau into two distinct parts that differ in terms of their facial development and tectonic structure. There are two geological units, which can be identified: the Těšín and Godulian units. The plateau (Fig. 12) is predominantly composed of sandstones and shales, with subordinate occurrences of conglomerates, marls, and limestones, as well as deeper geological formations known as Cieszynites [Mizerski 2014, Stupnicka and Stempień-Sałek 2016].

The municipality is dominated by podzols, brown soils, and leached soils, and in the southern part, there are also brown rendzina soils. The podzols are soils formed on sands, with poor structure for agriculture. Brown soils, formed by in situ biochemical weathering, have a more fertile structure. Brown soils contain calcium and have an alkaline reaction, while leached brown soils are more acidic and permeable, which means they can dry out periodically. Due to the type of bedrock, soils in the Hazlach



Source: Authors' own study based on: topographic-map [n.d.]

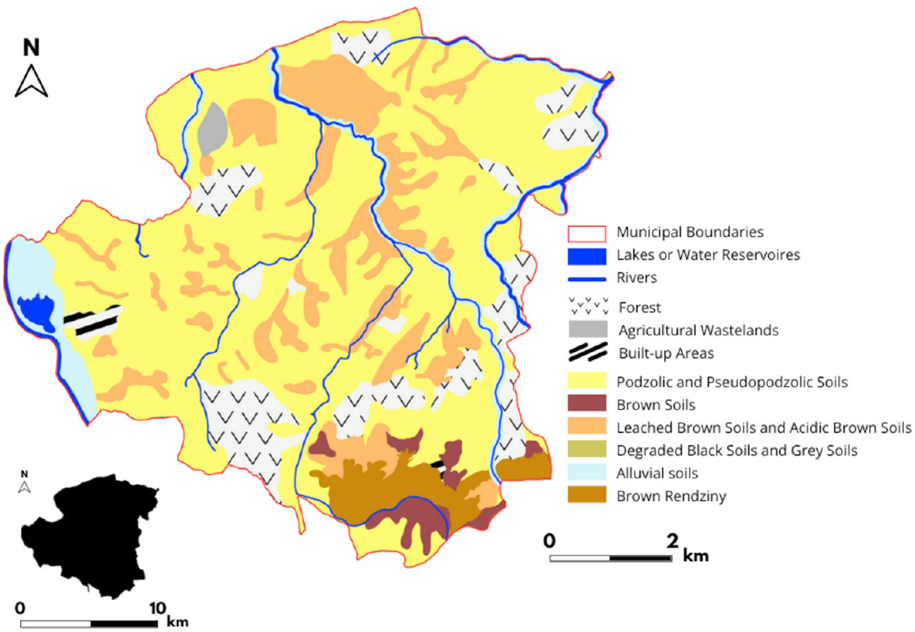
Fig. 11. Topographic map of the commune of Hazlach



Source: Authors' own study based on: Dziedzic and Jackowska [2021]

Fig. 12. Geological map of the commune of Hazlach (Poland)

municipality belong to the 'good for wheat arable suitability complex' (Polish soil classification for arable land in classes IIIa and IIIb), which indicates their importance in agriculture [Dziedzic and Jackowska 2021, Rozporządzenie 2012].



Source: Authors' own study based on: Dziedzic and Jackowska [2021]

Fig. 13. Simplified soil map of the commune of Hazlach

4. Discussion

Research and field studies have established that both soil and climate significantly influence vine cultivation, though the nature of their interaction varies across regional contexts. While vines do not inherently require highly fertile soils, evidence suggests that they exhibit optimal growth in loose, permeable, and moderately moist soil conditions. When considering which soil and ground conditions have the greatest impact on vine growth, it becomes apparent that the quality and nutrient richness of soil plays a critical role in determining yield abundance.

The scientific literature and comparative analyses indicate that vine growth is most effectively supported by soils characterised by loose structure, effective drainage, moderate moisture retention, and a high nutrient content. Soils such as chernozems and brown soils, which are prevalent in Rosalia (Austria) and Mikulov (Czech Republic) regions, provide high fertility, stable structural integrity, and favourable water-air relations. These features promote robust vine development and maximise yields. Conversely, sandy podzols and leached brown soils, as observed in Hazlach, may exhibit lower inherent fertility. However, they can still sustain effective vine growth when augmented by appropriate liming and cultivation practices, particularly under conditions of climate warming. Research conducted by Olewnicki [2018] and Bachowski et al. [2010] demonstrated the vital role that soil plays in mitigating the effects of extreme moisture fluctuations and supporting consistent growth under marginal climatic conditions. Furthermore, terrain features such as south- or southwest-facing slopes enhance solar exposure and air circulation, further promoting vine vitality.

In the municipality of Hazlach, the presence of gently rolling hills (250–300 m a.s.l.) and well-drained brown soils, combined with the moderating effects of the Moravian Gate, create increasingly favourable microclimatic conditions for viticulture. Although podzolic soils predominate, the incorporation of rendzina and leached brown soils with neutral to slightly alkaline pH on calcareous substrates augments the potential for vineyard expansion, particularly when paired with strategic varietal selection and soil enrichment practices.

When assessing the impact of soil types on wine quality and taste, the mineral composition and structural properties of the soil are critical. Permeable soils with moderate moisture facilitate the concentration of grape flavours, while specific mineral content can enhance the aromatic profile of the resulting wines.

Consequently, soil texture, structure, and mineral composition have substantial implications for the yield and quality of grape harvests. Soils that balance moderate fertility with effective drainage - such as chernozems and fertile brown earth - are particularly well-suited for supporting vine metabolism and establishing deep root systems that stabilise yields. Literature indicates that vines cultivated in balanced soils with adequate but not excessive nutrient levels, tend to produce grapes with heightened concentrations of sugars and aromatic compounds. For instance, in Rosalia, fertile loams coupled with long sunlight hours yield high-quality red wines, whereas in the Mikulov region, mineral-rich fluvial soils contribute to the production of complex white and red varieties with pronounced aromas. In Saxony, despite the lower temperatures and reduced sunlight hours, the fertility of the alluvial soils and the proximity to the Elbe River allow for productive vineyards, albeit with a focus on early-ripening or more delicate varietals.

In Hazlach, although the soils are generally less fertile than those found in Rosalia or the Mikulov region, the increasing number of sunny days and rising temperatures (from 7.6°C in 2010 to 10.9°C in 2024) are progressively enhancing agricultural conditions. Furthermore, deeper subsoils enriched with loess and clay layers provide moderate moisture retention, which is essential for grape development. These characteristics indicate that, while total yields may not yet match those of more established regions, appropriate soil and varietal management practices could yield grapes of commendable quality and typicity.

5. Conclusion

The municipality of Hazlach, despite being situated outside Poland's traditional wine regions, shows increasing potential for viticulture and associated enotourism that can be attributed to its distinctive environmental features. Situated in the Kończyce Plateau and influenced by the Moravian Gate, this area benefits from frequent air circulation, milder winters, and a significant increase in the number of sunlight hours – all critical factors for successful vine cultivation. While the soils in Hazlach are less fertile compared to those in Rosalia or Mikulov, the region has similar terrain forms (including low hills and river valleys), which together with increasingly favourable climatic trends create a conducive environment for establishing a distinct viticultural terroir.

As demonstrated in the comparative analysis, successful wine regions effectively integrate soil potential with climatic conditions to create resilient and productive viticultural landscapes. In Hazlach, the expansion of vineyards (e.g., Château Kończyce Wielkie), grassroots vinification initiatives, and local government support (Cieszyn Wine Route) indicate a deliberate transformation of the cultural and physical landscape. The increasing presence of vineyards introduces new land use patterns, whereby traditional crops are supplanted by vine rows on sloped fields. This transition not only alters aesthetic perceptions but also contributes to the agricultural diversity of the region. The interaction of climate, soil composition, and bedrock type is crucial in establishing a unique terroir that serves as a distinctive habitat for viticulture. Although vines demonstrate an impressive ability to adapt to a variety of environmental conditions, they reach optimal growth when provided with abundant sunlight and protection from frost during colder months, yielding larger fruit.

Using the example of successful wine regions in the wider vicinity of Saxony (DE), Mikulov (CZ) and Rosalia (AT), potential advantages and disadvantages of expanding vineyards in southern Poland near the border with northern Moravia have been assessed. A couple of decades ago, this article would have seemed like pure fiction, but today's reality of perceptible global warming offers these possibilities. On the other hand, the development of new resistant grape varieties [e.g. PIWI and others, Regner et al. 2025] that are resistant to diseases and spring frosts strengthens these activities even in new northern areas that have very good chances for successful wine production.

By combining cultural heritage with emerging winemaking initiatives and improving the climate and topographical conditions for winemaking, Hazlach municipality can develop a distinctive terroir that will be expressed in the unique flavours of its wines. Furthermore, the ongoing expansion and cultivation of new vineyards in the region are expected to significantly reshape the landscape, enhancing its aesthetic appeal and agricultural status.

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