NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

Bulletin of Geography. Socio-economic Series, No. 70 (2025): 159-170
https://doi.org/10.12775/bgss-2025-0045

BULLETIN OF GEOGRAPHY. SOCIO–ECONOMIC SERIES

journal homepages:
https://apcz.umk.pl/BGSS/index
https://www.bulletinofgeography.umk.pl/

Landscape and landform potential for the development of small-scale vineyards: A scientific methodology for defining specific terroirs geographically with a case study of the rural commune of Hażlach in Poland

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How to cite:
Buława, B., Antonowicz, L., Cheluszka, K., Dylong, K., & Fernandez Torres, I. (2025). Landscape and landform potential for the development of small-scale vineyards: A scientific methodology for defining specific terroirs geographically with a case study of the rural commune of Hażlach in Poland. *Bulletin of Geography. Socio-economic Series,* 70(70): 159-170. DOI: https://doi.org/10.12775/bgss-2025-0045

Abstract. The research contextualises the emergence of viticulture in non-traditional wine regions as a result of climate change and examines the landscape potential for such development on the example of the rural commune of Hażlach in Poland. The research question addressed is how areas with specific landscape characteristics favourable to viticulture but not constrained by historical or industrial winemaking traditions possess a greater capacity to develop sustainable and identity-driven wine production models. These conditions are particularly conducive to fostering a unique terroir and supporting rural development based on cultural heritage. The methodology uses GIS-based terrain analysis, taking into account slope gradients, exposures, and proximity to water bodies, to identify optimal zones for viticulture. Eleven percent of the commune meets the criteria for site-specific terroir development. The research highlights the potential of the small-scale vineyard and oenotourism in Hażlach not only to establish a distinctive wine culture but also to facilitate the restoration of the landscape of small farmstead structures.

Article details:
Received: 7 June 2025
Revised: 27 October 2025
Accepted: 11 Decmber 2025

Key words:
small-scale vineyards,
terrain,
landscape,
viticulture,
oenotourism,
rural commune of Hażlach

Contents:

1. Introduction

The location of a vineyard depends on various factors (Seguin, 1986) that determine the potential of a given area for viticulture (vine-growing). Climate, topography, soil type, and subsoil characteristics form the basis for any successful venture (Bosak, 2010, 2013). Vineyards have commonly been established as part of a cultural tradition that has forged a strong bond with specific territories and are recognised as traditional winery landscapes in Europe. However, due to climate change (Maciejczak & Mikiciuk, 2018) and the rise in wine consumption, countries without a strong winemaking tradition—such as Poland—have gradually emerged as producers, mainly establishing small vineyards that, unlike traditional ones, are not shaped by a long-standing viticultural heritage (Waterson et al. 2017; Koźmiński et al., 2020; Pijet-Migoń & Królikowska, 2020). The impact of climate change on grape-growing conditions is widely recognised in the literature. This applies both to southern Europe, with its established winemaking traditions (e.g. Spain, Italy, the Balkans) (Cogato et al., 2018; Droulia & Charalampopoulos, 2022; Jaksic et al., 2023; Fernandes et al., 2024), and new regions that are gaining viticultural conditions as a result of global warming (e.g. Poland, Romania, and even Sweden and Norway) (Maciejczak & Mikiciuk, 2018; Irimia & Patriche, 2025; Paraschiv et al., 2025).

Since the concept of terroir is widely acknowledged not merely as a physical reality but as a cultural construct inextricably linked to a specific territory and its viticultural tradition, its predominance over the objective factors of soil, climate, and topography has, in many instances, engendered diversity in production that impedes a coherent understanding of these wines as part of a unified reality. This complexity not only hinders the intelligibility and recognition of European quality standards such as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) (European Commision, 2025) among consumers but also complicates the assessment process for experts. Moreover, it poses a challenge for emerging winemakers in creating products with distinctive and recognisable characteristics.

This phenomenon underscores the potential of nascent small vineyards which, unburdened by the constraints of a deeply entrenched winemaking heritage, may embrace a more scientific approach to the development and structuring of their production. In this way, the most propitious areas within a given territory could be precisely identified, and even the scale of vineyards could be optimised according to parameters that, to some extent, ensure a clearer and more deliberate concept of the wines they seek to craft.

To this end, we employed GIS-based methods, as explained in section 2. Studies using GIS methods to assess the potential (or changing conditions) of viticulture in the light of climate change have also been conducted in other European countries, such as Italy, Romania, and Bulgaria (Arnaudova & Popov, 2011; Cogato et al., 2018).

The focus of the study is on the characteristic landscape and topographic parameters, which consist of:

- site exposure, which specifies the orientation of the slope;
- slope gradient; and
- area of influence of water bodies and watercourses.

The most favourable slope orientation in the climatic zone of the commune is southern or similar exposure. A south-facing slope with suitable exposure improves the thermal conditions for the crops, especially during the climatic period of grape ripening. A south-facing slope with an inclination of 15° receives over 20% more solar energy in September compared to a flat terrain, resulting in an increase in the sum of active temperatures (SAM) by at least 100–150°C during the growing period (Szymanowski et al., 2007). The optimum synergistic effect is observed with a southern exposure and a slope gradient of 30°, resulting in a 60% increase in solar radiation intensity compared to flat terrain (Johnson & Robinson, 2017). Equally favourable conditions are found on south-western slopes with an inclination of no more than 15°, since slopes with a steeper gradient would remain shaded for a significant part of the day. Observations from the Rheingau region in the central Rhineland in Germany (located at the same latitude as Kraków and Tarnów in Poland) show that at a gradient of 20°, a west-facing slope receives around 16% less solar radiation in autumn compared to flat terrain. Similarly, the south-western slope receives on average 14% more radiation and the southern slope 35% more radiation than the plain area.

Eastern slopes were excluded from the study due to their undesirable warming in the first half of the day and heat radiation before sunset, which increases the diurnal temperature range. Western slopes were included in the study due to favourable warming in the latter part of the day and slow cooling at night (Jones et al., 2005). To specify the parameters of the study, slopes with southern, south-western, and western exposures were qualified by their gradients as follows:

- 5°–10° – moderately favourable,

- 10°–15° – favourable,
- 15°–20° – very favourable (slope inclinations of 20°–30°, which are rare in the study area, were also classified as very favourable).

The impact of water bodies and watercourses is classified as favourable and unfavourable (Heinricks, 2001). Significant changes have been observed in the local microclimate due to the construction of dam lakes in sheltered mountain valleys. For example, in the immediate vicinity of Lake Rożnów, the frost-free period increased on average by 10 days in spring and by 39 days in autumn. Large bodies of water accumulate heat and moderate the climate. In contrast, shallow watercourses, which cannot accumulate heat, negatively affect crops through increased evaporation and the associated increased risk of frost (Molga, 1980).

Empirical evidence underscores the significant impact of temperature-based indices on grape production. There is a clear correlation between favourable vintages and annual climatic conditions. One might assume that different grapevine varieties would respond less effectively to varying climatic conditions. However, vines typically adapt with remarkable versatility (Pastore et al., 2022), producing variations of the cultivar that may reduce the quality or quantity of production, but can just as easily enhance them. This has been evident with the introduction of new grape varieties in the Southern Hemisphere and in the valleys of California. Adaptation does not always yield superior wines, but it does foster uniqueness; in a market increasingly driven by demand for diversity, this can provide small-scale producers with significant opportunities for success.

The combination of the above-mentioned landscape and topographical factors determines the potential for the development of viticulture in the study area of the rural commune of Hażlach, located in the Cieszyn Silesia region (Myśliwiec, 2013). The selection of the Hażlach rural commune in southern Poland (Figs. 1–3) as the case-study area aims to illustrate a region where wine production was historically very limited but today offers a clear picture of the high demand and interest in wine culture, which has led to the emergence of small vineyards (e.g. Château Kończyce Wielkie, run by Marcin Lipski) (Fig. 4), viticulture associations, and a thriving oenotourism (wine tourism) sector (Schaefer et al., 2018). The most active local association is Cieszyn Wine Route, based in Château Kończyce Wielkie and also run by Marcin Lipski (*Stowarzyszenie Cieszyński Szlak Wina*, n.d.), which aims to develop viticulture and oenotourism in the Cieszyn Silesia region (Buława et al., 2022; Samorząd Gminy Hażlach, 2025).

The aim of the study is to assess the topographical and landscape potential of the Hażlach commune for the development of viticulture and oenotourism using a scientific approach as the basis for defining common small-scale terroir.

The research objective is to investigate how topographical and landscape conditions may impact the development of viticulture and oenotourism in rural communes with mixed and small-scale agricultural patterns.

Climate change is reshaping the geography of European viticulture by creating new areas with favourable environmental conditions for wine production and oenotourism, generally shifting it to northern continental climate zones. The central argument has been posed, that, using computational modelling, it is possible to identify zones where small-scale, site-specific terroirs can be defined—particularly in areas not constrained by winemaking tradition. These locations offer significant potential for the development of wines with distinctive identities, aligned with growing market demands for authenticity, origin, and recognizability.

To validate this argument, a case study is presented of the rural commune of Hażlach. This region offers a compelling example due to its homogeneous geomorphological features, consistent soil conditions, and historical agricultural tradition that supports small-scale cultivation. The prevailing climatic conditions—particularly moderate temperature decreases attributed to climate change – combine with uniform edaphic and solar exposure characteristics to create an environment conducive to the expression of a common and well-defined terroir.

The authors further argue that such conditions provide a unique opportunity to implement a more sustainable and efficient landscape-level production model. Unlike large-scale viticultural regions with high variability in soil composition, humidity, and slope orientation (exposure), areas like Hażlach can foster the emergence of coherent wine profiles that are not only economically viable but also contribute to biodiversity, cultural heritage, and the restoration of traditional small-plot farming systems.

In this context, scientific modelling becomes a strategic tool not only for identifying suitable viticultural zones but also for supporting regional development strategies based on landscape coherence, sustainability, and product differentiation. Ultimately, this approach enables the positioning of new wines in the market with a strong territorial identity and environmental value.

2. Methods and materials

The study is based on quantitative research, where the unit is a raster cell corresponding to a 1 m by 1 m grid in the actual terrain. Quantum GIS and Microsoft Excel were used along with a literature review on the subject of winemaking (Aklıbaşında & Bulut, 2014; Jovanović et al., 2025). A vector outline of the municipality was obtained using the Web Feature Service (WFS) from the Polish State Border Register (orig. *Państwowy Rejestr Granic (PRG)*), accessible at https://www.geoportal.gov.pl/pl/dane/panstwowy-rejestr-granic-prg/. Digital terrain model (DTM) data in ASC format and vector shapes in the SHP format were acquired via the Web Map Service (WMS) from the Polish Digital terrain model (orig. Numeryczny Model Terenu (NMT)) available at https://www.geoportal.gov.pl/pl/dane/numeryczny-model-terenu-nmt/. All used datasets are publicly available. All datasets used in the analysis are from 2023.

The object of the study is the landform (Figs. 4–5) of the Hażlach rural commune in Poland (Figs. 1–3) within its administrative boundaries, taking into regard geographical areas within its territory that share common geophysical, climatic, and topographical characteristics.

The Hażlach commune, located in southern Poland on the border between the Republic of Poland and the Czech Republic, lies at the junction of the Silesian Foothills and the Ostrava Basin. It covers approximately 49 km^2 and has a population of 10,800.

The **settlement structure** of the agricultural rural commune of Hażlach consists of 6 villages. The commune is located close to several towns and has a mixed settlement structure. The village of Hażlach dominates as the seat of the rural commune. Advanced rural sprawl is evident, and the villages are characterised by dispersed structures. Only the village of Zamarski has a distinct centre.

The local **landscape and landform** are characterised by gently undulating terrain, with elevations ranging from approximately 270 to 330 m a.s.l. The topography of the area includes low hills (Fig. 5), open valleys, pond areas, and a network of small rivers and streams, notably the Piotrówka River, which shapes the hydrological and microclimatic conditions of the region (Miłowski, 2020). The Hażlach commune is characterised by a fragmented small-scale agricultural and vernacular landscape with diverse land use (agricultural areas, woodlands, water bodies) and moderate forest cover.

Climate data from recent decades for Hażlach confirm global climate change trends. The average

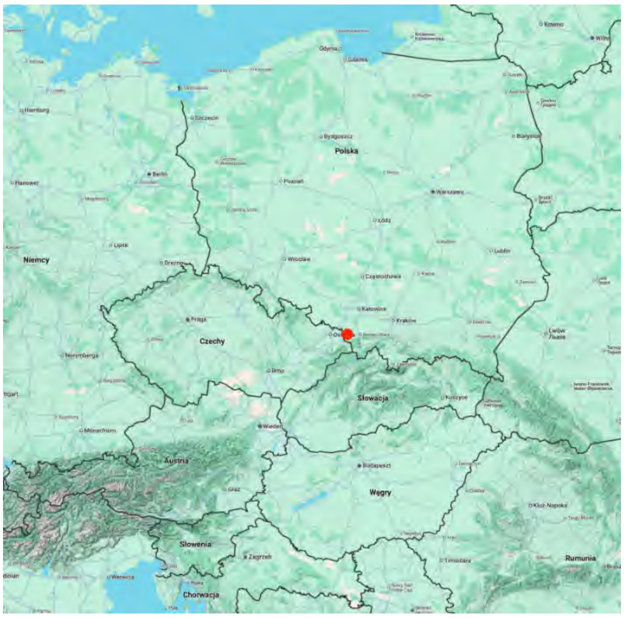

Fig. 1. Location of the Hażlach commune in southern Poland
Source: own elaboration based on Google Maps

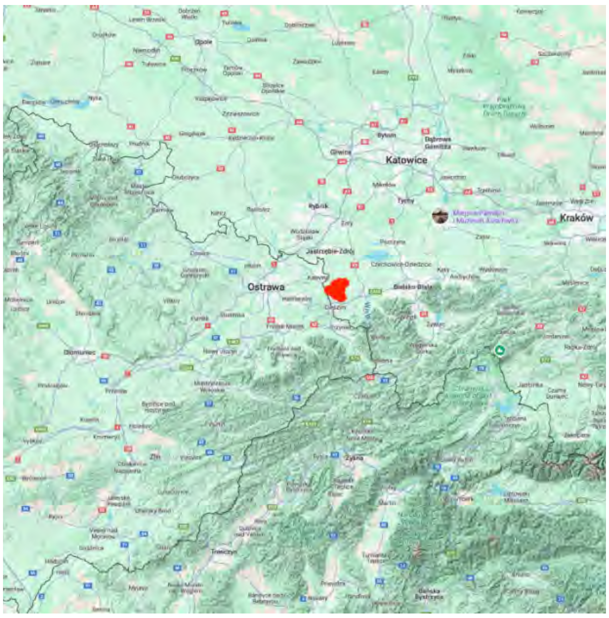

Fig. 2. Location of the Hażlach commune in the Moravian Gate
Source: own elaboration based on Google Maps

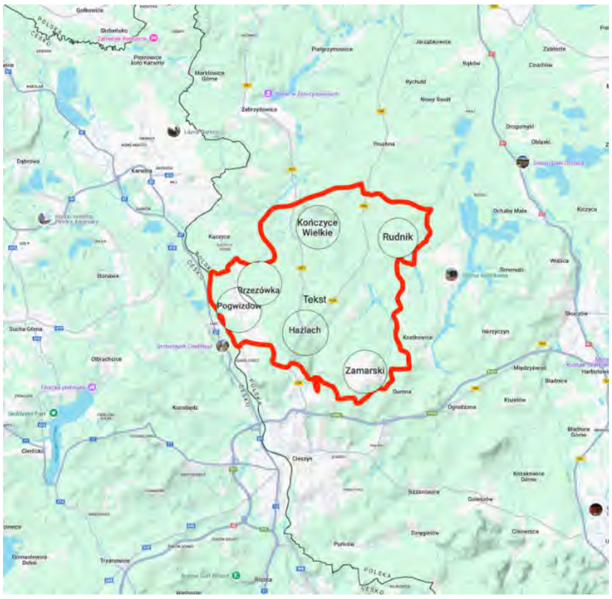

Fig. 3. Hażlach commune and its five villages
Source: own elaboration based on Google Maps

Fig. 4. Vineyard Château in Kończyce Wielkie
Source: B. Buława, 2023

Fig. 5. Landform in the Hażlach commune
Source: B. Buława, 2023

annual temperature in 2010 was 7.6°C and increased to 10.9°C in 2024. Insolation during the summer period has increased from 550–600 hours in 2010 to 750–800 hours in recent years. In the commune, annual sunshine averages 1,568 hours, annual precipitation amounts to approximately 1,122 mm, and the growing season lasts approximately 220 days (*Klimat IMGW-PIB*, n.d.; *Meteoblue*, n.d.). The Meteoblue portal also shows increasing monthly anomalies for positive temperatures and decreasing anomalies for negative temperatures. Precipitation anomalies are also increasing, both on a positive and negative scale (*Meteoblue*, n.d.). It should be noted that a number of written sources provide climatic and agricultural data on Hażlach (e.g. the spatial plan and development strategy); however, these sources are already several years old, so the data they contain are outdated.

The research criteria adopted for the study are as follows:

- slope exposures mapped in azimuth increments of 45°, with the classified favourable orientations being south, south-west, and west;
- slope inclinations ranging from 0° to 90°, with suitable values between 5° and 30°;
- negative impact of water bodies and watercourses, defined by a 15 m from the water body edges and a 15 m buffer from the watercourse axes.

An algorithmic study based on the analysis of raster underlay cells was concluded using QGIS software, and statistical analyses were carried out in Microsoft Excel. The study consists of the combined output of the common parts of the exposure and slope gradient analyses, from which the areas of the designated buffers around water bodies and watercourses were filtered out (Fig. 6). The results generated in QGIS were systematically verified for reliability by comparing the total area of the data obtained with the area of the commune. To interpret the results of the study, comparisons were made with selected reference wine regions of comparable cultivation area.

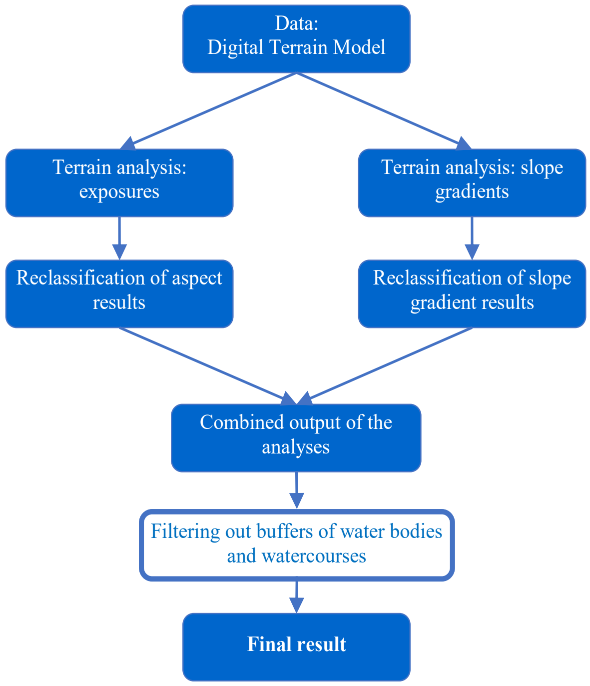

Fig. 6. Data analysis flow chart
Source: own elaboration

3. Results

The survey showed that in the rural commune of Hażlach 35% of the land topography consists of slopes with southern, south-western, and western exposures and 39% of the terrain has gradients between 5° and 30°. These characteristics, along with the shared agricultural culture, enable the formation of a distinctive, site-specific terroir for the area and the establishment of small-scale vineyards capable of producing wines with a unique and recognizable identity. The development of small-scale vineyards would support agriculture consistent with historical patterns, field sizes in the area, and, consequently, the existing landforms.

An analysis of exposures was carried out according to the adopted criteria to determine the percentage of the area meeting each criterion (Fig. 7). Using data from the terrain exposure model, the percentage of slopes satisfying the criteria was calculated (see Table 1). The reliability of the results obtained was verified (see Table 2).The data were reclassified to determine raster cells corresponding to slopes with attractive exposures, with a value of 1 indicating compliance with the assumed criteria and 0 indicating non-compliance (Fig. 8).

An analysis of slope gradients was carried out according to the adopted criteria to determine the percentage of the area meeting each criterion (Fig. 9). Using data from the slope gradient model, the percentage of slopes satisfying the criteria was calculated (see Table 3). The reliability of the results obtained was verified (see Table 4). The data were reclassified to determine raster cells corresponding to slopes with an attractive gradient, with a value of 1 indicating compliance with the assumed criteria and 0 indicating non-compliance (Fig. 10).

Sites meeting both the exposure and slope gradient criteria were assigned a value of 1 (attractive sites), and all others a value of 0 (Fig. 11). The common parts of the exposure and slope gradient criteria were obtained (see Table 5). The reliability of data was verified (Table 2).

Finally, buffers of water bodies and watercourses were excluded from selected areas (attractive sites) (Fig. 12). The applied offset was 15 m, in line with recommendations from the literature for small rivers or streams—that is, 15 m from each bank, giving a total buffer of 30 m) (Lewińska, 1969). The Table 6 shows the results of buffer exclusion for water bodies and watercourses, with the following categories:

- 0 – area of negative influence from water bodies outside the selected 'attractive areas' (i.e. the entire area of negative influence from water bodies and watercourses that does not affect the selected attractive sites, shown as blue pixels)
- 1 – area of negative influence from waterbodies in the selected 'attractive areas' (i.e. the entire area of negative influence from water bodies and watercourses that affects the selected attractive sites, shown as blue pixels overlapping green pixels).

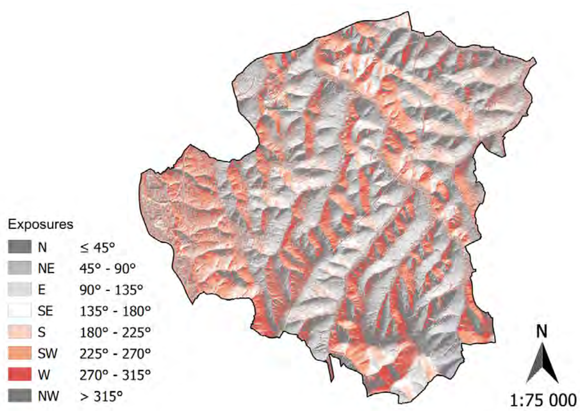

Fig. 7. Exposure analysis
Source: Cheluszka, 2023

Table 1. Summary of climate and terrain features of the analysed cases

No.	Geographical orientation	Pixels amount	Approx. percentage of coverage [%]
1	N	6,582,956	14
2	NE	6,981,798	15
3	E	6,690,828	14
4	SE	5,170,702	11
5	**S**	**4,802,921**	**10**
6	**SW**	**5,791,369**	**12**
7	**W**	**6,610,916**	**14**
8	NW	6,036,056	12
9	total	48,667,546	100
10	**attractive slopes**		**35**

Source: own elaboration

Table 2. Reliability of the results

Reliability of the results (summary of climate and terrain features)			
Area of the commune	Area from data	Difference [pixels]	Difference [%]
49,000,000	48,667,546	332,454	**0.68** – not significant
Reliability of the results (the common parts of the exposure and slope gradient criteria)			
Area of the commune	Area from data	Difference [pixels]	Difference [%]
49,000,000	48,667,546	332,454	**0.68** – not significant

Source: own elaboration

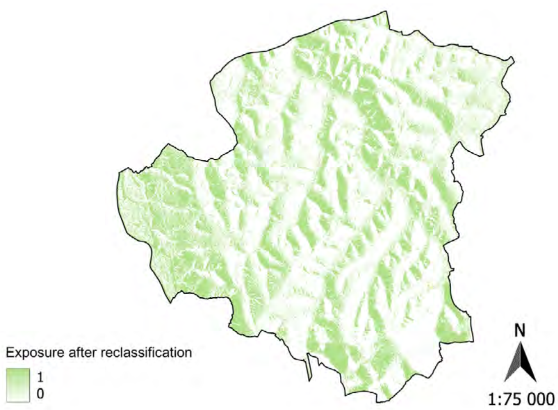

Fig. 8. Slope with attractive exposures
Source: Cheluszka, 2023

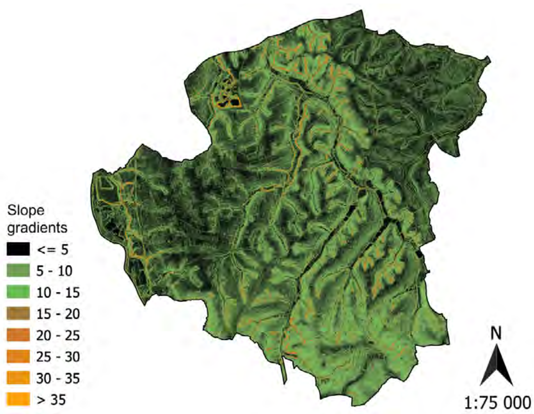

Fig. 9. Slope gradient analysis
Source: Cheluszka, 2023

Table 3. The percentage of slopes with the adopted criteria

No.	Slope [gradient]	Pixels amount	Approx. percentage of coverage [%]
1	< 5	29,424,873	61%
2	**5°–10°**	**13,058,260**	**27%**
3	**10°–15°**	**3,317,673**	**7%**
4	**15°–20°**	**1,433,071**	**3%**
5	**20°–25°**	**769,628**	**2%**
6	**25°–30°**	**418,491**	**1%**
7	30°–35°	190,299	0%
8	> 30	99,319	0%
9	total	48,711,614	
10	**attractive slopes**		**39%**

Source: own elaboration

Table 4. Reliability of the results (the percentage of slopes)

Area of the commune	Area from data	Difference [pixels]	Difference [%]
49,000,000	48,711,614	288,386	**0.59** – not significant

Source: own elaboration

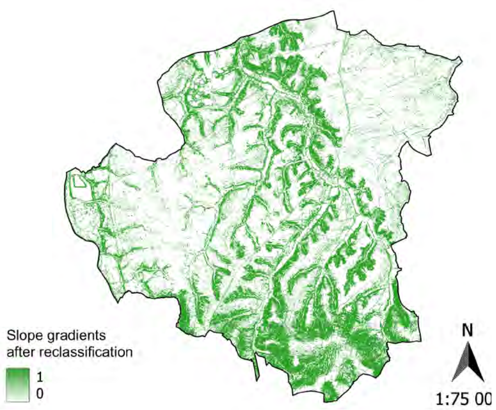

Fig. 10. Slopes with attractive gradients
Source: Cheluszka, 2023

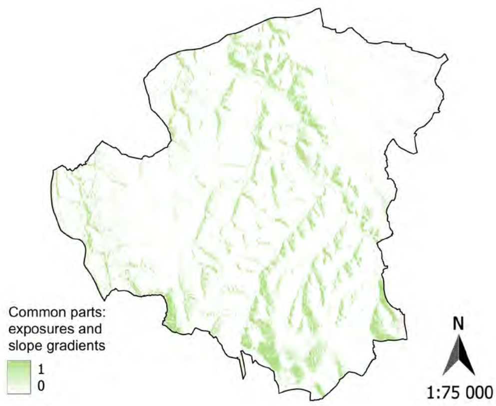

Fig. 11. Attractive areas
Source: Cheluszka, 2023

Table 5. The common parts of the exposure and slope gradient criteria (attractive sites)

Value [0;1]	Pixels amount	Approx. percentage of coverage [%]
0	42,657,663	88
1	**6,009,883**	**12**
total	48,667,546	

Source: own elaboration

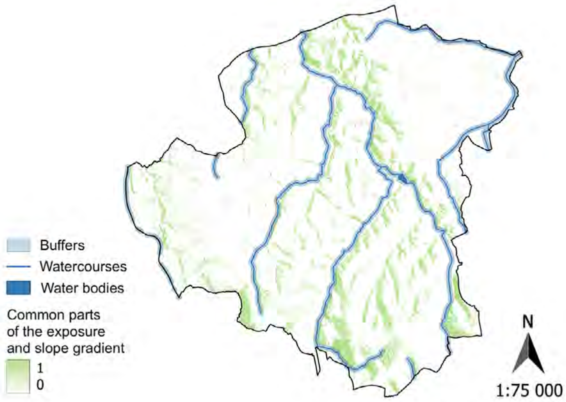

Fig. 12. Buffers of water bodies and watercourses
Source: Cheluszka, 2023

Table 6. The buffers of water bodies and watercourses impacting attractive sites (common parts of the exposure and slope gradient criteria)

Value [0;1]	Pixels amount	Approx. percentage of coverage [%]
0	3,148,761	85
1	**574.447**	**15**
total	3,723,208	

Source: own elaboration

Table 7. Summary of results: common parts of the exposure and slope gradient criteria with water body and wetland buffer

Area of the commune [px]	Exposure and slope gradient criteria (attractive sites) [px]	Buffer of water bodies and watercourses [px]	Result [px]	Percentage of the commune's area suitable for future viticulture [%]
49,000,000	6,009,883	- 574,447	**5,435,436**	**11.09**

Source: own elaboration

Table 8. Comparison of the study area with selected reference regions

No.	Wine sub-region	Approx. cultivated area (vineyards) [ha]
1	**Hażlach rural commune**	**544**
2	**Bohemia region:**	
3	– Mělník sub-region	360
4	– Litoměřice sub-region	293
5	**Vienna region:**	
6	– Vienna sub-region	467
7	**Burgenland region:**	
8	– Burgenland sub-region	150
9	**Lower Austria region:**	
10	– Traisental sub-region	696
11	– Carnuntum sub-region	356
12	**Styria region:**	
13	– West Styria sub-region	195

Source: own elaboration

Total – the entire area of negative influence from water bodies and watercourses (i.e. the checksum of the areas without influence and with influence on the selected areas, shown as total blue pixels, both overlapping green pixels and outside them).

The total area of the Hażlach commune (approximately 49 km^2) is covered by 49,000,000 pixels, and the area meeting the exposure and slope gradient criteria (attractive sites) reaches 6,009,883 pixels. After excluding the buffer area of water bodies and watercourses (574,447 pixels), the remaining area amounts to 5,435,436 pixels, representing approximately 11% of the area of the Hażlach commune that could be suitable for future viticulture and related oenotourism expansion (see Table 7). This would affect up to 11% of the entire area of the commune, representing a significant transformation of the landscape.

The results were compared to selected wine subregions with similar vineyard areas in the Czech Republic (Vina z Moravy, Vina z Čech, n.d.) and Austria (Tesch, 2023) (see Table 8).

4. Discussion and conclusion

The characteristic landscape and topographic parameters presented by Bosak (2010) demonstrate the attractiveness of the Hażlach commune for the development of viticulture and oenotourism.

The analysis of slope exposures in the Hażlach commune shows that they are evenly distributed in all directions, and the adopted criterion of southern, south-western, and western exposures accounts for 35% of the total area of the commune. Most of the slopes are less than 5° in gradient. The qualifying slopes, with gradients between 5° and 30°, account for 39% of the total area of the commune. To identify correlations between the determined criteria, a QGIS algorithm was used to calculate the combined output of the common parts of the exposure and slope gradient analyses. The selected areas (attractive sites) meeting the exposure and slope gradient criteria constitute 12% of the total area of the commune. The negative impact of water bodies and watercourses, defined by the area of the applied 15 m buffer from the water body edges and watercourse axes, was filtered out from the results. After excluding the areas of water bodies and watercourses, the designated areas constitute 11% of the total area of the Hażlach commune.

The scale of the study conducted with QGIS software yields results that are significantly more precise than those of previous general studies or analyses in other geographical contexts aimed at identifying potential areas for viticulture and oenotourism development. These findings challenge broader regional-scale models, which tend to focus more on the potential for establishing protected designations of origin (PDOs) rather than on identifying specific terroirs capable of producing distinctive and recognisable wines.

A comparative analysis was carried out on wine sub-regions of similar surface area, which showed that the Hażlach commune has landscape features that are conducive to the development of viticulture and oenotourism and that could support the definition of a specific, identifiable terroir for small-scale vineyards (Bosak, 2013).

The results confirm the central argument in this case study and provide a compelling argument for local authorities and residents to guide the development of the commune and the region towards viticulture, wine production, and the expansion of oenotourism. As a result, local strategic and spatial planning should take into account the indicated 11% of the municipality's area, its distribution, composition and spatial structure. All these activities will strengthen the bond between the rural environment and the local community (Buława et al., 2022). The identified landscape potential offers an opportunity to enhance the regional diversity and to formulate a well-grounded strategy that supports multi-dimensional socio-economic development within both the rural commune and the wider region (Pijet-Migoń & Królikowska, 2020). Entrepreneurship and innovation are interconnected in multiple ways, particularly through their strong links to economic development and industrial regeneration. Moreover, previous research integrates knowledge of entrepreneurship and innovation (Sorcaru et al., 2024).

According to an ecophysiographic study (Miłowski, 2020), the Hażlach commune features high-quality agricultural soils, particularly in valley areas, along with valuable natural elements such as forest patches, riparian zones, and mid-field rows of trees, that contribute to local biodiversity. These features are crucial for spatial planning, environmental protection, and sustainable land management. The combination of preserved agricultural structures and diverse natural landscape forms provides a solid foundation for developing environmentally sustainable viticulture and rural tourism initiatives.

Based on the results of the study, the rural commune of Hażlach possesses landscape and terrain potential for establishing new vineyards, developing oenotourism, and initiating a shift toward more sustainable agriculture in which diversity plays a central role. Moreover, introducing a pattern of small-scale vineyards integrated into the landscape would help reduce land cover / land use (LCLU) conflicts (Cegielska et al., 2025) and foster more sustainable agriculture in a territory that, over the past century, has been transformed into a landscape dominated by intensive, high-yield farming.

This strategy of introducing small vineyards into territories previously dominated by large-scale intensive monocultural farming models will reconnect the region with its agricultural roots, landscape, and architecture, while also improving soil quality. The efficacy of this scientific approach to identifying suitable locations and the optimal scale for establishing a network of small vineyards lies in its ability to implement a sustainable model of land and landscape management. This model will be grounded in diversity and human-scale agriculture, ensuring long-term environmental balance and resilience.

References

Aklıbaşında, M., & Bulut, Y. (2014). Analysis of terrains suitable for tourism and recreation by using geographic information system (GIS). *Environmental Monitoring and Assessment*, 186: 5711–5719. https://doi.org/10.1007/s10661-014-3814-6.

Arnaudova, J., & Popov, K. (2011). The use of gis in viticulture microregioning in the area of Suhindol, Bulgaria. *Bulgarian Journal of Agricultural Science*, 17(3): 357-363.

Bosak, W. (2010). Siedlisko winnicy - topografia i mezoklimat (Vineyard habitat – topography and mesoclimate – in Polish). Available at: https://www.winologia.pl/teksty_lokalizacja.htm.

Bosak, W. (2013). Klimat i rejonizacja upraw winorośli (Climate and regionalization of grape cultivation – in Polish). Available at: https://www.winologia.pl/poradnik_klimat.htm.

Buława, B., Buława, P., & Nagel, P. (2022). *Krajobraz jako narzędzie rozwoju. Gmina Hażlach* (Landscape as a tool for development. The municipality of Hażlach – in Polish). Wydawnictwo Wyższej Szkoły Technicznej w Katowicach, Katowice. DOI: https://doi.org/10.54264/M001.

Cegielska, K., Różycka-Czas, R., Gorzelany, J., & Olczak, B. (2025). Land use and land cover conflict risk assessment model: Social and spatial impact of suburbanisation. *Landscape and Urban Planning*, 257: 105302. DOI: https://doi.org/10.1016/j.landurbplan.2025.105302.

Cogato, A., Pirotti, F., Meggio, F., & Marinello, F. (2018). Utilizing GIS tools to analyze viticultural choices under climate change scenario in North-East of Italy. Cogato, A., Pirotti, F., Meggio, F., & Marinello, F. (2018, April). Utilizing GIS tools to analyze viticultural choices under climate change scenario in north-east of Italy. *EGU General Assembly Conference Abstracts*, 1056.

Droulia, F., & Charalampopoulos, I. (2022). A review on the observed climate change in europe and its impacts on viticulture. *Atmosphere*, 13(5): 837. DOI: https://doi.org/10.3390/atmos13050837.

European Commision. (2025). Geographical indications and quality schemes explained. Available at: https://agriculture.ec.europa.eu/farming/geographical-indications-and-quality-schemes/geographical-indications-and-quality-schemes-explained_en (Accessed: 5 June 2025).

Fernandes, A., Kovač, N., Fraga, H., Fonseca, A., Radonjić, S., Simeunović, M., Ratkovic, K., Menz, C., Costafreda-Aumedes, S., & Santos, J. (2024). Challenges to Viticulture in Montenegro under Climate Change. *ISPRS International Journal of Geo-Information*, 13(8): 270. DOI: https://doi.org/10.3390/ijgi13080270.

Heinricks, G. (2001). *A viticultural primer for investors and growers: Starting a vineyard in prince edward county?* Prince Edward County Economic Development Office, Canada.

Irimia, L.M., & Patriche, C.V. (2025). Geographical distribution and valuation possibilities of new areas suitable for viticulture in Romania as a result of climate change. *Present Environment and Sustainable Development*, 18(2): 367. DOI: https://doi.org/10.47743/pesd2024182021.

Jaksic, D., Maraš, V., Blesic, M., Beleski, K., Ivanišević, D., Basha, E., La Notte, P., Petrovic, M., & Bradić, I. (2023). The viticulture and wine production potential of the western balkans region (southeastern Europe) in light of climate change. *Congreso Mundial De La Vina Y El Vino 5-9 de Junio, Espana, Cádiz/Jerez.*

Johnson, H., & Robinson, J. (2017). *World Atlas of Wine 8th Edition*. Octopus Publishing Group.

Jones, G., White, M., Cooper, O., & Storchmann, K. (2005). Climate change and global wine quality. *Climatic Change*, 73: 319–343. DOI: https://doi.org/10.1007/s10584-005-4704-2.

Jovanović, R., Almeida García, F., & Cortés-Macías, R. (2025). Open geodata for developing wine tourism in viticultural regions in Serbia. *Tourism*, 73(2): 355–366. DOI: https://doi.org/10.37741/t.73.2.13.

Klimat IMGW-PIB. (n.d.). Retrieved August 20, 2025, from https://klimat.imgw.pl.

Koźmiński, C., Mąkosza, A., Michalska, B., & Nidzgorska-Lencewicz, J. (2020). Thermal conditions for viticulture in Poland. *Sustainability (Switzerland)*, 12(14): 5665. DOI: https://doi.org/10.3390/su12145665.

Lewińska, J. (1969). Ocena wpływu sztucznych zbiorników wodnych na reżim termiczny (Assessment of the impact of artificial water reservoirs on the thermal regime – in Polish). *Folia Geographica. Seria B, Geographica Physica*, 1: 123-135.

Maciejczak, M., & Mikiciuk, J. (2018). Climate change impact on viticulture in Poland. *International Journal of Climate Change Strategies and Management*, 1(2): 254-264. DOI: https://doi.org/10.1108/IJCCSM-02-2018-0021.

Meteoblue. (2025). Available at: https://www.meteoblue.com/en/climate-change/hażlach_poland_3098033 (Accessed: 20 August 2025).

Miłowski, T. (2020). *Opracowanie ekofizjograficzne dla gminy Hażlach* (Eco-physiographic study for the municipality of Hażlach – in Polish). Gmina Hażlach.

Molga, M. (1980). *Meteorologia rolnicza* (Agricultural meteorology – in Polish). Państwowe Wydawnictwo Rolnicze i Leśne.

Myśliwiec, R. (2013). *Uprawa winorośli* (Viticulture – in Polish). PWRIL Państwowe Wydawnictwo Rolnicze i Leśne.

Paraschiv, V., Flaviana, C., & Voicu, C.-G. (2025). *Climate Changes And Agricultural Resilience. Viticulture in Northern Europe*. Impressum Chișinău Republica Moldova.

Pastore, C., Frioni, T., & Diago, M.-P. (2022). Editorial: Resilience of grapevine to climate change: From plant physiology to adaptation strategies. *Frontiers in Plant Science*, 13: 994267. DOI: https://doi.org/10.3389/fpls.2022.994267.

Pijet-Migoń, E., & Królikowska, K. (2020). Rebirth of viticulture and associated changes in the rural areas of Lower Silesia, SW Poland. *Geographia Polonica*, 93: 321–340. DOI: https://doi.org/10.7163/GPol.0176.

Samorząd Gminy Hażlach. (2025). Retrieved May 25, 2025, from Available at: https://samorzad.gov.pl/web/gmina-hazlach/winne-korzenie-i-perspektywy-naszego-regionu (Accessed: 25 May 2025).

Schaefer, R., Olsen, J., & Thach, L. (2018). Exploratory wine consumer behavior in a transitional market: The case of Poland. *Wine Economics and Policy*, 7(1): 54-64. DOI: https://doi.org/10.1016/j.wep.2018.01.003.

Seguin, G. (1986). 'Terroirs' and pedology of wine growing. *Experientia*, 42(8): 861–873. DOI: https://doi.org/10.1007/BF01941763.

Sorcaru, I.A., Muntean, M.-C., Manea, L.-D., & Nistor, R. (2024). Entrepreneurs' perceptions of innovation, wine tourism experience, and sustainable wine tourism development: the case of Romanian wineries. *International Entrepreneurship and Management Journal*, 20(2): 901-934.

Stowarzyszenie Cieszyński Szlak Wina. (2015). Available at: https://cieszynskiszlakwina.pl (Accessed: 6 June 2025).

Szymanowski, M., Kryza, M., & Smaza, M. (2007). A GIS approach to spatialize selected climatological parameters for wine-growing in Lower Silesia, Poland. In: K. Střelcová, M. Blaženec, & J. Škvarenina (eds.), *Bioclimatology and natural hazards*. Springer Dordrecht.

Tesch, K. (2023). Dokumentation Österreich Wein Stand 18. Oktober 2022. Available at: https://www.oesterreichwein.at/fileadmin/user_upload/PDF/Doku/Dokumentation_OEsterreich_Wein_2021_Gesamtdokument_20221018.pdf.

Vina z Moravy Vina z Čech. (2025). Available at: https://www.vinazmoravyvinazcech.cz/en/news/4936364-statistics (Accessed: 5 June 2025).

Waterson, L., Quinn, J., Gleeson, B., Bennett, S., Andrew, M., Barton, R., Slater, L., Brunton, J., Maxwell, V., & Ranger, H. (2017) *Winne szlaki: 52 Weekendy w Najlepszych Winnicach Świata* (Wine trails: 52 Weekends in the World's Best Vineyards – in Polish). Lonely Planet. Pascal.