IDENTIFYING VULNERABILITIES AND THREATS
TO CULTURAL HERITAGE IN SERBIA'S VITICULTURAL SUBREGIONS

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Abstract. This study seeks to map the impact of human activities in the wine-growing areas of Serbia by developing a Human Influence Index (HII), which takes into account the degree of protection of cultural heritage according to the Law on Cultural Assets. By comparing the HII with categories of cultural heritage protection, the goal is to identify subregions where cultural heritage protection needs to be increased, especially in areas with high human impact. The methodology is based on the analysis of several geographically relevant factors, including population density, land use changes, infrastructure access, and light pollution, in order to create a comprehensive depiction of human impact. By linking this with the existing legislation, the aim is to identify the discrepancies between the formal protection of cultural assets and their real vulnerability, with a view to improving the protection and preservation of wine-growing heritage. The urbanization factor has contributed much to the distortion of cultural heritage in the wine-growing areas of Serbia, and partial differences exist according to zones with regard to preserving cultural sites. In this regard, the results of research underpin the necessity to apply protectionist strategies in view of the influence of human impact on the territory. The green zone, with monasteries of exceptional significance, requires a balance between natural and cultural heritage, while the red zone is more susceptible to urbanization and requires careful urban planning not to jeopardize the cultural assets. Attention ought to further focus on research which uses modern technology in their use of data, and most specifically research about developing methodologies related to the insertion of protective zones into urbanistic plans in order for long-term safeguarding of the wine-growing cultural heritage of Serbia to become certain.

1. INTRODUCTION

Human-modified ecosystems, with settlements, infrastructure, agricultural and forest lands, dominate Earth's surface, stretching over more than three-quarters of the land not covered by ice (Ellis & Ramankutty 2008). Direct and indirect human impact on ecosystems has led to a global biodiversity crisis, which threatens species and ecosystems on all continents (Butchart *et al.*, 2010; Rodríguez-Rodríguez & Bomhard, 2012). With increased human impact come a number of environmental issues, including soil degradation, habitat destruction, a decrease in biodiversity, and a threat to the sustainable development of society.

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In today's context of growing anthropogenic pressures, increased urbanization, a decrease in green areas, and more intensive and changing land use patterns, the assessment of human activities is a crucial component in the preservation of natural and cultural heritage. Due to the need for accurately measuring the degree of anthropogenic impact, the Human Influence Index (HII) was developed. This index combines information on population density, transportation systems, land use, and nighttime luminosity, facilitating a measure of the overall human impact on natural and cultural resources (Ursu *et al.*, 2017).

Determining the methods of measuring human impact, many researchers use this quantified HII as an index of how human activities affect ecosystems. The Human Impact Index (HII) refers to anthropogeographical landscapes due to various human activities (Hill *et al.*, 2021). The HII has been used to assess human activity and factors (such as urbanization, agriculture and deforestation) in relation to different ecosystems from mountainous subregions (Rodríguez-Rodríguez & Bomhard, 2012), the Tibetan Plateau (Lauritson, 1991), forest ecosystems, agrarian areas, etc. Human impact on the ecosystems of the Great Hingan Mountains has increased over the past 150 years, peaking during periods of immigration, deforestation, and land conversion, demonstrating the effectiveness of HII application in assessing such impacts, as well as its potential for conservation (Han *et al.*, 2021).

Beyond its role in environmental assessments, the application of remote sensing methods has improved the accuracy in identifying human effects, as illustrated in research focused on safeguarding cultural heritage in vulnerable locations like Svalbard (Thuestad *et al.*, 2015). The uniqueness of this methodology stems from the amalgamation of various factors and the use of geospatial analysis, which provides a strong and flexible approach suitable for different spatial and conservation scenarios. This study introduces an original approach by linking the spatially explicit HII index to the legal protection status of cultural properties, thus enabling the identification of vulnerable zones threatened by intense human pressures.

Vineyard areas represent a combination of culture and nature, a key element of the country's cultural heritage, with its aesthetic, ecological, landscape and production functions. Several vineyard landscapes are on the UNESCO World Heritage List, such as: Langhe-Roero and Monferrato in Italy and Lavaux in Switzerland – they represent centuries-old traditions of viticulture and human adaptation to natural processes (Settimini, 2020; Reynard & Estoppey, 2021). The concept of *cultural landscapes* was introduced in 1992, and vineyards are often considered dynamic landscapes. However, there are challenges in recognizing the specific characteristics of heritage and making the connection between those characteristics and the protection and management of territories (Prats, 2012; Porcal-Gonzalo, 2023). These landscapes preserve viticultural heritage and are an example of the cooperation between man and nature.

HII use in viticultural areas is particularly relevant given that vineyards are dynamic environments at the boundary between natural heritage and cultural heritage. The research here proposes a novel approach by integrating the spatially explicit HII index with the legal protection status of the cultural assets, thereby enabling identification of weak points subjected to intense human pressure.

This article aims to map the impact of human activities in the wine-growing subregions of Serbia, calculating a Human Influence Index (HII) that takes into account the degree of protection of cultural assets according to the Law on Cultural Assets. By comparing the protection and HII categories of cultural property, the aim is to identify subregions where heightened cultural heritage protection is required, especially in highly human-influenced zones. However, it should be noted that cultural heritage protection at times occurs against the economic benefits of wine production that bring a lot of advantages

to local traders and communities. In the context of Serbia's wine-growing regions, such an approach has not been examined in detail to date. Consequently, this study can be viewed as a possible contribution towards developing a systematic evaluation of the human impact on cultural heritage areas.

Wine tourism is an important determinant in the conservation of cultural heritage and sustainable development in wine regions. In Germany's Mosel Valley, tourism is considered an integral part of the conservation of steep-slope terraced vineyards that are at risk of abandonment (Job & Murphy, 2006). Wine tourism also helps preserve viticultural landscapes, the traditions, and practices that form part of a region's cultural heritage (Némethy *et al.*, 2016). The link between industrial heritage and wine tourism contributes to the aspect of sustainable development. A recent example from a case study in Vila Nova de Gaia, in Portugal, shows that residents are fairly tolerant of wine tourism due to various economic and cultural benefits (Andrade-Suárez & Caamaño-Franco, 2020). For wine tourism development in Drama, Greece, the collaboration with various partners and stakeholders in regards to its development has to take advantage of cultural heritage (Karampatea *et al.*, 2024). Overall, wine tourism is one of the vital tools in preserving cultural heritage while facilitating economic growth within wine regions.

The originality of this research lies in the application of the HII specifically to the wine-growing subregions of Serbia, linking it with the legal protection of cultural assets according to the Law on Cultural Assets. By using HII as a tool, this study introduces a new approach to assessing the impact of human activities not only on ecosystems but also on cultural assets, particularly in areas of high cultural significance, such as wine-growing regions. These areas are particularly vulnerable to threats such as urbanization, industrialization, and tourism, making them relevant for assessing human impact and the need for their protection. Serbia is suitable for this research due to its specific challenges regarding urbanization, industrialization, and the lack of adequate protection for cultural assets, especially in wine-growing regions. Serbia is distinctive due to its large wine-growing regions being located in areas with insufficiently developed infrastructure for the protection of cultural heritage, which creates an additional challenge in preserving these areas.

2. STUDY AREA

The total wine-growing area of Serbia amounts to 23,675 km², and 99.86% of it lies below 800 meters above sea level. Wine-growing areas are divided into three main wine regions, further subdivided into 22 wine regions (79 vineyards). The most common white wine varieties in Serbia include: Italian Riesling, Rhein Riesling, Chardonnay, and Sauvignon Blanc, while domestic varieties are Smederevka and Župljanka. Among red wines, the most common varieties are Cabernet Sauvignon, Prokupac, Merlot, and Burgundy, with Muscat Hamburg and Kardinal being the most common of all. Serbian viticulture has gone through periods of stagnation caused by wars, poor economic conditions, and unfavourable weather conditions, after which partial efforts of vineyard restoration and extension have been made (Jovanović *et al.*, 2022; Jovanović *et al.*, 2023).

Geographically, the wine-growing areas of Serbia are situated between 41°50' and 46°10' North latitude, with vineyards mostly on hilly terrains at altitudes ranging from 80 to 500 m. The climatic conditions are favourable for viticulture, allowing the cultivation of various grape varieties. Agro-economic conditions are also advantageous, which is why Serbia is known for the production of high-quality grapes and wines.

The wine-growing area studied for this analysis includes 16 wine-growing regions with active grape cultivation and wine production, not including those relying solely on the processing of imported grapes (Fig. 1).
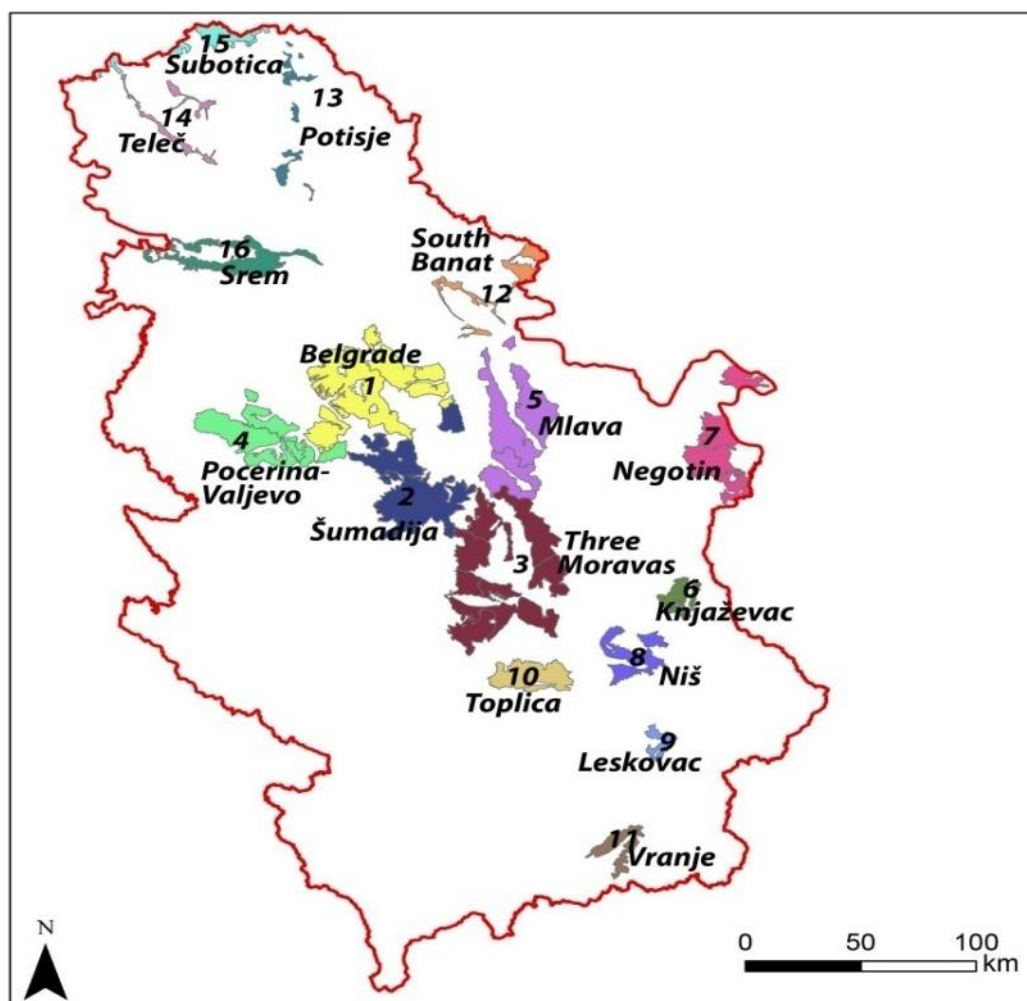
Fig. 1 – Wine-growing subregions in Serbia.

Source: Author's elaboration

Serbia is distinctive due to its large wine-growing regions located in areas with an insufficiently developed infrastructure for the protection of cultural heritage, which creates an additional challenge in preserving these areas.

3. DATABASE AND METHODOLOGY

Methodology and Data for Assessing Human Impact in the Wine-Growing Areas of Serbia

Urban accessibility and transportation infrastructure may play a role in safeguarding and showcasing cultural heritage by inducing visitor travel and cultural exchange. Although, when human activity intensity passes beyond sustainable levels or is in conflict with protection, it can potentially harm environmental values and threaten cultural site integrity. To that end, the Human Influence Index (HII) is an analytical and discriminative method for detecting positive and, possibly, adverse human impacts on protected cultural landscapes, rather than categorically labelling human presence as negative.

This study uses an adapted version of the Human Influence Index (HII), based on the approach developed by Sanderson *et al.* (2002). Several studies, including Fritz *et al.* (2000), Ekim *et al.* (2021), Carver and Fritz (2016), Cao *et al.* (2019), Carver *et al.* (2013), and Ma & Long (2020), have examined whether an area is considered "natural" or heavily influenced by human activity. However, Sanderson and colleagues (2002) were pioneers in applying this index to the map, and assessing the boundaries of human impacts across various regions. The primary objective of this method is to evaluate human activity influences and give a spatial presentation of such impacts on the viticultural subregions in Serbia, aiming at environmental protection, the preservation of cultural heritage, and wine tourism development.

Eight geospatial layers representing the principal dimensions of human pressures were included in the analysis: population, principal road networks, railway proximity, urban settlements, land use/land cover type, riverbanks, navigable rivers, and night-time light intensity. The following data sources were used to obtain the layers:

- OpenStreetMap (OSM, 2024) – for infrastructure networks like roads, railways, and rivers.
- CORINE Land Cover (2018) – for land cover and land use type.
- Statistical Office of the Republic of Serbia (2022) – for population density data by territorial unit.
- VIIRS Nighttime Lights – for steady night light emissions indicating urbanization and economic activity.
- Google Maps (2024) – for further information on settlements and infrastructure elements.
- Military Geographical Institute (1988) – for the boundaries and spatial extent of urban zones based on historical topographic maps.

The calculation of eight layers (variable impact assessments) in the wine-growing area of Serbia refers to: highways, railways, navigable rivers, riverbanks, urban polygons, land cover categories, number of trees and night light stability values. HII represents the cumulative effect of the above-mentioned factors on a scale used to assess the degree of human impact, with values ranging from 0 (no human impact) to 64 (significant human impact). The values on this scale represent the cumulative impact of human activities on wine-growing regions, considering various factors such as population density, infrastructure, land use changes, the presence of transportation and water routes, and light pollution. Each of these factors contributes to the overall index in a way that reflects its significance and intensity in a given area.

The following sections detail the specific geographic layers analysed in this study for HII calculation, along with the criteria and methodology applied to each layer:

Layer – Population Density in Wine-Growing Areas (inhabitants/km²)

For the 1961–2022 period, the population distribution in certain wine-growing areas of Serbia shifted from rural to urban areas. According to the 1961 census, there were 2,629,774 people living in these wine-growing subregions, whereas the 2022 census recorded 3,139,914 inhabitants. This reflects an increase of 510,140 people, a result not driven by birth rates, but rather by the migration from rural to urban areas, contributing to the concentration of the population in cities and the depopulation of rural areas (Jovanović, 2020). Population density in wine-growing areas (inhabitants/km²) was determined using the Census of Population, Households, and Dwellings data (Republic Statistical Office, 2022), specifically for settlements within the analysed wine-growing subregions. Higher population density is reflected in higher values, ranging from 0.5 inhabitants/km² (value 0) to 9.5–10 inhabitants/km² (value 10).

Layer – Railway

In recent decades, this mode of transport has become less and less useful, especially in devastated wine-growing areas. Regarding the density of the railway network (km/km²), it is the smallest in the Negotin wine-growing subregion (Negotin, Mihajlovac and Ključ wine-growing districts) and the Three Moravas subregion (Jovac, Župa, Levač and Jagodina wine-growing districts) – 0.00 km/km². The highest density is in the Niš wine-growing subregion: the Svrljig wine-growing district (11.91 km/km²) and the Čegar wine-growing district (9.57 km/km²). Apart from the Niš region, the highest density of the railway network is in the wine-growing region of Vojvodina (Deliblato Sandstone, West Teleč and Middle Potisje wine-growing districts) with a density of 11.8 km/km. The data were obtained from Open Street Maps (OSM) (2024).

In the assessment of railway traffic, 2 zonalities were used: up to 2 km in relation to the railway (value 8), and above 2 km (value 0).

Layer – Main Roads

In terms of road infrastructure, certain wine-growing areas of Serbia feature a network of major roads, including highways and first- and second-order roads. Highways pass through about a fifth of the vineyards in the total area designated as wine-growing subregions in Serbia. For the evaluation of the main roads within the selected wine-growing sub-subregions, the classification focused on highway and first-order roads. These roads are considered essential for connectivity and accessibility within the region.

For the purposes of this study, three distance-based categories were established to assess the proximity to major roads:

1. Zone 1 (0–2 km): Areas within 2 km of a main road are assigned a value of 8, indicating high accessibility and a potential human influence due to the proximity of the transportation infrastructure.
2. Zone 2 (2–15 km): Areas between 2 and 15 km from a main road are assigned a value of 4, reflecting moderate accessibility.
3. Zone 3 (15 > km): Areas more than 15 km away from a main road are assigned a value of 0, indicating limited access to and minimal human influence from road infrastructure.

These values were used together with the ArcGIS 10.8 software to visualize and analyse the impact of road infrastructure on the wine-growing subregions. The closer the area is to major roads, the higher the potential for human activity and impact. The data for assessing navigable rivers were extracted from Open Street Maps (OSM) (2024).

Layer – Navigable Rivers

Water traffic in tourism generally refers to maritime transport, which includes overseas, oceanic, river, and lake transport. The analysis of threats to the cultural heritage related to navigable rivers includes considering both the risks and the benefits these rivers bring. While Serbia is a landlocked country, it is home to the navigable Danube River and several smaller navigable rivers. Because of this, some rivers, such as the Danube, Sava, and Tisza, connect with very important trade routes. Such a position enables the easy placement of products into both domestic and foreign markets. On top of this, proximity to a river can support wine tourism since it allows for boat trips and a further promotion of wine-growing areas.

In the studied wine-growing subregions, four navigable rivers are included in this category: the Tisza, Sava, Danube, and Morava. These are the only navigable rivers in Serbia, with others depending on seasonal water levels and being limited in terms of the types of vessels and ships they can accommodate.

This category includes two groups based on navigability: rivers with a navigable stretch of up to 15 km (value 4) and rivers with a navigable stretch greater than 15 km (value 0). Geospatial data for this layer were sourced from Open Street Maps (OSM) F (2024).

Layer – River Bank
The proximity of riverbanks, in conjunction with sports and recreational opportunities, affects the land and creates a specific microclimate suitable for certain grape varieties, which further influences the production of distinctive wines and the development of unique wine subregions.

In the studied area, a total of 215 rivers and smaller streams have been registered. The classification is based on the distance from the riverbanks, with several distinct groups created according to proximity. The data for this classification were obtained from Open Street Maps (OSM) (2024).
The following zones are defined:
1. Zone 1 (0–15 km): Areas within 15 km from the riverbanks are assigned value 4, reflecting a higher degree of human influence and access to water resources. This represents areas that are most closely influenced by the rivers, where human activities like agriculture and settling are more intensive as a result of being closer to water bodies.
2. Zone 2 (15–30 km): Areas between 15 km and 30 km from the riverbanks (value 2), with a moderate influence from the river system. These subregions still feel the impact of the rivers but to a lesser extent, and the human influence on the landscape becomes more spread out.
3. Zone 3 (>30 km): more than 30 km from the riverbanks, human population influences are much weaker and, usually, the value is 0. In this zone, rivers will have a small effect on the surroundings, and areas are kept farther from access to water.

Layer – Night Stable Light Value
This layer considers the satellite night images – VIIRS Nighttime Lights – to establish the degree of brightness across different locations. Data was extracted from the VIIRS Nighttime Lights satellite images for the selected wine-growing subregions, and processed further. It classifies the images into three categories based on brightness, namely from 1 to 38 – value 3, from 39 to 88 – value 6, and above 89 – value 10. These categories are used to assess the intensity of artificial light during the night, as an indicator of human activity and urban development. High levels of nighttime light usually indicate high levels of economic activity and a more developed infrastructure, which can be a factor affecting the potential for tourism and the related activities in those areas (Krikigianni *et al.*, 2019; Nello *et al.*, 2017; Devkota *et al.*, 2019; Checa and Nel, 2018).

Layer – Urban Areas
This category represents all larger settlements and city centres within the studied wine-growing areas. Two classifications stand out: areas inside urban polygons (value 10), and areas outside urban polygons (value 0). During the latest viticultural regionalization in 2015, larger and smaller urban centres were included in each viticultural region, such as Subotica, Valjevo, Kragujevac, Požarevac, Niš, Paraćin, Jagodina, Kruševac, Prokuplje, Vranje, etc. Certain cities, including Leskovac, Negotin, and Vršac, are located in the immediate vicinity of the wine-growing subregions. The data for the urban areas were sourced from the Military Geographic Institute (1988) and Google Maps (2024).

Layer – Categories of Land Cover
These categories were obtained from the satellite images of land cover and its use, specifically from the CORINE Land Cover 2018 dataset. Four categories were derived from the analysis: urban areas with the value of 10, agricultural areas with the value of 6, forests with the value of 4, and water bodies with the value of 2. This classification enables the differentiation of land cover types within the wine-growing subregions and helps assess the impact of land use on viticulture.

The CORINE Land Cover 2018 dataset describes the status and changes of the European landscape, primarily in terms of human settlements distribution, agricultural classes, and natural zones. This set is used to identify zones of high viticulture potential and those potentially facing environmental problems.

It is combined into a single calculation for the HII by giving each of these multiple layers an absolute value representing how much that layer adds to or otherwise influences the wine-growing region, further weighing the results to represent which factor it influences most: a combination of access to rivers, population density, infrastructure, and land use. The formula is expressed as:

$$HII = \sum_{i=1}^{n}(V_i \times W_i)$$

Where:

V_i is the values assigned to each variable (e.g., values for proximity to rivers, population density, light pollution, etc.)

W_i are the weights reflecting the significance of each variable in the overall impact.

HII is the total for the wine-growing subregions, with values ranging from 0 (no human impact) to 64 (high level of human impact).

Cultural Heritage Protection and Evaluation Methodology Based on the Law on Cultural Property

The criterion for the valorisation of cultural heritage is based on the degree of protection afforded by the state, i.e., the Law on Cultural Property. According to this Law, three categories of protection stand out: cultural property of exceptional importance, cultural property of great importance, and other cultural property. Cultural assets of exceptional importance have the highest degree of protection and are assigned the highest value. As the degree of protection decreases, so does the value assigned to the property (Table 1). Based on this, cultural heritage in the wine-growing subregions of Serbia was classified into three main categories: (1) *Monasteries*, representing unique cultural and spiritual centres (cultural properties of exceptional importance); (2) *Sacral objects*, including churches, mosques, and synagogues, which hold significant religious and cultural value (cultural properties of great importance); and (3) *Monuments*, encompassing non-religious structures such as statues and memorials that serve as historical and cultural landmarks (other cultural properties). The data for evaluating the cultural heritage in this study was sourced from Open Street Maps (OSM) (2024) and topographic maps (Military Geographic Institute, 1988). The data for evaluating the cultural heritage in this study was sourced from Open Street Maps (OSM) (2024) and through field research.

Table 1

Evaluation of cultural heritage in the wine-growing areas of Serbia according to the degree of protection based on the Law on Cultural Property, Republic of Serbia

Protected cultural property	Value
Cultural properties of exceptional importance	9
Cultural properties of great importance	7
Other cultural properties	5

Based on the Law on Cultural Heritage ("Official Gazette of the Republic of Serbia", Nos. 71/94, 52/2011 – Constitutional Court decision, and 99/2011 – other law), the sites are classified into three categories: cultural properties of exceptional importance (assigned a value of 9), cultural properties of great importance (value 7), and registered cultural property (value 5). These values were assigned proportionally to the level of protection, with a higher degree of protection implying a greater significance for the analysis.

4. RESULTS

Navigable rivers have the most significant influence along the Danube and the Tisa, particularly in the regions of Fruška Gora, Srem, Bačka, and the Negotin area, where rivers play a significant role in transport and accessibility (Fig. 2). Population density is mostly concentrated in wine areas near towns such as Topola, Aranđelovac, Smederevo, and Novi Sad, while sparsely populated areas are concentrated in eastern Serbia – especially Negotin, Knjaževac, and Župa – indicating the very rural character of these regions.

Railway connections are more developed in central and northern Serbia, in the areas of Srem, the Danube, and parts of Bačka, and much less in Župa, Negotin, and hilly southern and eastern Serbia. Longer riverbanks are found in areas such as Fruška Gora, the Negotin district, and western Bačka, which can contribute to the formation of more favourable microclimatic conditions and greater landscape beauty. A dense network of main roads is recorded in Šumadija – particularly in the Topola and Kragujevac areas – and Srem, Bačka, and the wider Belgrade area, while eastern and southern Serbia are less developed in terms of road network.

Nighttime light intensity is most prominent in wine regions near major cities such as Novi Sad, Belgrade, Smederevo, and Aranđelovac, indicating a high level of urbanization and human activity. In contrast, rural areas like Župa, Negotin, and Knjaževac show very little or no light pollution, confirming their natural and less anthropogenically modified character. Urban areas are mostly concentrated around Fruška Gora, Subotica, Smederevo, Topola, and Belgrade, while rural landscapes have been preserved in the wine regions of Župa, the Timok area, and Negotin.

Finally, the natural land cover – such as forests and vegetation – is prevalent in hilly and forested regions, such as Fruška Gora, Zlatibor, and the Timok region, while urban surfaces are concentrated near larger cities, and water bodies are located along major rivers in Srem, Bačka, and the Negotin region. These spatial patterns reflect the diversity of factors shaping the degree of human presence and infrastructural development in wine-growing areas, providing a foundation for the further evaluation of their accessibility, preservation, and potential for sustainable wine tourism development.
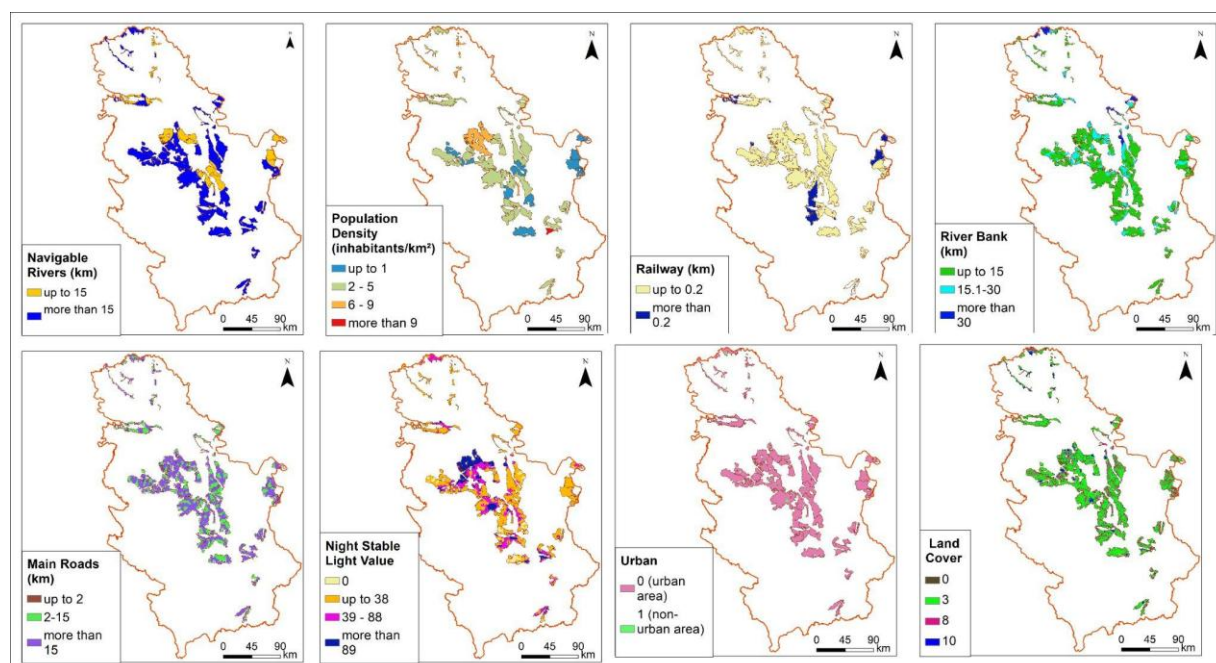

Fig. 2 – Thematic maps used in the assessment prior to HII calculation.

Source: Authors' elaboration.

Based on the calculation of the HII, the authors propose protective zones for the cultural heritage in the wine-growing areas of Serbia, categorizing them into three zones based on HII values: green (0–16), yellow (17–32), and red (32–64) (Fig. 3). They represent different levels of human impact, with the classification serving as a criterion for assessing the degree of influence on cultural heritage. The green zone would represent an area of strict protection, preserving the original or slightly modified landscape. This would be the zone of maximum scientific and practical values, and here, every kind of construction, resource exploitation, or any modification of the original landscape – such as the wine route through vineyard conservation – will be prohibited. The protection of the cultural heritage in these zones is very important and ensures the conservation of the main historical and spiritual landmarks, together with minimal human influence.
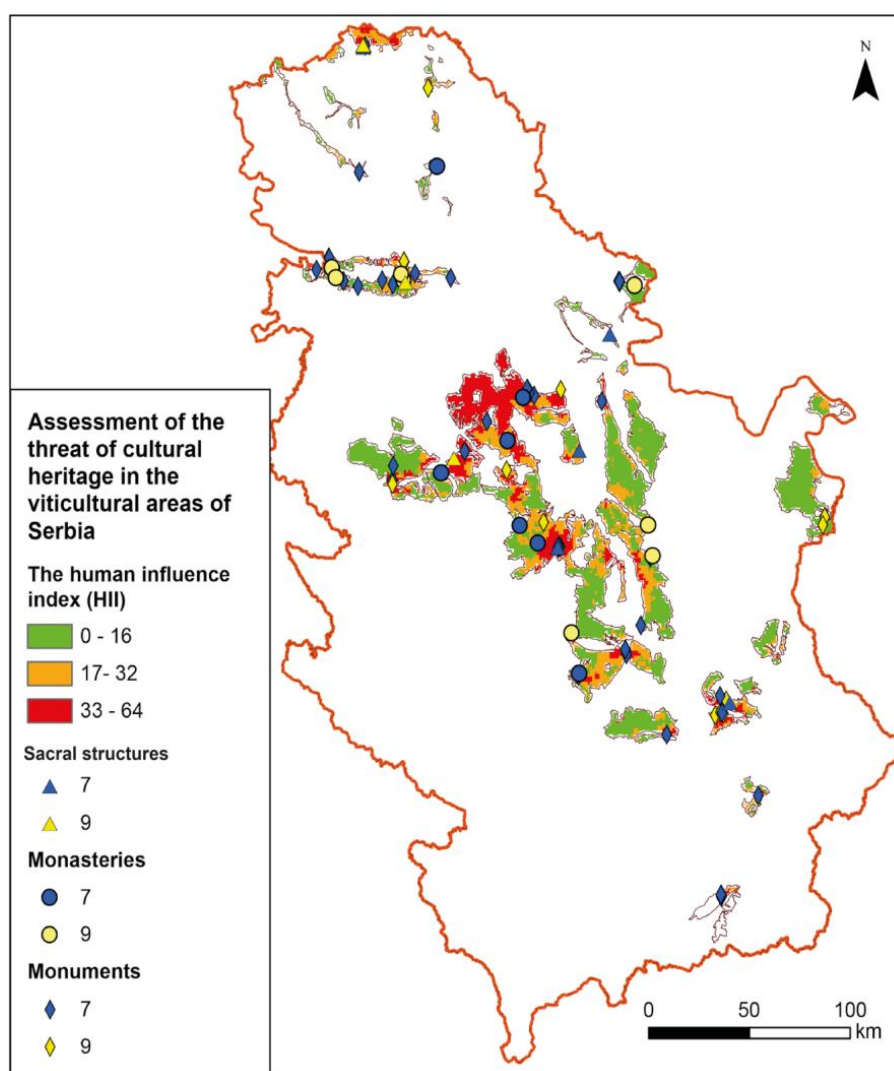

Fig. 3 – HII with Protective Zones and Assessment of Cultural Heritage Threats in the Wine-Growing Areas of Serbia.

Source: Authors' elaboration.

Firstly, the results are presented (Figure 3), and then the new knowledge is interpreted. The green zone, which represents an unchanged or minimally altered landscape, is located away from the

immediate vicinity of cities in Serbia's wine-growing subregions. According to the Human Impact Index (HII), this zone is characterized by the lowest human impact, with values falling within the 0–16 range. The green zone is the most dominant for monasteries across all protection values (9, 7, and 5). Monasteries classified as cultural properties of exceptional importance (value 9) make up 87.50% of this zone. These include: Ravanica Monastery (Three Moravas Region, number 3 on Figure 1), Mesić Monastery (12), Velika Remeta Monastery (16), Krušedol Monastery (16), Đipša Monastery (16), Divoš Monastery (16), and Ljubostina Monastery (3). In the case of monasteries rated with a 7 (cultural property of great importance), they make up 42.86%, and include: Ramača Monastery (2), Drenča Monastery (3), and Chapel (13). For other cultural properties (value 5), the representation in the green zone is 33.33%.

In the green zone, churches do not dominate as much as monasteries. They are present only in as cultural assets of great importance (value 7), accounting for 14.29% of the zone. One example is the Orthodox Church (12). In value 5 (other cultural assets), churches represent 23.08%. Monuments are the most dominant in value 7, with a share of 38.18%. In the green zone, monuments of great cultural importance include: the Medieval City of Stalać (3), Aleksandar's Mine and Senje's Mine (3), the Old Centre of Irig (16), the Old Pharmacy, the Former People's Committee Building (12), the Anđa Ranković Kindergarten Building (12), The Building on Victory Square (12), the building in Žarko Zrenjanin's Street (12), Jovan Steria Popović's House (12), the House of Two Guns (12), Kokordija Building (12), the Townhouse (12), Brankovina (4), the Water Mill (16), Village House (16), the Birthplace of Gligorij Vozarević (16), Grugurevci (16), and Lukarevina Meadow (3). Next, in value 9, the share is 22.22%. The following monuments in the green zone are assigned this value: the Bishop's Palace (12), Farm House (16), Rogljevo Wineries (7), and Rajac Wineries with the Old Cemetery (7). In value 5, a total of 9.38% of monuments are represented.

The yellow zone is the most dominant among monasteries, with a grade of 5, accounting for a total share of 41.67%. The next value, rated 7 (cultural assets of great importance), has a share of 14.29%, and includes Rajinovac Monastery (1). A cultural asset of exceptional importance, located in the yellow zone, which makes up 12.50% of the total share is Manasija Monastery (3). Churches in the yellow zone are most dominant in the value of cultural heritage of exceptional importance (33.33%), an example of which is Sretenje Church (16). In this same zone, monasteries rated 7 dominate, with a share of 14.29%, such as St. George Monastery (2). Other cultural assets (grade 5) contribute amount to 7.69%.

The yellow zone is the least dominant for monumental heritage, with a share of 27.78% for cultural assets of exceptional importance. These include the following monuments: Marićević Gully (2), the Peace Chapel in Sremski Karlovci (16), the Old Town Centre of Sremski Karlovci (16), the site of the 1697 battle (13), and Sobrašice (2). A total of 12.73% of cultural properties of great importance are monuments such as: the Tower of Vrdnik (16), the Partizan Base Centre (14), Čornok (14), Acumincum - Gradina (16), Great Hum Hill (8), the House of Cincar (1), and Mihaljevac Forest (16). A total of 9.38% of monuments belong to the value rated 5.

The red zone is the most dominant among churches, particularly in the value with a rating of 7 (71.43%): the Church of the Holy Great Martyr Demetrius (15), the Church of Saint Teresa of Avila (15), the Franciscan Church (15), the Old Church of the Descent of the Holy Spirit (2), and the Latin Church (8). In value 9 (cultural assets of exceptional importance), churches make up 66.67%, including: the Synagogue (15) and the Memorial Church with an Ossuary (1). A total of 69.23% of churches belong to value 5.

Of the monuments, they are most dominant in value 5 at 81.25%, with categories 9 and 7 tied at 50.00% and 49.09%, respectively. Among these, within the green zone are some of the most famous monuments designated as cultural monuments of great importance: the Old Bath (11) and the Tower of Nenadović (4), while the cultural properties of exceptional importance are the Bubanj Memorial Park (8) and Skull Tower (8). The biggest group consists of the less important monuments in value 5.

As far as monuments are concerned, value 5 dominates with 81.25% of monuments, followed by categories 9 (50.00%) and 7 (49.09%). Some notable monuments in value 7 include the Old Bath (11), the Tower of Nenadović (3), and the old city centre of Kragujevac (1). Cultural properties of exceptional importance (value 9) include the Bubanj Memorial Park (8), Skull Tower (8), and Smederevo Fortress (2). Additionally, there are several other cultural properties of great importance, such as the Residence of Prince Miloš and the District Court building (2). There are no monasteries of exceptional importance in the red zone. Monasteries rated 7 (42.86%) include Drača Monastery (Kragujevac wine-growing district), Bogovađa Monastery (Kolubara-Ljig wine-growing district), and Pavlovac Monastery (in the Avala-Kosmaj wine-growing district). Monasteries in value 5 account for 25.00%.

The results indicate that monasteries of exceptional cultural importance are concentrated in the green zone, while monuments in this value are fewer. Churches and museums are also rare in this zone. In contrast, the red zone, which has been most impacted by human activity, contains the highest concentration of other types of cultural heritage. The research demonstrated a visible trend of a high urbanization level with a drop in cultural heritage preservation. The green zone, according to the HII, comprises areas with minimal landscape alteration and is the most dominant for monasteries, especially for those classified in value 9 as cultural properties of exceptional importance. This zone includes monasteries such as Ravanica, Mesić, Velika Remeta, and others that make up 87.5% of the properties in this value. A great part of the area is occupied by monasteries rated 7, such as Ramača and Drenča. This zone is relatively poor in churches and there are fewer monuments present here compared to other zones.

The yellow zone is the area of active protection, with a partly changed landscape where revitalization can be done without a high risk to the cultural heritage. The yellow zone includes monasteries like Manasija; churches prevail in the value of cultural properties of exceptional importance, like Sretenje Church. There are fewer monuments than in the red zone but still some very important sites exist, such as Marićević Gully and the Old Town Centre in Sremski Karlovci.

The red zone involves a high concentration of the impact of urbanization and anthropization, and it shows the highest concentration, especially in the value of cultural properties of great importance – value 7. It is dominated by churches like the Church of the Holy Great Martyr Demetrius and the Latin Church, while monuments of exceptional cultural significance are the Synagogue and the Memorial Church with an Ossuary. The development of urbanization is a big threat to the natural resources and cultural heritage of the wine-growing area of Serbia. During the past decades, built-up areas have been extensively developed at the expense of arable land, pastures, and meadows. The industrialization, urbanization, and suburbanization processes are changing the traditional vineyard landscape and decreasing the visibility of many rare and attractive landscape types. Therefore, numerous historical and cultural landscape structures and units are in a state of being endangered and disappearing.

The largest number of monasteries of exceptional value (value 9) is concentrated in the green zone, which is least impacted by human influence. This could be attributed to historical and geographical factors: throughout Serbia's turbulent history, monasteries were always built in inaccessible and geographically isolated areas to remain as protected as possible from enemies. The after-effects have been their better preservation to date, allowing them to resist the modern trends of construction, urbanization, and industrialization. Other reasons that contribute to such concentration and domination of monasteries in the green zone include religious and cultural significance. Monasteries have always been the centre of spirituality and culture for Serbs, which further contributed to the former's better preservation. On the other hand, the presence of churches and monuments in the red zone is due to the greater pressure from construction, infrastructure, residential, and commercial buildings that have been most affected by urbanization and anthropization. This has brought about the expansion and modernization of cities, exposing this group of monuments to a higher risk of degradation. For instance, the old town centre of Kragujevac with the continuous building in the city's centre presents such risks.

It means a protection mechanism needs to be put in place within the process of urbanization, in balance with the preservation of cultural landscapes, such as wine-growing areas in the red zone. In other words, it is a question of urban planning development by taking care not to jeopardize the survival of winegrowing areas but supports cultural heritage and wine production tradition preservation. In the green zone, it is important to maintain the specific characteristics of the wine-growing landscape to ensure that monasteries and vineyards remain in harmony with both the natural and cultural heritage, thus contributing to the longevity and development of the winemaking tradition in these subregions.

5. DISCUSSION

The results of the study reveal that cultural heritage in wine-growing areas is distributed along green, yellow, and red zones, as activities depend on the level of human influence. Value 9 monasteries, that is, those of exceptional significance, would fall mainly in the green zone, since most were built in isolation for their protection. Examples include monasteries in the Srem subregion (such as Krušedol, Hopovo, and Grgeteg), as well as those near Negotin and Žiča near Kraljevo, which have historically been situated in less urbanized landscapes. Perhaps this is the reason they have survived the onslaught of urbanization and industrialization. These findings agree with Schlee (2017), who highlights that historical context and spatial relationships are what define buffer zones.

The red zone is highly affected by urbanization and includes the highest number of churches and monuments, which are in danger due to urban expansion and infrastructure development, particularly in urban centres such as Kragujevac, Sremski Karlovci, and Niš. According to the ICOMOS International Committee on Historic Towns and Villages (2013), planning should be made to integrate protective zones that overlap urban development for the protection of cultural heritage. Similarly, Conradin and Hammer (2016) suggest transitional zones that are less restrictive, while supporting sustainable development and the protection of cultural values.

The red zone represents the area with the most significant changes, urbanization, and anthropization. In this zone, areas such as the urban surroundings of Kragujevac and parts of the Novi Sad municipalities would be developed, rural households with traditional architecture would be improved, and buildings of cultural and historical importance would be preserved, along with the necessary infrastructure. The establishment of heavy industry would be prohibited in this zone, while the development of other industrial, tourist facilities, hunting and fishing activities, and various forms of tourism would be subject to strict limitations.

Based on the results of the HII, the yellow zone would serve as an area of active protection, encompassing a protected area, or part of it, within a partially altered landscape. Examples for this zone include the wine-growing landscapes of Topola (Oplenac), Vršac vineyards, and parts of Šumadija, where revitalization and restoration efforts could be carried out without harming the wine-growing districts or their cultural heritage. Natural resources would be used in a sustainable, strictly controlled manner, and traditional activities would continue. Industrial facilities would be excluded, while catering activities and accommodation establishments would be limited. A controlled development of tourist infrastructure would also be permitted.

According to this study, the yellow zone is an area where revitalization can be done with minimum risks to the cultural heritage. Versaci and Cardaci (2014) underline that the protective approach has to always vary from site to site; the standard distance of protection they propose is 500 meters, which is at the moment adopted by the French practice. This research finding challenges the notion of and presents the need for flexibility in the approach, depending on the context.

The protective mechanisms must be adapted according to each zone. In the green zone, the balance of natural and cultural heritage, including monasteries and vineyards, should be preserved in order for

the tradition of winemaking to endure. This is especially characteristic of regions such as Fruškagora, Negotin, and Župa, whose viticulture is inextricably bound up with historical religious locations. In the red zone, it is necessary to restrict the role of urbanization using the tools of urban planning: creating protection and transition zones in order to ensure preservation and modernization.

These results confirm similar works dealing with the proper establishment of protective zones. As underlined by Khamis and Kamarudin (2014), the advantages of a multiple regression analysis for land assessment can also be underlined for the configuration of protective zones, which Martin and Piatti (2008) also maintain. Future research might develop new methods in the context of cultural heritage management, using advanced approaches such as fuzzy sets and machine learning, as recently suggested by Gnat (2021).

Cultural and natural heritage in Croatia, Slovenia, Macedonia, and Montenegro are exposed to a variety of threats and challenges. Material cultural heritage preservation in Serbia and North Macedonia is mainly threatened by inadequate protection, unsatisfactory maintenance, and the lack of financial resources (Penjišević *et al.*, 2024). In Slovenia, oil pollution from shipping is the biggest threat to coastal cultural heritage and ecosystems (Perkovič *et al.*, 2016). UNESCO is also involved in the protection of heritage, such as the region of Ohrid in North Macedonia, which has been classified as a World Heritage site but is also exposed to uncontrolled tourism and urban development (Majhoshev & Koteski, 2019). Such problems are currently being tackled through the implementation of sustainable development strategies for Southeast European countries, focusing on the integrated management of cultural and natural heritage and their contribution to regional development (Pickard *et al.*, 2008). Improving awareness, digitization, and the enforcement of regulations are recommendations that would enhance heritage preservation efforts across the region (Majhoshev & Koteski, 2019; Penjišević *et al.*, 2024).

6. CONCLUSION

Most significant differentiating factors of these Serbian regions are variations in human pressures and impacts, with clear boundaries showing according to these intensities: a green, a yellow, and a red zone. The green zone, least subjected to urbanization and industrialization processes, consists of the main object of cultural significance such as monasteries, predominantly identified by value 9 and extremely well-preserved because of their geographical distance and historical values. On the other hand, the red zone represents that area which is most affected by human activity in the sense of churches and monuments being highly exposed to urbanization and infrastructural development. In the green zone, the primary goal ought to be to maintain the balance between natural and cultural heritage, especially in the context of viticulture and monastic complexes, while the red zone requires careful urban development planning, where the protection of cultural values should be a priority. Given the increasing urbanization and the pressures coming from infrastructure development, protecting the wine-growing areas and their cultural heritage becomes both a challenge and an opportunity for the further development of sustainable tourism and wine production models.

Future research should focus on further applying modern technologies such as artificial intelligence and machine learning in analysing and assessing the impacts of urbanization on cultural heritage. Additionally, it is important to develop methodologies for integrating protective zones into urban planning strategies, which would allow for cultural heritage preservation to be viewed not as an obstacle to development, but rather as an integral part of it.

Although the literature on the protection of cultural heritage in wine-growing areas is limited, this research opens the door for further studies and the application of new methodological approaches in cultural heritage management, particularly in the context of viticulture. In this regard, it is recommended that future research explore the specifics of Serbia's viticultural heritage, with an emphasis on preserving traditional winemaking methods in line with the protection of cultural and natural resources.

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