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Factsheets on a common understanding of AWO typologies and challenges

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RESPOnD AT A GLANCE

Small-scale Alpine vineyards represent a remarkable blend of ecological integrity, cultural heritage, and economic significance. Situated within distinctive landscapes and microclimates, these vineyards are increasingly vulnerable to the impacts of climate change and shifting environmental conditions.

Rising water scarcity, drought stress, and extreme weather events are contributing to a decline in wine quality and threatening the long-term viability of viticultural practices. This poses a serious risk to traditional cultivation methods that have shaped regional identities and supported local economies for the past generations.

In response to these changes, the RESPOnD project seeks to collaboratively develop Ecosystem-based Adaptation (EbA) strategies and sustainable development pathways with winegrowers and policymakers. By validating EbA approaches in specific pilot areas and disseminating practical knowledge, RESPOnD aims to foster climate-resilient management and governance within Alpine Wine Orchards (AWO).

The present report provides a common understanding on AWO in the Alpine Space in the form of a collection of short documents, one per each RESPOnD pilot region, where the main attributes, ecosystem services provided, climate change impacts and challenges are described.

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1. Introduction

1.1 Context of the document

The RESPOnD project (Climate Resilient Alpine Wine Orchards) aims to enhance the climate resilience of Alpine Wine Orchards (AWO) by empowering actors in the wine sector to adopt Ecosystem-based Adaptation (EbA) strategies. The project aims to co-create knowledge on AWO by working in multiple Living Labs (LL) across seven winegrowing regions within the Alpine Space (Jaramillo et al., 2025).

This deliverable provides a common understanding on AWO in the Alpine Space in the form of a collection of short documents, one per each RESPOnD winegrowing pilot region.

Throughout the document, the reader will:

- Recognize each pilot region through its main attributes.
- Identify the ecosystem services that are important in each pilot region.
- Identify the most important regional climate change impacts.
- Become familiar with the challenges that the wine sector in each pilot region is currently facing.

For each region, a set of selected maps will also show its relevant characteristics.

1.2 Living Lab – Phase 1

The RESPOnD LL are organized into three phases; each phase is designed to address a specific aspect of the project and enables its development through a continuous learning and co-production process. This deliverable specifically focuses on phase 1 (Figure 1).

Phases	2024	2025		2026		2027
	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Phase 1						
Phase 2						
Phase 3						

Figure 1. Living Labs' phases timeline. Each period refers to the 6 months intervals during which specific activities have been planned in the project.

Each of the RESPOnD pilot regions differs in their perspectives, viticultural practices, and stakeholder experiences. The collection of these diverse viewpoints from a local scale provides the foundation to build a common understanding of AWO in the Alpine Space. To gather the necessary information, during phase 1 of the LL, the RESPOnD project partners were provided with a survey to build knowledge on

the commonalities and differences of AWO in the Alpine Space. The survey guided the setup of phase 1 of the LL and resulted in a summary of the main characteristics of each pilot region involved in the project. To reach this objective the survey included four main topics:

1-Attributes: Described as quality or characteristic of the AWO. This topic included 9 categories (e.g., Land use/management, Climate, Cultural); for each category suggested examples were provided.

Research question: *Which attributes of the pilot region best represents it from the perspective of local stakeholders?*

2-Ecosystem services: Defined as the contributions that ecosystems provide to the human well-being. This topic included 12 ecosystem services categories.

Research question: *What are the ecosystem services that the stakeholders recognize of utmost importance in the pilot region?*

3-Climate change impacts: Described as the effect caused by an alteration in the regional or global climate. Here four main impacts were provided, change in precipitation patterns, increase in extreme events (droughts, floods), increase in temperature and increased CO_2 concentration.

Research question: *Based on the experiences of stakeholders, what are the most important climate change trends in the area and what are related impacts?*

4-Challenges: An open question was provided to give voice to the wine sectors actors in relation with the challenges that they face nowadays.

Research question: *Did stakeholders mention any other problems or challenges for viticulture in the pilot area, aside from the negative impacts of climate change?*

Project partners provided feedback on the survey in the form of a document where they summarized the main characteristics of their pilot region based on the input received from stakeholders from the wine sector in a set of workshops (see Table 1). This information was then gathered and organized in a set of homogeneous factsheets that are presented in this deliverable.

Table 1. LL Phase 1 – Workshop dates

Project Partners	LL – Phase 1
EURAC - Laimburg	Conducted on 11.06.2025
UBT-PES	Conducted on 20.06.2025
CERVIM	Conducted on 25.06.2025
5TNP	Conducted on 07.08.2025
Weinidylle - WAB	Conducted on 29.01.2025
PNRBV - CCITA	Conducted on 27.11.2025
RDA ROD - UNG	Conducted on 05.11.2025

a)

b)

c)

d)

Figure 2. Living Lab 1 set-ups within the Alpine Space. a) South Tyrol, IT; b) Ballons des Vosges, FR; c) Vipavska dolina , SI; d) Franken, DE.

In addition to the co-created knowledge in each pilot region, this document includes a series of bioclimatic and geomorphological indicators, as well as maps of other ecosystem conditions (e.g., land use, soil organic carbon). The maps not only provide a visual representation of the projects' areas but aim at informing the public about the characteristics and conditions of each pilot region. The similarities and differences shed light on the diverse typologies of wine making areas present in the Alps. The inclusion of these maps should also provide insights into the current conditions of each pilot region that can support the development of the next steps of the RESPOnD LL.

2. Pilot region: Alto Adige/Südtirol

Characterization of the region

South Tyrol is an autonomous province in northern Italy that lies between Austria and Switzerland. The region is characterised by its diverse landscape which includes deep valleys, steep mountain peaks and a mix of geological formations. South Tyrolean landscapes are dominated by forests, permanent and alpine grasslands, and sparsely vegetated areas. Agricultural landscapes are typically located in the valley floors (e.g., apple orchards), or in the valley's slopes (e.g., viticulture.). The viticultural landscape is shaped by its small-scale and diversified structure, with over 5,000 individual winegrowers managing 5,800 hectares of vineyards (Landesverwaltung für Landwirtschaft und Forstwirtschaft, 2025). The small-scale structure and stable economy maintain the winegrowing sector which is closely linked to cultural tradition and keep younger generations interested. Tourism is another defining element as eco- and agrotourism link the local wine with landscape heritage. The climatic conditions, with mild sunny days, warm soils, cool nights and good ventilation, allow the cultivation of more than 20 different grape varieties, including indigenous varieties such as Lagrein, Schiava, and Gewürztraminer (Südtirol Wein, 2017, 2025). In South Tyrol the widespread vineyard greening norm improves soil stabilization while support water retention. However, the increasing need for irrigation on the part of stakeholder reflects changing climatic conditions. South Tyrol high-quality wine production is recognised worldwide, and since 1976 the region has been officially registered with the status of Protected Designation of Origin.

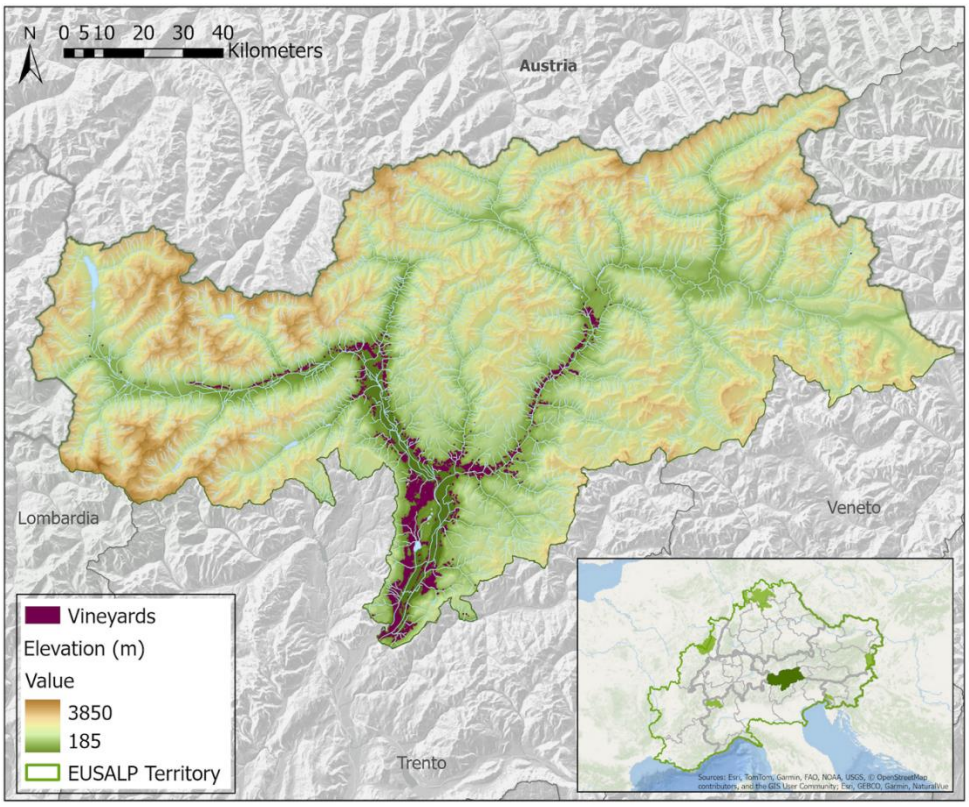

Figure 3. Map of the pilot region South Tyrol and localization of its vineyards. Source: Elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 4. Example of a typical vineyard landscape in South Tyrol. Source: Heidi Simion.

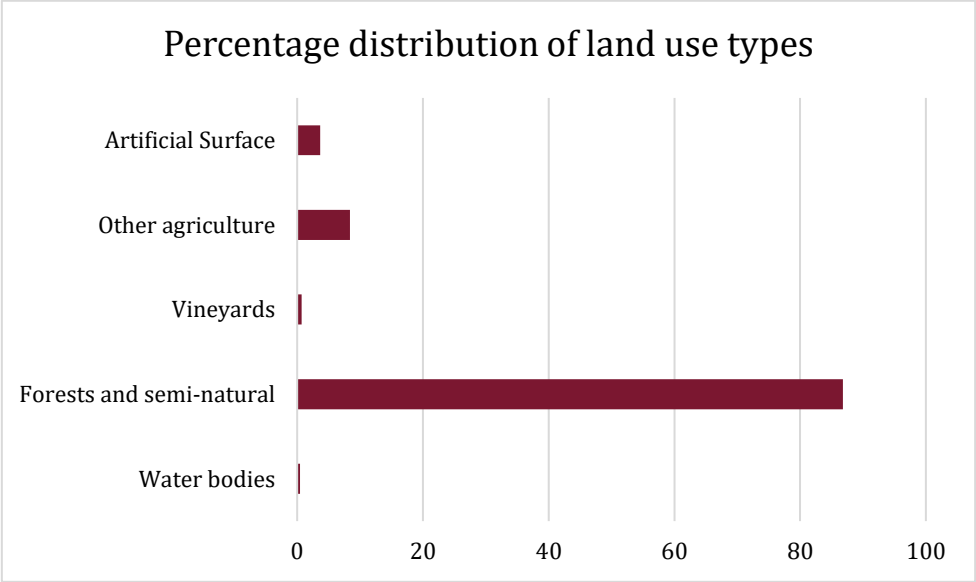

Figure 5. Macro categories of land use classes in South Tyrol. Source: Marsoner, T. et al., 2023; European Environmental Agency, 2025.

Ecosystem services in South Tyrol

During the first phase of stakeholder involvement in South Tyrol, the local actors indicated important ecosystem services for viticulture in the region (Table 2).

Table 2. Ecosystem services relevant to South Tyrolean viticulture.

Ecosystem Service	Relevance for the area
Crop production	Economic considerations play an important role in South Tyrolean high-quality wine production. Stakeholders agree that without financial stability, there would be no vineyards in the long term. For stakeholders crop production is the basis upon which many other services depend.
Landscape aesthetics	The appealing viticultural landscape in the region attracts tourist from all over the world. Here, the aesthetic value of the landscape is an important driver of the tourism sector, and it is not limited to wine tourism. In addition, the region´s multifunctionality is evident in the way tourism and wine production are linked, with both sectors strengthening each other.
Cultural heritage	Over time, the wine sector in South Tyrol has experienced multiple changes. Stakeholder points of views differ, as the use of new varieties and the practices are no longer the ones used in former times. However, they agree that the continuation of vine cultivation itself is a living tradition and an essential part of local identity. The wine sector in South Tyrol is alive as younger generations are still interested in the sector.
Maintaining populations and habitats	Stakeholders pointed to the decline in biodiversity over recent decades. They suggested the reintroduction of hedgerows and trees within the plots to offer shade and habitats for birds. Although South Tyrol cultivation is nowadays intensive, greening in the vineyards is perceived as an important source of biodiversity.
Soil processes/ Regulation of water and erosion	Healthy soil is perceived by stakeholders as a fundamental basis for long-term vineyard productivity. Practices such as cover cropping increase soil organic matter and nutrient cycling and are implemented by many wineries. Water use is primarily regulated by consortia that regulate licenses. Wells are often shared by multiple growers which have fixed turns where they are allowed to irrigate.

Climate change impacts in South Tyrol

Multiple climatic impacts are increasingly impacting South Tyrolean viticultural landscapes. The most tangible influences reported by stakeholders are the following:

- Changes in precipitation patterns are perceived as the most important climate change impact as drought stress is present in the area. Due to this stress, stakeholders highlight the importance of water availability to ensure high-quality wine production, emphasising that drip irrigation is essential for grape growing.
- The rise in temperature is also a concern among winegrowers as pest and disease pressure is increasing while other significant impacts, such as loss of acidity and higher sugar content in grapes, directly influence the grape quality and harvest timing.

- Extreme weather events, such as flooding and landslides, waterlogging during heavy rainfall, and increased soil erosion, are increasingly worrying the stakeholders in terms of potential damage to the crop.

Challenges for viticulture in South Tyrol

Beyond climate change, some further challenges were highlighted by stakeholders in South Tyrol, which include:

- The traditional values within viticulture are declining as fewer practices are continued just for tradition. In South Tyrol, the economic considerations are increasingly prioritised leaving aside the traditional practices.
- The loss of landscape features, such as hedgerows and trees within vineyard plots, was stressed by the stakeholders. These structures used to be common and provided habitats for wildlife. However, they have largely disappeared, reducing the area's ecological diversity.

Annex I: South Tyrol maps

A. Bioclimatic maps

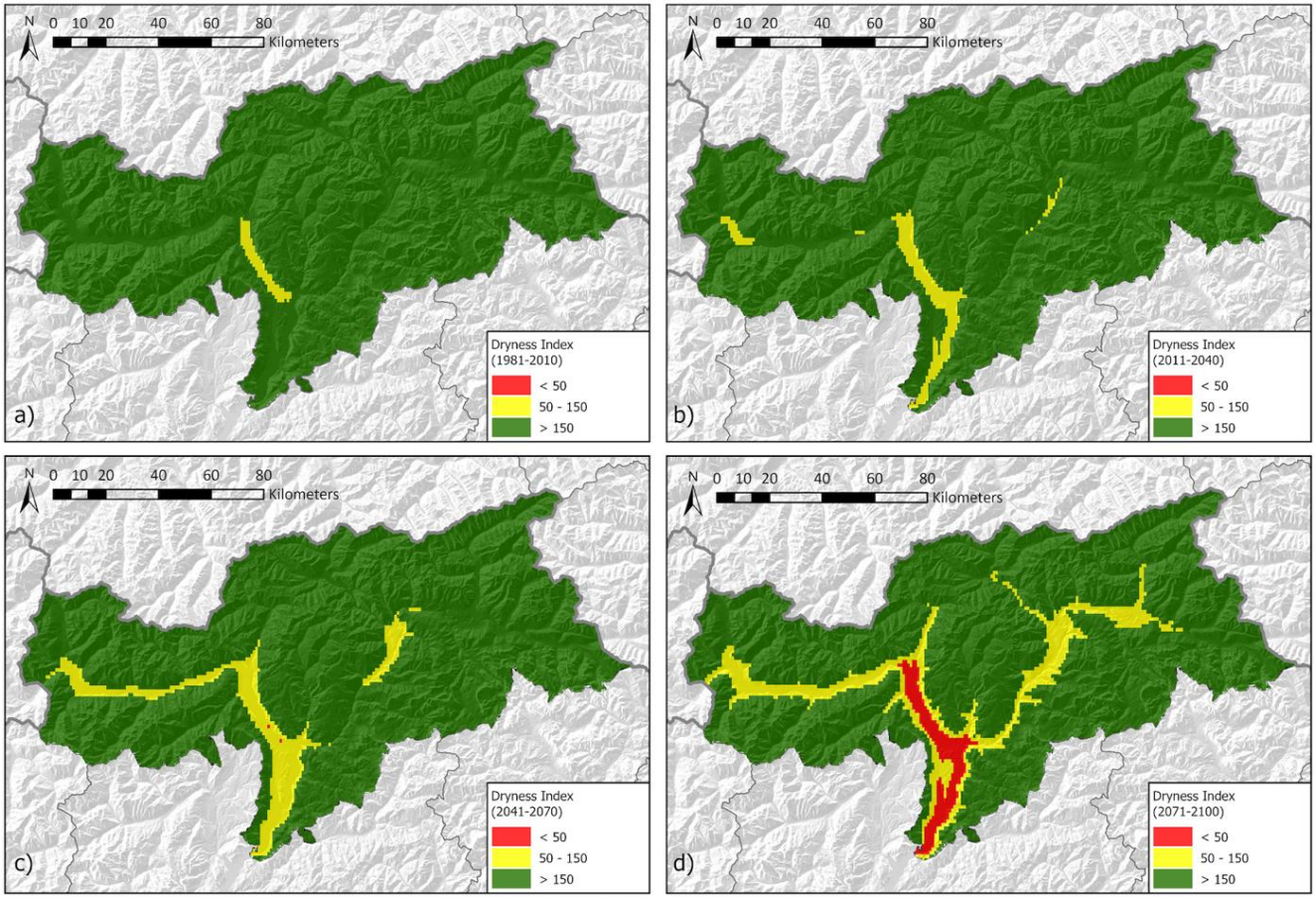

Figure 6. Dryness Index for the pilot region under SSP3 at different time steps for the pilot region. The Dryness Index evaluates soil water availability (in mm) for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

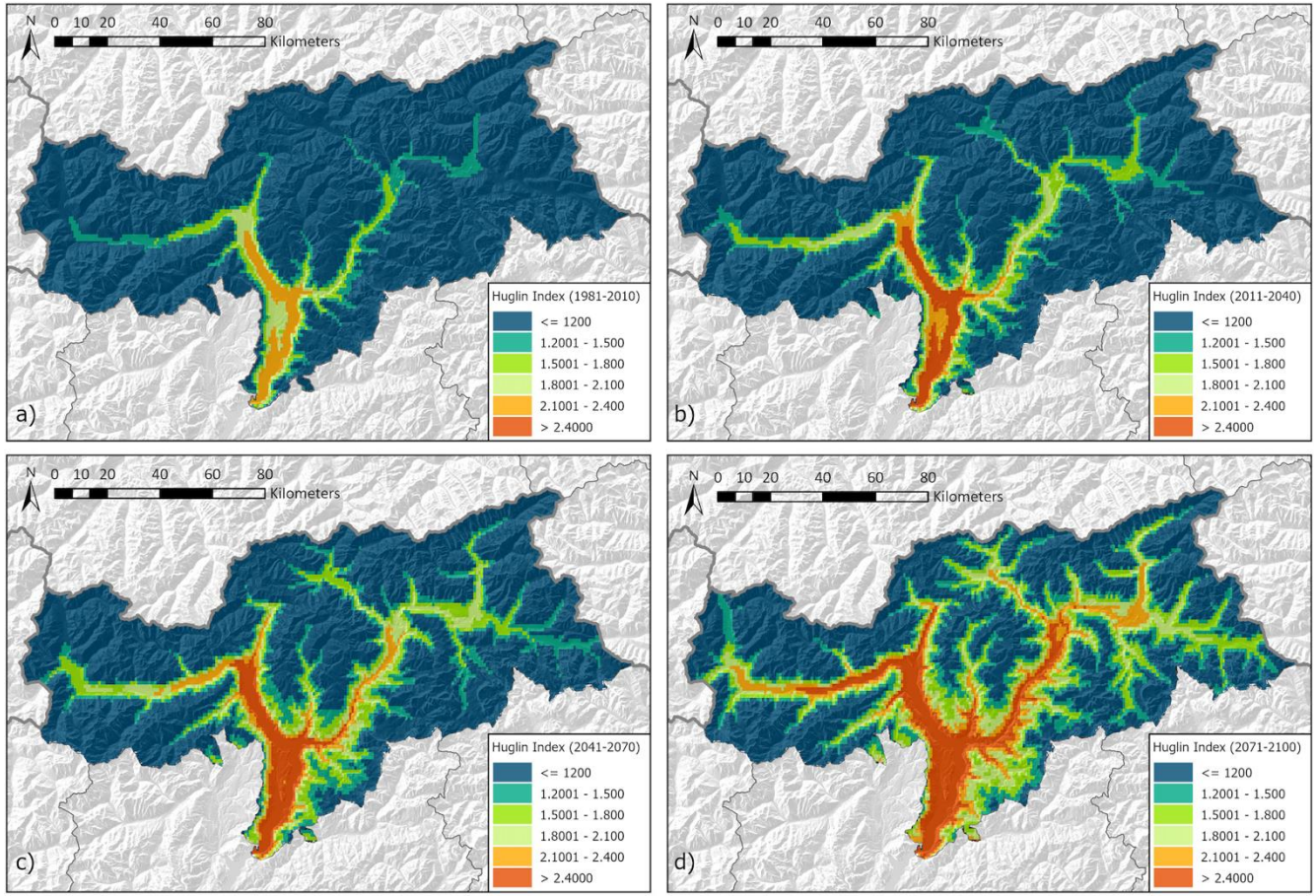

Figure 7. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin Index describes the accumulated thermal conditions (in Growing Degree Days (GDD)) in a wine region during the vegetation period, which is related to the potential grape sugar content. Source: own elaboration based on data from Tscholl et al. 2024.

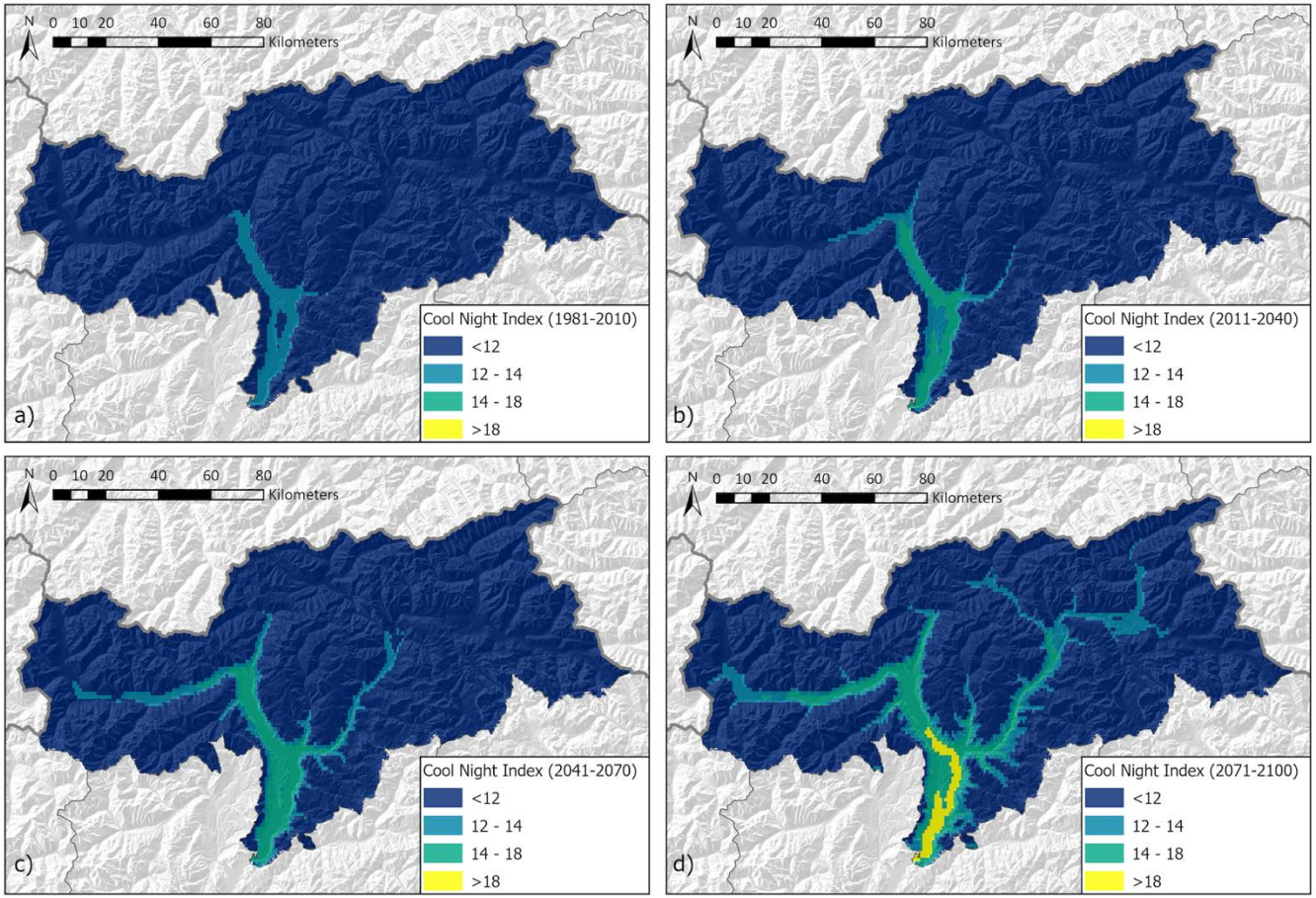

Figure 8. Cool Night Index for the pilot region under SSP3 at different time steps for the pilot region. The CoolNnight Index accounts for minimum temperatures (in °C) during September, providing an estimate of temperature conditions during the ripening stage. Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

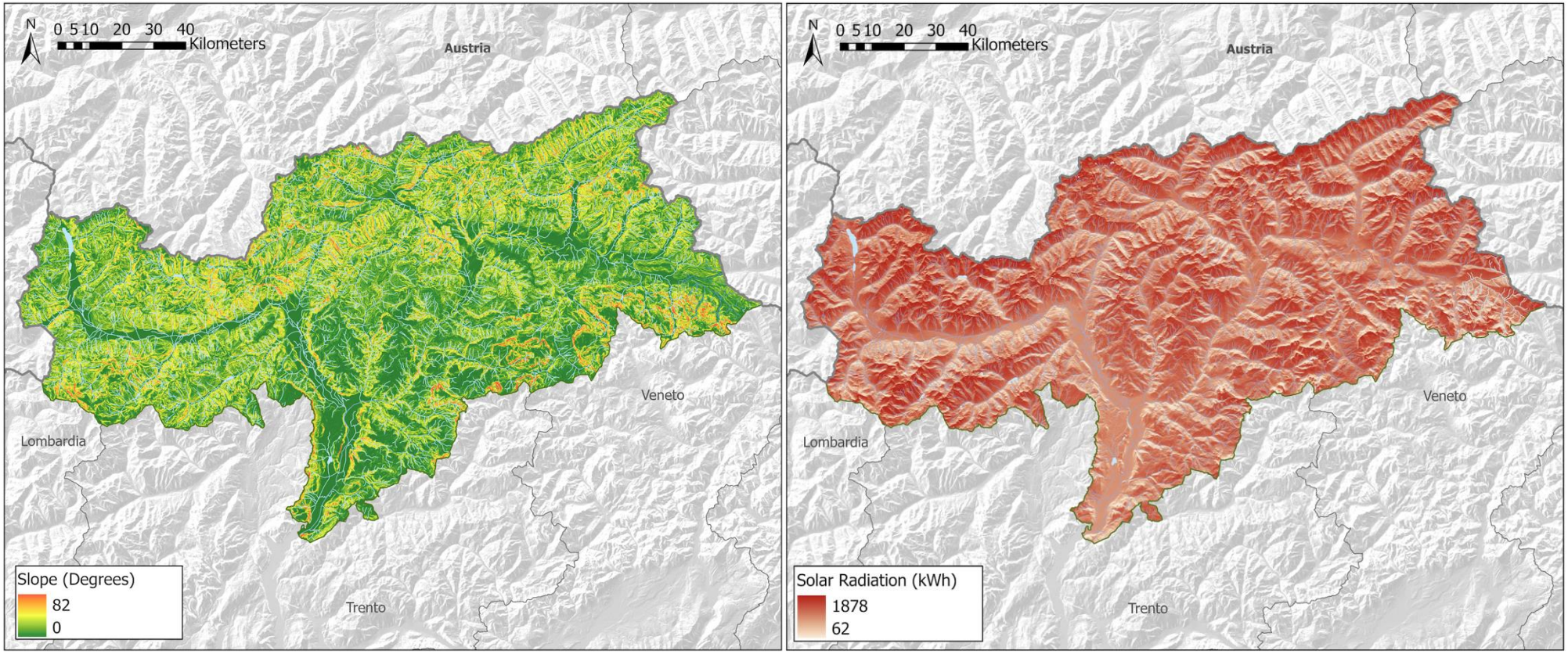

Figure 9. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: own elaboration based on data from EEA, 2014.

C. Land use and soil

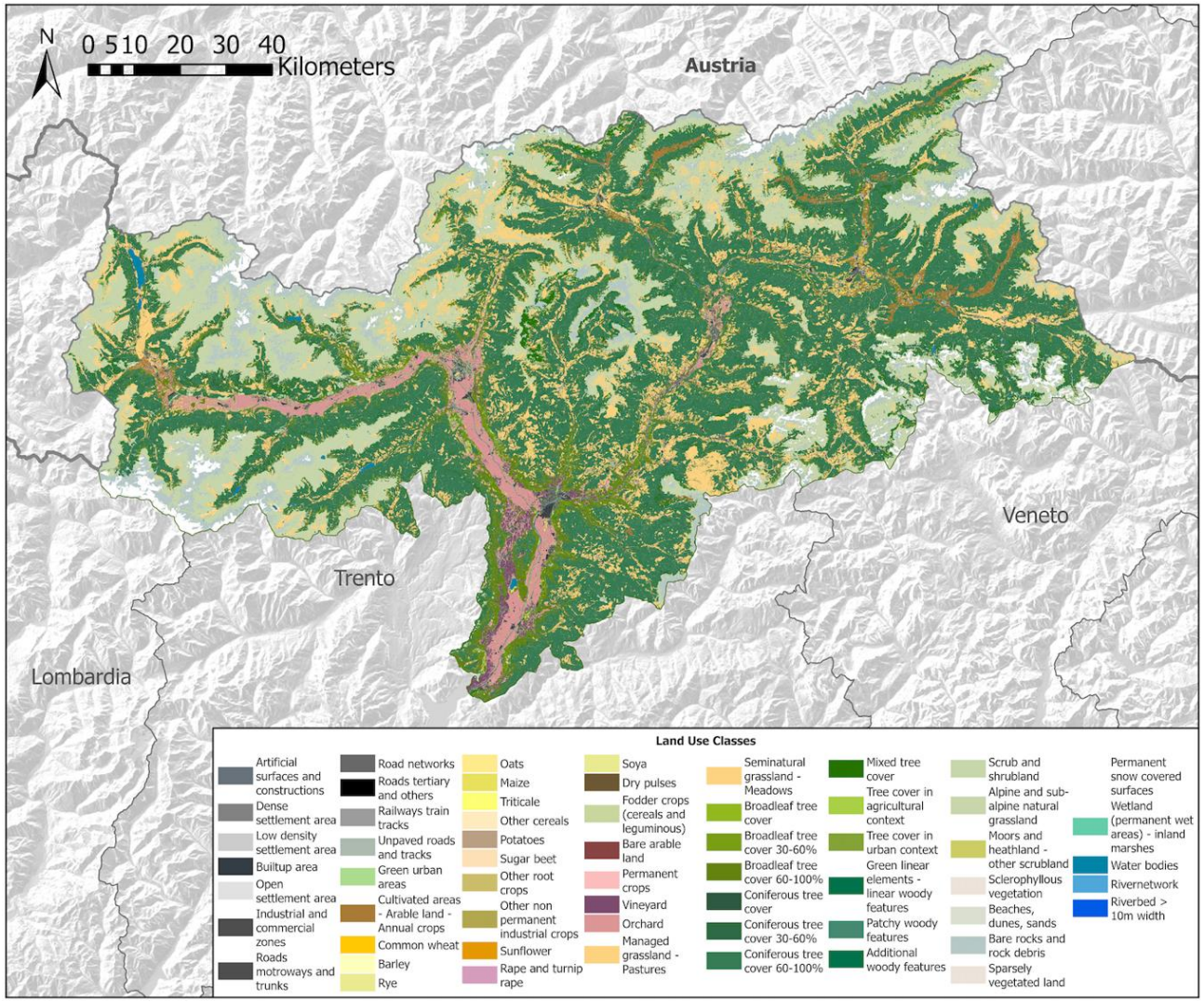

Figure 10. Land use land cover in the pilot region. Source: own elaboration based on data from Marsoner, T. et al., 2023.

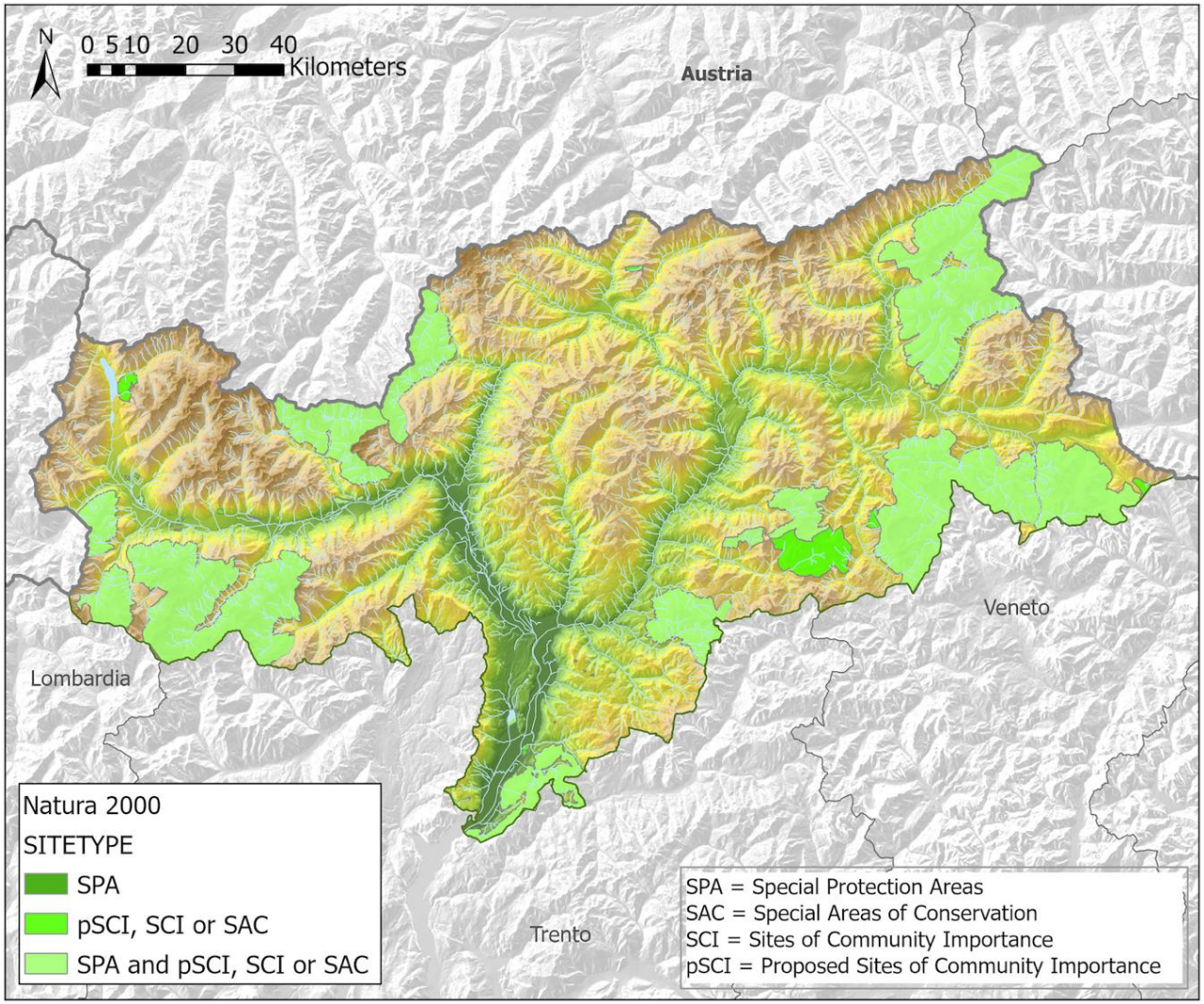

Figure 11. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

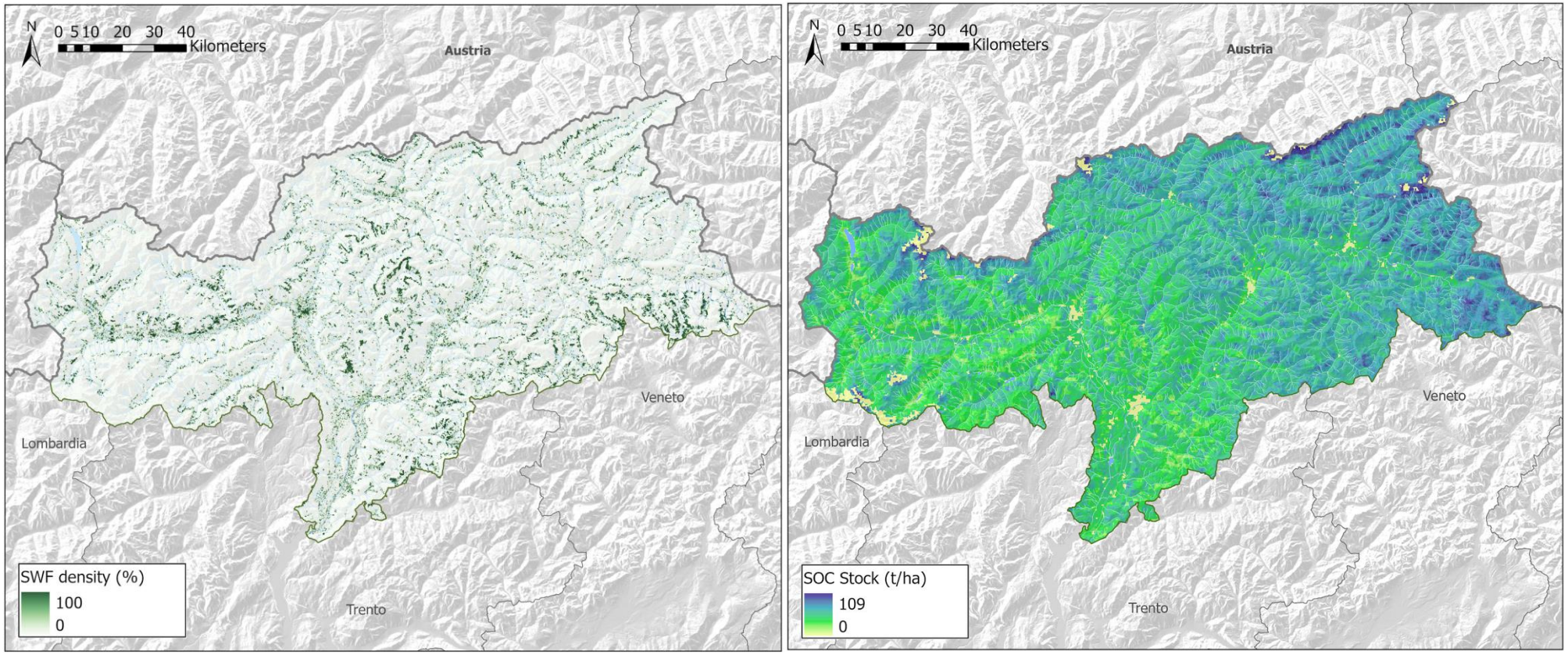

Figure 12. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right).
Source: own elaboration based on data from EEA, 2025; Isric, 2025.

3. Pilot region: Cinque Terre

Characterization of the region

The pilot region “Cinque Terre” is located in north-western Italy, its area includes five small villages and a narrow coastal zone (Raso et al., 2021). The name "Cinque Terre" derives from the five cities that comprise it, Riomaggiore, Manarola, Corniglia, Vernazza and Monterosso al Mare (Terranova, 2006). It is considered an example of human-modified landscape where local farmers transformed the original slope topography (Brandolini, 2017). The transformations of the landscape over thousand years, converted steep, rocky slopes into cultivable strips, supported by a dry-stone walls network. The Cinque Terre pilot region is represented by the interplay between its cultural landscapes, human presence, and environmental diversity. The viticultural landscape of Cinque Terre is not just a beautiful scenic view but also a vital infrastructure for slope stabilization, erosion control, and protection against extreme weather. High-quality wine production in the region demands certain and multidisciplinary skills, combining viticulture, marketing, and enology. Among the specialities of Cinque Terre, the grapes from the vineyards Bosco, Albarola and Vermentino are the ones needed to produce the well-known wine Sciacchetrà (Cinque Terre National Park, 2026). In Cinque Terre, tourism is considered a controversial topic, while it can sustain local economy in the other hand could be intense and overwhelming, causing concerns about its impacts as sometimes tourists visit the villages without exploring the rural context in which they are.

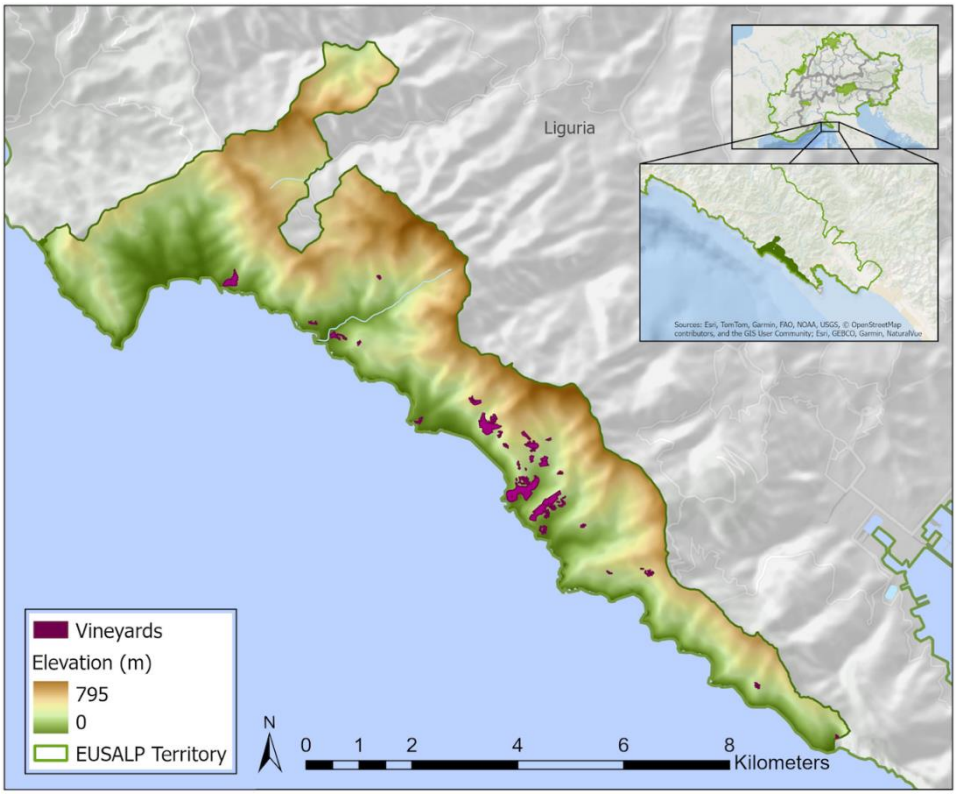

Figure 13. Map of the pilot region "Cinque Terre" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 14. Viticultural landscape in Cinque Terre.

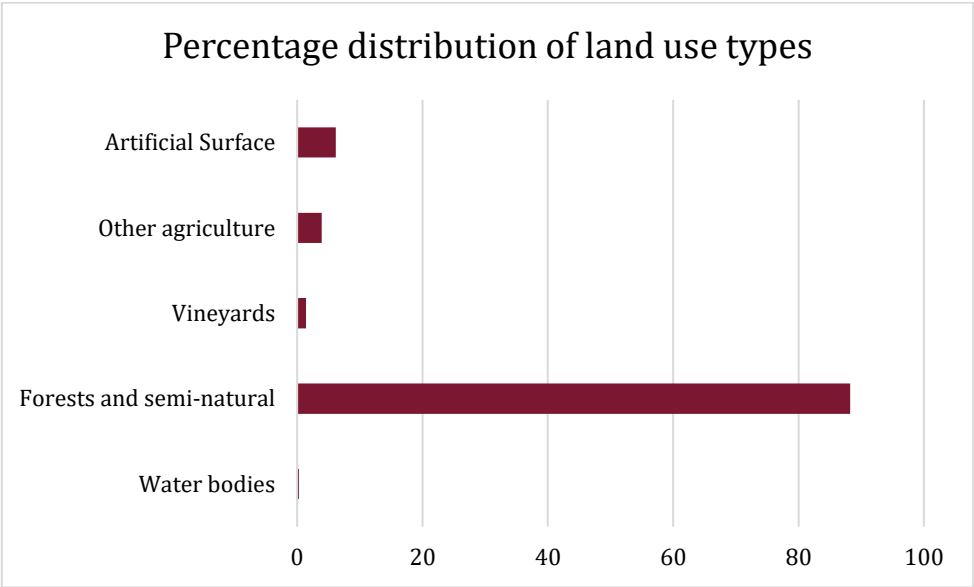

Figure 15. Macro categories of land use classes in Cinque Terre. Source: Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Ecosystem services in Cinque Terre

During the first phase of the stakeholder involvement in Cinque Terre, local actors prioritized the ecosystem services important for viticulture in the region (Table 3).

Table 3. Ecosystem services relevant to Cinque Terre viticulture.

Ecosystem Service	Relevance for the area
Crop production	In Cinque Terre, high-quality wine production is one of the priorities of the region. Winegrowers maintain the traditional terraced vineyards and other rural activities. Stakeholders recognize that wine production supports local livelihoods while preserving the agricultural identity of the area.
Regulation of water and erosion	Stakeholders in Cinque Terre recognize the importance of the regulation of water and erosion as an ecosystem service. The presence of vineyards in steep slope is prone to erosion, however due to the network of dry-stone walls, slope stabilization and erosion can be controlled. In addition, these structures protect the region from possible extreme events (i.e. landslides) and safeguard biodiversity and human settlements.
Cultural heritage	The preservation of cultural heritage and tradition is fundamental in Cinque Terre. Not only because the National Park is recognized as World Heritage Site since 1997, but also because it has carried a lot of traditions over the centuries, such as the terraced landscapes, agricultural practices, and dry-stone wall craftsmanship, representing a living heritage.
Landscape aesthetics	The area's unique scenery and cultural authenticity attracts many tourists. In Cinque Terre, tourism plays an important role. Stakeholders acknowledge that tourism supports the local economy but are concerned about the impact of mass tourism. Raising awareness is essential to preserve the ecosystem.

Climate change impacts in Cinque Terre

Climate change is increasingly threatening the ecological stability and cultural identity of Cinque Terre. The local stakeholders know that addressing this issue requires integrated adaptation strategies. They recognize the following impacts:

- Changes in precipitation patterns are not only evident from irregular and unpredictable rainfalls, but also by the increase of prolonged dry periods and consequent drought stress, which threaten the vineyards health.
- The extreme weather events in Cinque Terre, such as heavy rainfall or storms, threaten the structural integrity of the terraced slopes and dry-stone walls. The impacts on these structures can increase the risk of landslides. Stakeholders are aware that maintaining these walls is essential for landscape preservation and community protection.

The rise in temperatures affect the grape quality causing an earlier grape maturation and therefore an anticipation of the harvest timing. The high temperatures also cause sunburn of the leaves and a strong stress in the plants.

Challenges for Cinque terre viticulture

Beyond climate change, some other challenges have been highlighted by stakeholders in Cinque Terre, which include:

- The lack of convergence and unity among wine actors which impedes collective initiatives and shared strategies.
- The declining agricultural profitability, combined with advanced average age of farmers and land abandonment, is making it hard to keep the traditions alive and attract a new generation of farmers.
- The lack of winemaking infrastructures is another concern as this makes it difficult for producers to carry out the processes of vinification.
- The presence of mass tourism can become a controversial activity, as visitors may be unaware of the ecosystem and disrespectful toward the rural context.

Annex II: Cinque Terre

A. Bioclimatic maps

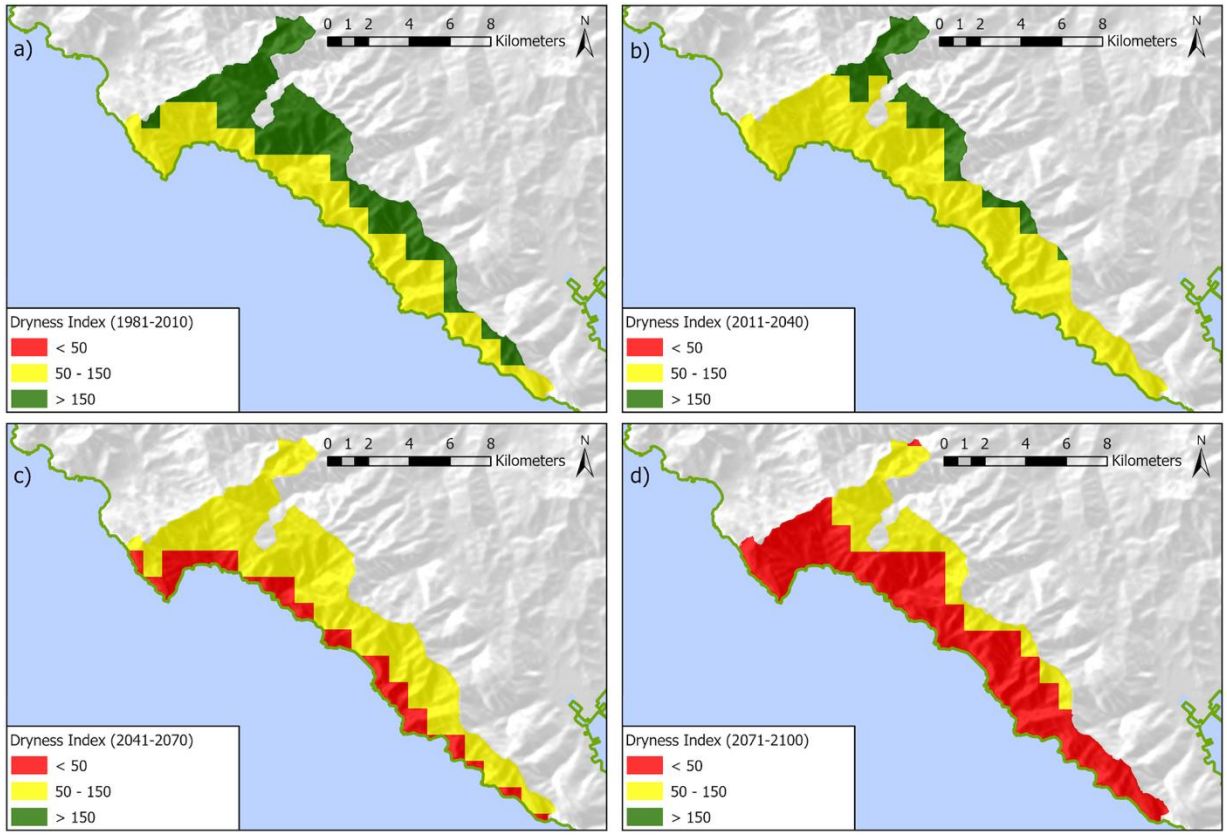

Figure 16. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Data source: own elaboration based on data from Tscholl et al. 2024.

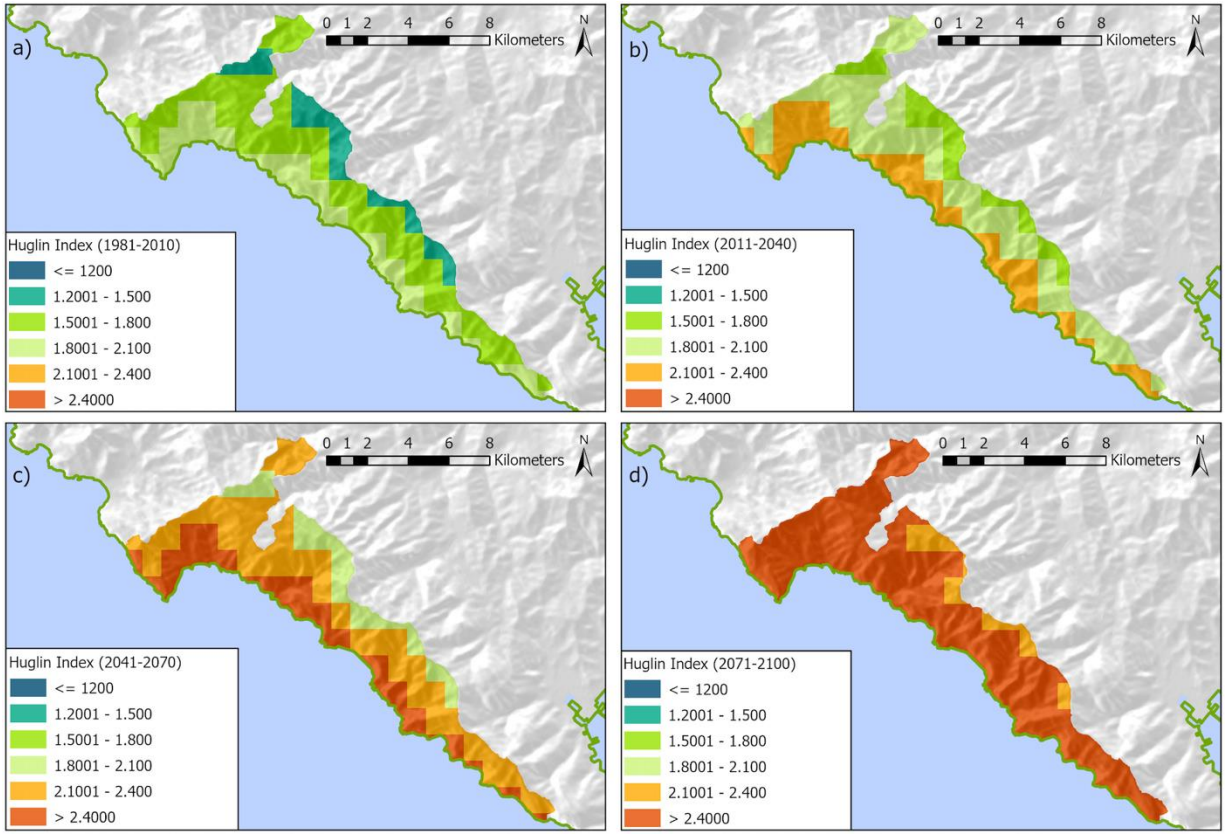

Figure 17. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Data source: own elaboration based on data from Tscholl et al. 2024.

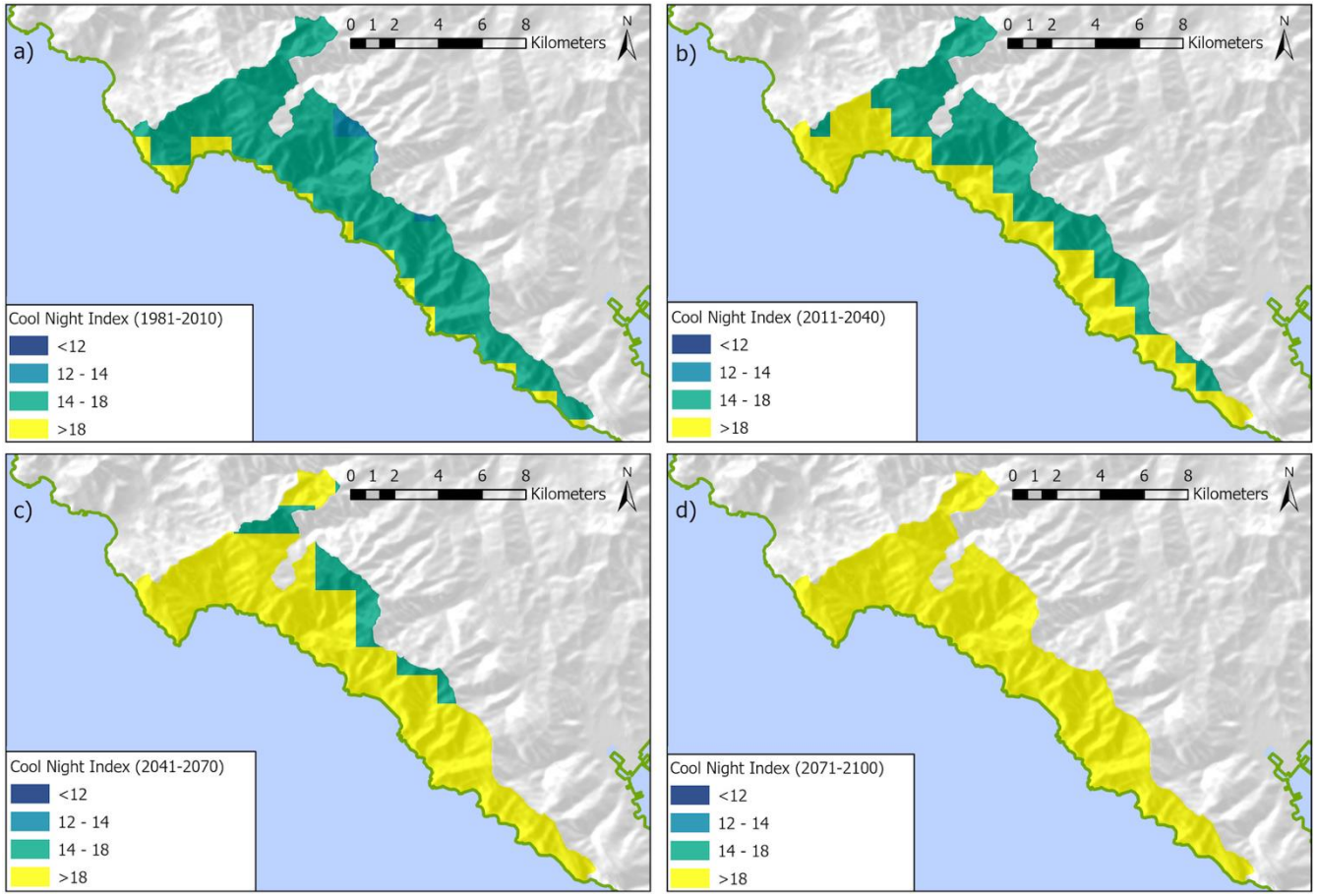

Figure 18. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Data source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

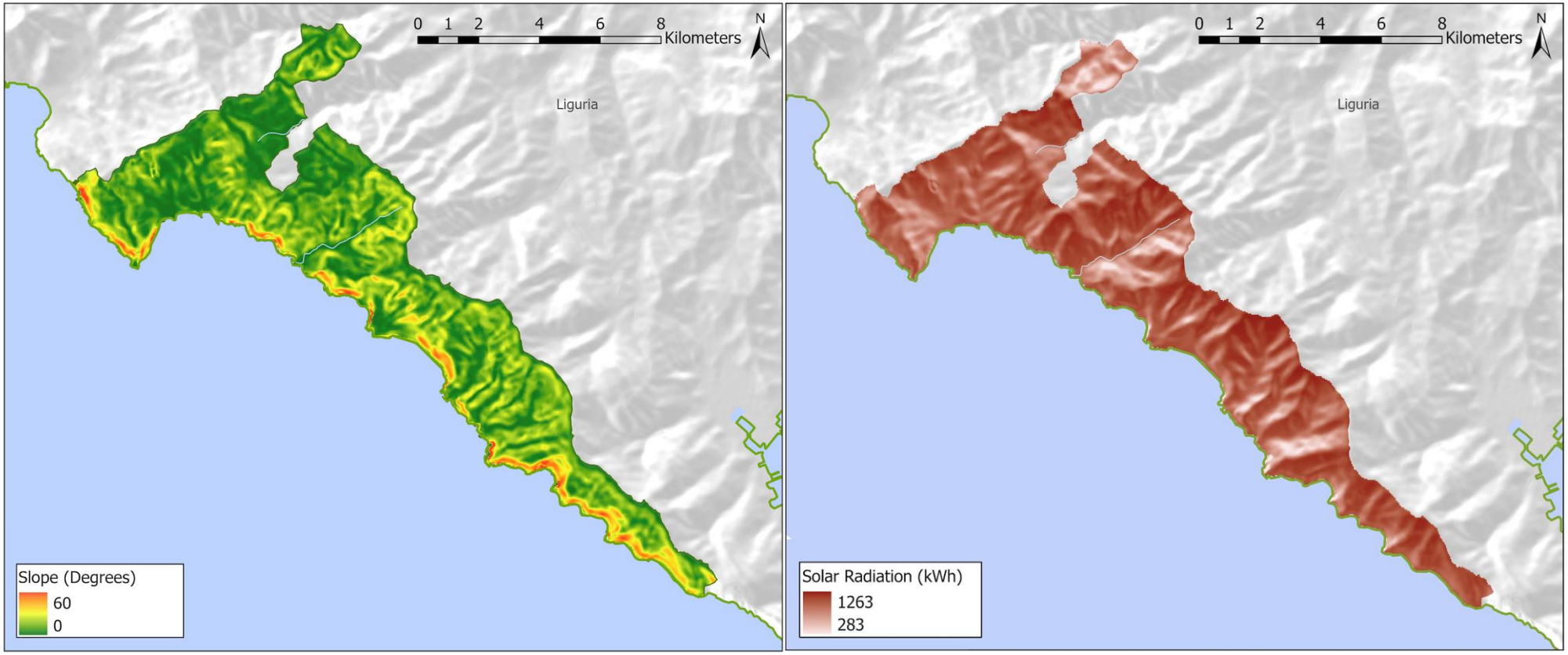

Figure 19. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Data source: own elaboration based on data from EEA 2014.

C. Land use and soil

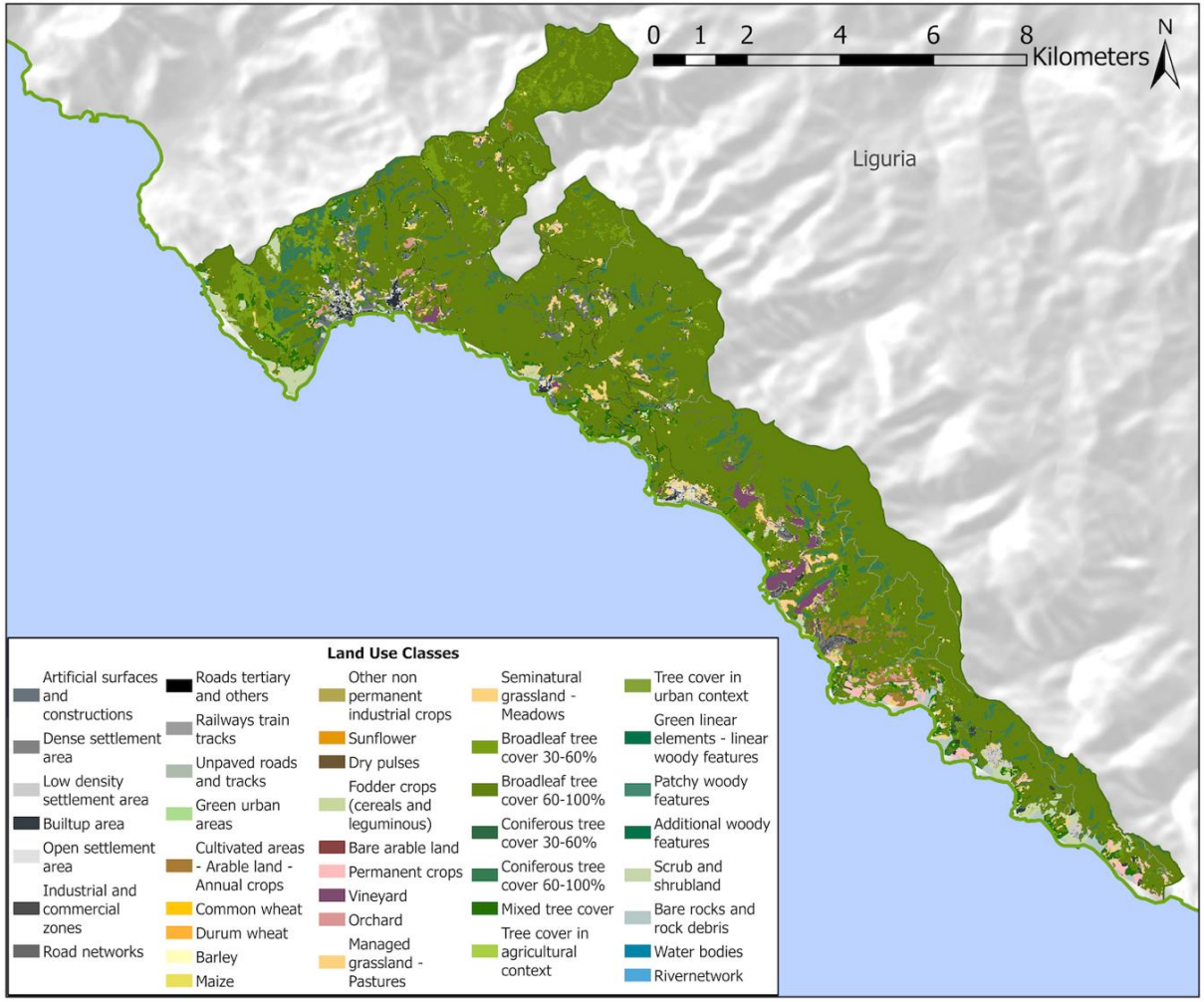

Figure 20. Land use land cover in the pilot region. Data source: own elaboration based on data from Marsoner, T. et al., 2023.

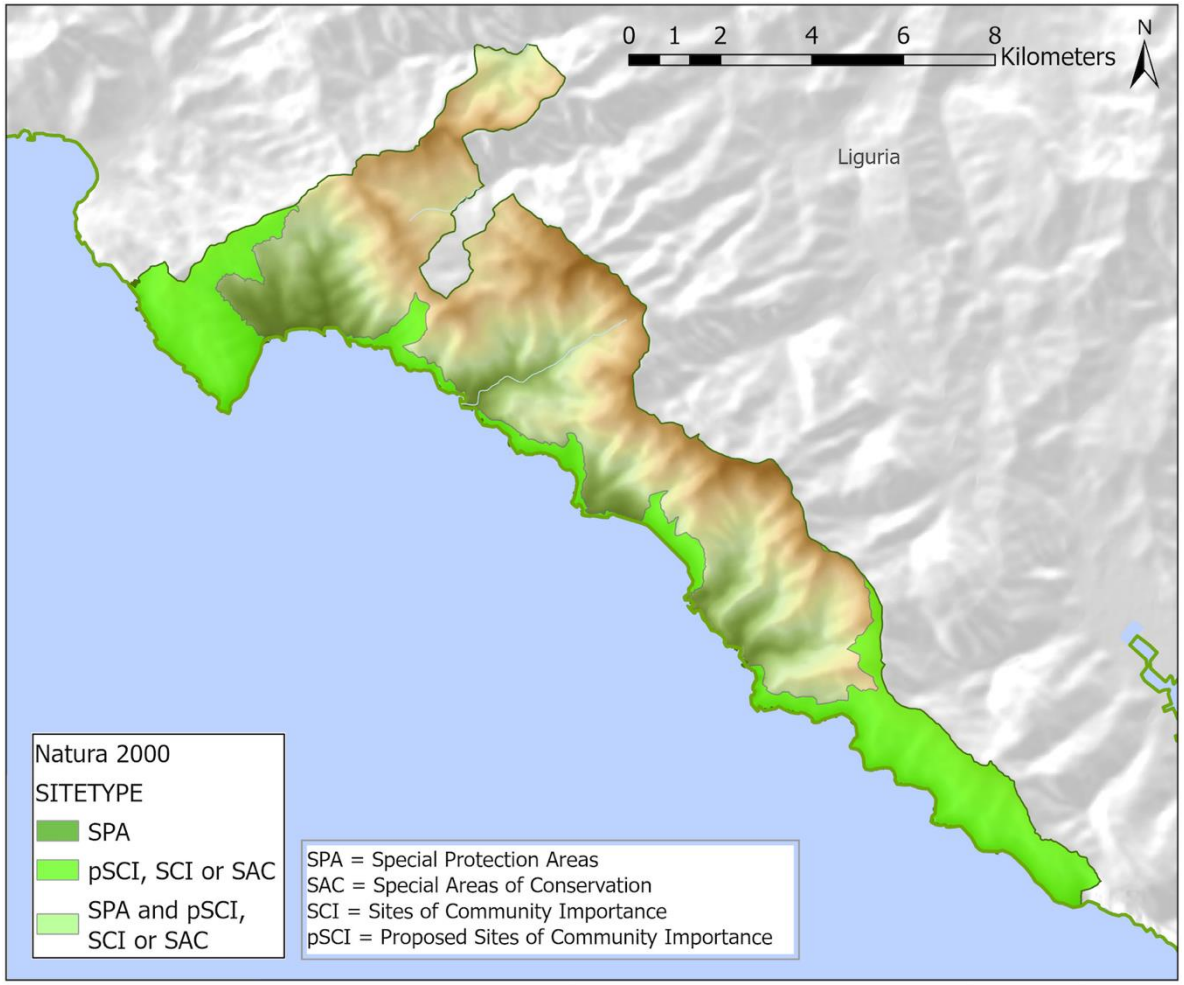

Figure 21. Presence of Natura 2000 sites. Data source: own elaboration based on data from EEA 2024.

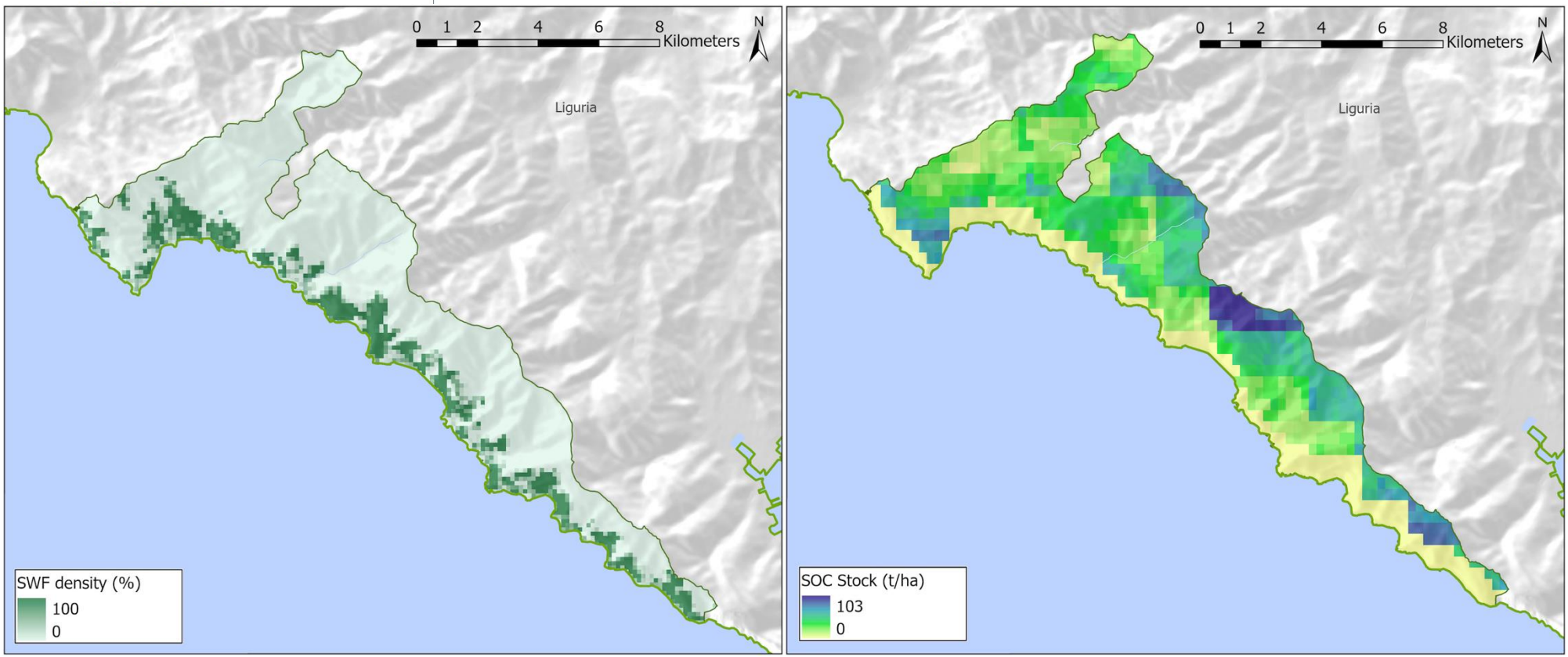

Figure 22. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right). Data source: own elaboration based on data from EEA, 2025; Isric, 2025.

4. Pilot region: Valle d'Aosta

Characterization of the region

Valle d'Aosta is a small region located in northwestern Italy. The viticultural landscape develops in a unique mountain environment, with steep slopes at high elevations. Valle d'Aosta is characterized by a continental climate with cold winters and hot summers (Vacchiano et al., 2012). The significant temperature variations and the exposure experienced by the vineyards influence not only aroma, but also disease exposure and resistance. Viticulture in Valle d'Aosta is also defined by its terroir, soils are usually of morainic origin, deep (100–150 cm) or moderately deep (50–100 cm). They are characterised by abundant skeleton, a prevalence of sand (generally over 50%) and a low clay content. Soils present also sufficient organic matter and nutrient content to support productive development. The practices developed in the region helps to improve the soil properties. High-quality wine production in Valle d'Aosta represents also its identity as small-scale family businesses run the sector. The most representative autochthonous varieties are Petit Rouge, Bonda, Cornalin, Crovassa, Fumin, Mayolet, Neyret, Roussin, Vuillermin, Vien de Nus, Ner d'Ala. In total, Aosta Valley recognizes 38 grape varieties for cultivation, including locally adapted biotypes such as Aosta Valley Nebbiolo's Picotendro. Since the 1990s, the Institut Agricole Régional has promoted and continues researching these grapes to preserve germplasm and support vineyard renewal, helping maintain biodiversity and distinctive wine characteristics that strengthen market differentiation. Valle d'Aosta high-quality wine production is recognised worldwide, and since 1999 the region has been officially registered with the status of Protected Designation of Origin.

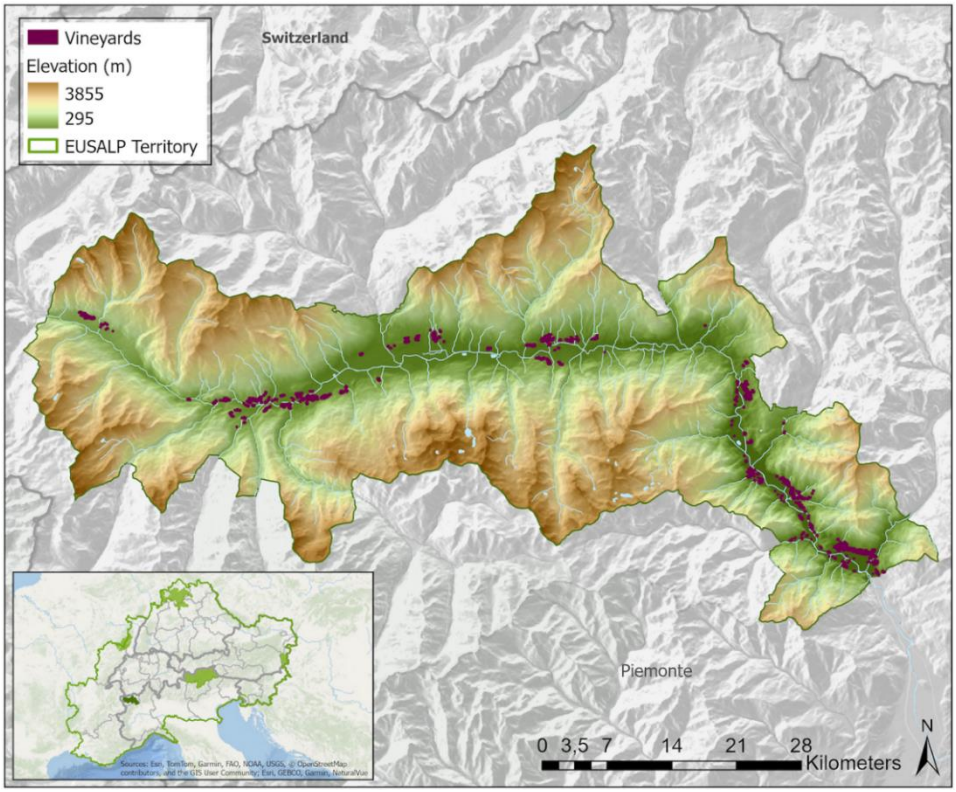

Figure 23. Map of the pilot region "Valle d'Aosta" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 24. Viticultural landscape in Valle d'Aosta. Source: CERVIM.

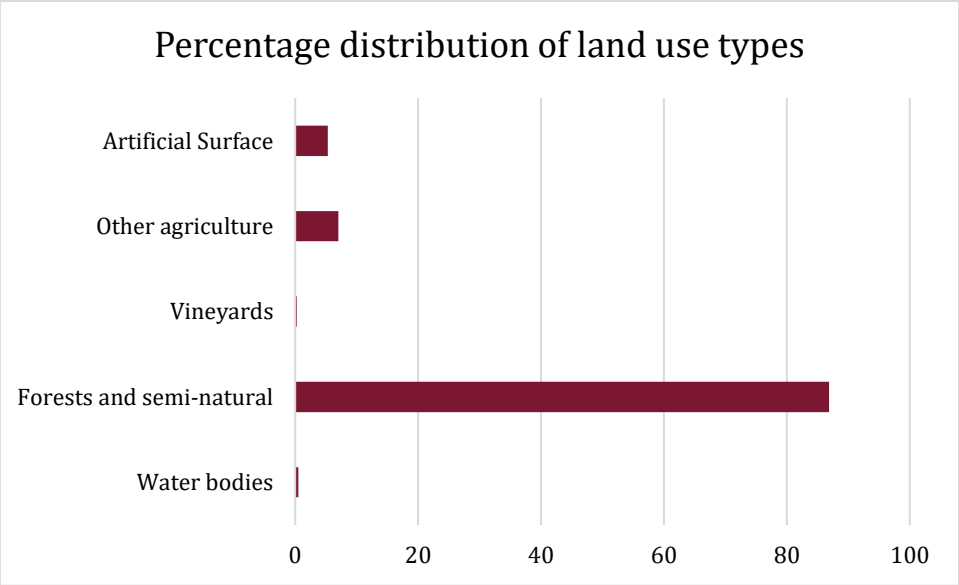

Figure 25. Macro categories of land use classes in Valle d'Aosta. Source: Macro categories calculated based on data from Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Ecosystem services in Valle d'Aosta

During the first phase of stakeholder involvement in Valle d'Aosta, local actors prioritized the following ecosystem services for viticulture in the region (Table 4).

Table 4. Ecosystem services relevant to Valle d'Aosta viticulture.

Ecosystem Service	Relevance for the area
Crop production	Stakeholders prioritize the agricultural productivity in Valle d'Aosta. In a context of severe territorial and climatic constraints, it´s important for them to ensure the productive capacity of the vineyards, which is the economic and identity base of the sector.
Regulation of water and erosion	Stakeholders are aware of the events that often occur in the mountain context, such as landslides, mudslides, irrigation. At the same time, they know that terraced viticulture requires constant maintenance to prevent degradation and erosion, therefore the regulation of water and erosion play an important role in Valle d'Aosta.
Enhancing landscape aesthetics, heritage and learning activities	In Valle d'Aosta tourism plays a crucial role and therefore the related cultural ecosystem services are very important. Over time, a series of projects has been developed to expand agritourism, and for wineries to organize tasting events. In addition, projects that promote walking/cycling routes have been created, such as 'Route des vignobles alpins' (Alpine Wine Route).

Climate change impacts in Valle d'Aosta

Valle d'Aosta viticulture is increasingly affected by the current climatic trends. The most tangible impacts on viticulture are the following:

- Changes in precipitation patterns is highly perceived by stakeholders through its immediate and tangible consequences on production; water stress being the main impact. Stakeholders' concerns rise due to the complexity of irrigation in the mountain context.
- The rise in temperatures affect the grape quality in general, in Valle d'Aosta the intense radiation cause sunburn and accelerate the ripening, lower the acidity, and increase the sugar content. The rise in temperatures also increase the pest pressure and influence the spread of diseases, such as flavescence dorée.
- Extreme weather events such as late frosts threat the wine production in Valle d'Aosta. Stakeholders recognize that although the impacts are not daily, they represent a threat for the sector.

Challenges for Valle d'Aosta viticulture

Beyond climate change, some other challenges have been highlighted by stakeholders. In particular, stakeholders emphasize the need for improvements in the sector, particularly in soil quality, vineyards' accessibility, and collaboration among producers. On the other side, stakeholders recognized that biodiversity is a strong aspect in the sector.

Annex III: Valle d'Aosta

A. Bioclimatic maps

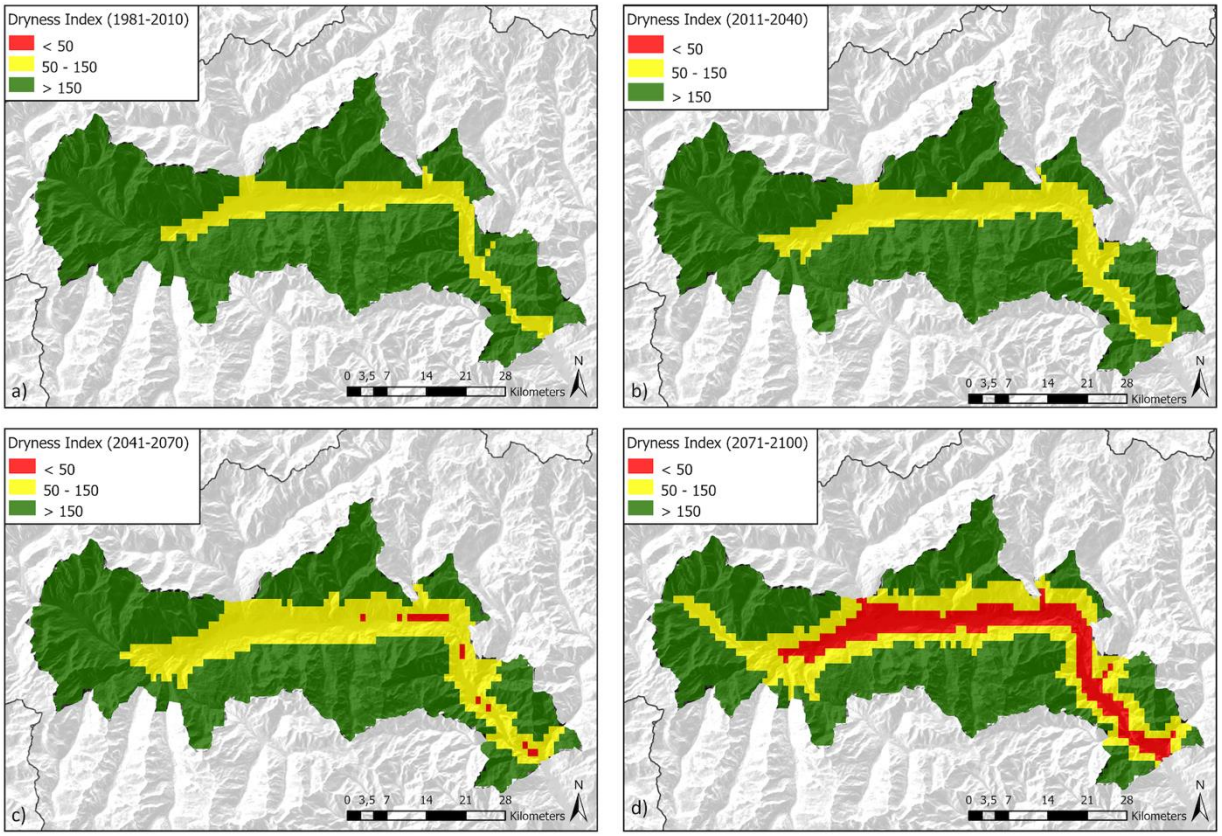

Figure 26. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

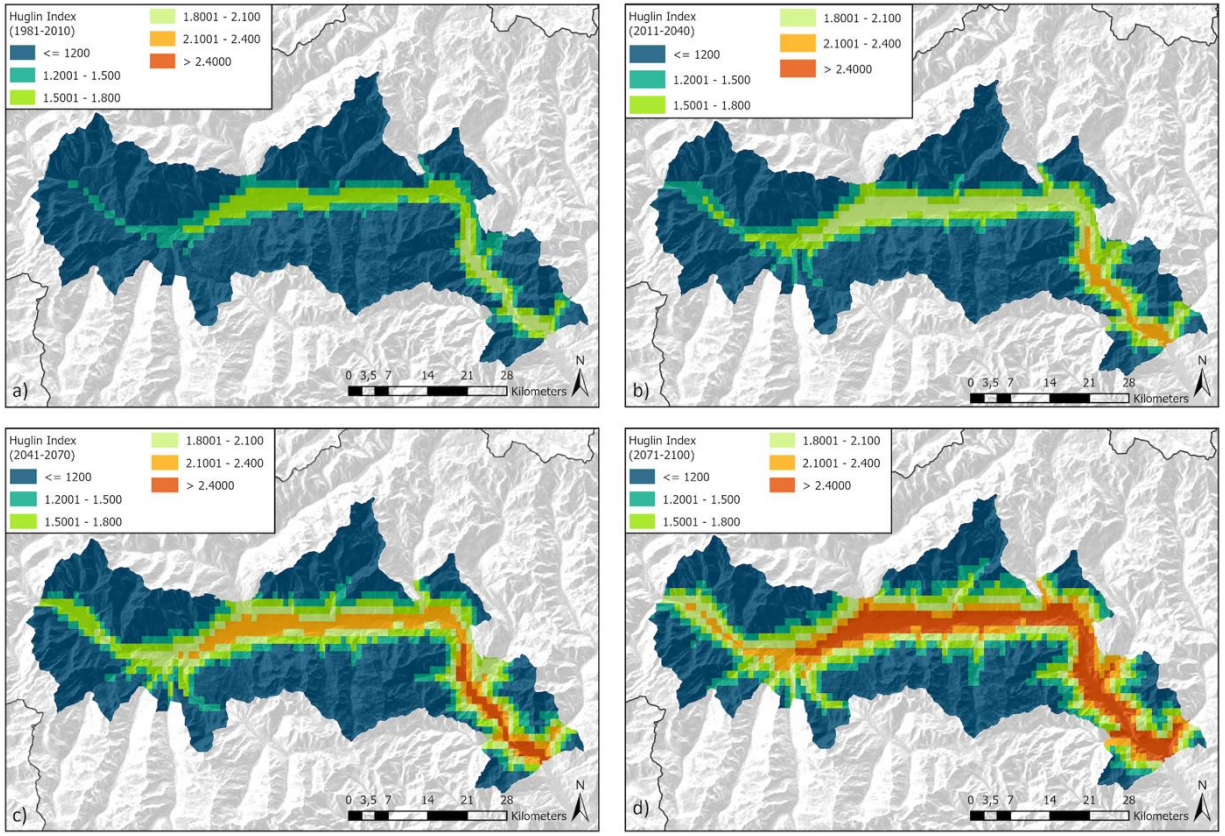

Figure 27. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Source: own elaboration based on data from Tscholl et al. 2024.

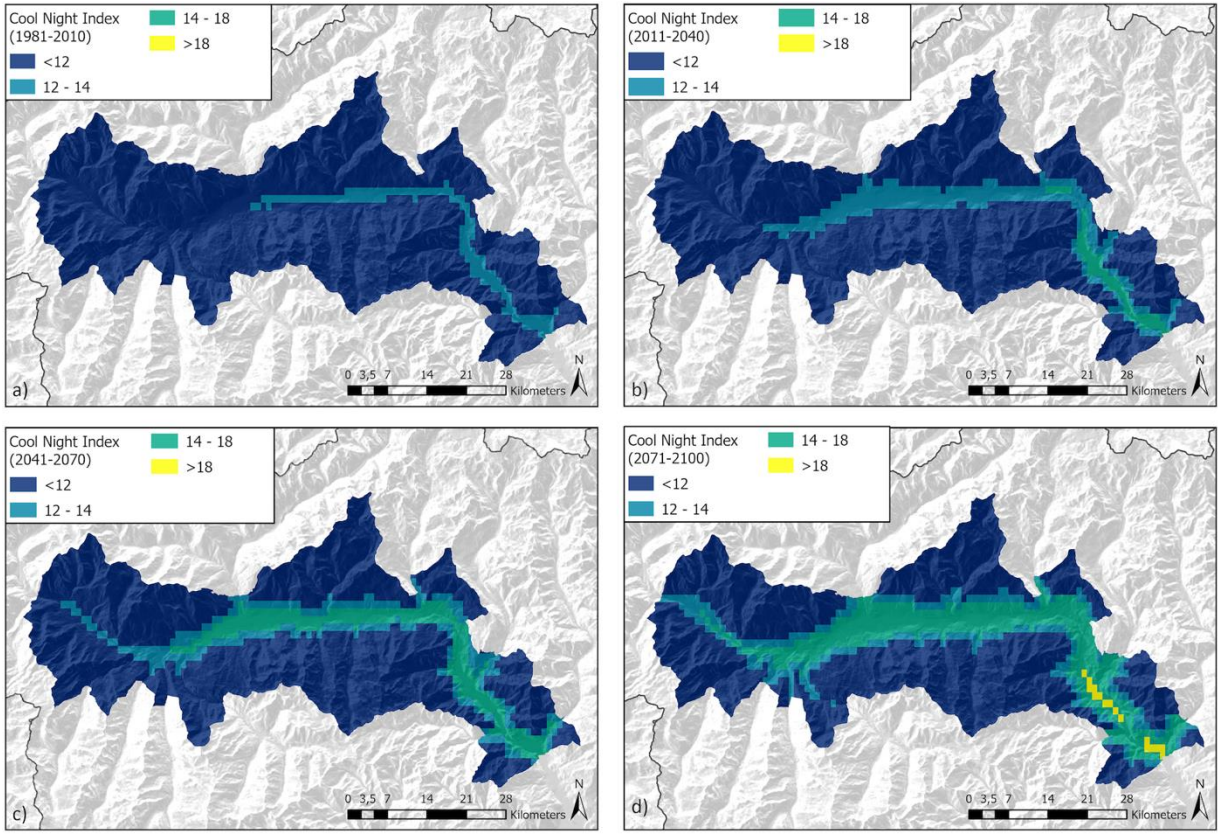

Figure 28. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

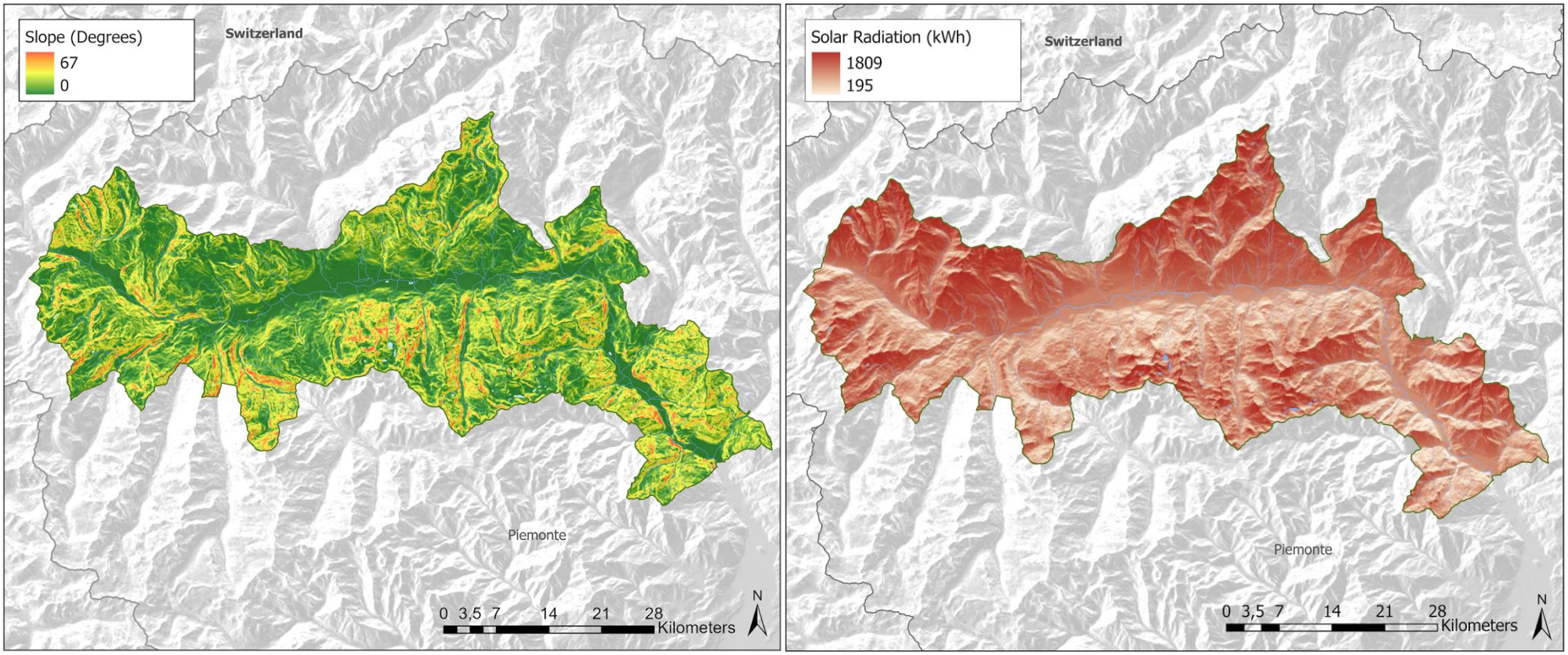

Figure 29. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: own elaboration based on data from EEA, 2014.

C. Land use and soil

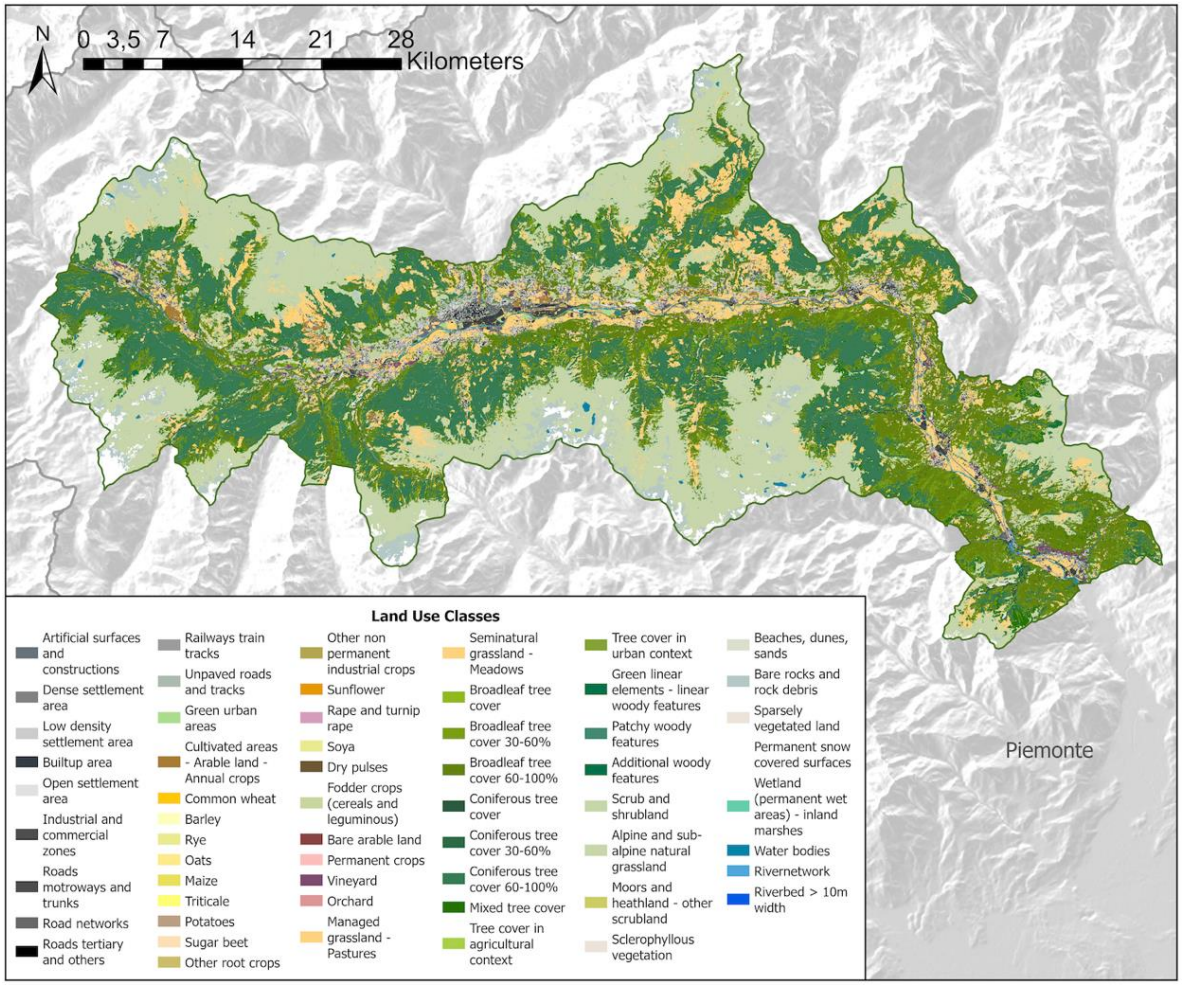

Figure 30. Land use land cover in the pilot region. Source: own elaboration based on data from Marsoner, T. et al., 2023.

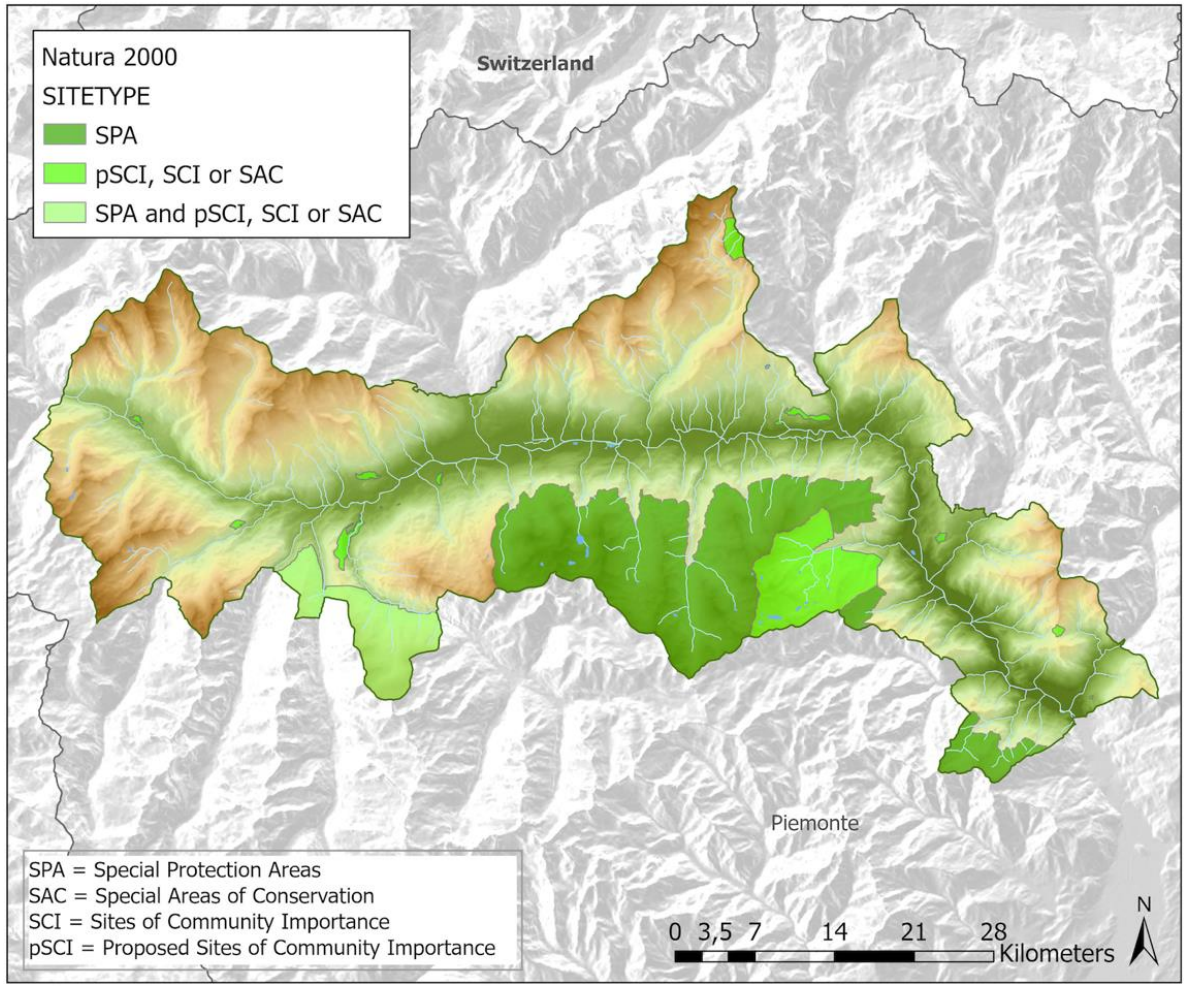

Figure 31. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

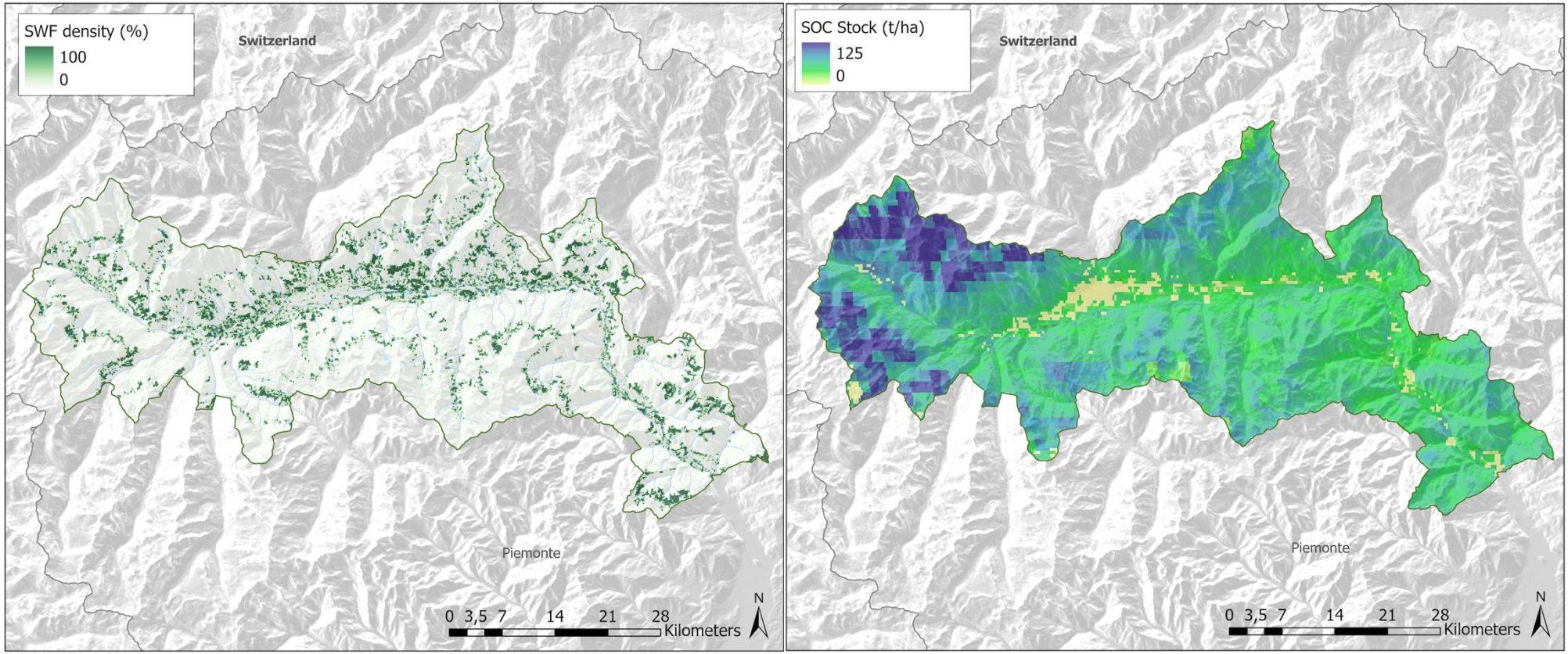

Figure 32. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right).
Source: own elaboration based on data from EEA, 2025; Isric, 2025 **.**

5. Pilot region: Ballons des Vosges

Characterization of the region

Vineyards in Ballons des Vosges are located on the foothills of the Vosges mountains and include areas that can reach up to 40 to 50% of slope. The area is characterized by a semi-continental climate with hot, dry summers and cold winters. Stakeholders pointed out that a change in summer droughts and heavy rainfall in autumn/winter is increasingly threatening the traditional cycles of the area. The mosaic of soils (granite, limestone, marl, sandstone, loess and volcanic), and low organic matter content in Ballons des Vosges gives the wines their typical characteristics making the 51 Grands Crus of the AOC Alsace an exceptional area for winemaking. Here, seven grape varieties dominate the region, Sylvaner, Pinot Blanc, Pinot Gris, Riesling, Muscat, Pinot Noir and Gewurztraminer (Parc naturel regional des Ballons des Vosges, 2026). The specific climatic characteristics together with the presence of an extended network of terraces supported by dry-stone walls make Ballons des Vosges a special place to visit, stakeholders emphasized that the unique landscape has become part of the region's heritage and its ecological impact on biodiversity.

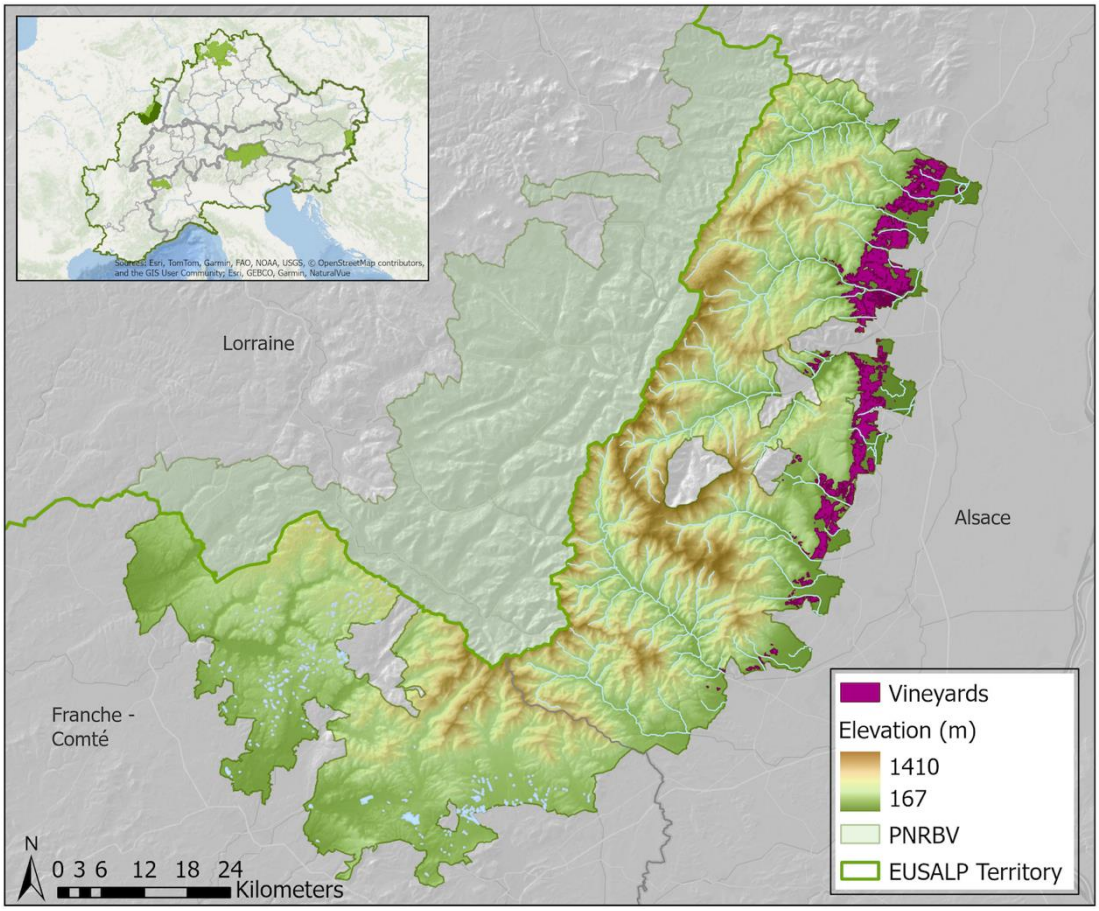

Figure 33. Map of the pilot region "Ballons des Vosges" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023, European Environmental Agency, 2025 and Batista, F. & Pigaiani, C., 2021.

Figure 34. Example of a typical vineyard landscape in Ballons des Vosges. Source: Facchi Benoit.

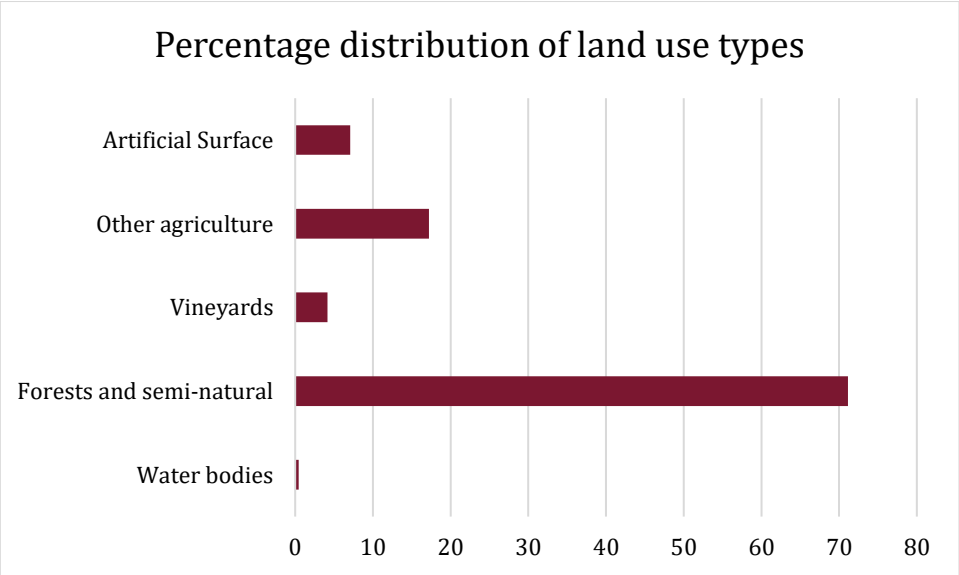

Figure 35. Macro categories of land use classes in the pilot region Ballons des Vosges. Source: Marsoner, T. et al., 2023, European Environmental Agency, 2025 and Batista, F. & Pigaiani, C., 2021.

Ecosystem services in Ballons des Vosges

During the first phase of stakeholder involvement in Ballons des Vosges a set of ecosystem services important for viticulture in the region in the region were prioritized (Table 5).

Table 5. Ecosystem services relevant to Ballons des Vosges viticulture.

Ecosystem Service	Relevance for the area
Regulation of water and erosion	Stakeholders stressed out that the hydrological aspect is one of the most important in the region, with a focus on water regulation through dry-stone terraces, as they drain and filter water on the vineyard slopes. The presence of terraces and dry-stone walls networks along the viticultural landscape of Ballons des Vosges decrease the risk of erosion.
Soil processes	In hand with the impacts on the terraces due to the regulation of water, soils can also be affected, stakeholders are concerned about the soil process and aware that a sustainable action can be developed to improve the soil fertility.
Maintaining populations and habitats	The vineyards in Ballons des Vosges Natural Park cover approximately 5,000 hectares on the eastern foothills of the park. The preservation of nature, populations and habitats are one of the aims of the park in association with Natura 2000 Zone Collines sous-vosgiennes, Real Environmental Obligation.
Landscape aesthetics	The viticultural landscape on the eastern side of the park is an appealing scenery for those visiting the park. Tourism in the region has also implemented due to wine tourism activities considered as another important activity within Ballons des Vosges.
Regulation of detrimental organisms and biological processes	In Ballons des Vosges the winemakers understand the importance of organisms, therefore they are trying to find a well-balanced ecosystem between a rich biodiversity and the management of detrimental organisms. Bringing back more diversity will reduce the spread of harmful species in vineyards. Flowering ground cover, vitiforestry and dry stones walls are just examples of the practices developed in Ballons des Vosges.

Climate change impacts in Ballons des Vosges

Ballons des Vosges viticulture is affected by the current climatic trends.

- Stakeholders stressed that the main problems in the area are related to water resource management.
- They also pointed out that the extreme weather events such as heatwaves and droughts influence on the water redistribution, essential for vine growth but also increase the erosion and threat the terraces and dry-stone walls.
- Stakeholders also recognized that the increase in temperatures in Ballons des Vosges put grapes varieties under pressure.

Challenges for Ballons des Vosges viticulture

Beyond climate change, some other challenges have been highlighted by stakeholders in Ballons des Vosges, which include:

- Maintaining expertise in dry stone construction is the priority in Ballons des Vosges as vineyards are planted on slopes of varying steepness, and the terraces are generally supported by dry stone walls networks.
- Stakeholders in Ballons des Vosges want to establish a circular economy for dry stone walls where the resources can be maintaining within the region.
- Winegrowers aim to preserve the natural landscape, heritage, and biodiversity.

Annex IV: Ballons des Vosges

A. Bioclimatic maps

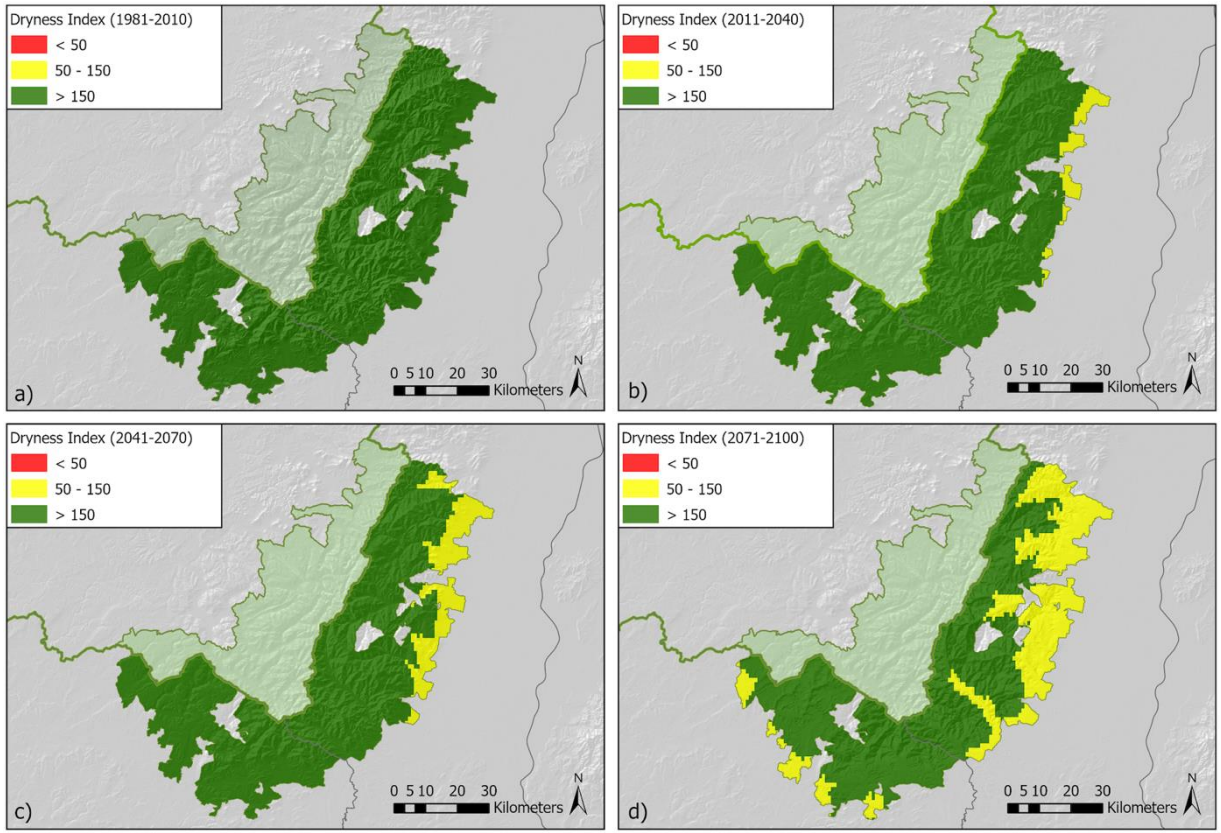

Figure 36. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

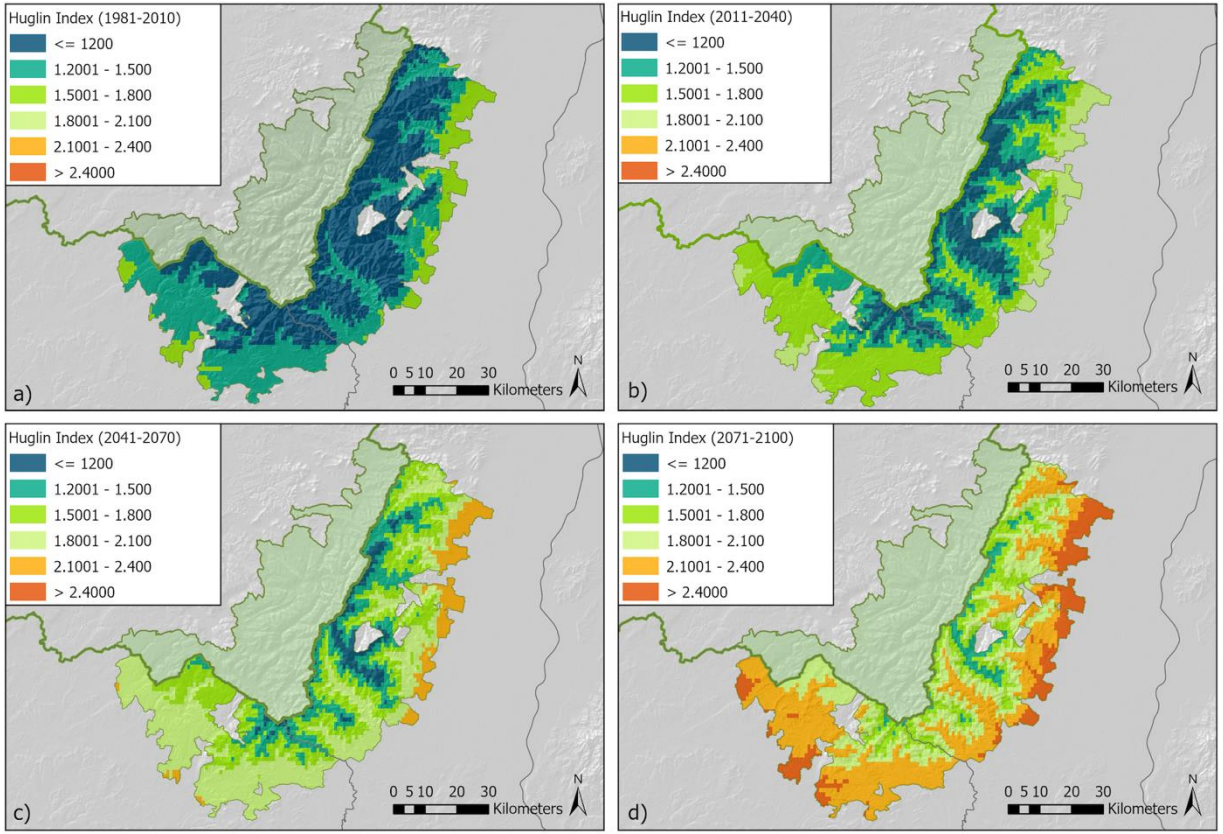

Figure 37. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Source: own elaboration based on data from Tscholl et al. 2024.

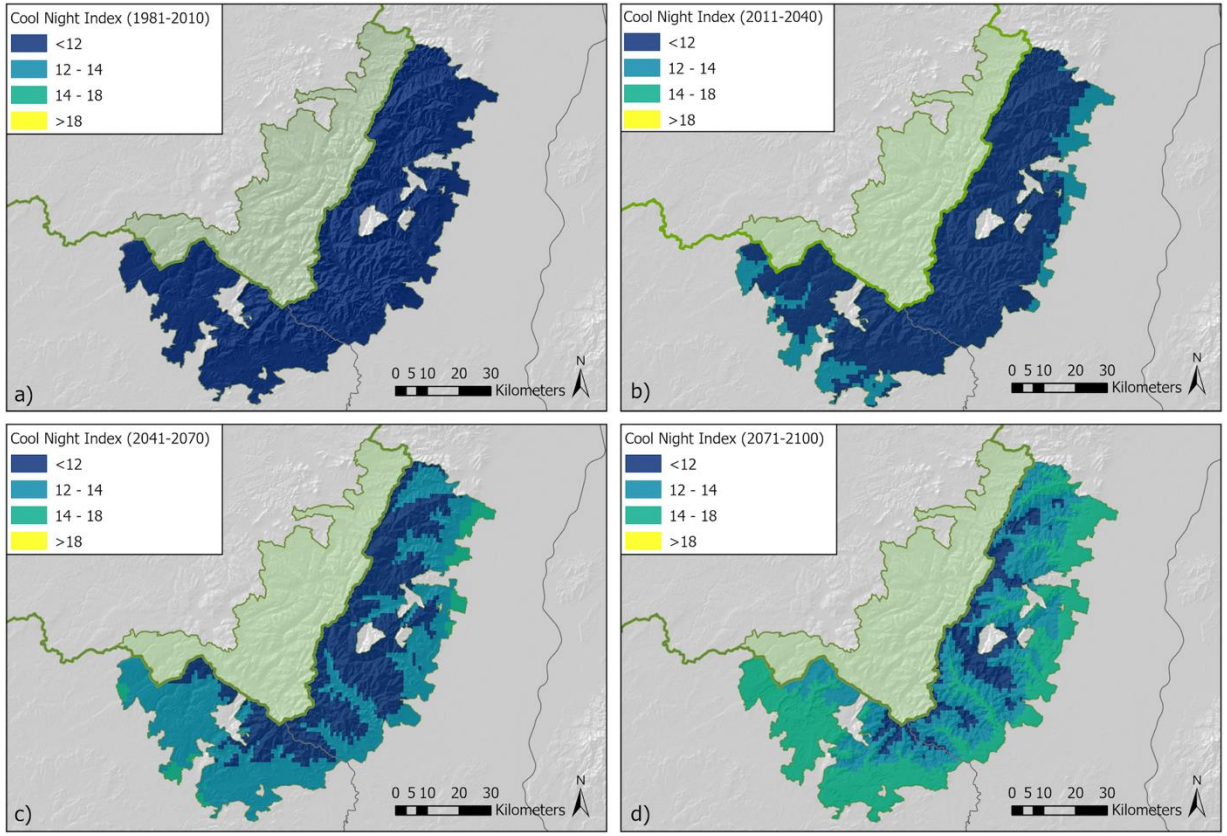

Figure 38. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

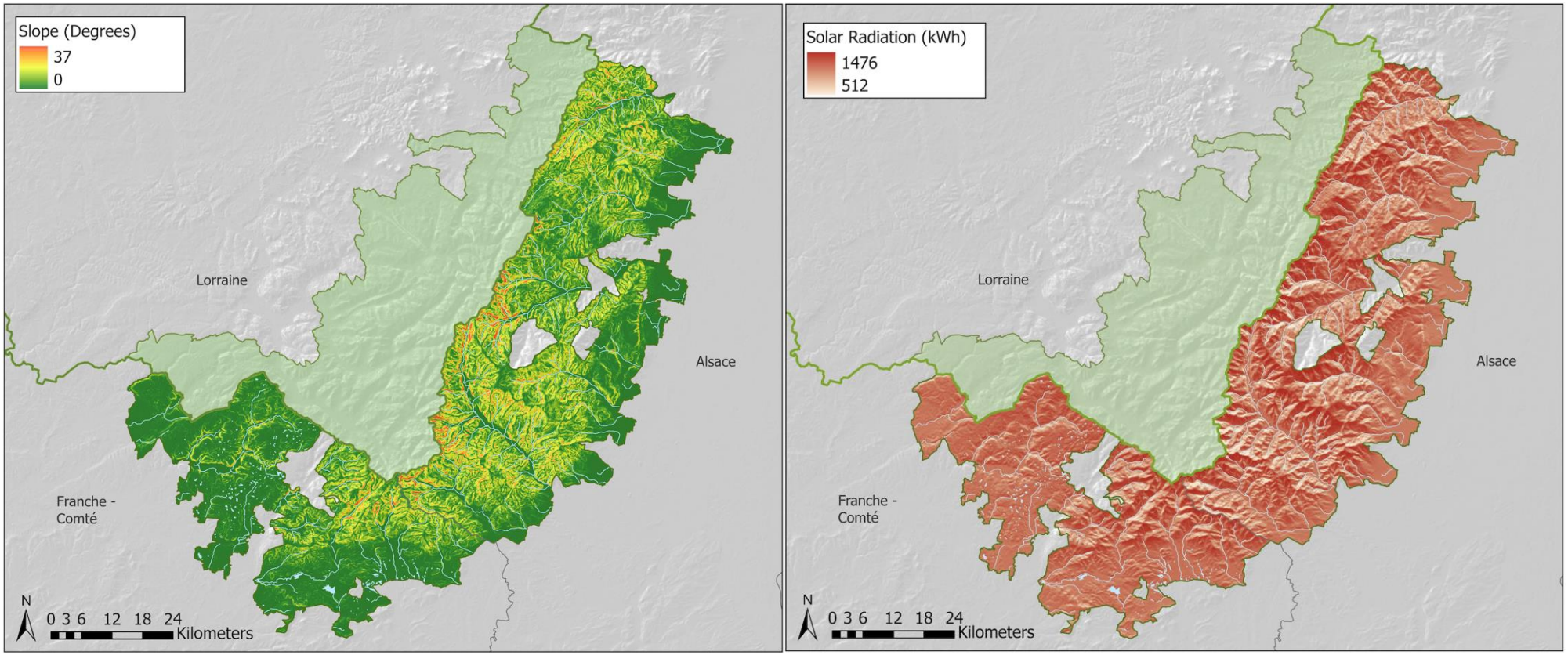

Figure 39. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: own elaboration based on data from EEA, 2014.

C. Land use and soil

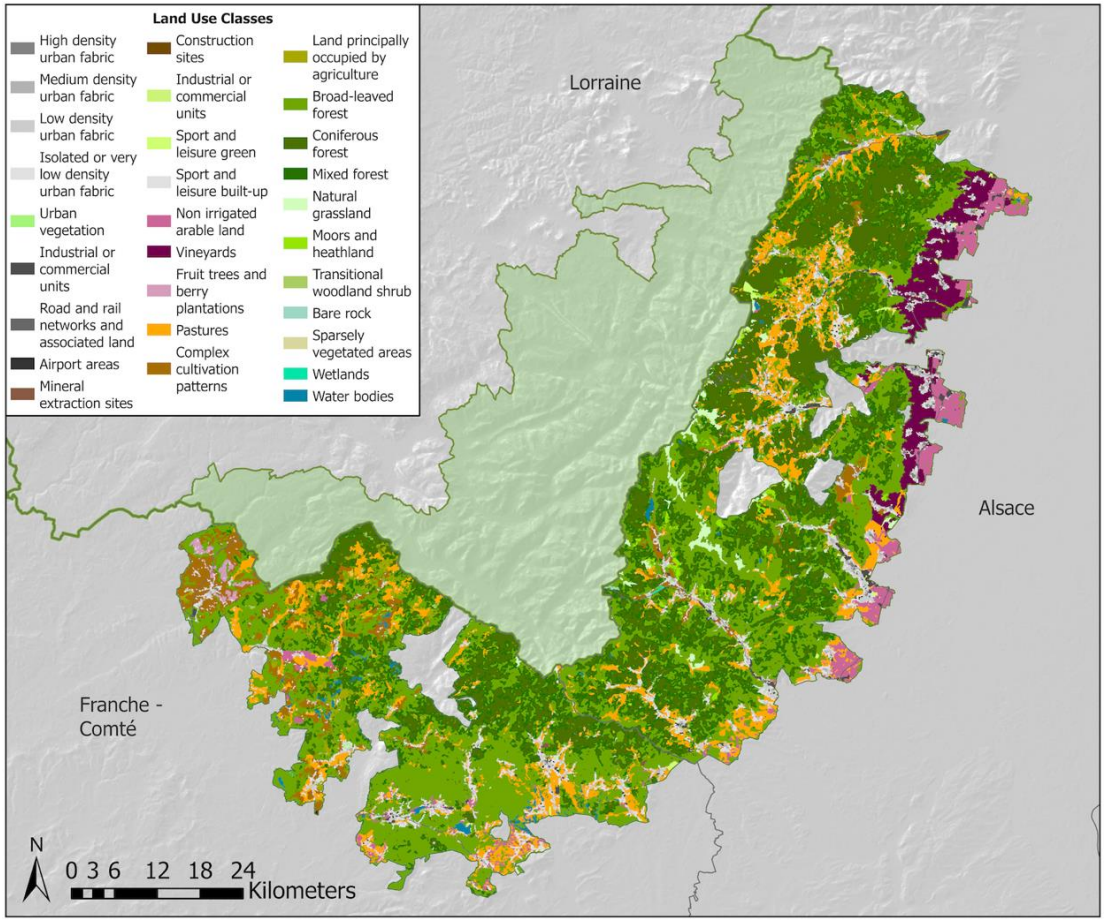

Figure 40. Land use land cover in the pilot region. Source: own elaboration based on data from Batista et al. 2021.

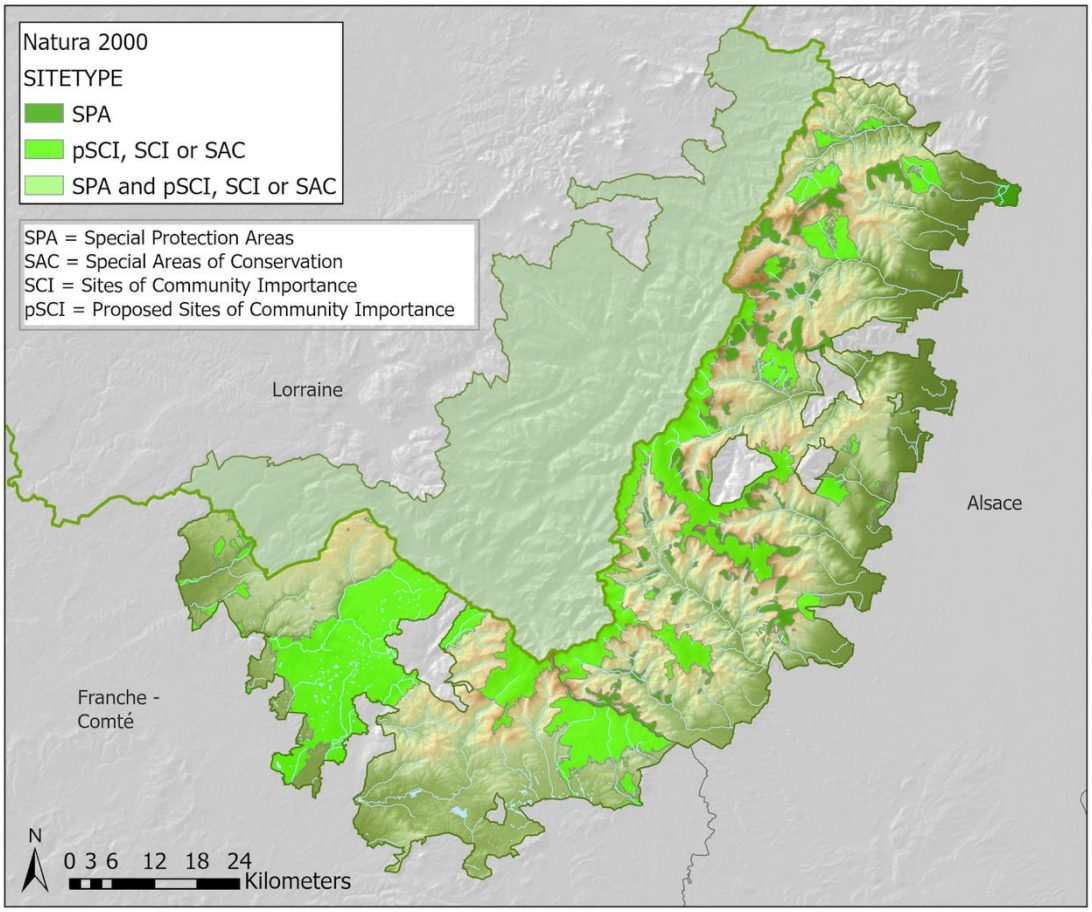

Figure 41. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

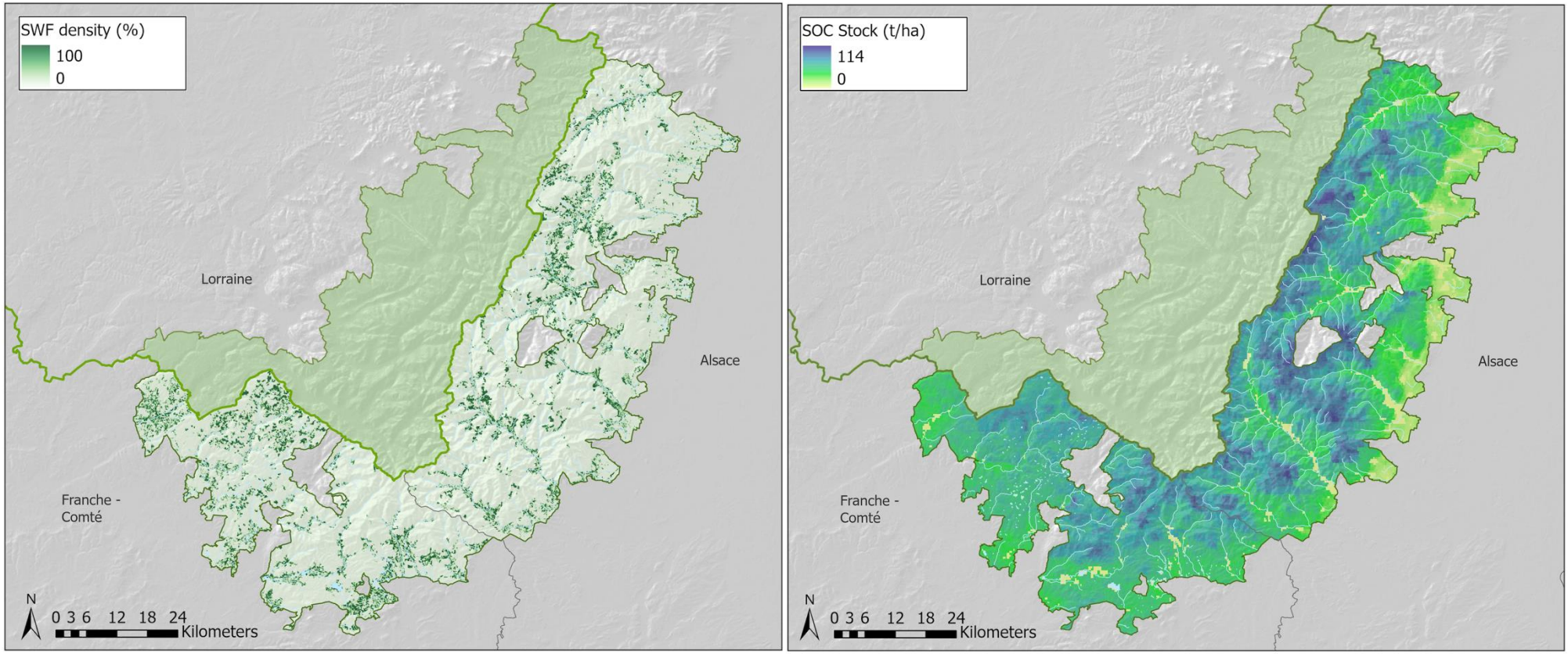

Figure 42. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right). Source: own elaboration based on data from EEA, 2025; Isric, 2025.

6. Pilot region: Südburgenland

Characterization of the region

South Burgenland, also known with the name "Eisenberg" from the name of the geographical indication for wine localized in the area, is one of the smallest wine regions in Austria, and is located in the southeast of the country (Burgenland tourism agency, 2026). The region is characterised by a unique cultural landscape and grapevines' varietal identity. The area is influenced by a continental Pannonian climate with warm days and cool nights (Austrian Wine, 2026). South Burgenland rolling hills are home to a patchwork landscape of fields, flower-filled meadows and vineyards. Viticulture occupies around 528 hectares at elevations from 202 to 464 meters above the sea level. In South Burgenland the vines grow mainly on sandy and clayey, partly ferrous loam soils (European Commission, 2011). South Burgenland is a region suitable for different wines and includes Blaufränkisch and Welschriesling among its main varieties. Blaufränkisch produces wines with clear structure, mineral depth and spicy character red wine characterised by iron-rich slate soil. Welschriesling give fresh white wines with fine acidity. The region ambassador due to its historical significance is Uhudler, a wine made from non-vitis-vinifera grape varieties such as Concord or Isabella, characterized by intense flavours of wild strawberries and blackcurrant. South Burgenland high-quality wine production is recognised worldwide, and since the 2009 vintage, typical Blaufränkisch wines from southern Burgenland have been marketed under the designation Eisenberg DAC. The low intensity vineyards cultivation of the area, which is usually managed through manual labour, greening systems, and the avoidance of large-scale monocultures facilitate the promotion of biodiversity by using near-natural practices supported by the structured environment with forests, meadows and hedges. Wine tourism in the area is growing and helps preserving the original character of the region, also thanks to the unique Uhudler tradition.

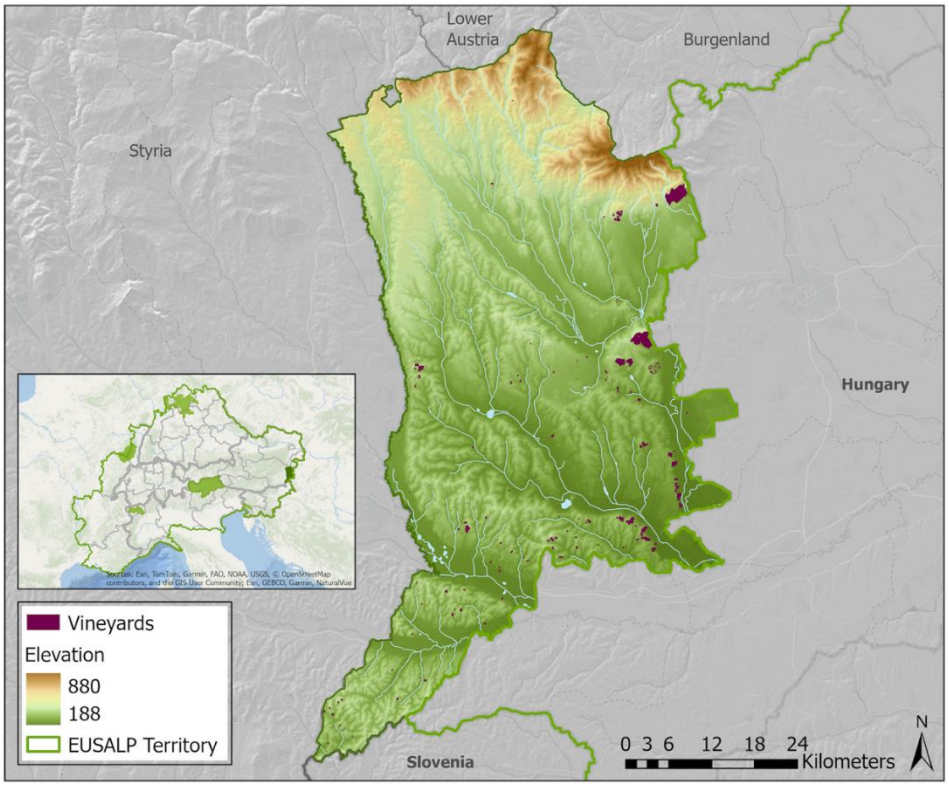

Figure 43. Map of the pilot region "South Burgenland" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 44. Example of a typical vineyard landscape in South Burgenland.

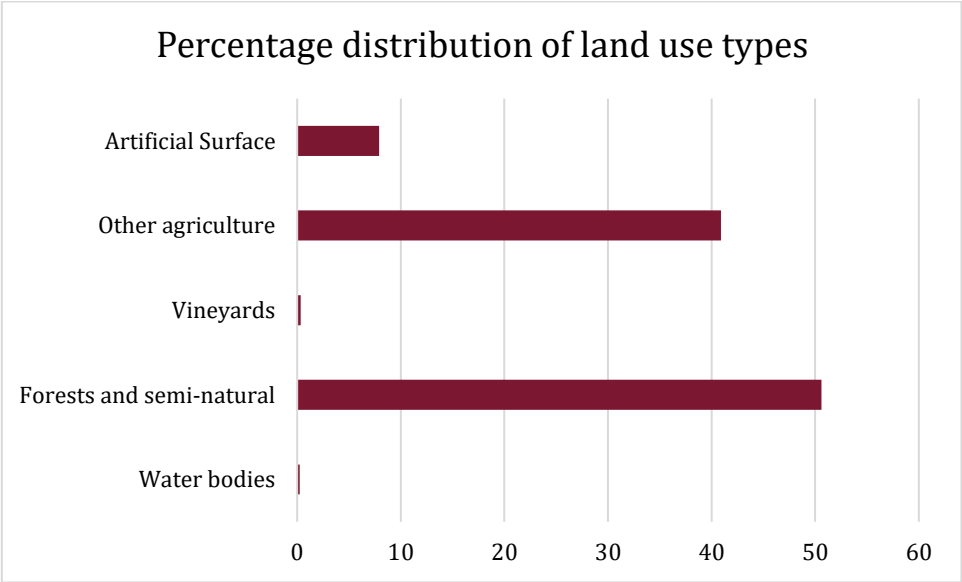

Figure 45. Macro categories of land use land cover classes in South Burgenland. Source: Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Ecosystem services in South Burgenland

During the first phase of stakeholder involvement in South Burgenland, the local actors of the wine sector indicated what the important ecosystem services for viticulture in the region are (Table 6).

Table 6. Ecosystem services relevant to South Burgenland viticulture.

Ecosystem Service	Relevance for the area
Crop production	In South Burgenland high-quality wines production, especially from the varieties Blaufränkisch, Welschriesling, and the varieties involved in the production of Uhudler wines, plays an important role in the economy of the region. The high-quality wines are also considered as a backbone on the culinary aspect and therefore wine production is considered very important.
Maintaining populations and habitats	South Burgenland contributes to biodiversity and preservation of habitats due to the diverse mosaic of vineyards. Along the landscape structures such as hedgerows provides refuges for numerous animal and plant species.
Soil processes	Most of the vineyards in South Burgenland are located on sedimentary deposits, which are mainly silty, but also sandy and gravelly (Austrian Wine, 2026). These soil characteristics influence the wines produced here, for example the mineral-driven, earthy Blaufränkisch wines (Austrian Wine, 2026). The maintenance of soil processes is of great importance in Burgenland and is obtained through greening and extensive soil cultivation; for example, the greening and terracing help to regulate water and erosion, especially during heavy rainfall events.
Regulation of Detrimental Organisms	The region acts as a natural regulator of biological processes by promoting beneficial organisms through its landscape structure which harbours natural predators for pests and therefore have an added value for winegrowers.
Filtration and storage by organisms	Carbon storage in vines, vineyard soils, greenery and accompanying vegetation contributes to the reduction of greenhouse gases as part of climate regulation and is perceived as an important service in the area.
Landscape aesthetics	The aesthetic of viticultural landscape in South Burgenland not only enhances the quality of life of the local population, but also drives wine and nature tourism, with the increasing numbers of tourists being a sign of this. In addition to the aesthetic landscape, tourists come to Burgenland for thermal springs and festivals.
Cultural heritage	South Burgenland traditions are not only embedded in the cultivation methods but also in the unique wine that is produced in this area. The icon example of this is the Uhudler cultivation, which is a unique heritage of this area.

Climate change impacts in South Burgenland

Shift in climatic conditions are increasingly evident in South Burgenland viticultural landscapes. Stakeholders are aware of the climatic trends in the region and recognize that preventive measures

such as forecasting models, canopy management, etc could be implemented to improve the resilience of the vineyards.

The most tangible impacts are:

- The rise in temperatures, that set a marked shift in harvest timing. The earlier ripening and sunburn risk are, among the others, impacts that are threatening the quality of wines. Grapes are processed under heat stress increasing the risk of undesired fermentation processes. In addition, there is an increase in vines dieback, partly due to harmful organisms being every year more frequently and intensely.
- The extreme weather events such as hail, late frost, heavy rainfall, and drought are also of importance in the region as they are occurring more frequently and severely. Stakeholders made clear that extremes events result in yield losses and structural damage to vineyard.

Challenges for South Burgenland viticulture

Beyond climate change, there are other challenges that have been highlighted by stakeholders in South Burgenland, which include:

- A decline in the wine sector, identified by a decrease in the vineyard area as well as the number of active winegrowers. The access to land is becoming difficult due to fragmented ownership, generational turnover, and limited leasing opportunities, which by the hand of and aging population of winegrowers and the lack of successors put in risk the future of the wine sector in the region.
- The need to reduce the carbon footprint of wine production is another challenge raised by stakeholders. South Burgenland near-natural practice not only promotes biodiversity but wants to go further in the circle process of its wine, a promising approach is the development of reusable bottle systems, which would help reduce packaging waste and emissions.
- The increasing need of taking decision including multiple environmental, social and environmental criteria is another challenge mentioned by local stakeholders. They suggested that a digital municipal database with site-specific and climate-related information could support growers in making more informed decisions.
- Landscape abandonment is another key concern between stakeholders. Landscape features with cultural value are increasingly at risk due to abandonment and might require financial support and societal appreciation to safeguard the regional identity.

Annex V: South Burgenland

A. Bioclimatic maps

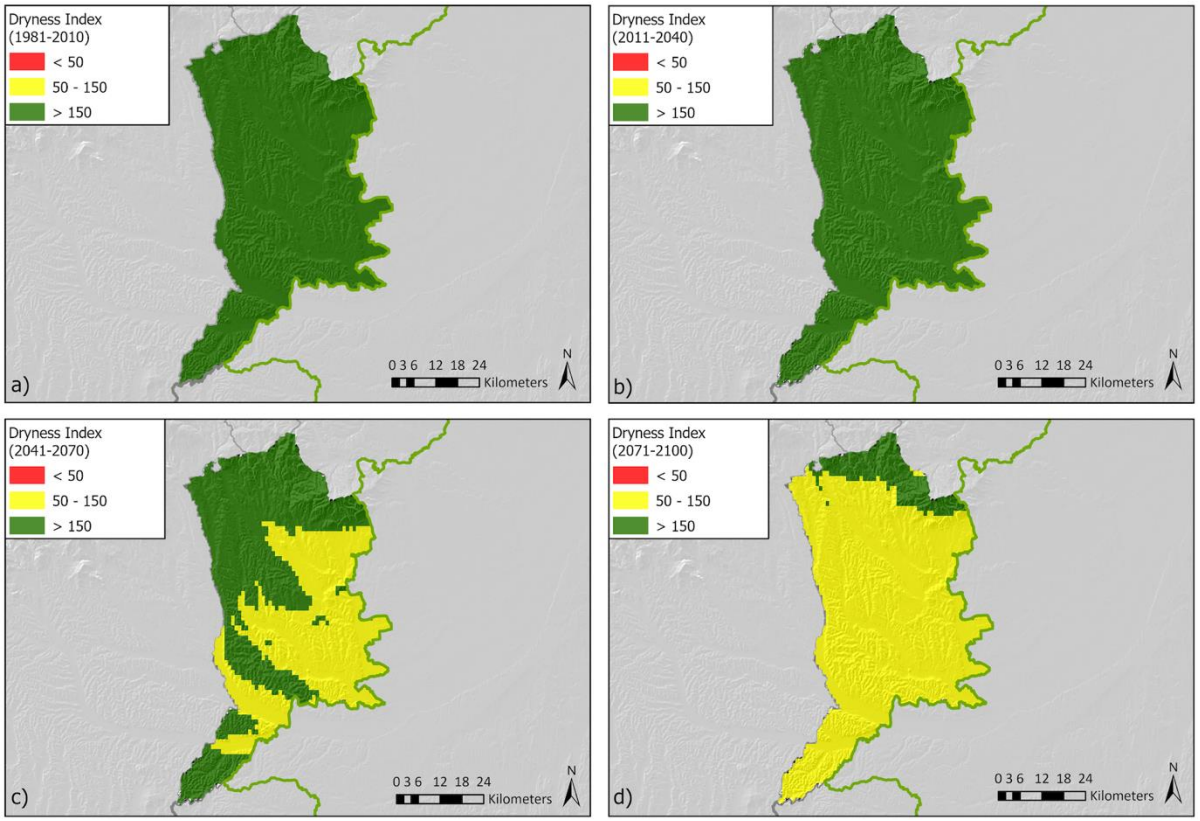

Figure 46. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

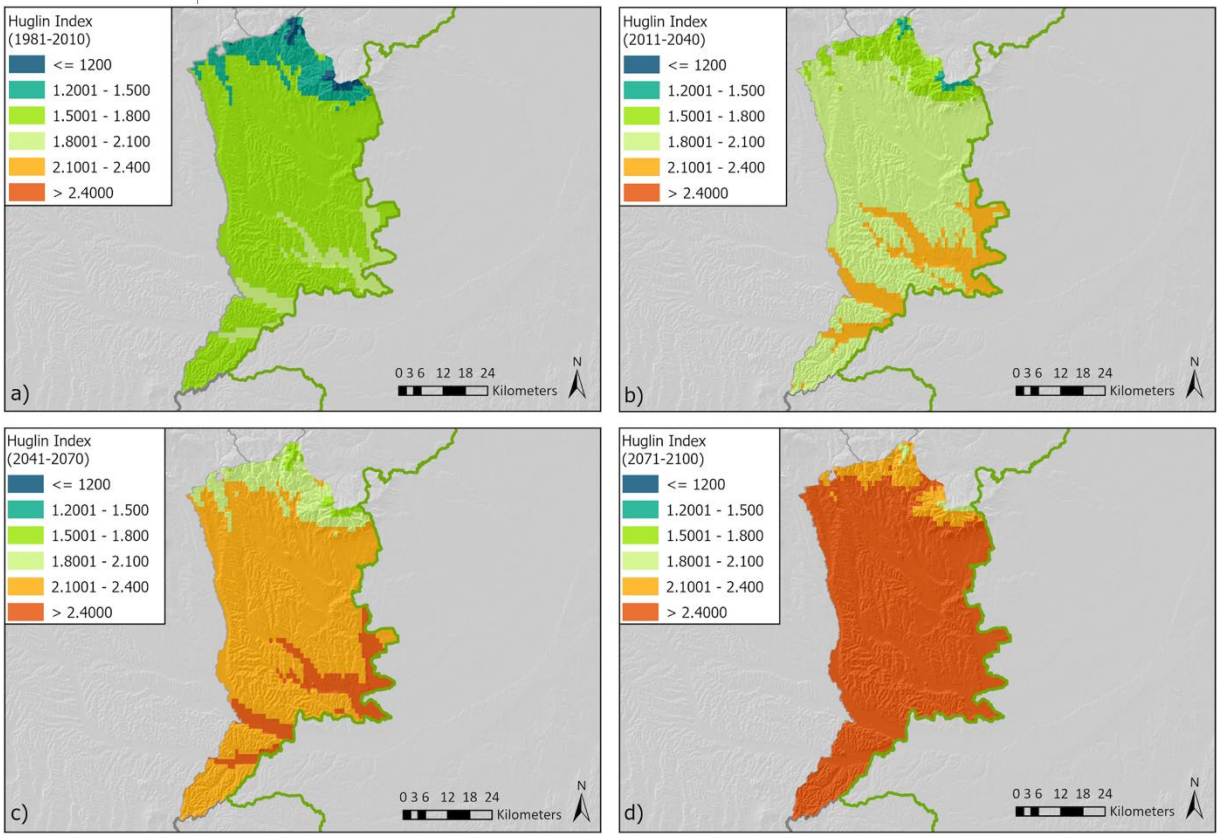

Figure 47. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Source: own elaboration based on data from Tscholl et al. 2024.

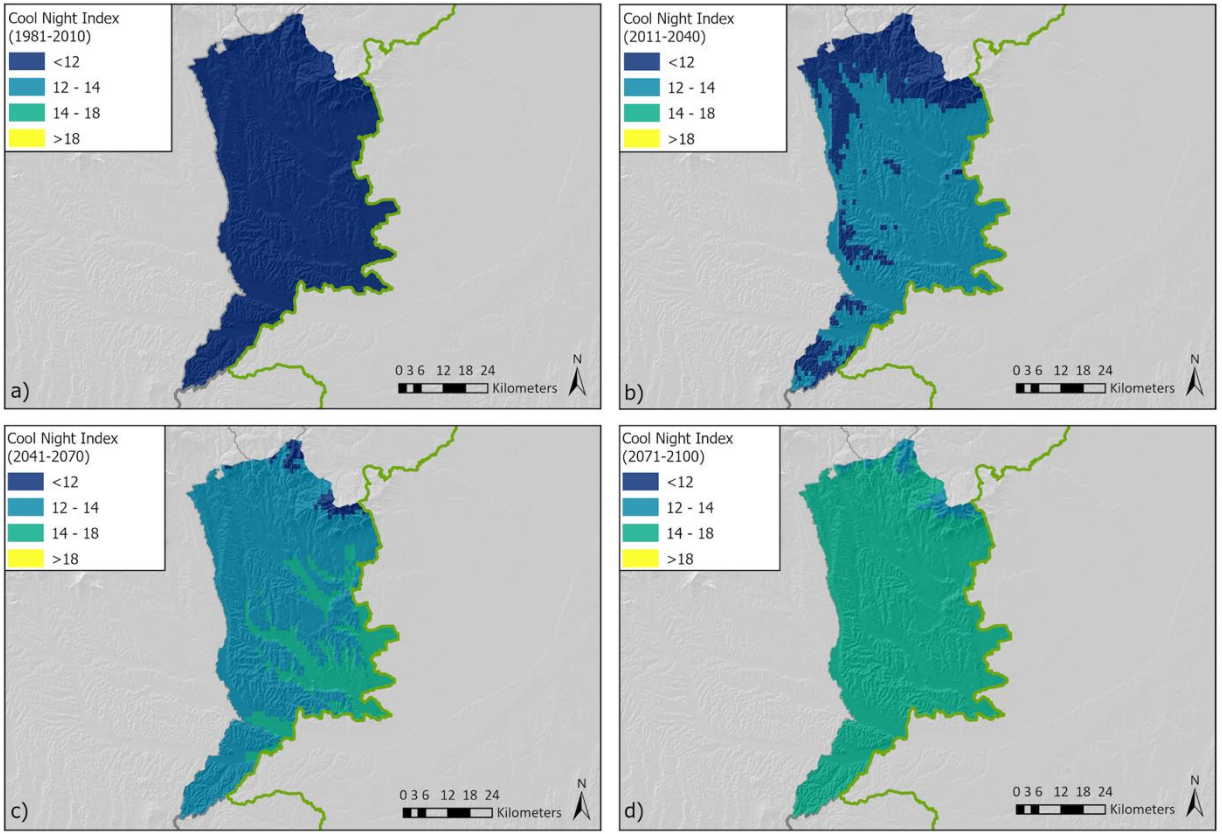

Figure 48. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

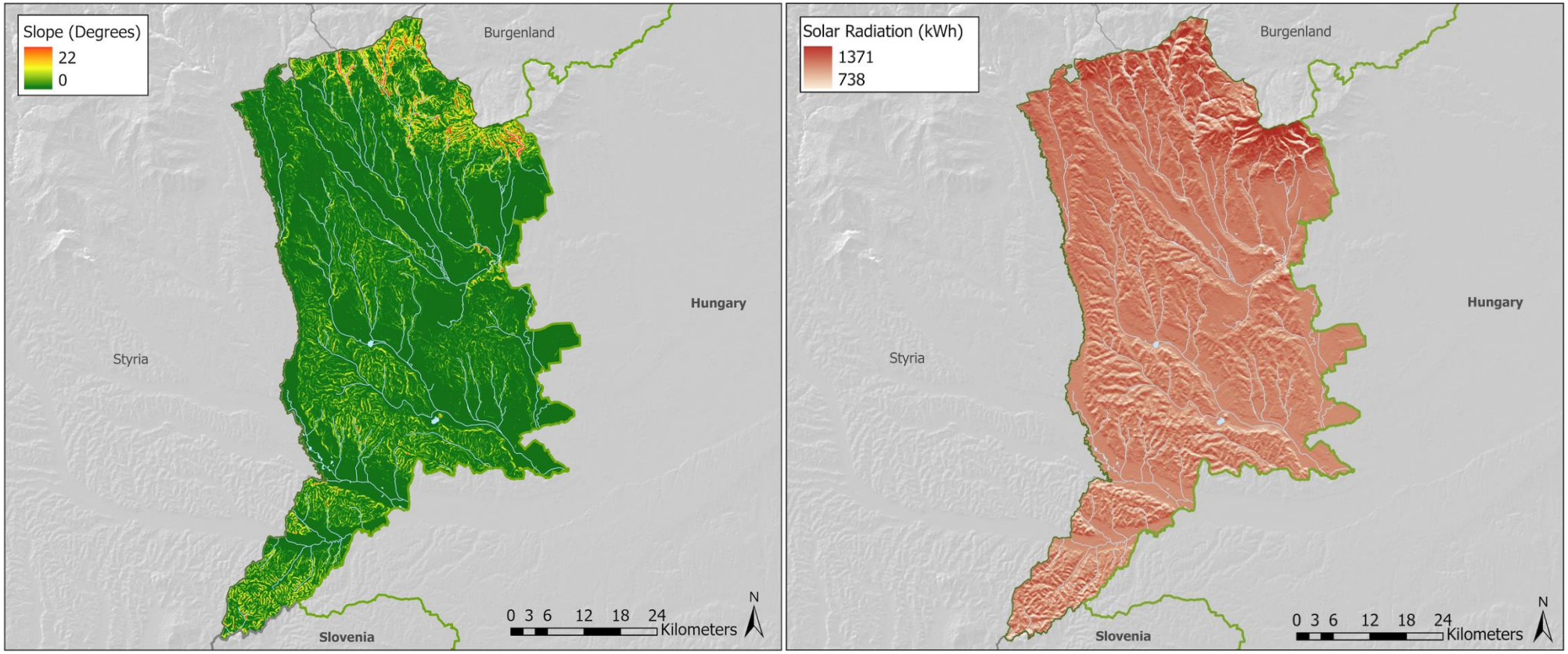

Figure 49. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: EEA, 2014.

C. Land use and soil

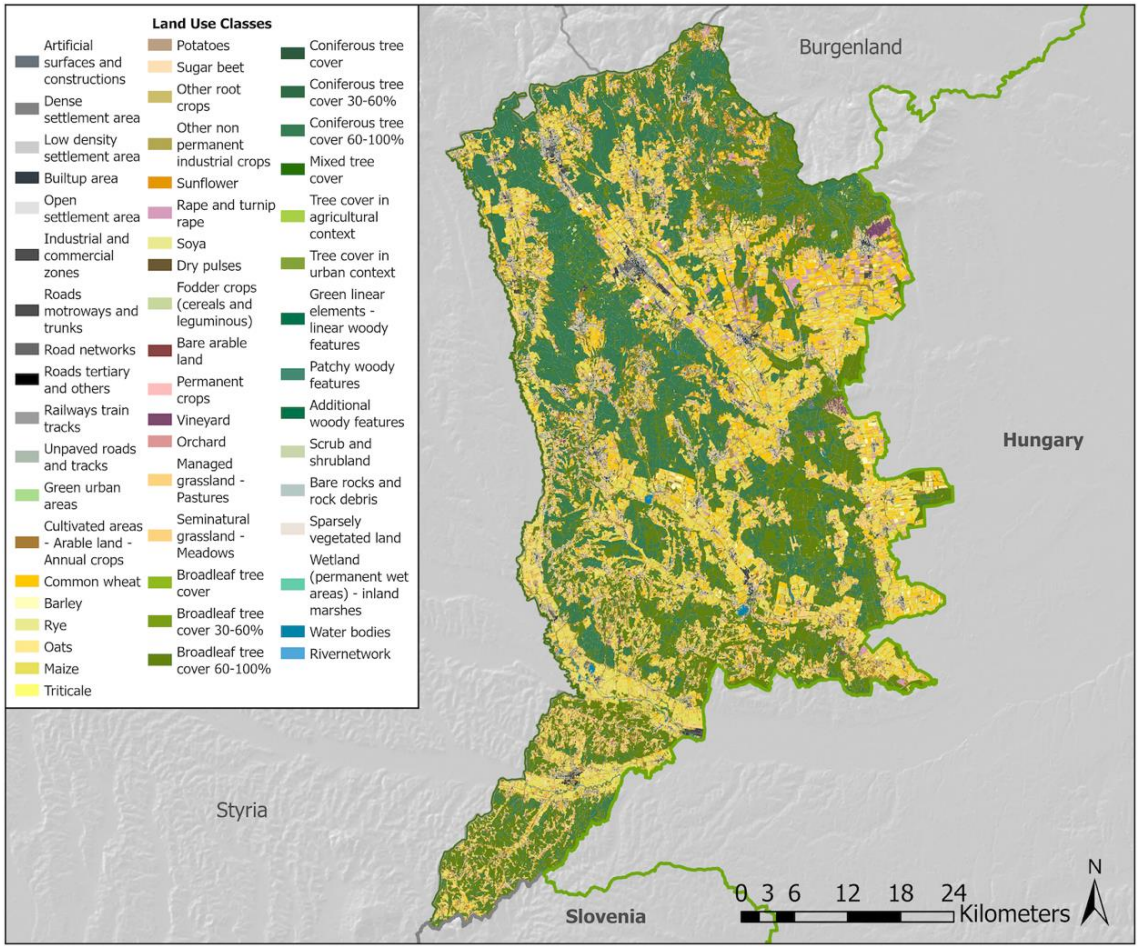

Figure 50. Land use land cover in the pilot region. Source: own elaboration based on data from Marsoner, T. et al., 2023.

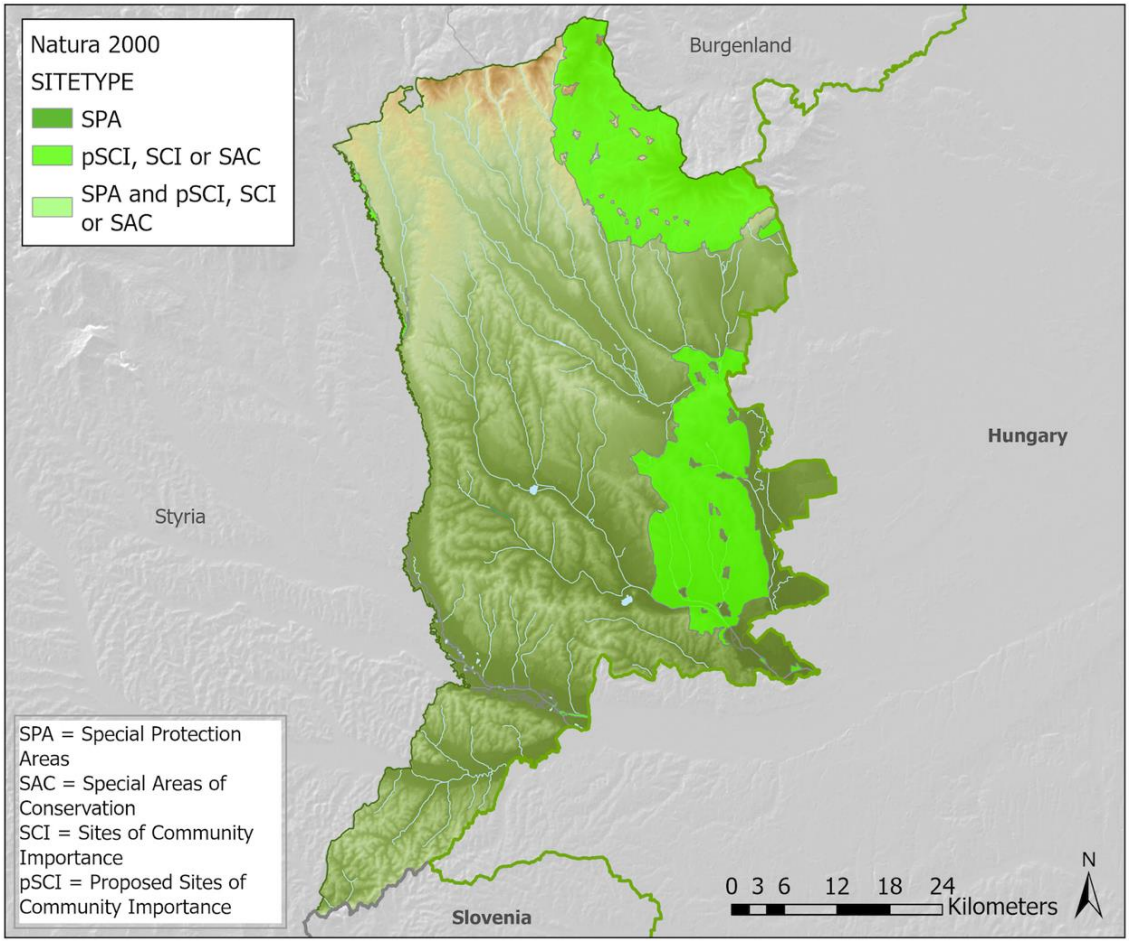

Figure 51. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

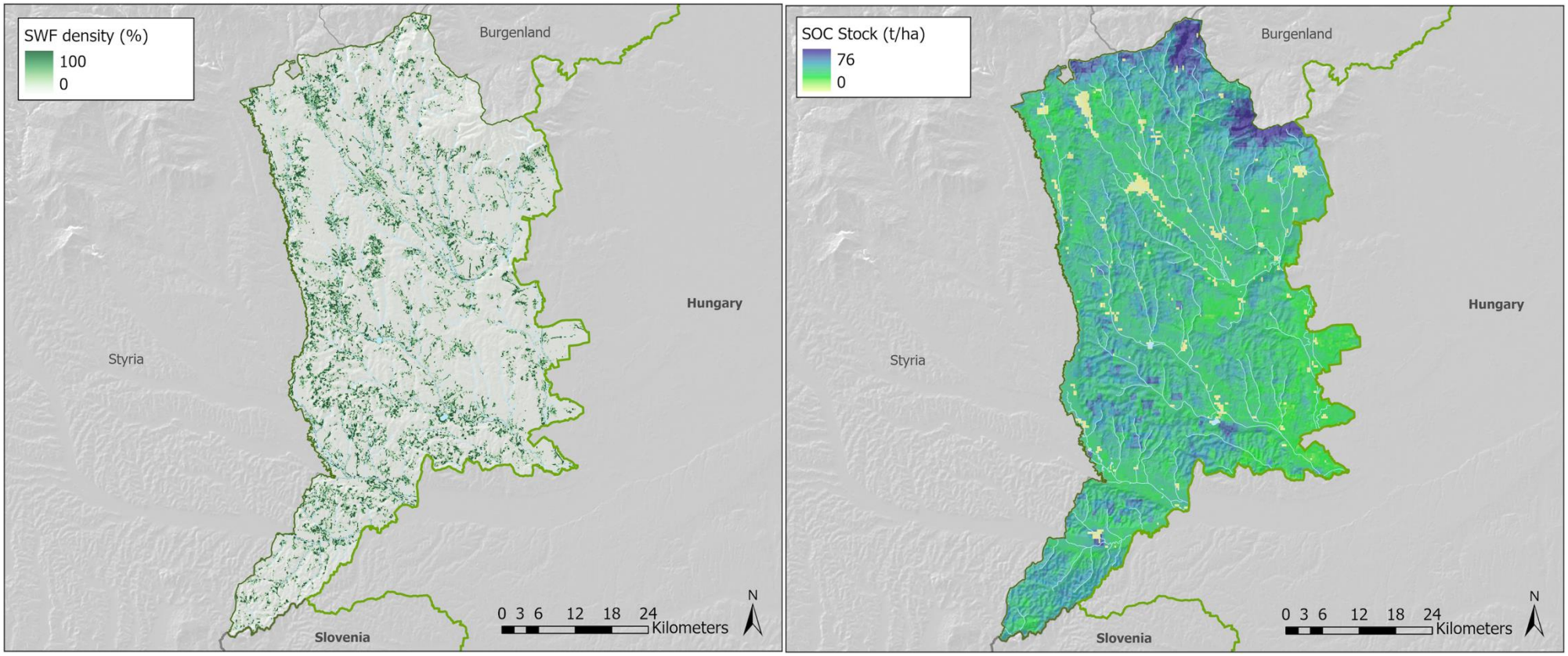

Figure 52. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right). Source: own elaboration based on data from EEA, 2025; Isric, 2025.

7. Pilot region: Vipavska dolina

Characterization of the region

The Vipava Valley is located in western Slovenia, between the Nanos and Karst Plateaus, and is one of Slovenia's wine-growing areas with the oldest tradition. The area is characterized by the strong local wind "burja / bora wind" with recorded speeds reaching up to 235 km/h. The area has a sub-Mediterranean climate with mild winters and dry, hot summers (ECOVINEGOALS, 2022). The geomorphology plays an important role here, as the valley is interrupted by slopes and hills and bordered by high plateaus. In the Vipava Valley, the viticultural landscape is characterized by fragmented vineyards scattered across the hills, and arable land and orchards in the valley floor. The Valley's identity relies on its high-quality wines. Stakeholders pointed out the importance of white grape varieties, and the local and indigenous varieties such as Zelen and Pinela. These indigenous varieties even if accounting for 7% and 5,8% respectively of the grape's varieties in the region, represent an important element for local stakeholders (ECOVINEGOALS, 2022). The Vipava Valley winegrowers want to preserve the indigenous grape varieties, which reflects their respect for tradition and close connection to local culture. Vipava Valley high-quality wine production is recognised worldwide, and since 2006 the region has been officially registered with the status of Protected Designation of Origin.

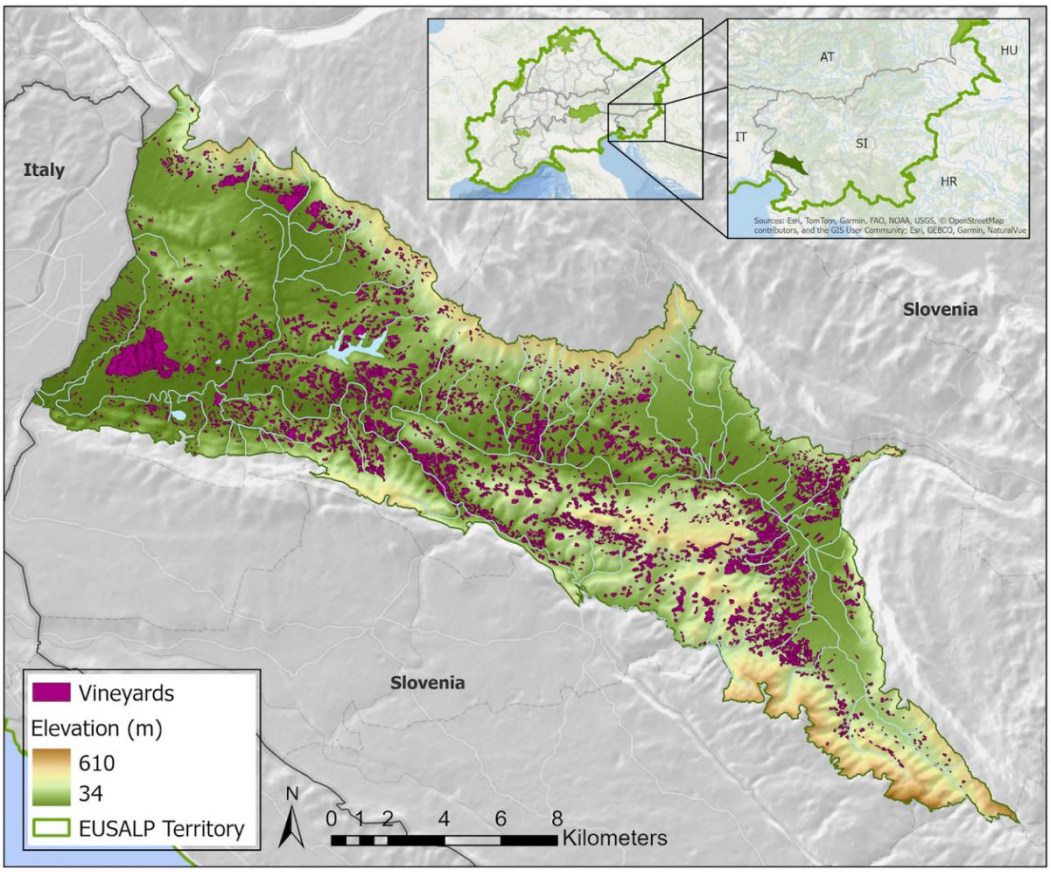

Figure 53. Map of the pilot region "Vipava Valley" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 54: Viticultural landscape in Vipava Valley. Source: Jan Čermelj.

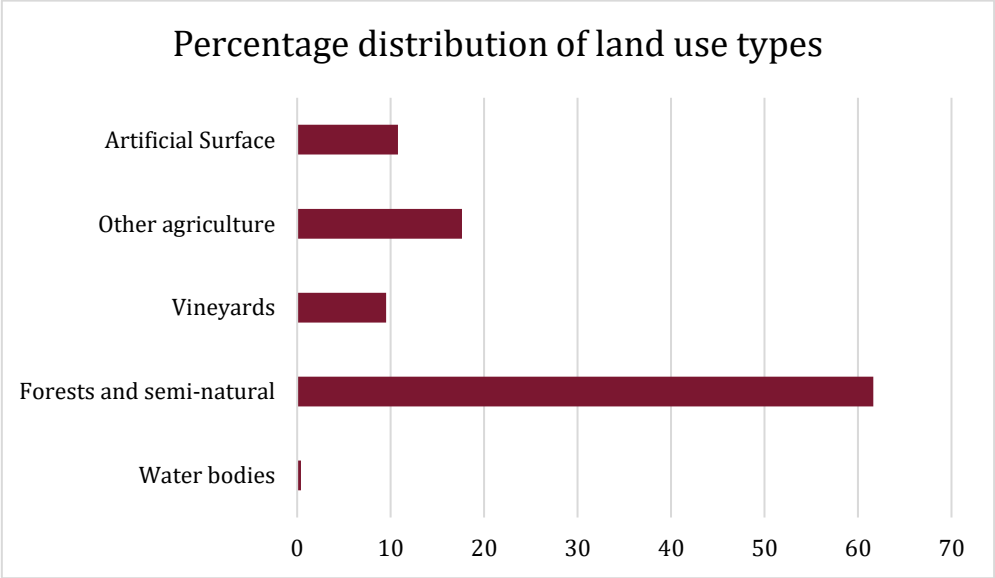

Figure 55. Macro categories of land use classes in Vipava Valley. Source: Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Ecosystem services in Vipava Valley

During the first phase of stakeholder involvement in Vipava Valley, actors from the wine sector prioritized the following set of ecosystem services for the region (Table 7).

Table 7. Ecosystem services relevant to Vipava Valley viticulture.

Ecosystem Service	Relevance for the area
Crop production	Stakeholders pointed out the importance of the high-quality wine production in the region. The Vipava Valley is particularly recognized for its dry white wines from their natives' varieties Zelen and Pinela. The region of Primorska (of which the Vipava Valley is a part of) provides with the 52 % of the total grape wine production in Slovenia (Kerma, 2012).
Regulation of water and erosion	In the Vipava Valley, vineyards are located on slope areas and depending on the location (e.g., face south, south-east or -west,) the influences of strong winds, hot and dry summers and mild winters can increase the impact on the vineyards. Therefore, the vegetation cover and terraced systems is important to prevent soil loss, reduce runoff, and maintain long-term soil fertility. The terraces that face on the south, south-east or -west, experience more drought (higher evapotranspiration) during summer, compared to, e.g., terraces that face on the north or the vineyards in the plain of the Valley.
Maintaining populations and habitats	Stakeholders in Vipava Valley highlight the importance of ecological balance provided by healthy landscapes. Presence of pollinators (e.g. bees and wild insects) is fundamental for crop production in the area. Preservation of habitats such as hedgerows and riparian zones also serve as ecological corridors and support wildlife, while natural pest control provided by birds or targeted introduction of selected autochthons yeast with antifungal properties reduces the dependence on, e.g., chemical inputs.
Cultural heritage	Vipava Valley heritage is represented by its autochthonous and local grapevine varieties, in particular, Zelen, Pinela, and Rebula. Stakeholders are proud of their cultivation as this contributes to the preservation of genetic diversity, landscape identity, and cultural continuity.
Landscape aesthetics	The viticultural landscape in the Vipava Valley is characterized by vineyards scattered across the hillsides and a mosaic of fields in the flat part. This creates a unique scenario that complemented by the agricultural practices is particularly appreciated by tourists. Tourism plays a big role in Vipava Valley even if it is not only connected to wine, but also to gastronomy and outdoor recreation (i.e. cycling, paragliding).

Climate change impacts in Vipava Valley

In the Vipava Valley the increase of drought periods, as well as long-lasting periods of heavy rainfall are some examples of effects of climate change. The most tangible impacts can be summarized in the following points:

- Changes in precipitation patterns in the Vipava Valley are causing drought periods, that combined with higher evapotranspiration, impact the quality in the sector by putting pressure on water resources.
- The change in frequency and intensity of extreme weather events such as hail, frost, severe storms and heavy rains, is increasingly affecting soil loss (i.e., through runoff). These events not only have a direct impact as physical damage to vineyards but also increase production risks over the years.
- Significantly warmer growing seasons due to rise in temperatures are leading to earlier budbreak followed by accelerated ripening. As a result, grape varieties reach higher sugar levels sooner, leading to high alcohol content and unbalanced quality of the wines. In addition, higher temperature are causing sun burns on the grape berries surfaces with negative impact on grape quality.

Challenges for Vipava Valley viticulture

Beyond climate change, some other challenges have been highlighted by stakeholders in Vipava Valley, including:

- The need for support from authorities. It was indicated that coordinated agricultural and viticulture development strategies are necessary, for example by providing financial assistance during extreme events.

Stakeholders suggested facing the challenges with water management, suggesting that the introduction of a crisis irrigation strategy with clear rules to ensure restricted and jointly regulated water use during critical periods could help local viticulture.

Annex VI: Vipavska Dolina

A. Bioclimatic maps

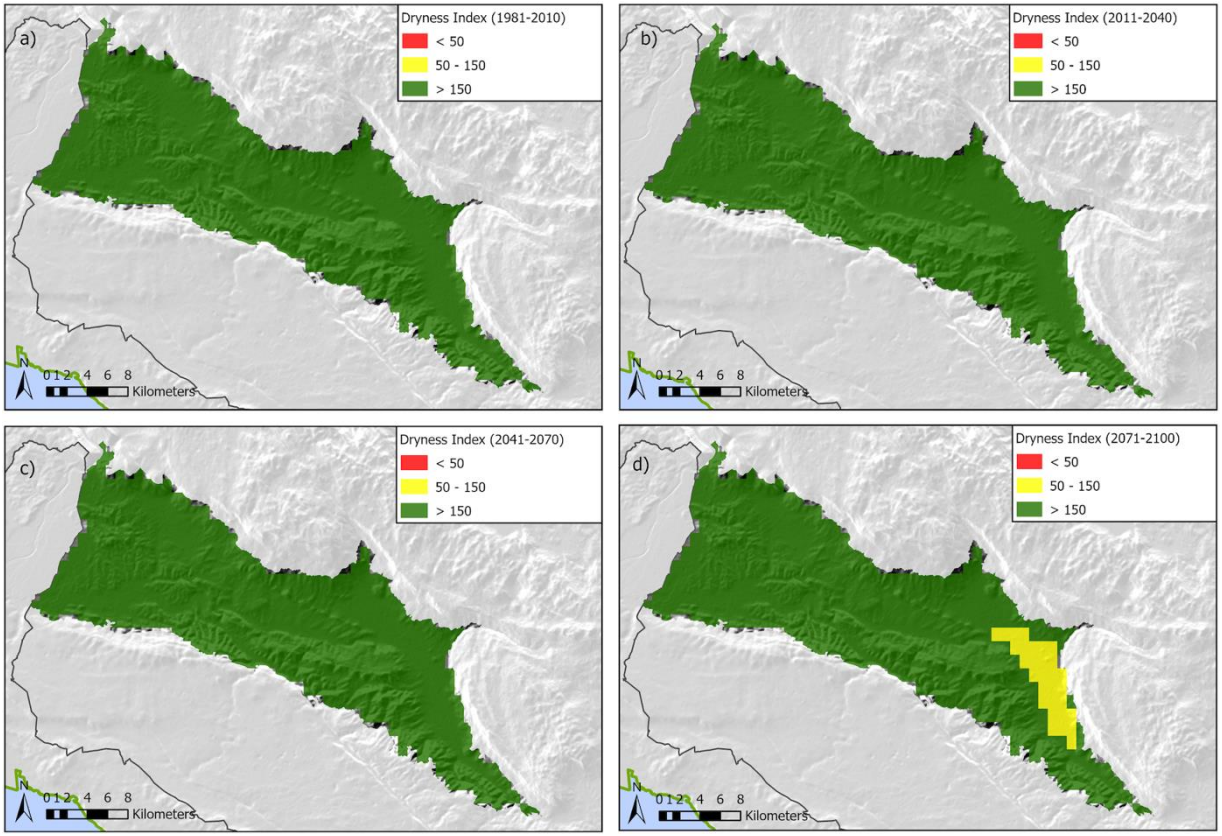

Figure 56. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

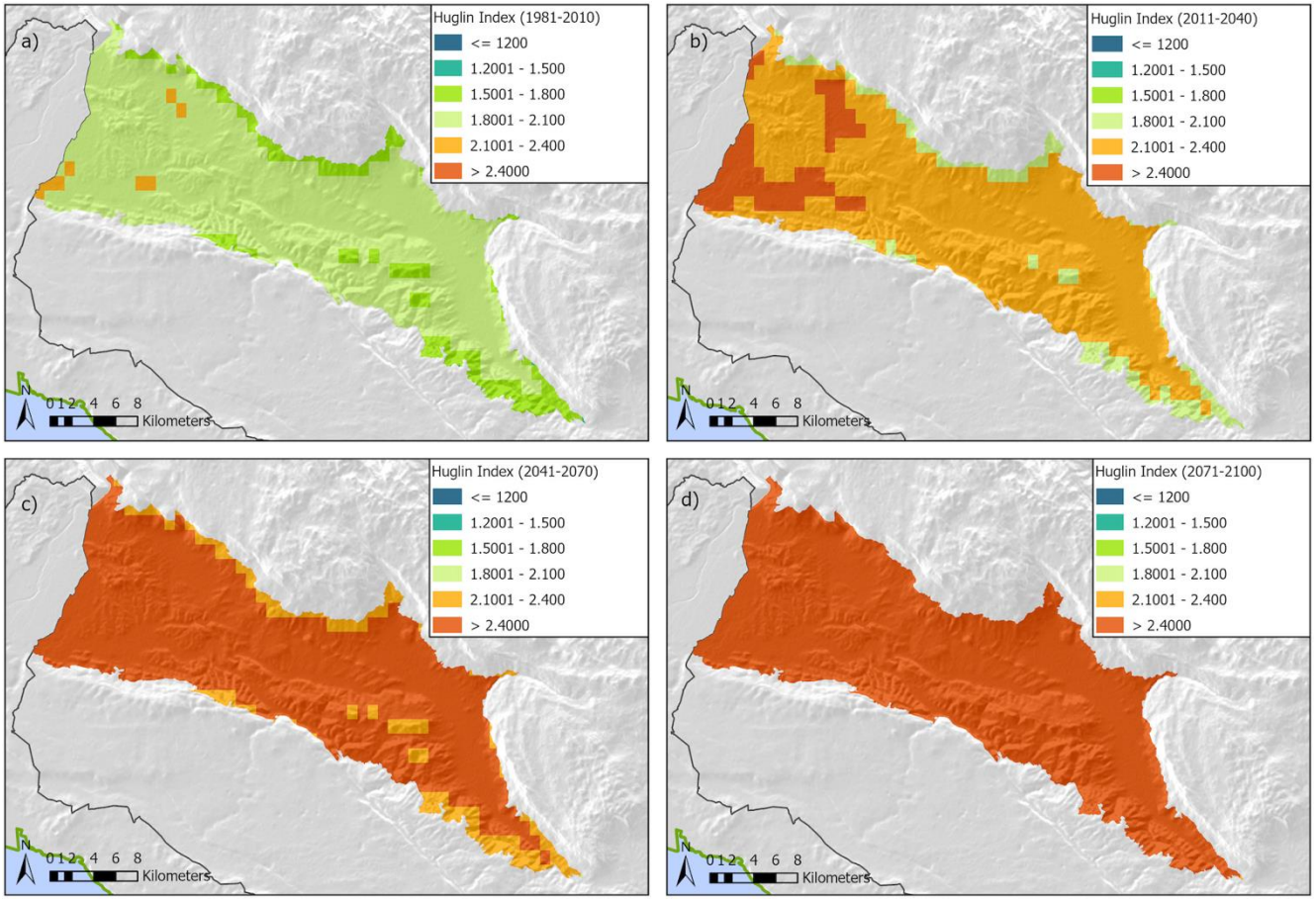

Figure 57. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Source: own elaboration based on data from Tscholl et al. 2024.

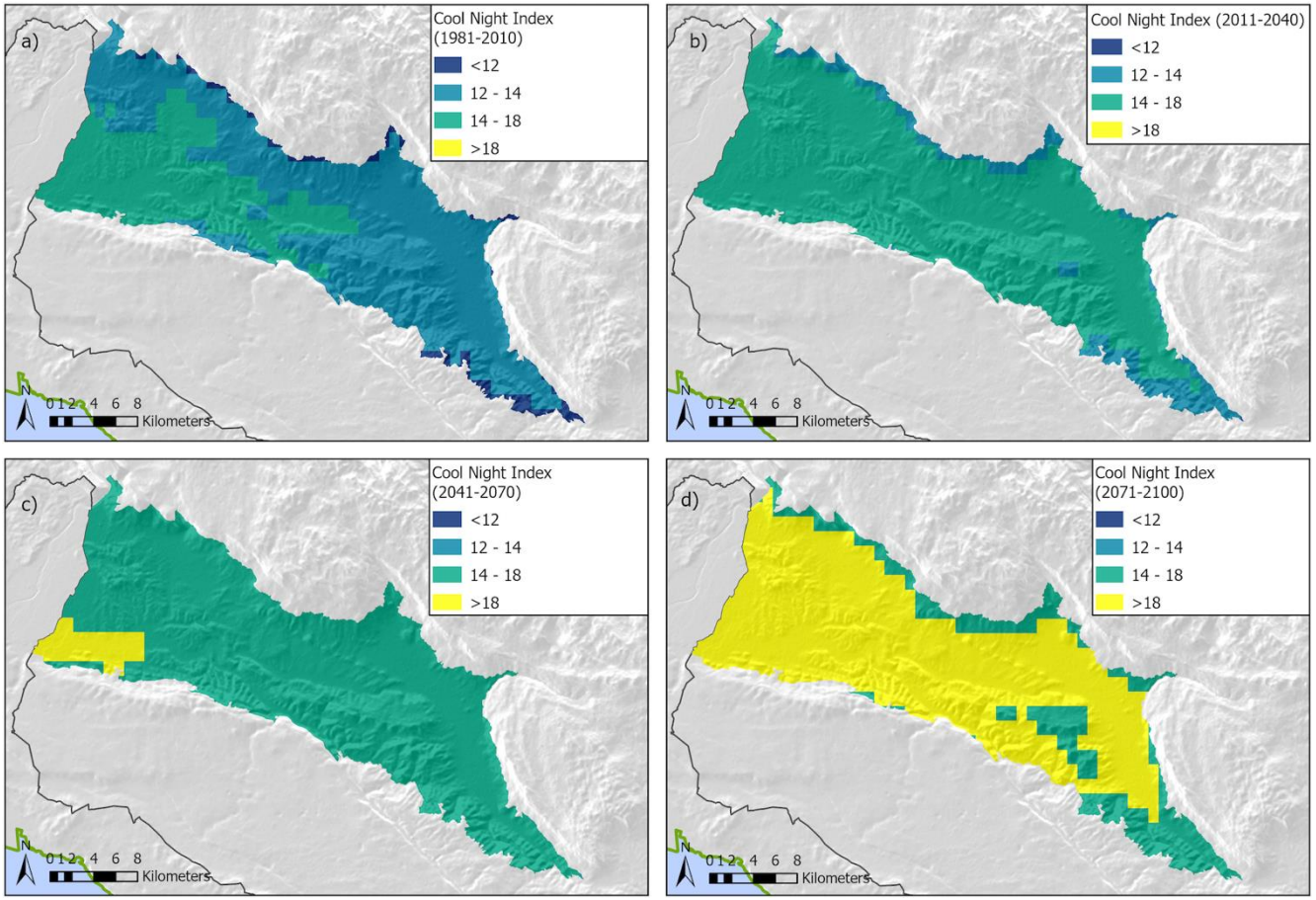

Figure 58. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

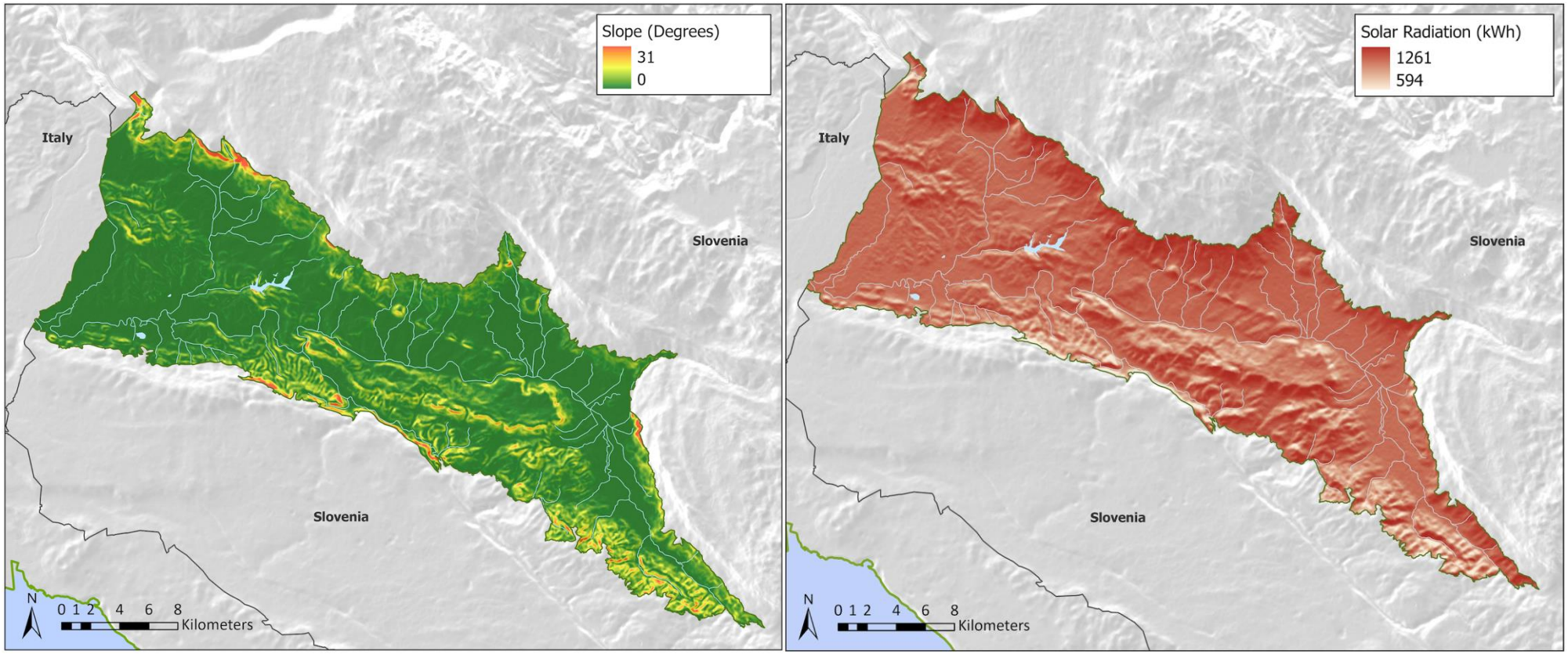

Figure 59. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: own elaboration based on data from EEA, 2014.

C. Land use and soil

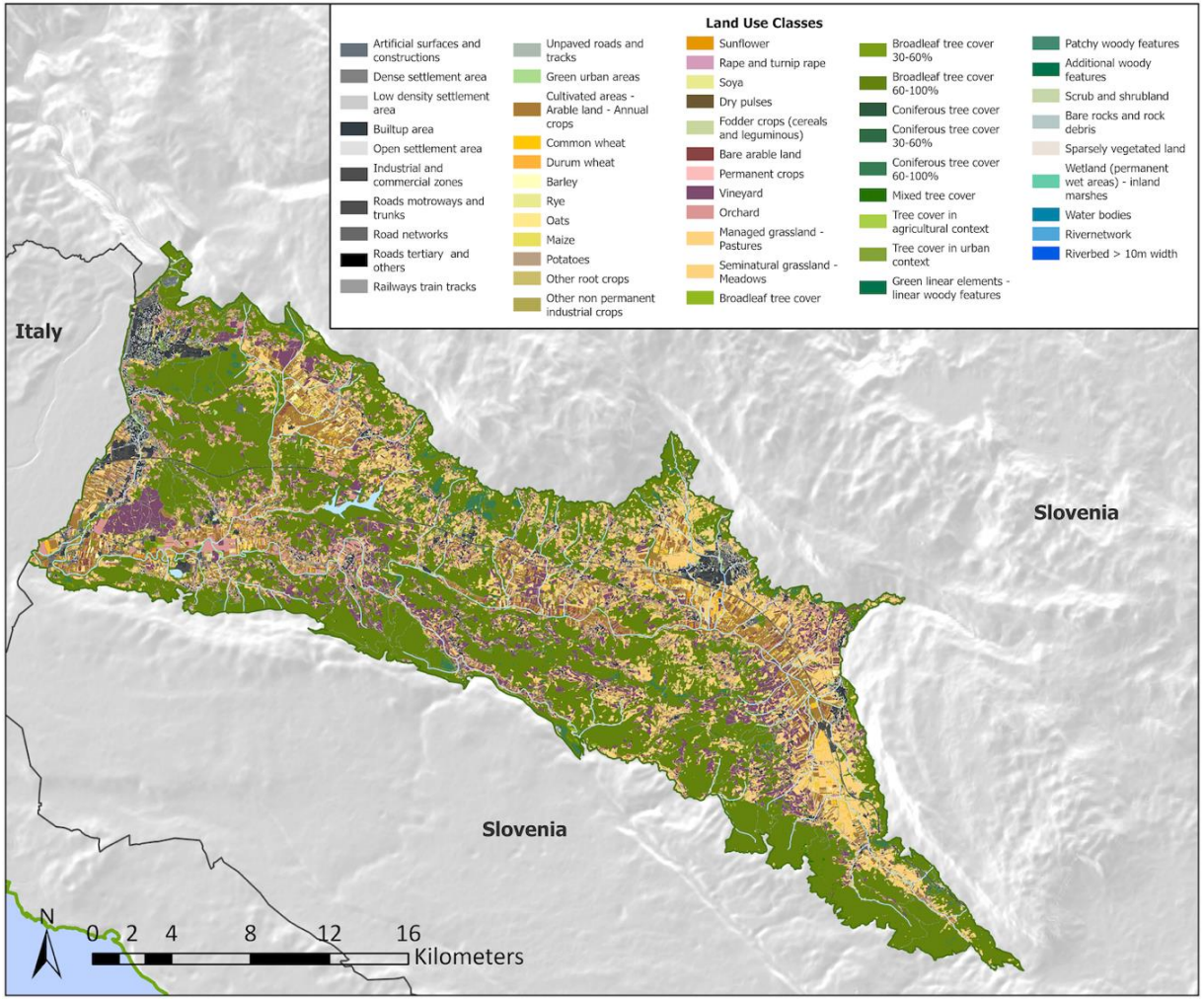

Figure 60. Land use land cover in the pilot region. Source: own elaboration based on data from Marsoner, T. et al., 2023.

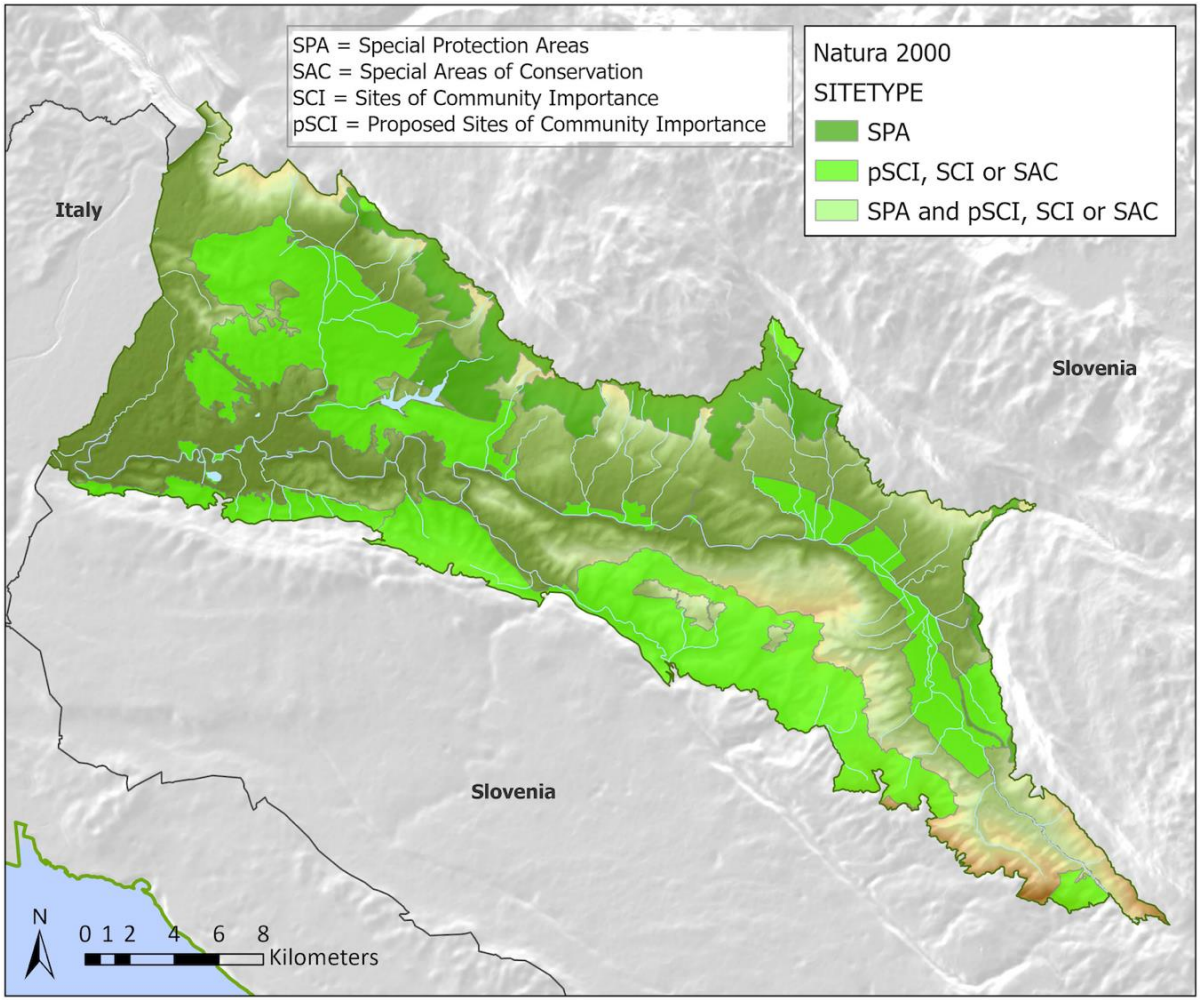

Figure 61. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

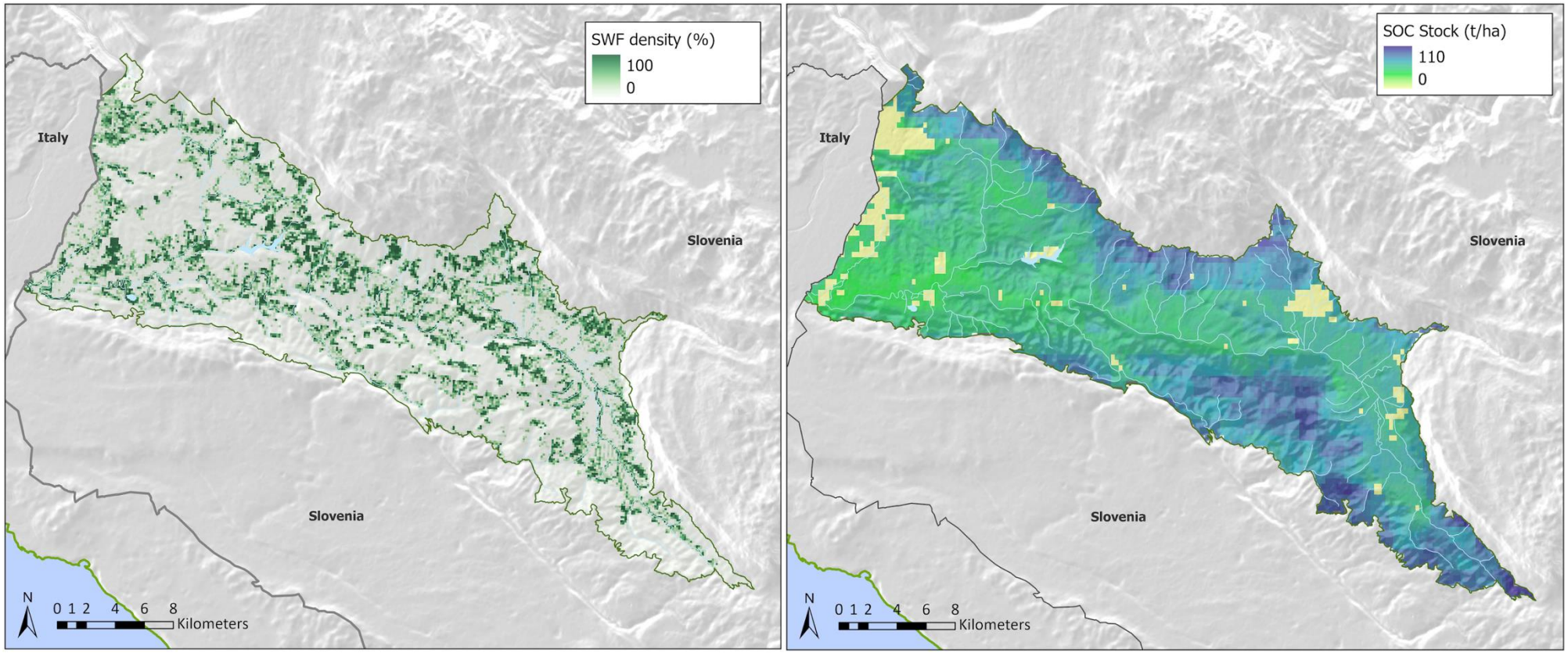

Figure 62. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right). Source: own elaboration based on data from EEA, 2025; Isric, 2025.

8. Pilot region: Franken

Characterization of the region

Franconia is one of Germany's historical wine-producing regions, dating back to the 8th century (Bock et. al., 2011). Located in north-western Bavaria within a transitional climate zone characterized by hot summers, cold winters, and low annual precipitation, Franconia is a region suitable for dry wines, its flagship variety is Silvaner. One of the winemaking traditions of the region is represented by the traditional "Bocksbeutel", a bottle known for its unique, rounded, and flattened shape that is used for wine in the area. The viticultural landscape is one of the defining elements of the region, even if it constitutes only a part of the total agricultural area. Franconia is framed by the low mountain ranges of Spessart, Odenwald, Rhön, Hassberge, and Steigerwald and distinctive for its tradition of cultivating in steep slopes along the Main River, which often requires the intensive use of manual labour for vineyard management. The surrounding landscape (e.g., fragmented parcels) in the Franconian viticultural region enriches the experience attracting a significant number of tourists. Franconia's small-scale family-run wineries (e.g., with 5-10 hectares of vineyards) allow visitors to meet winemakers personally, thus giving an added value to their experience of the region. Nowadays, a total of 6,272 hectares of vineyards are cultivated in the region reflecting a substantial economy for the region (LWG, 2025). Franconian high-quality wine production is recognised worldwide, and since 1973 the region has been officially registered with the status of Protected Designation of Origin.

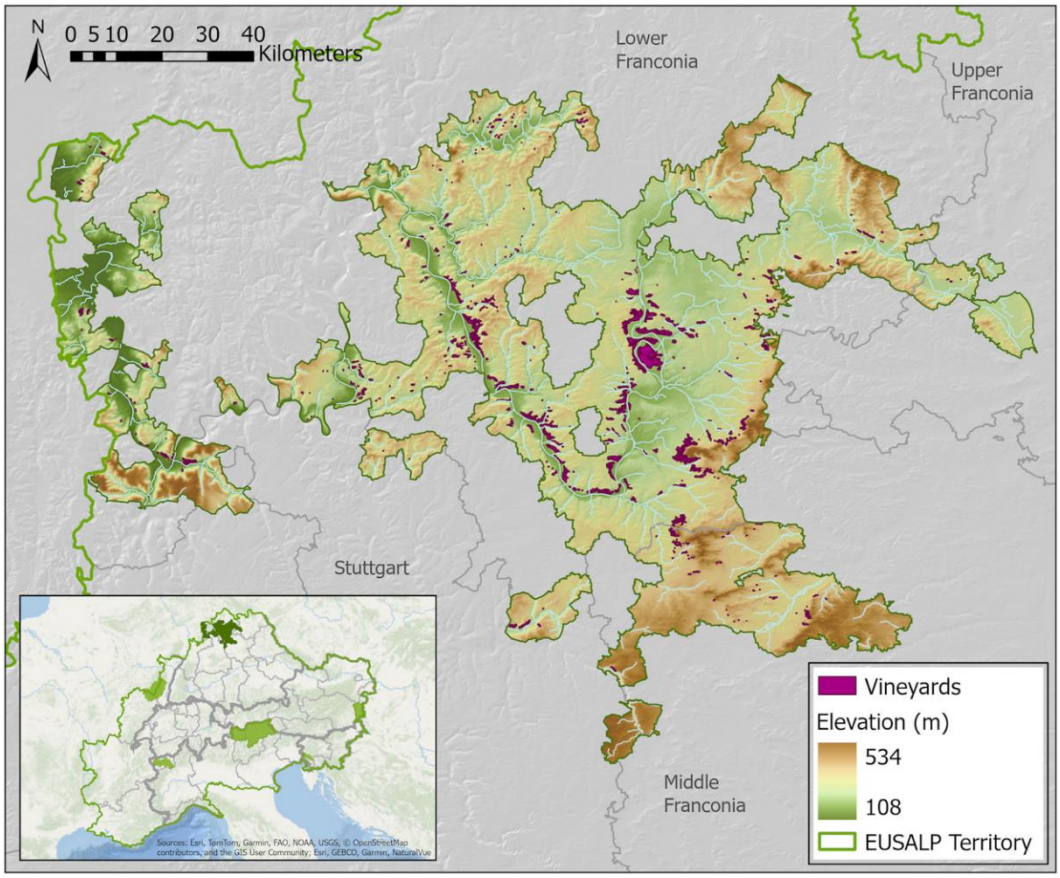

Figure 63. Map of the pilot region "Franconia" and localization of its vineyards. Source: elevation data from European Environment Agency, 2014; vineyards calculated based on Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Figure 64. Example of a typical vineyard landscape in Franconia. Source: Jo Leonhardt on Unsplash.

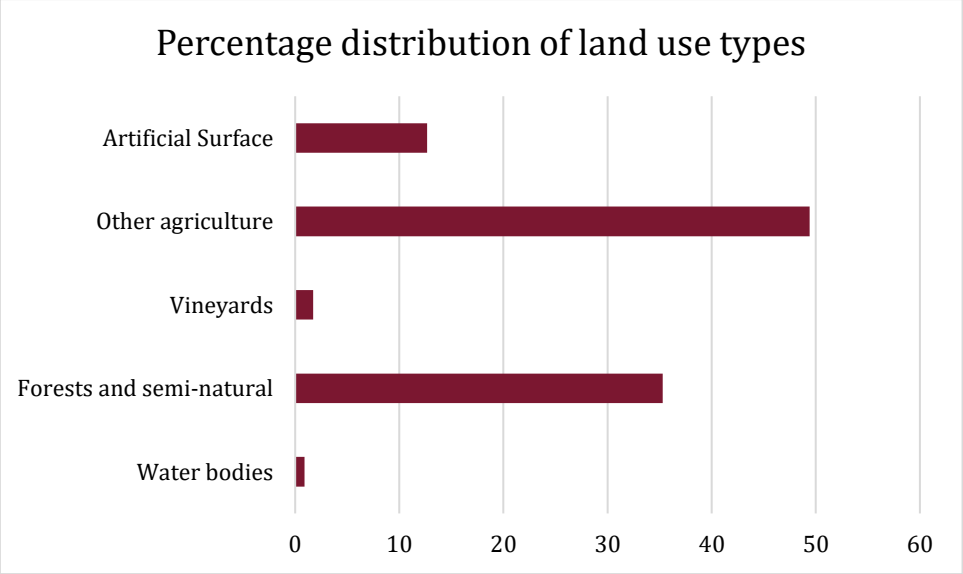

Figure 65. Macro categories of land use classes in Franconia. Source: Macro categories calculated based on data from Marsoner, T. et al., 2023 and European Environmental Agency, 2025.

Ecosystem services in Franconian viticulture

During the first phase of stakeholder involvement in Franconia, the local actors of the wine sector indicated the most important ecosystem services for viticulture in the region (Table 8).

Table 8. Ecosystem services relevant to Franconian viticulture.

Ecosystem Service	Relevance for the area
Soil processes	Soil quality, health, water infiltration and carbon storage represent a group of elements that Franconian stakeholders defined as the "capital" for viticulture in the region. The importance of soil management is one of the priorities in Franconia, therefore winegrowers are closely interested in working with nature to enhance soils' properties. Strategies as mulching, the use of compost or biochar between others are some examples that have implemented, at different extents, in their fields.
Regulation of water and erosion	Extreme events in Franconia, such as droughts and heavy rains, highlight the importance of managing certain elements in the vineyards (e.g., soil structure and inter-row cover). Regulation of water and erosion (e.g., to increase water availability and infiltration rate) would allow winegrowers to enhance their resilience. Franconian winegrowers have been working on improving resilience in their vineyards, for example by intensively using cover crops in the interrow.
Climate regulation	While this service is not directly benefitting viticulture, Franconian stakeholders recognize the capacity of vineyards to support the regulation of the micro-climate in nearby urban areas. The simple presence of vineyards serves as a green buffer that can help to reduce the urban heat effect.
Maintaining populations and habitats	In Franconia the presence of small-scale ecological structures in vineyards (e.g., hedgerows) helps the species by providing multiple habitats. Franconian stakeholders pointed out that maintaining these elements is the key to enhance biodiversity. One emerging topic is the use of agroforestry in vineyards, which is only used in some areas. Through proper management, these structures not only support the biodiversity but also enrich the appearance of the landscape, supporting cultural ecosystem services.
Cultural heritage	Franconian viticulture is more than high-quality wine production. It is a cultural heritage created by long-standing traditions. Franconian stakeholders highlight that the vineyards cultivated along the river, together with the surrounding landscape structures, create a unique cultural landscape for locals and visitors alike. Winegrowers are proud of their region and showed their desire to keep Franconia recognized not only for its high-quality wine but also for their producers and their histories.

Climate change impacts in Franconia

Franconia viticulture is affected by the current climatic trends. The most tangible impacts in the Franconian viticulture are:

- The changes in precipitation patterns, that produce long dry periods in the region. Together with increased evaporation due to rising temperatures and increasing water stress they disrupt the grape growth, leading to imbalances in growth that threaten vineyards and yields, especially on steep slopes.
- The increase of extreme weather events, such as heavy rainfall, late frosts and hail, is an increasing risk for Franconian viticulture and influence the crop quality and quantity. The cultivation in steep slopes increases the probability of erosion in case of some of these extreme events, with the related damages and costs.
- The rise in temperature has encouraged the emergence of invasive species and diseases that were previously unknown in the region in recent years, as well as increasing the spread of existing pests.

Challenges for Franconian viticulture

Beyond climate change, some other challenges have been highlighted by stakeholders in Franconian viticulture, which include:

- The international competition that drives market prices downward putting economic pressure to Franconian viticulture. At the same time, local producers are concerned about shifting toward high quantity production while overall wine consumption declines.
- Changes in land use as new areas become suitable for high-quality wine production (especially in less steep areas) are threatening traditional production areas and potentially changing the traditional landscape structure.
- The important role that winegrowers play in the protection and sustaining of the Franconian cultural landscape, its benefits, and values is becoming increasingly less appreciated by the public.
- The creation of green infrastructures in vineyards to support biodiversity, e.g., through agroforestry, and the economic pressures might create conflicts if it does not allow for economically sustainable production.

Annex II: Franken

A. Bioclimatic maps

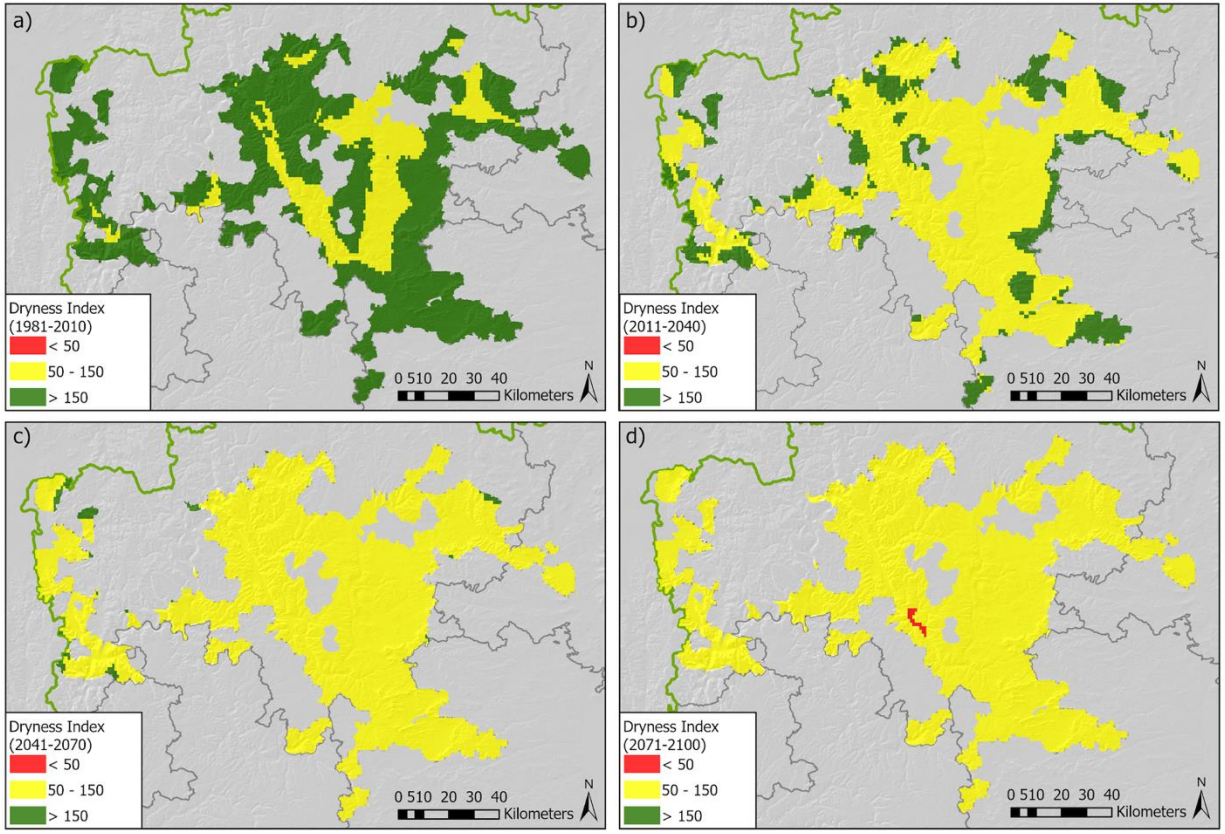

Figure 66. Dryness index for the pilot region under SSP3 at different time steps for the pilot region. The dryness index evaluates soil water availability for vine development, by estimating soil water reserves, precipitation, and potential evapotranspiration (mm). Source: own elaboration based on data from Tscholl et al. 2024.

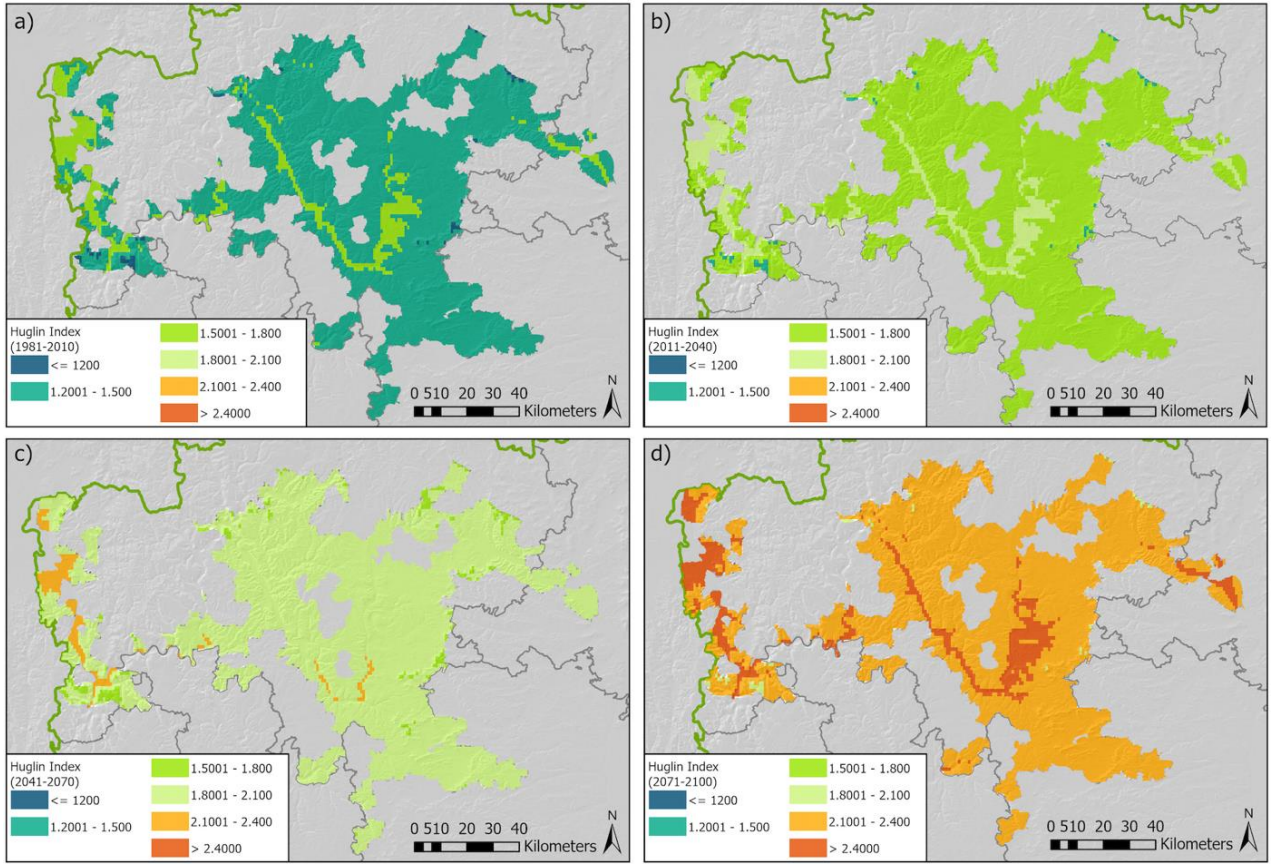

Figure 67. Huglin index for the pilot region under SSP3 at different time steps for the pilot region. The Huglin index describes the thermal conditions in a wine region during the vegetation period, which is related to the potential grape sugar content (GDD). Source: own elaboration based on data from Tscholl et al. 2024.

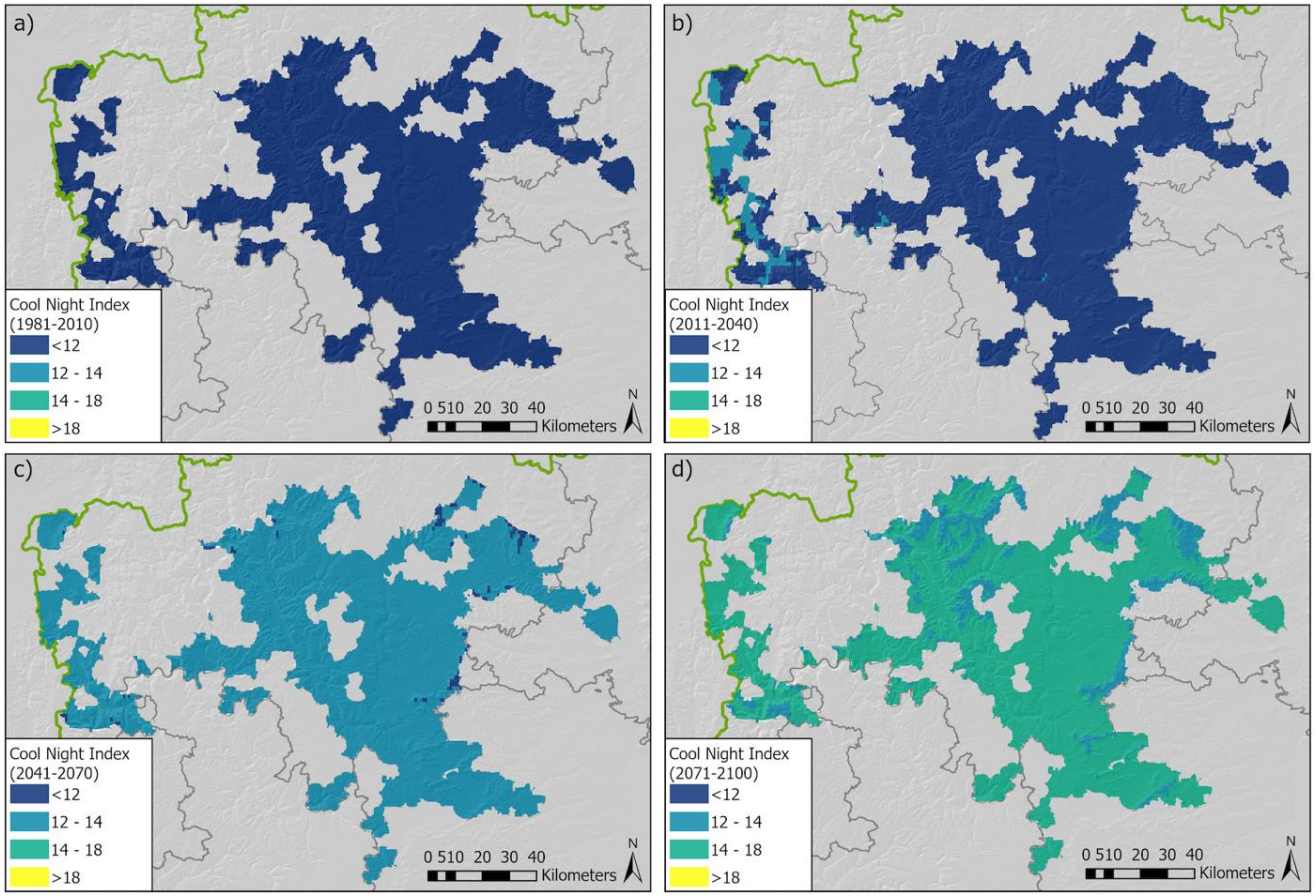

Figure 68. Cool night index for the pilot region under SSP3 at different time steps for the pilot region. The cool night index accounts for minimum temperatures during September, providing an estimate of temperature conditions during the ripening stage (°C). Source: own elaboration based on data from Tscholl et al. 2024.

B. Geomorphology

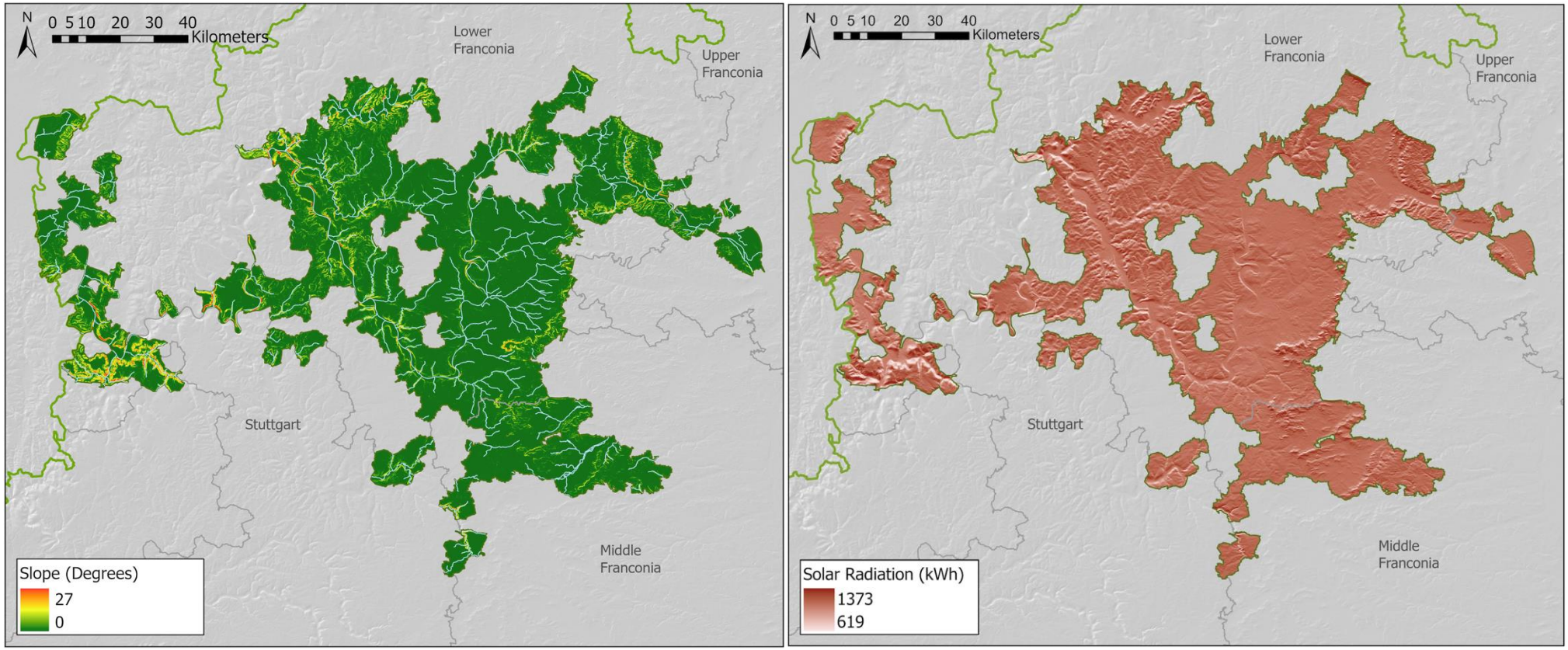

Figure 69. Slope (in degrees, left) and solar radiation (in kWh, right) in the pilot region. Source: own elaboration based on data from EEA, 2014.

C. Land use and soil

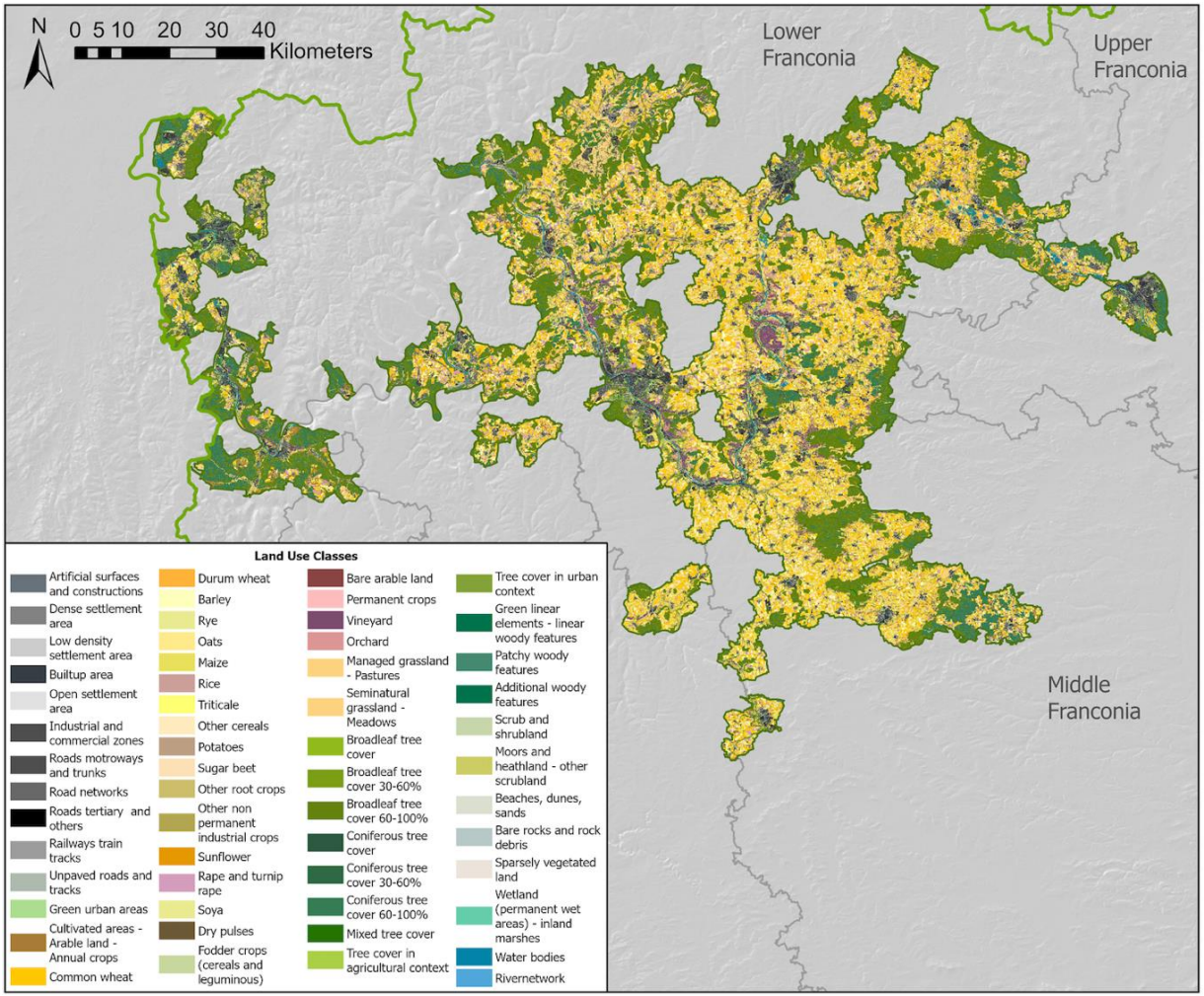

Figure 70. Land use land cover in the pilot region. Source: own elaboration based on data from Marsoner, T. et al., 2023.

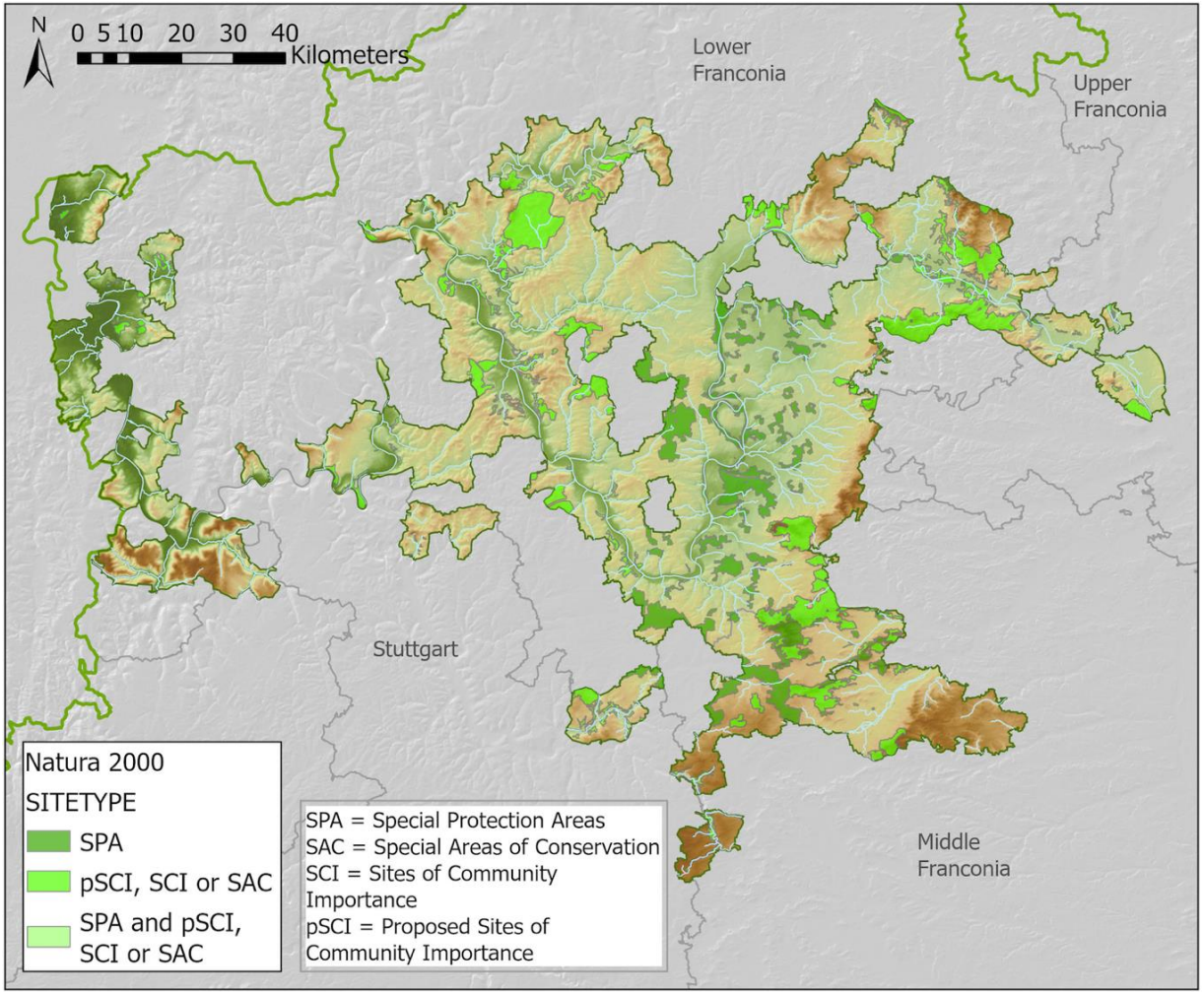

Figure 71. Presence of Natura 2000 sites. Source: own elaboration based on data from EEA, 2024.

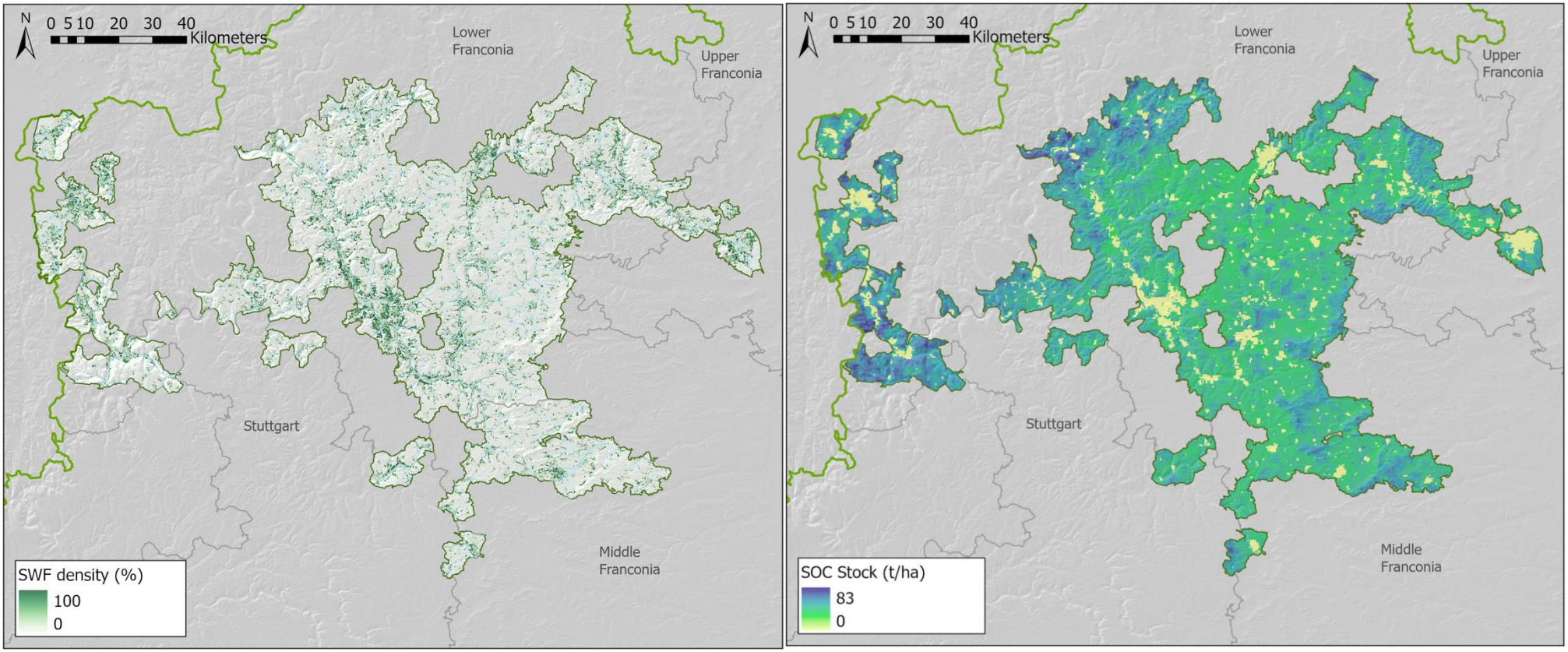

Figure 72. Density of small woody features (in density per ha, left) in the pilot region and soil organic carbon stock (in t/ha, right). Source: own elaboration based on data from EEA, 2025; Isric, 2025.

9. Key insights

Understanding the similarities and challenges among pilot regions is useful to characterize different types of AWO and find tailored solutions to make them more resilient to climate change. The phase 1 of the RESPOnD LL provided space for co-creation of knowledge on AWO specificities. Through the discussion with different actors from the wine sector, attributes, ecosystem services, climate change impacts and challenges were prioritized in each pilot, giving an overview of commonalities and differences among them.

Attributes

High-quality wine production is among the most important characteristic of the surveyed AWO. This is reflected in the status of Protected Designation of Origin that some of the pilot regions have, and shows how diverse and rich biophysical conditions are in the Alpine Space, enabling the cultivation of a wide variety of grapes. Most of the pilot regions are characterised by a specific set of vine varieties. Some examples are the Silvaner in Franken, Lagrein in South Tyrol, Zelen and Pinela in the Vipavska Dolina Valley.

Attributes related to the categories of climate, geomorphology, and land use/management are very important for stakeholders to characterize their pilot regions. Climate is a dominant attribute that was the most used to characterize RESPOnD AWO. This reflects the relevance of this attribute for viticulture and the final characteristics of wines. Some regions have very specific conditions, e.g., the "burja / bora" wind that characterizes Vipavska Dolina. Other biophysical attributes are also considered important, such as the mosaic of different land uses in Franken and Südburgenland, while the presence of an extended network of dry-stone walls in Cinque Terre and Ballons des Voges have been mentioned as important attributes by stakeholders from those regions.

The analysis of the survey from the different regions shows that the character of AWO emerges from the interplay between cultural heritage, economic activity, and ecological systems. Stakeholders from the RESPOnD pilot regions recognize that the traditions and practices developed in their individual areas constitute authentic cultural heritage, which must be carefully preserved and passed through generations. The creation of a typology of AWO attributes therefore needs to consider multiple factors, such as geomorphology, climate and land use, and analyse how these elements, together with human agency, shape the characters that make each region unique.

Ecosystem Services

Stakeholders recognize the importance of ecosystem services and the contributions that the AWO provide to human well-being. Since vineyard landscapes are created with the purpose of producing wine, the crop production service is considered particularly important. However, also other categories of ecosystem services are highlighted by the participants in LL1.

Regulating services are perceived as crucial across all the pilot regions. In particular, the regulation of water and erosion, the support of soil processes, pest and disease control and the capacity of maintaining populations and habitats (e.g., to increase biodiversity in vineyards) were discussed in depth. Given the increase in the frequence of extreme events, the issue of water regulation in steep slopes is particularly important for RESPOnD stakeholders. This is evident in

Franken, where water related issues are at the centre of the debate for adaptation. The availability of habitats for different species is also highlighted in multiple regions, for example in Ballons des Vosges it is considered important in relation to the presence of Natura 2000 areas, while in South Tyrol it is pointed out how viticultural landscapes intensification has caused a progressive loss of green infrastructure and corridors.

Cultural ecosystem services are considered of key importance for AWO. The value of cultural heritage (e.g., in relation to production practices or historical landscapes) and aesthetically appealing landscapes is seen as a very important characteristic. In Südburgenland the unique Uhudler tradition attracts people, in Valle d'Aosta projects such as an Alpine Wine Route or the promotion of walking/cycling routes in the area are actively supported. In some cases, wine tourism is only a fraction of bigger flows of tourist that visit a region because of its unique characteristics, as in the case of Cinque Terre pilot region.

From the survey it appears that stakeholders from the wine sector are aware of the deep interlinkages between nature and AWO landscapes, although their preference for ecosystem services differs between regions. The focus lies usually on the ecosystem services that have a tangible impact on grape production and vineyard management (i.e., regulating services), but also added values such as heritage and aesthetics (i.e., cultural services) are recognized for their usefulness in supporting the mountain viticulture.

Climate change impacts

Climate change and its impacts on AWO are clearly tangible for stakeholders in all considered regions. This is probably the characteristic of RESPOnD pilot regions that has been most discussed so far within the individual regions. The main impacts of climate change that were discussed are the changes in precipitation patterns, increase in extreme events, and increase in temperature, with multiple effects on wine production.

The increase in temperatures puts at risk the high-quality wine production and its typicity, influences vines' phenology leading to a shift in the harvest time, and modifies the sugar and acid contents of grapes. Temperature increase is also seen as a problem regarding diseases and pests, e.g., in Valle d'Aosta, Franken and South Tyrol.

Extreme events, such as hail, late frost, heavy rainfall, and drought, increasingly result in yield losses and structural damage to vineyard (e.g., cause by water runoff, damage of dry stone walls, problems related to water redistribution). This was pointed out in various regions, highlighting the difficulty for long term planning in the management of vineyards in presence of these events, e.g., Vipavska Dolina, Südburgenland, Franken.

The factsheets highlight that stakeholders are aware of the risks and impacts of climate change, therefore it is evident that stakeholders are already starting to put in place, or at least planning, a set of adaptation practices to ensure production under new climates. In this context, they specifically recognize the added values that ecosystem-based adaptation solutions can provide to their production and are therefore interested in discussing this topic more in depth.

Challenges

The challenges currently faced in each pilot region vary across the AWO in the Alpine Space and the importance of socio-economic variables in each region. Each pilot region has specific characteristics, and their socio-economic factors play an important role in defining current and

future challenges. For example, in South Tyrol, stakeholders pointed out that the economic factors are increasingly prioritised leaving aside practices and traditions related to traditional values of viticulture. Declining agricultural profitability, along with an increase in average age of farmers was stressed as a problem in Franken, Cinque Terre, and Südburgenland. Lack of convergence among wine actors and the need for tailored instruments for the wine sector was perceived by stakeholder in Vipavska Dolina and Cinque Terre.

General problems mentioned by the stakeholders are related to the profitability of mountain viticulture, the lack of infrastructures, the potential for land abandonment due to structural conditions of mountain areas, and the lack of generational turnover in winemakers. This requires a reconsideration of the unique conditions of mountain viticulture to provide more instruments to support this activity.

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