Interreg Alpine Space

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PlanToConnect

Planning instruments and processes for GBI network planning and implementation in the Alps

Analysis of planning practices on establishing GBI networks for connectivity in the Alpine Space

Deliverable 2.1.1 Ecological connectivity, green and blue infrastructure networks and spatial planning in the Alpine Space

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This publication is a policy survey report jointly produced by the partners of the PlanToConnect project. The objective is to provide an overview of current policy framework and planning practices about Green and Blue Infrastructure networks and ecological connectivity in the EU and in the EUSALP macro-region. The report identifies challenges and opportunities for a better integration of these networks into spatial planning instruments and for their harmonization across administrative and cross-border areas in the Alpine Space.

Planning instruments and processes for GBI network planning and implementation in the Alps

Regione Veneto, June 2024

Table of Contents

List of Tables

List of Figures

List of Annexes

SECTION 1

EU AND EUSALP POLICY FRAMEWORKS FOR ECOLOGICAL CONNECTIVITY AND SPATIAL PLANNING

1 EU policy framework for ecological connectivity

The PlanToConnect project analyses the topic of ecological connectivity from the perspective of its integration into spatial planning policies and systems in the EU and, in particular, in the Alpine Space.

The EU policy framework for ecological connectivity is comprehensive and multifaceted, integrating various legislative instruments, strategies, and funding mechanisms. This approach aims to ensure that natural habitats and species are connected across the landscape, facilitating the movement and genetic exchange necessary for biodiversity conservation and ecosystem resilience.

EU member states are responsible for implementing these policies and directives at national and regional levels. They should develop national spatial planning strategies along with national biodiversity strategies and action plans that include specific measures for enhancing ecological connectivity.

1.1 Ecological connectivity in the EU environmental policies

The EU environmental policies and strategies are interlinked to form a comprehensive approach towards biodiversity conservation, habitat restoration, and sustainable land use. These initiatives collectively promote ecological connectivity, which is essential for maintaining healthy ecosystems and biodiversity, as well as the mutual interactions that enable ecosystems to adapt to changes. The following policies are particularly relevant for the implementation of ecological connectivity in the Alpine Space:

- **EU biodiversity strategy 2030,**
- **New EU Forest strategy 2030 and the 3 billion trees planting pledge.**
- **EU Nature restoration law (regulation)**
- **EU water framework directive**
- **EU Pollinators initiative**

Ecological connectivity is a recurring theme in all these strategies, emphasizing the need for connected habitats to maintain biodiversity, ecosystem health, thus resilience. It also promotes agricultural and forestry practices that enhance landscape connectivity.

1.1.1 EU biodiversity strategy 2030

The new EU Biodiversity Strategy for 2030 (adopted in 2023) - *Bringing nature back into our lives* is one of the main pillars of the European Green Deal. The new Strategy includes a comprehensive and ambitious long-term Action Plan for the protection of nature with clear commitments and actions by 2030 for the benefit of people, climate and planet.

Building on early environmental laws and in particular on the **Habitat directive the strategy includes** a special focus on ecological networks with the commitment **to enlarge the existing Natura 2000 areas** with strict protection for areas with high biodiversity and climate value.

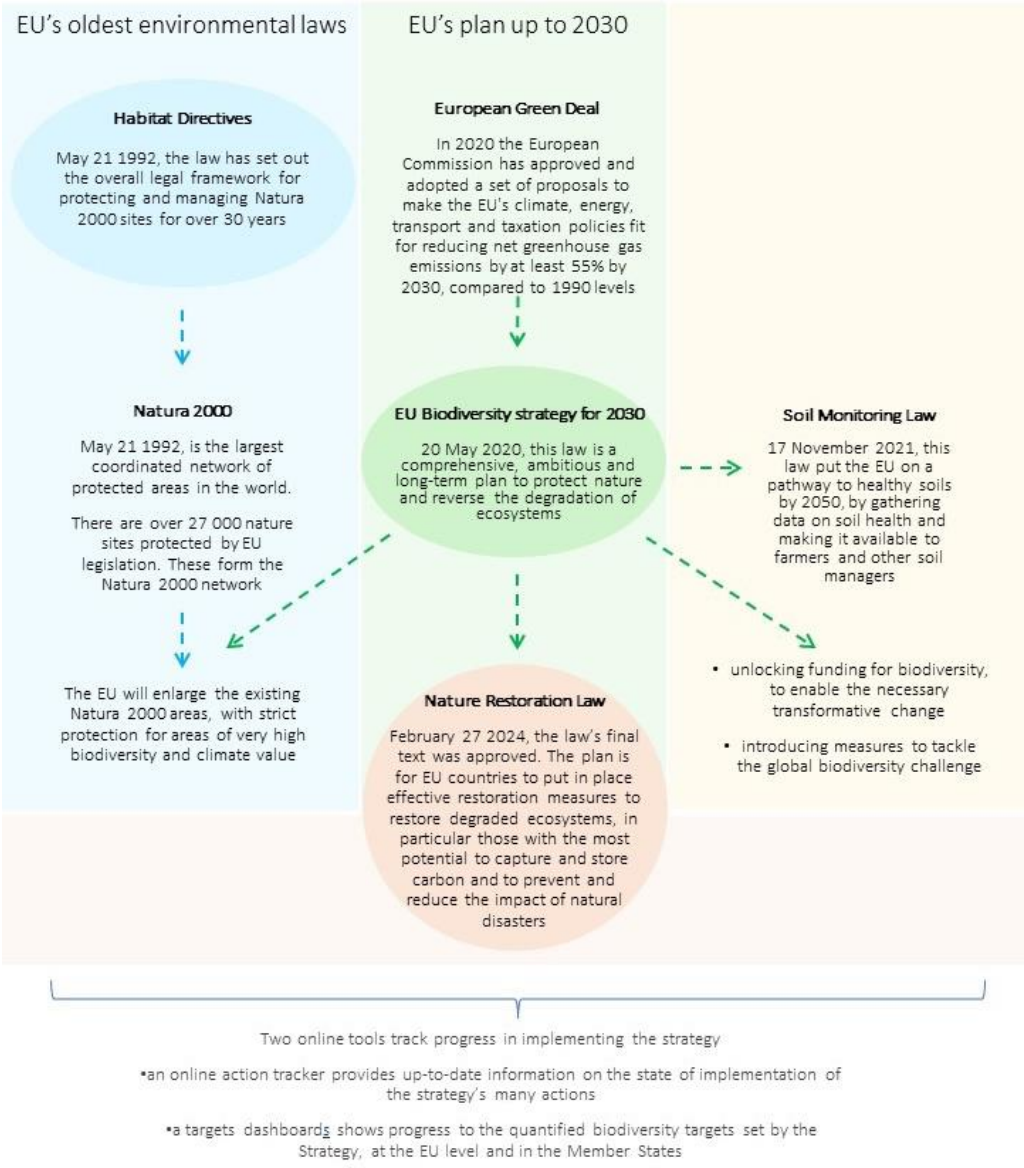


Figure 1: Legislative framework on the environmental strategies for the European Union

In terms of **Strategic goals**, the Biodiversity Strategy for 2030 aims to:

- To protect at least 30% of the EU's land and sea areas by 2030. This target includes both protected areas and "Other Effective Area-Based Conservation Measures" (OECMs, see paragraph 2.1.2).

- Ensure the conservation of species and habitats of EU and national concern.
- Establishing a larger EU-wide network of protected areas. The EU will enlarge existing Natura 2000 areas[1] with strict protection for areas of very high biodiversity and climate value.
- Increase ecological connectivity among habitats within and outside Protected Areas in natural and human-dominated landscapes, thus enhancing the ecological integrity and resilience of ecosystems while maintaining and fostering connections between human well-being and nature.

Achieving the 30% biodiversity target requires a multifaceted approach that includes both traditional protected areas and OECMs, along with a strong emphasis on ecological connectivity. By integrating these elements, the EU can ensure more comprehensive and effective biodiversity conservation, contributing to the overall resilience and health of ecosystems. This strategy not only protects biodiversity but also supports ecosystem services that are vital for human well-being and climate change mitigation.

The main tool for the implementation of these objectives is **the EU Nature Restauration Law**, an EU nature restoration plan, aiming to restore degraded ecosystems, in particular those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters. The EU first Nature Restoration Law include binding restoration targets for specific habitats and species.

The strategy also includes actions aiming at unlocking funding for biodiversity, strengthening governance, improving knowledge, financing, and investments, and addressing the global biodiversity challenge.

Box 1 - action tracker** and the **targets dashboard

Two online tools were introduced to track progress in implementing the strategy: an **action tracker** and the **targets dashboard**, which illustrates progress toward the quantified biodiversity goals set by the Strategy, at the EU level and in the Member States. Under the EU Biodiversity Strategy for 2030, the EU and its Member States agreed to carry out more than 100 activities by 2030, that can be monitored through the action tracker: as of the last update made available through the tool, 50 actions were completed, 46 in progress (of which 5 were to be concluded by 2024) and 8 delayed. In this framework:

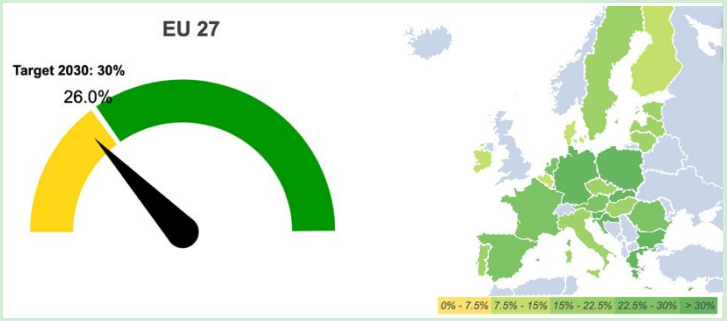
- target 1 is specifically related to legally protect a minimum of 30% of the EU land area and a minimum of 30% of the EU sea area, and integrate ecological corridors, as part of a true **Trans European Nature Network (TEN-N,** see paragraph 2.1.4).

[1] c

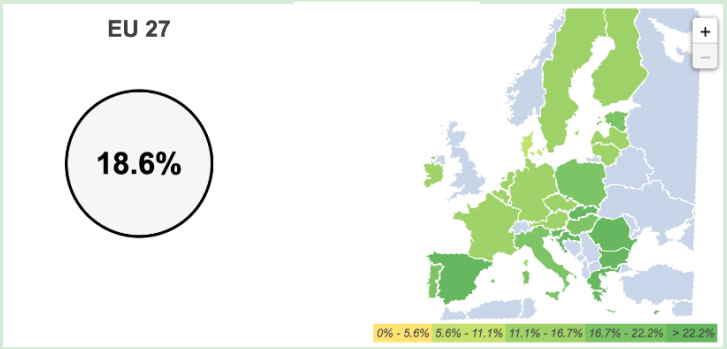
- Under target 3 (Effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately), action 5, which was due by 2023, is particularly relevant for this project, as it is related to **progress significantly in legally designating new protected areas and integrating ecological corridors**. While, action 8 promotes and **supports investments in green and blue infrastructure** and **cooperation among Member States to set up ecological corridors**.

Target 1: Legally protect a minimum of 30% of the EU land area and a minimum of 30% of the EU sea area, and integrate ecological corridors, as part of a true Trans-European Nature Network.
Subtarget 1.1: Legally protect a minimum of 30% of the EU land area

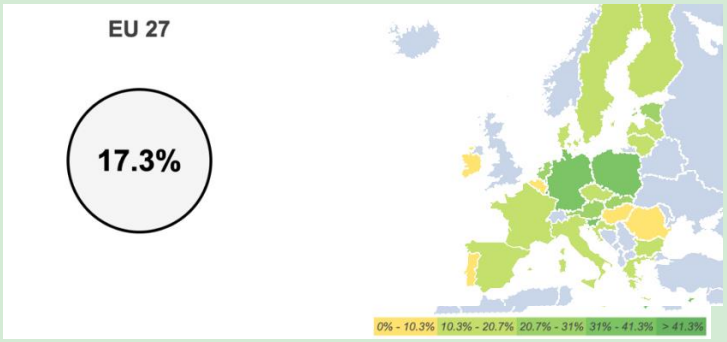
Indicator 1.1.1: Terrestrial protected area coverage



Indicator 1.1.2: Natura 2000 terrestrial protected area coverage



Indicator 1.1.3: Nationally designated terrestrial protected area coverage



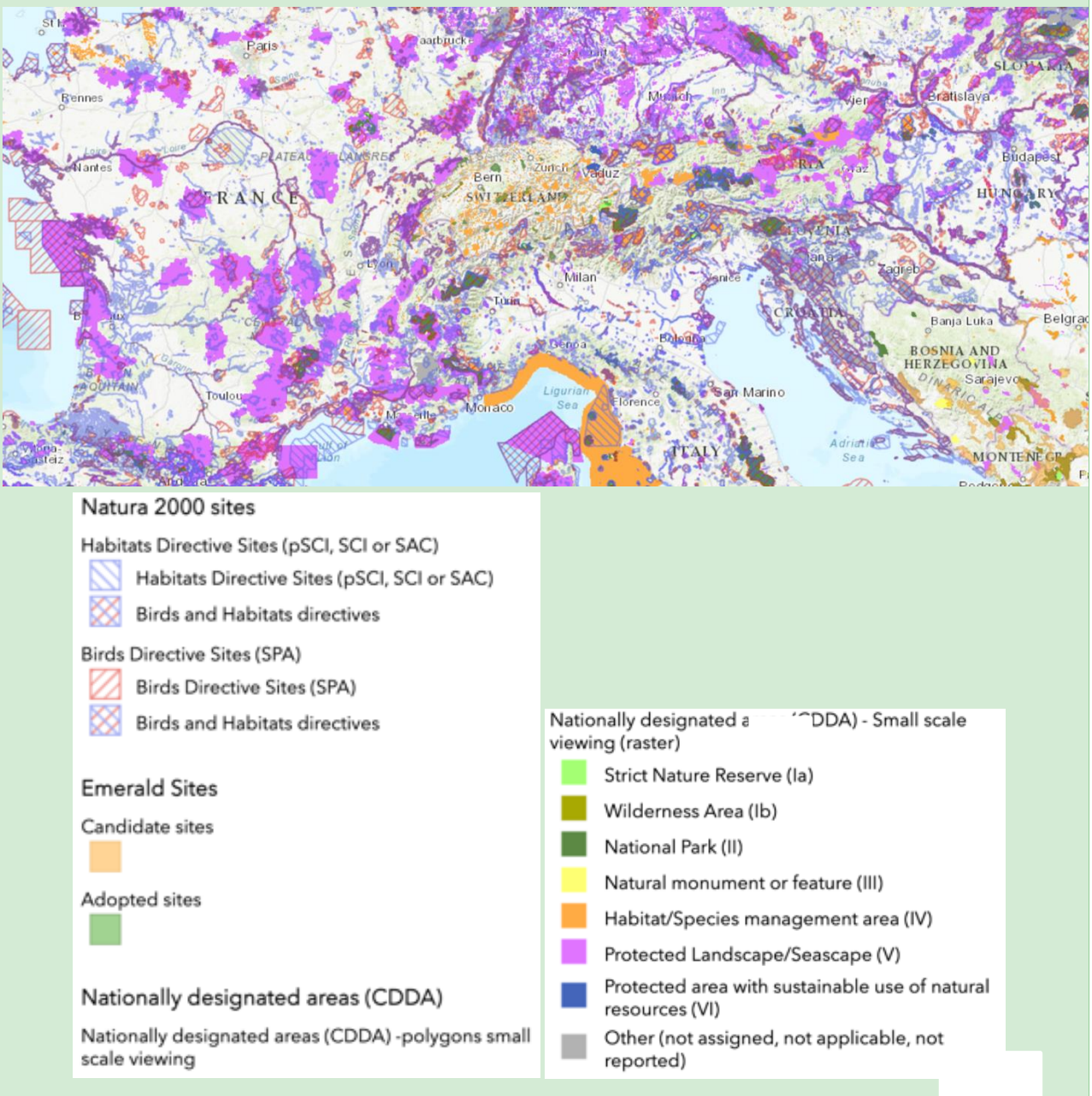


Figure 2: Protected sites in Europe (source: EEA)

1.1.2 New EU Forest Strategy 2030 and the 3 billion Trees planting pledge

The 2021 new **EU Forest Strategy**[2] aims to ensure that forests contribute to biodiversity conservation, resilience to climate change and provision of ecosystem services. In doing so it supports the development of forest management practices that maintain and enhance ecological connectivity. It also supports implementing projects to restore degraded forest landscapes, enhance habitat quality, and reconnect fragmented forest areas. It encourages reforestation of degraded lands and afforestation of suitable non-forest lands to increase forest cover and connectivity, creating and maintaining ecological corridors that connect forest patches, allowing wildlife to move freely and access different habitats. This includes maintaining riparian buffers, hedgerows, and forest strips and incorporating forests into green infrastructure networks, which also include parks, urban forests, and greenways that connect natural areas within and across urban and rural environments.

The strategy is a **flagship element of the European Green Deal** and a key action under the EU biodiversity strategy for 2030, pursuing the biodiversity and climate neutrality objectives enshrined in the European Green Deal and the EU biodiversity strategy for 2030. The strategy aims to improve the quantity and quality of EU multi-functional forests, by reversing negative trends and increasing their resilience against the high uncertainty brought about by climate change. Its goals are:

- Achieve a net increase in forest area and health by 2030.
- Enhance biodiversity in forests, aiming for a 20% increase in protected forest areas.
- Support sustainable forest-based economies[3], creating green jobs and boosting rural development.
- Sequester significant amounts of carbon to help meet EU climate targets.

Key actions directly related to improving habitat quality and **potential for ecological connectivity** and continuity include:

- Protecting EU last remaining primary and old-growth forests.
- Ensuring forest restoration and reinforced sustainable forest management for climate adaptation and forest resilience.
- Re- and afforestation of biodiverse forests, including by planting 3 billion additional trees by 2030.
- Providing financial incentives for forest owners and managers for improving the quantity and quality of EU forests.

[2] https://environment.ec.europa.eu/strategy/forest-strategy_en

[3] A relevant EU legislation that addresses forest biodiversity in this regard is the Provisional Agreement to Reinforce the EU Renewable Energy Directive of 2023, which excludes the use of forest biomass from important areas for biodiversity and carbon stock (see https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022DC0221)

A connected initiative is the **3 billion Trees Planting Pledge**[4], to plant at least 3 billion more trees across Europe by 2030. This pledge is an important part of the EU overall policy to battle climate change, increase biodiversity, and create a healthier and more resilient environment. The 3 billion trees, if planted strategically, represents a significant step forward in combating climate change, increasing biodiversity and improving the quality of life in Europe.

Condition for counting trees in the framework of afforestation is **the land chosen for planting that must be selected to contribute to habitat restoration, ecological connectivity, and provision of ecosystem services** (in particular, but not only carbon sequestration). The pledge of planting 3 billion additional trees by 2030 is part of the plan to tackle the protection and restoration of nature (see the chapter on Nature restoration law). An important issue is ensuring connectivity benefits; **afforestation should be carried out at landscape level to strengthen connectivity** with natural or semi-natural areas (forests, agricultural landscape). **Land planning is also essential** for the proper functioning of forest, agroforestry and urban forest ecosystems to connect habitats in space and time, through **green infrastructure and ecological corridors**. Forest aesthetics are often neglected in policy and legislation, but this too has a high cultural and spiritual value for citizens and in passing their inheritance to future generations.

Healthy forests and healthy trees can provide a very significant share of ecosystem services.

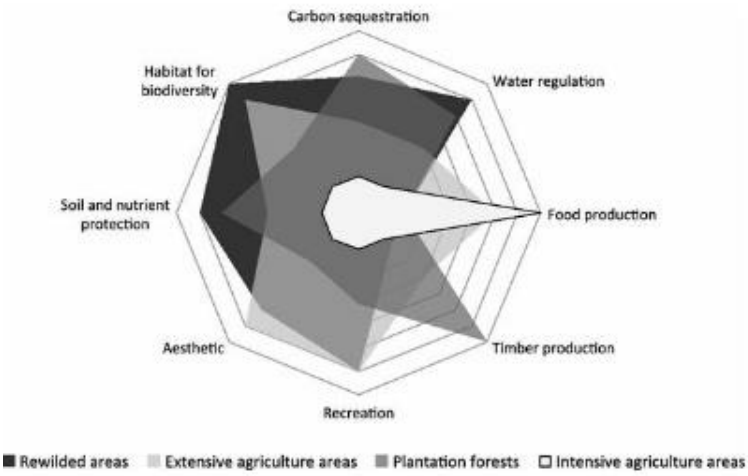


Figure 3: Qualitative assessment of the ecosystem services provided by rewilding, afforestation, extensive agriculture and intensive agriculture in Europe (source: EU, {COM(2021) 572 final})

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021SC0651&qid=1672917506492 and https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030/3-billion-trees_en

Forests have many other advantages than **carbon sequestration**: they provide essential habitats for numerous species, nesting and hibernating opportunities (including for pollinators), and provide other critical ecosystem services, such as water cycle regulation, soil protection and erosion control, oxygen release and air filtering. **A corridor of appropriate riparian vegetation** provide additional benefits to water bodies (e.g. rivers, aquifers), including stabilising riverbanks, providing aquatic habitats and shelter, regulating surface and ground water flows, improving water quality by avoiding soil erosion, eliminating pollution by trapping or filtering water pollutants, thus resulting in better water quality, avoiding excessive water temperature, thanks to shading, which can also reduce the impacts of eutrophication. Under certain conditions, trees can also promote aquifer recharge by reducing water runoff. This also helps preventing floods and mitigate droughts by retaining and storing excess rainwater. Trees also have an important **social value** in terms of promoting recreation and wellbeing. All these advantages can in turn generate economic benefits by reducing the need for water treatment, or in soil and water bodies' restoration techniques.

Trees in forests form part of extremely complex ecosystems, where they are home to around 80% of the world biodiversity. The more biodiverse the ecosystem, the more diverse the services and benefits it can provide (i.e. higher multifunctionality).

Trees that are part of extensive forest and grassland systems greatly improve soil quality and the capacity of soil to accumulate carbon. This enables additional plant species to grow and enhances species richness, attracting more pollinators and wildlife. Such systems can also have a positive impact on cattle productivity. Agroforestry systems are beneficial to soil chemistry and prevent erosion while protecting or even restoring the topsoil. It is estimated that such systems provide up to 45% more benefits for biodiversity and up to 65% for the ecosystem than conventional production systems.

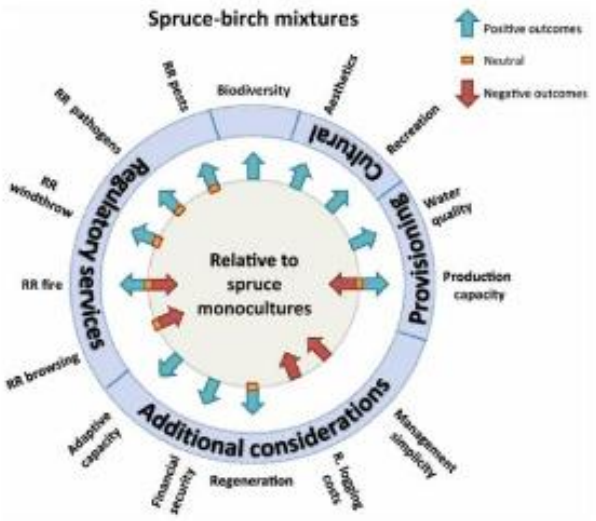


Figure 4: Example of ecosystem service implications of replacing monocultures with mixed species stands in commercial forest alternatives in Sweden. RR stands for reduced risk (source: EU, {COM(2021) 572 final})

Agroforestry systems enhance the environment in agricultural landscapes. Trees located on agricultural land, such as those that define field boundaries, hedges, and portions of landscape features, are crucial for reducing **habitat fragmentation** (**to provide species 'stepping stones'**), promoting gene flow. Field margin habitats are typically free of pesticide use, which results in a richer invertebrate fauna that serves as a food supply for birds and mammals, which in turn draws larger predators. Furthermore, field margins can offer great places for birds to nest.

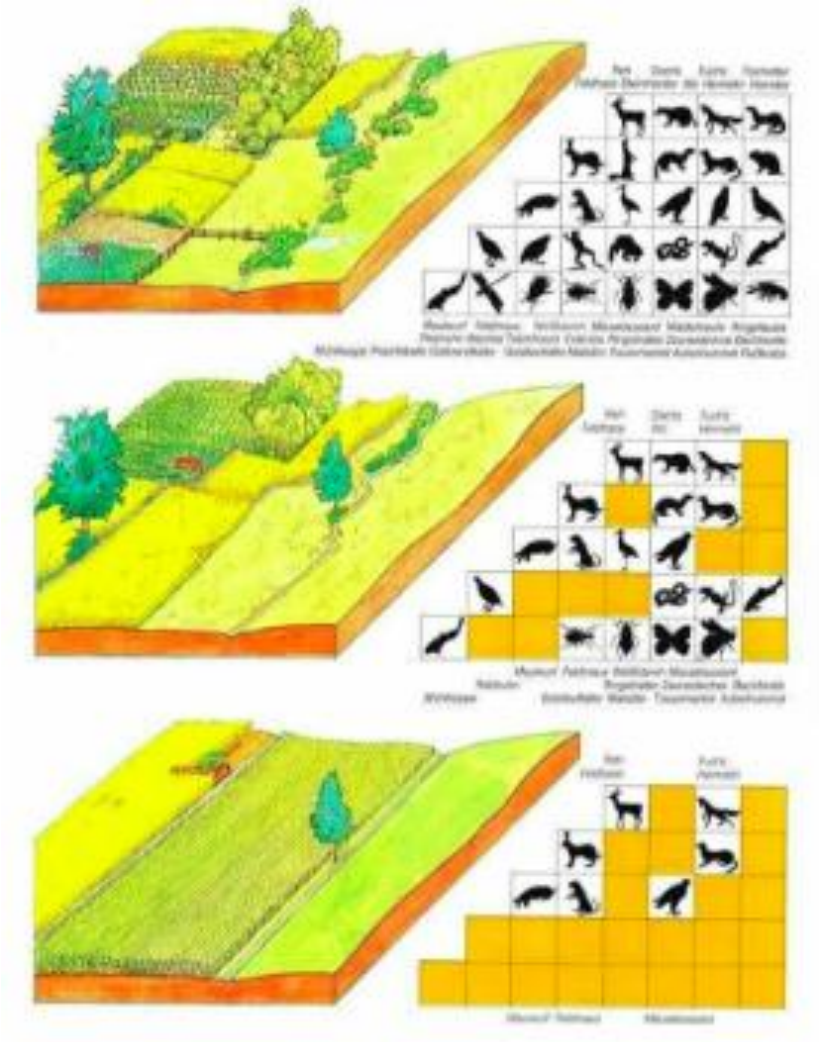


Figure 5: Linkages between habitat heterogeneity and biodiversity (source: EU, {COM(2021) 572 final})

They also enhance the functioning of the agro-ecosystem lowering runoff and the risk of soil erosion, and acting as wind breakers to lessen wind erosion. Planting trees on damaged, abandoned, and marginal lands also promotes biodiversity (protecting species that would

otherwise be at risk of extinction), soil stabilization, water purification, and soil retention. Overall, agroforestry sustains biodiversity and improves resilience at plot scale, thus it can also increase production and profitability.

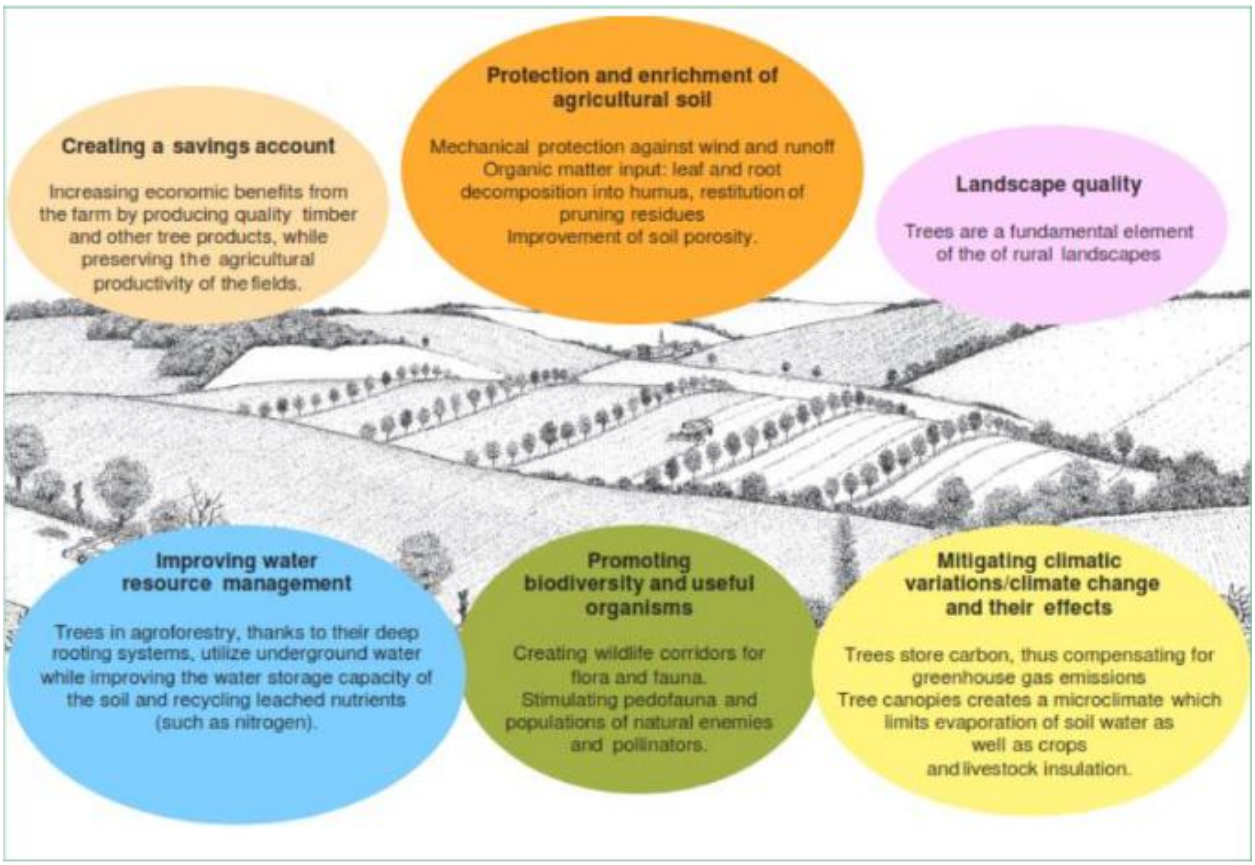


Figure 6: Potential benefits from introducing agroforestry in the agricultural landscape (source: EU, the 3 Billion Tree Planting Pledge For 2030 Accompanying the document {SWD (2021) 651 final})

1.1.3 European Nature Restoration Law

The 'Regulation of the European Parliament and Council on nature restoration', often referred at as 'Nature Restoration Law', is a momentous initiative in the EU legislation, aimed at reversing the degradation of natural environments in Europe. It is the main tool for the implementation of the new Biodiversity strategy 2030 and establishes ambitious aims and targets for restoring degraded ecosystems throughout the EU. The **key elements** of the law are:

- **Binding Restoration Targets**: the law mandates that at least 20% of the EU land and sea areas be restored by 2030. By 2050, all ecosystems in need of restoration should be

addressed. Specific targets include restoring peatlands, forests, grasslands, wetlands, rivers, lakes, and marine habitats.

- **Biodiversity and Climate Goals**: the law aims to improve the health of 30% of habitats by 2030, increasing to 60% by 2040 and 90% by 2050. It also focuses on reversing the decline of pollinator populations forest, agricultural and marine ecosystems, restoring river's connectivity and enhancing urban green spaces.
- **Implementation and Monitoring**: EU member states are required to submit National Restoration Plans within two years of the law enactment, outlining how they will achieve the targets. Progress will be monitored and reported regularly, with the European Environment Agency providing technical reports.

Ecological connectivity is recognized as a critical component by the law, focusing on creating connected habitats to support species migration and genetic flows. This involves removing physical barriers in rivers, creating green corridors, and restoring wetlands to enhance habitat continuity. The proposal contains the following specific targets:

- **Targets based on existing legislation** (for wetlands, forests, grasslands, river and lakes, heath & scrub, rocky habitats and dunes), improving and re-establishing biodiverse habitats on a large scale, and bringing back species populations by improving and enlarging their habitats.
- **Forest Ecosystems**: achieving an increasing trend for standing and lying deadwood, uneven aged forests, forest connectivity, abundance of common forest birds and stock of organic carbon.
- **Agricultural Ecosystems**: increasing grassland butterflies and farmland birds, the stock of organic carbon in cropland mineral soils, and the share of agricultural land with high-diversity landscape features; restoring drained peatlands under agricultural use.
- **Marine Ecosystems**: restoring marine habitats such as seagrass beds or sediment bottoms that deliver significant benefits, including for climate change mitigation, and restoring the habitats of iconic marine species such as dolphins and porpoises, sharks and seabirds.
- **River Connectivity**: restoring at least 25,000 kilometres of rivers to free-flowing status by removing barriers.
- **Urban Ecosystems**: no net loss of urban green spaces by 2030, and a progressive increase in green spaces by 2040 and 2050.

Other obligations will similarly require **increasing connectivity to restore pollinator populations**, such as **implementing "buzz lines**" where insect pollinators could move across landscapes.

In the framework of the EU biodiversity strategy, the law complements and synergistically supports the implementation of all other EU initiatives and strategies on climate change and biodiversity loss (e.g. the new EU Forest Strategy 2030, the three billon's trees initiative) as well as EU environmental spatial development strategies and objectives (e.g. the Green and blue Infrastructure strategy, the Trans European Nature Network initiative and the Green Europe objective of the Territorial Agenda 2030).

Examples of Nature restoration success stories are published in the EC website[5].

Figure 7: Restoration projects across Europe (source: UE)

1.1.4 EU water framework directive

The European Union's Water Framework Directive (WFD) indirectly addresses connectivity by emphasizing the need to maintain and enhance connectivity within and between water bodies. With the goal of achieving "good ecological status" for all European water bodies, the directive recognizes that the health and ecological functioning of aquatic ecosystems depend on the free movement of water, sediment and biota between different habitats. To this end, it identifies threats to connectivity, such as dams, weirs and other physical barriers,

[5] https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law/success-stories_en

in river basin management plans (RBMPs). Barriers are considered a significant pressure on at least 20 percent of EU river water bodies, contributing to the failure to achieve good ecological status (EEA, 2021) and are responsible for a 93 percent decline in freshwater migratory fish in Europe since 1970 (Deinet et al., 2020). As a result, member states are encouraged to adopt measures that promote connectivity and integrated water management approaches. However, the EU Water Framework Directive does not include direct measures to improve connectivity.

1.1.5 EU Pollinators initiative

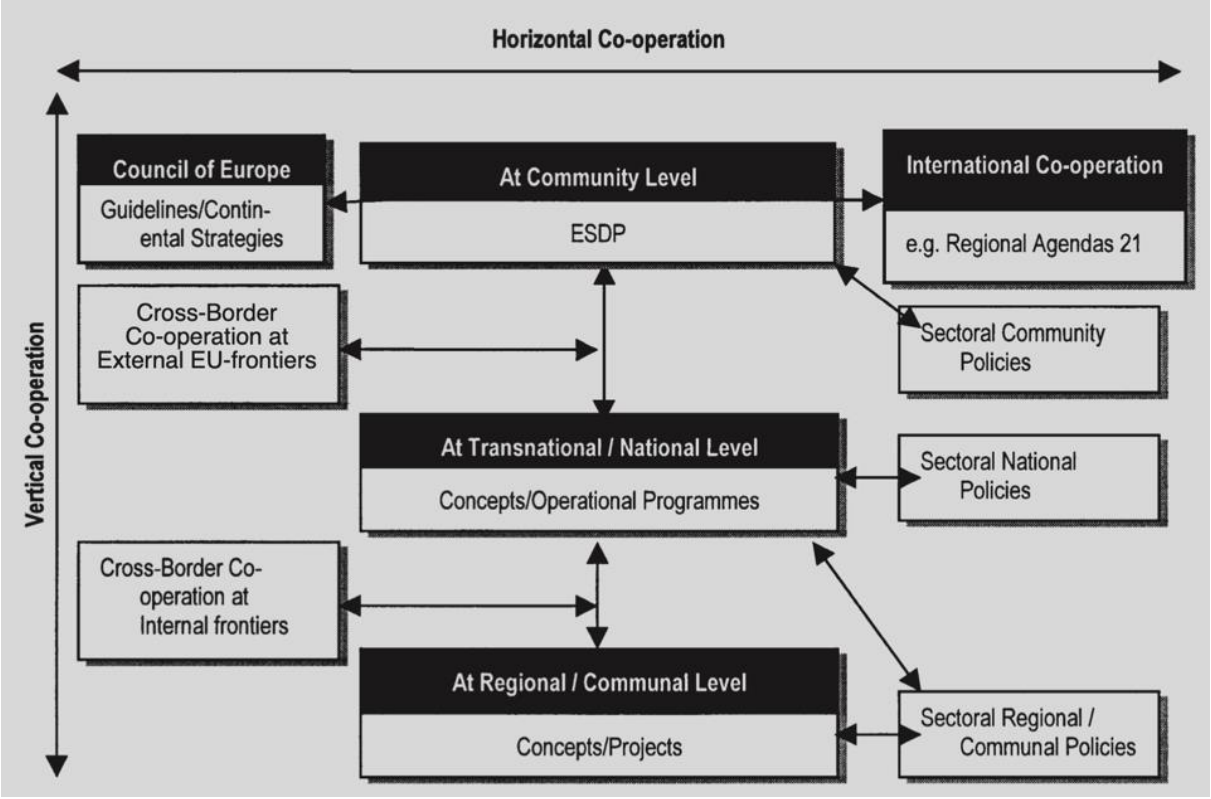
Connectivity is the theme of the European Pollinator Initiative (EC, 2023) through the promotion of well-connected, high-quality habitats for pollinators. These functional ecological corridors (referred to as "buzz lines") aim to enable the movement of species in search of food, shelter, and nesting and breeding sites, as well as constitute migration routes for species in the face of climate change. Connectivity for pollinators is particularly important in agricultural lands, but also in urban areas, with the expectation that the expansion of green and blue infrastructure will benefit pollinators in these environments as well. **By 2027**, the **Commission and member states are to develop a draft network of ecological corridors for pollinators** and **develop a plan of measures for its implementation**.

1.2 Ecological connectivity in the EU spatial development perspective

The **European Spatial Development Perspective** (ESDP) and the **Territorial Agenda 2030** are key policy frameworks, aimed at promoting sustainable and balanced spatial development across Europe. Both frameworks emphasize the importance of ecological connectivity to support biodiversity, ecosystem services, and overall environmental sustainability.

1.2.1 European Spatial Development Perspective ESDP

The **European Spatial Development Perspective** (ESDP)[6], adopted in 1999, is a policy framework of the European Community, within which the European Union is planning to develop and coordinate spatial development policies compatible with the need for sustainable, balanced and polycentric development in both transnational and territorial cooperation.



[6] https://www.eea.europa.eu/policy-documents/european-spatial-development-perspective-esdp

Figure 8: Ways of Cooperation for spatial development (source: ESDP)

Although not legally binding per se, ESDP offers guidelines and objectives that have a substantive impact on spatial planning and development policies at different levels of governance. One of the key themes of the ESDP is the promotion of ecological connectivity, which is essential for preserving biodiversity and ensuring sustainable land use. Key aspects to this regard include:

- **Polycentric Spatial Development**. The ESDP promotes a polycentric spatial development model to reduce regional disparities and encourage balanced growth across Europe. This model supports the creation of a network of cities and regions that are well-connected by infrastructure and green corridors, enhancing ecological connectivity.
- **Sustainable Land Use.** Strengthening urban-rural linkages is a central goal of the ESDP. This involves promoting sustainable land use practices that protect natural resources and biodiversity. Establishing green belts and ecological corridors between urban and rural areas can help maintain ecological connectivity.
- **Protection and Management of Natural Resources**. The ESDP emphasizes the sustainable management and protection of natural resources, including landscapes, water, and biodiversity. It advocates for the creation and maintenance of ecological networks that connect protected areas ensuring the continuity of natural habitats and supporting biodiversity.
- **Trans-European Networks**. In addition to promoting transport and energy networks, the ESDP highlights the importance of trans-European ecological networks. These networks aim to connect natural habitats across national borders, facilitating species migration and genetic exchange.

1.2.2 Territorial agenda 2030

The **Territorial Agenda 2030**, adopted in December 2020, builds on the principles of the ESDP and provides a strategic framework for spatial planning and regional development in Europe. It focuses on addressing current and future challenges, including those related to ecological connectivity. Key elements of the Territorial Agenda 2030 related to ecological connectivity include the following goals:

Balanced and Sustainable Spatial Development:

- **Green Infrastructure**: the agenda promotes the development of green infrastructure to enhance ecological connectivity and support ecosystem services. It calls for integrating green infrastructure into spatial planning at all levels.
- **Functional Regions**: it encourages the creation of functional regions that incorporate natural landscapes and biodiversity corridors, fostering connectivity across administrative boundaries.

Climate Action and Resilience:

- **Nature-Based Solutions**: Emphasizes the role of nature-based solutions in enhancing resilience to climate change. This includes the restoration of natural habitats and the creation of ecological corridors to support species adaptation and migration.
- **Ecosystem-Based Adaptation**: it promotes ecosystem-based adaptation strategies that enhance ecological connectivity and contribute to climate resilience.

Biodiversity and Ecosystem Services:

- **Protecting and Restoring Biodiversity**: the agenda highlights the importance of protecting and restoring biodiversity as a mean to enhance ecosystem services and ecological connectivity.
- **Integrated Spatial Planning**: it calls for integrated spatial planning approaches that incorporate biodiversity conservation and the creation of ecological networks.

Territorial Cohesion and Governance:

- **Cross-Border Cooperation**: it encourages cross-border cooperation to address ecological connectivity challenges that span over national borders. This includes joint projects and strategies to create transboundary ecological corridors.
- **Multi-Level Governance**: it promotes a multi-level governance approach that involves local, regional, national, and EU-level actors in planning and implementing measures to enhance ecological connectivity.

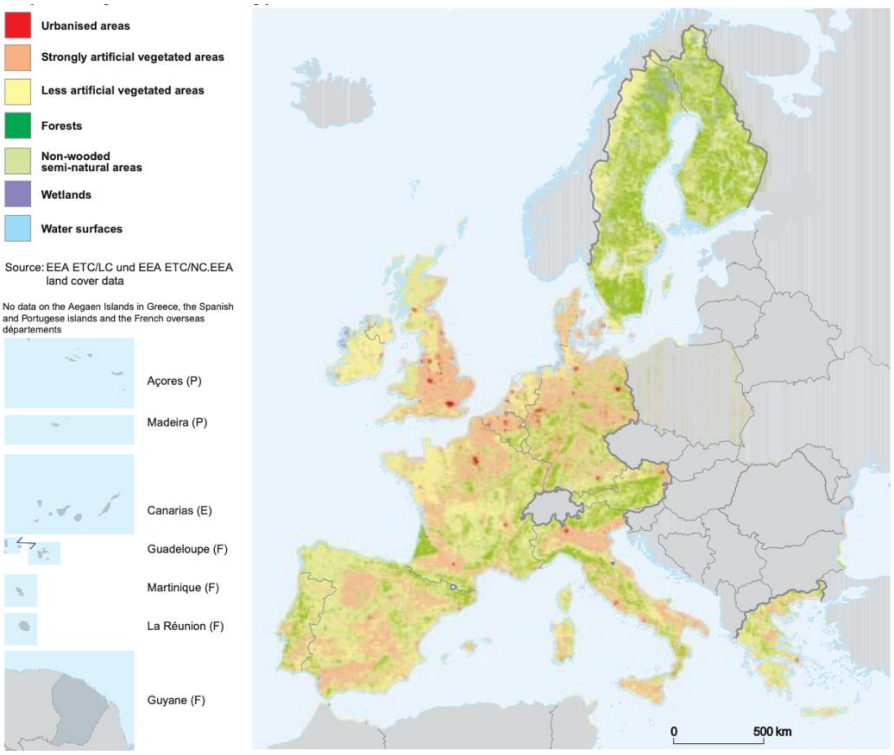


Figure 9: Main Land use distribution (source: ESDP)

2 EU policy relevant to ecological connectivity in spatial planning

As mentioned in the previous chapters, within the strategic framework for spatial planning and regional development provided by ESDP and the Territorial Agenda, ecological connectivity is implemented through various Key **EU policy provisions, strategies and initiatives that translate its principles into concrete actions**. These include:

- **The Natura 2000 network, articles 3, 6 and 10 of the habitat directive**. Art 3 of the habitat directive specify that the N2000 network is composed by 2 typologies of elements: Natura 2000 sites and corridor/stepping stones. Natura 2000 sites are mandatory elements and consists of special area of conservation and special protection areas (identified under the Birds directive). Corridor/stepping stones under the art 10 are not mandatory elements and include planning and management of landscape elements outside protected sites, encouraging their integration into land-use planning and land-use policies aimed at maintaining and restoring connectivity in fragmented landscapes through conservation and prevention measures. Art 6 requires that plans and projects that may have a significant effect, not only on-site conservation objectives, but also on the overall coherence of the network be subject to an environmental impact assessment to avoid fragmentation or degradation of habitats and to ensure that connectivity is not disrupted;
- **Other effective area-based conservation measures** (OECMs): are part of the toolkit for implementing the EU Biodiversity Strategy 2030. OECMs are geographically defined areas managed under other regulatory frameworks than protected areas that contribute to conservation objectives. They are a promising tool for engaging a wider range of stakeholders in efforts to conserve and strengthen ecosystem connectivity and resilience across the EU;
- **The EU Green and Blue infrastructure strategy**, promoting the development of a network of natural and semi-natural areas designed to provide a wide range of ecosystem services, thus operationalizing the 2030 Biodiversity strategy through investments in GI and their integration into spatial development plans at all planning levels. It supports ecological connectivity and nature-based solutions in agriculture, forestry, climate change mitigation, disaster prevention, energy, transport, health, and research;
- **The Trans-European Network for Nature (TEN-N)**. It is closely related to the Natura 2000 network and it is implemented under the GI Strategy, to create a coherent network of green spaces that enhances connectivity across Europe, complementing the existing Trans-European Network for Transport (TEN-T) and energy networks.

Ecological connectivity is key issue in these initiatives, emphasizing the need for connected habitats to maintain biodiversity and ecosystem health. They specifically address:

- **Ecological Corridors and Networks**, to use landscape-level planning to create a large-scale Green and Blue Infrastructure network of connected natural and semi-natural areas. Develop and maintain ecological corridors that connect protected areas and other important habitats.

- **Urban and Rural Integration**, to combine green infrastructure into spatial and urban planning to connect urban green spaces with rural and natural areas.
- **Cross-Border Cooperation**, to encourage cross-border initiatives to maintain and enhance ecological connectivity across national boundaries and to collaborate on transboundary projects that restore and connect habitats.
- **Multifunctionality of green and blue infrastructures** (GBI), to design networks that not only benefits biodiversity but also addresses climate change, natural risk reduction, and human well-being. In this perspective connectivity is seen as a proxy to maintain fundamental ecological process linked to biodiversity that underpin the provision of multiple benefits (ecosystem services).

2.1.1 Connectivity and the Natura 2000 Network

In the European policies for the Environment protection and biodiversity support, two Directives mark the turning point from the previous actions: the **Habitats Directive** (Directive 92/43/EEC) and the **Birds Directive** (Directive 2009/147/EC). The first directive aimed to preserve natural habitats and wild fauna and flora. It established the Natura 2000 network of protected areas across the EU. Ecological corridors were considered essential for maintaining ecological connectivity between these protected areas. The second directive focused on the conservation of wild birds and their habitats. It complemented the Habitats Directive by protecting avian species and their migration routes, which often coincide with ecological corridors.

Figure 10: Natura 2000 European network (source: https://natura2000.eea.europa.eu)

In the building of the Natura 2000 network the issue of ecological connectivity is addressed by Articles 3, 6 and 10 of the Habitat directive with reference to ensuring the construction and maintenance of a **coherent** network of protected areas:

- **Article 3 establishing the Natura 2000 network as a coherent ecological network of protected areas across the EU.** Art 3 established the primary objective of the Habitats Directive, which is the conservation of natural habitats and wild fauna and flora within the European Union. It required Member States to take appropriate measures to maintain or restore natural habitats and species listed in Annexes I and II of the Directive at a favourable conservation status. Member States committed to designate Special Area of Conservation (SACs) for habitats and species of Community interest identified under the directive and Special Protection Areas (SPAs) identified under the birds directive. Article 3 also emphasized the importance not only of conserving biodiversity and maintaining ecological balance through the protection of habitats and species but of building a **coherent ecological network** of protected areas across the EU. The purpose of this network is to ensure the long-term survival of Europe most valuable and threatened species and habitats. Ecological connectivity is implicitly supported by the requirement to maintain the overall coherence of this network, facilitating the movement of species between protected areas. To this end art 3 specify that coherence should be pursued by means of art. 10.

- **Article 10: Assuring ecological coherence of the Natura 2000 Network**. The article encourages member states (not mandatory) to manage landscape features outside of protected sites, essential for the migration, dispersal, and genetic exchange of wild species, thus supporting ecological connectivity and the **overall coherence** of the Natura 2000 network. It encourages member states to manage and maintain features such as rivers, hedgerows, ponds, and small woodlands that function as ecological corridors or stepping stones, thereby promoting connectivity between habitats.

- **Article 6: Integrating Natura 2000 sites into broader spatial planning and land-use policies**, **conservation and preventive measures, impact assessment**. It outlines measures to maintain and restore habitats and species in a favourable conservation status. It encourages a landscape-level approach to conservation, integrating Natura 2000 sites into broader spatial planning and land-use policies. This helps maintain and restore connectivity across fragmented landscapes. Paragraph 3 requires that plans and projects that may have a significant effect, not only on-site conservation objectives, but also on the overall coherence of the network be subject to an environmental impact assessment to avoid fragmentation or degradation of habitats and to ensure that connectivity is not disrupted. In case of overriding public interest, compensatory measures must be taken to ensure the **overall coherence** of Natura 2000 is protected, which often involves enhancing ecological connectivity elsewhere. The European Commission provides guidance documents to help Member States implement Article 6 effectively, including advice on compensatory measures to safeguard the overall

coherence of the network and improve ecological connectivity[7]. Compensatory Measures could include creating new habitats, enhancing existing ones, or creating new corridors to offset the impact on connectivity.

2.1.2 The EU Green and Blue infrastructure strategy

The main the proposal of the new EU biodiversity strategy is to establish a larger EU-wide network of protected areas on land and at sea by expanding the EU protected areas (including Natura 2000 sites) to 30% coverage (with one third of these areas under strict protection) by 2030. The strategy approach to reach the 30% of protected Europe's land and sea includes not only formal protected areas but also areas managed under other frameworks that contribute to conservation goals. Other Effective Area-Based Conservation Measures (OECMs) are a conservation designation complementing traditional protected areas like N2000 sites, national, regional parks and nature reserves. The EU follows the global criteria for OECMs outlined by the Convention on Biological Diversity (CBD) but adapts them to fit the European context. The criteria include:

1. **Geographically Defined Area**: The area must have clear geographical boundaries.
2. **Effective Governance and Management**: The area must be governed and managed in ways that achieve sustained biodiversity conservation.
3. **Biodiversity Outcomes**: The primary outcome must be the effective and sustained conservation of biodiversity.
4. **Associated Ecosystem Services and Values**: The area may also provide ecosystem services and support cultural, spiritual, and socio-economic values.

Examples of Potential OECMs in the EU may include farmland managed under **Agri-Environment Schemes** that supports wildlife habitats; certain **marine areas managed primarily for sustainable fisheries** might also qualify, provided they result in significant conservation outcomes; **private lands managed for conservation purposes** through conservation easements or agreements could be recognized as OECMs; **urban green spaces** managed in ways that provide habitats for biodiversity could also be considered, provided they meet the criteria.

The governance of OECMs can involve various stakeholders, including **Government Bodies** (at national and regional level that manage land and marine areas), **Private Landowners** (as individuals or organizations managing private lands for conservation),

[7] Managing Natura 2000 sites "The provisions of Article 6 of the Habitats Directive 92/43/EEC" (2019/C33/01) p. 43 paragraph 5.4.2. 'Overall coherence' of the Natura 2000 network in the guidance doc at the following link: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019XC0125(07)

Local Communities (Communities managing lands through traditional practices), **NGOs and Civil Society** (organizations involved in conservation initiatives).

Beside expanding the network of areas contributing to biodiversity conservation beyond traditional protected areas OECMs are a promising tool for engaging a wider range of stakeholders in conservation efforts including enhancing connectivity and resilience of ecosystems across the EU.

2.1.3 The EU Green and Blue infrastructure strategy

In 2013, the European Commission launched an EU GI strategy. Green Infrastructure (GI) are defined as '*strategically planned networks of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings." (EC: Communication, 2013). This network of green (land) and blue (water) spaces can improve environmental conditions […] and enhances biodiversity.* ***The Natura 2000 network constitutes the backbone of the EU green infrastructure*** (EC 2021).

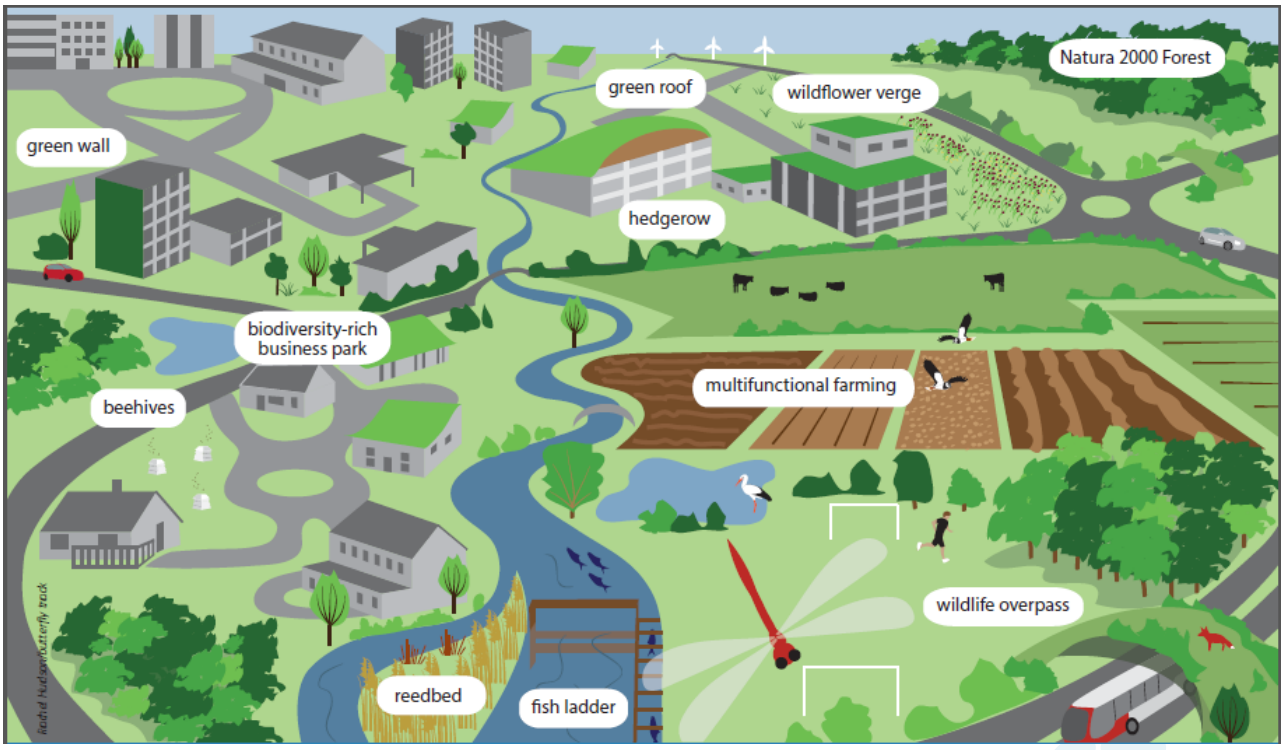


Figure 11: Green and Blue Infrastructure configuration in EU policies (source: European Commission, 2013)

The EU Green Infrastructure Strategy aligns with both the ESDP and the 2030 Territorial Agenda by promoting the development of a network of natural and semi-natural areas

designed to provide a wide range of ecosystem services, thus operationalizing the 2030 Biodiversity Strategy through investments in GI and their integration into spatial development plans. It supports the creation of ecological corridors, nature-based solutions in agriculture, forestry, climate change mitigation, disaster prevention, energy, transport, health, and research.

Green infrastructure are interventions (including conservation and restoration of ecological connectivity) aimed at reducing biodiversity loss and the resulting degradation of ecosystems, thereby restoring their key functions (e.g., water cycle, nutrient cycles, primary production, soil formations) that underlie the provision of the multiple ecosystem services of provisioning, climate regulation, and cultural services that constitutes the benefits to people, as in the following figure.

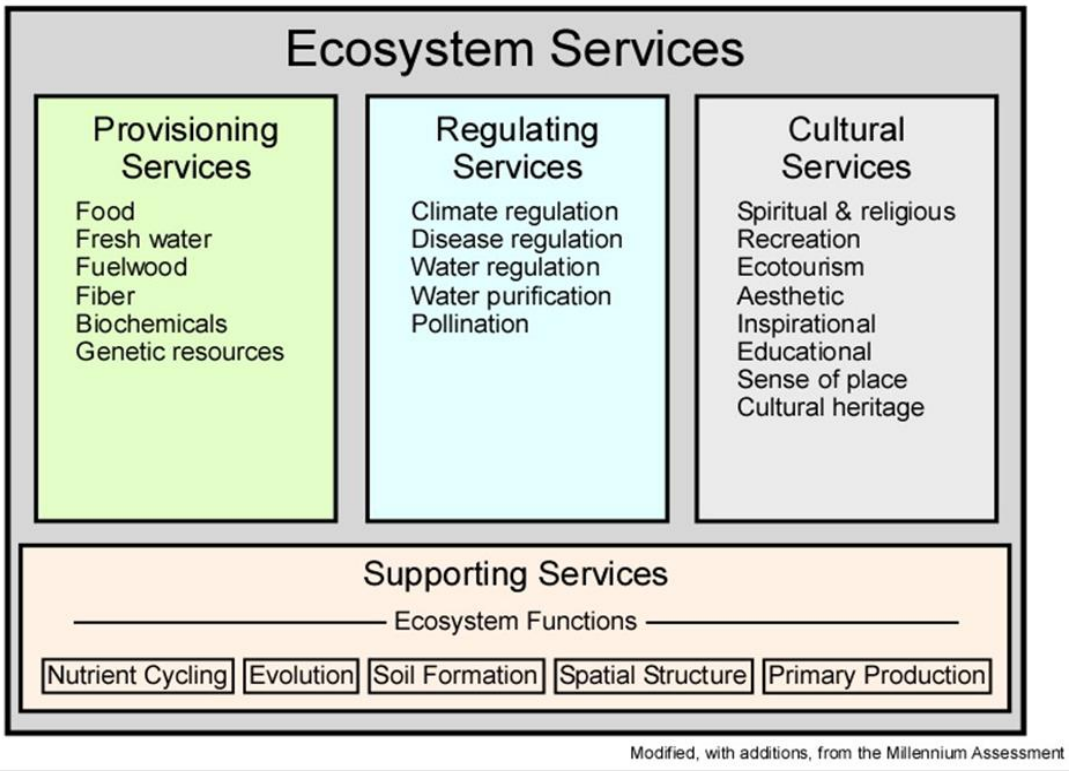


Figure 12: Ecosystem services provided by green and blue infrastructures

The Natura 2000 network of protected areas constitutes the backbone of the EU green infrastructure[8] (EC 2021).

[8] https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en#:~:text=The%20EU%20Green%20Infrastructure%20Strategy,deliver%20their%20services%20to%20people.

Local and regional governments have an important role in evaluating environmental issues and **safeguarding natural capital** and GI offers a frame to integrate and strengthen the **coherence between the objectives** of different policy sectors.

The GBI strategy helps the EU achieving its climate adaption and biodiversity goals by encouraging nature-based solutions that are both cost-effective and sustainable alternatives to traditional grey infrastructure. For example, restoring wetlands can be a more efficient way of managing water quality and providing habitats for species than building water treatment plants. Furthermore, **Blue infrastructure** focusing on aquatic ecosystems such as rivers, lakes, wetlands, and coastal areas play an important role in managing water supplies, sustaining biodiversity, and minimizing the effects of climate change.

Regarding the integration of GBI into spatial planning, consideration is given to the mapping approach proposed in the **2019 report "Strategic Green Infrastructure and Ecosystem restoration"** by JRC (Joint Research Center) and EEA (European Environment Agency).

GI mapping has been demonstrated to enhance nature protection and biodiversity beyond protected areas, to deliver ecosystem services such as climate change mitigation and recreation, to prioritize measures for defragmentation and restoration in the agri-environment and regional development context, and to find land allocation trade-offs. **Three key GI principles of connectivity, multifunctionality and spatial planning** are used by the Joint Research Centre in case studies selected in urban and rural landscapes. The report provides guidance for the strategic design of a well-connected, multi-functional, and cross-border GI, and identifies knowledge gaps. See box 2.

Box 2 - "Strategic Green Infrastructure and Ecosystem restoration" report
by JRC (Joint Research Center) and EEA (European Environment Agency)

According to the report not all green and blue areas qualify as GI. Only areas that are rich in biodiversity and lead to the delivery of ecosystem services or, for semi-natural components, those which directly enhance biodiversity and ecosystem services including green bridges and ecoducts qualify as green and blue infrastructure. In contrast, intensive land uses such as monoculture are not considered as green infrastructure.

About design GBI networks, the report highlights two complementary planning approaches. One starting from a physical mapping of existing GI components identifying and delineating landscape elements such as protected areas, ecological networks, other protected areas, etc. To ensure that those elements lead to the delivery of multiple ecosystem services, the second functional approach also takes into consideration ecosystem service-based mapping targeting connectivity and delivery of multiple ecosystem services such as provisioning, regulating and cultural services.

The following figure illustrates the two approaches, indicating that they are interconnected and should be considered as two complementary perspectives since GI is made of biodiversity-rich habitats, which also provide multiple ecosystem services.

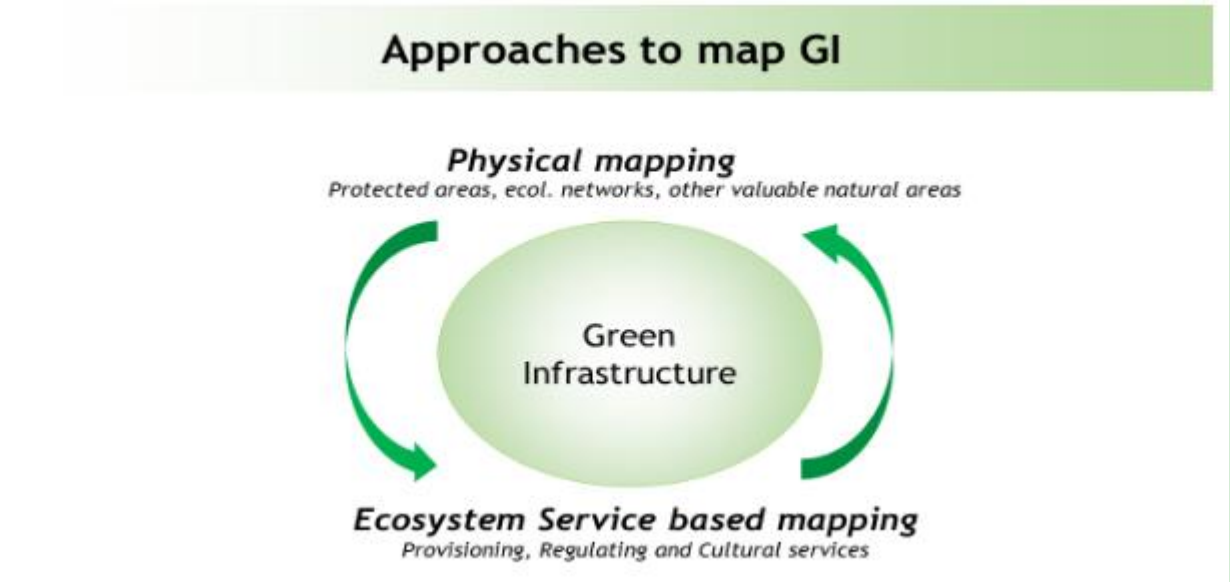


Figure 13: Approaches to map GI: physical mapping and ecosystem services based mapping

The combination of the two approaches embraces two underlying key principles of the GI concept, i.e. connectivity and multi-functionality (Mell, 2017). Connectivity directly relates to the enhancement of biodiversity and the ecosystem service of habitat provision. Connectivity refers to the enhancement of species' ability to move between areas and can be of a structural nature (i.e. habitat continuity) or functional nature (i.e. how landscapes allow various species to move and expand to new areas without necessarily being physically connected) (Baro et al. 2015). The lack or loss of connectivity reduces the capability of organisms to move and interfere with pollination, seed dispersal, wildlife migration and breeding, thus also impacts ecosystem services.

Multi-functionality represents the ability of GI to provide not only habitat (ecological) services but many other ecosystem services (e.g. ecological/regulating, social/cultural, and/or economic/provisioning) simultaneously on the same spatial area (Mell, 2017). Ensuring healthy ecosystems and maintaining long-term delivery of multiple ecosystem services within a well-connected GI network is supporting the objectives of numerous EU policy sectors, such as cohesion, water, energy, transport, agriculture, climate and biodiversity. This is part of a real "resilience strategy" able to cope with potentially changing conditions to human populations in the future, and thereby contributing to the European Union's 2050 vision of living well within the limits of the planet (European Commission, 2013)

***The physical mapping approach** (Figure 3.1) focuses on the identification and physical delineation of landscape features (GI network) consisting of green and blue elements (e.g. Trame*

verte et bleue in France) to support and enhance nature, natural processes and natural capital within a region. This approach has a physical and mapping connotation of landscape elements that qualify for the GI network regardless of their functions.

The concept is scale-dependent and extensively employed in urban and rural areas, for example when looking into the share and connectivity of green urban areas in a city, or when using pre-existing landscape elements like protected sites or small woody features in rural areas to define the core elements of the GI network.

***The ecosystem service-based mapping approach** (Figure 3.1.) of GI is to be understood as assessing the capacity of the land to provide ecosystem services. In contrast to the physical mapping approach, which refers to the delineation of physical landscape elements, the ecosystem service-based mapping approach further adds a function to the physical element. Benefits of well-functioning GI elements are expressed in terms of ecosystem services they deliver. Biodiversity-related services, and their values (ecologic, social and economic) are accounted for and approaches serve to strengthen the recognition of the human dependency on nature (Benedict and McMahon, 2006; Mell, 2008). The ecosystem services concept can thus offer a valuable approach for linking human and nature, i.e. the human-well-being and the current and potential environmental conditions (European Commission, 2018) as well as arguments for the conservation and restoration of natural ecosystems (Benedict and McMahon, 2002).*

It is important to recognise that ecosystems provide services that may contribute to other, possibly conflicting policy requirements. In these cases, the ecosystem service-based mapping dimension of a GI network may be complex, imprecise or biased due to the generalisation of data or missing data that are essential to depict the bundle of sometimes hidden but important services for different policy sectors and objectives. To overcome these difficulties, measuring approaches and mapping systems should be versatile enough to accommodate the requirements of different policy sectors and maximize the number of ecosystem services that can be assembled within the same GI.

2.1.3.1 Green infrastructures and Natural Capital preservation

Green and blue infrastructures are integral components of natural capital. The development of the concept of **Natural Capital** in recent decades reflects a recognition that environmental systems play a fundamental role in determining a country economic output and social well-being, providing resources and services, and absorbing emissions and wastes.

According to this way of thinking, a nation wealth is grounded in four core stocks of capital: manufactured/built capital (e.g. machines and buildings), human capital (e.g. people, their

skills and knowledge), social capital (e.g. trust, norms, and institutions) and natural capital (e.g. minerals and ecosystem services). In addition, financial capital plays an important role as a medium of exchange between the four underlying capital stocks and, sometimes, as a source of economic imbalances and instability.

Natural capital is the most fundamental of the forms of capital since it provides the basic conditions for human existence, delivering food, clean water and air, and essential resources. It sets the ecological limits for our socio-economic systems, which require continuous flows of material inputs and ecosystem services (part 1 in figure 14). Yet, it is not accounted for in nations wealth accounting systems. It includes many aspects of natural capital, such as biodiversity, clean air, land, and water are both limited and vulnerable.

The **complexity** of natural systems and irreversibility of much environmental change mean that replacing natural capital with other forms of capital is often impossible or carries significant risks. Mismanagement of natural capital often occurs because its full value is not reflected in policy trade-offs and economic choices. This problem pervades decision-making at all scales, from the microeconomic (e.g. via market prices that fail to reflect a product full cost and benefits), up to the macroeconomic (e.g. in excluding environmental values from national accounts and shifting environmental impacts to other countries).

The European Union (EU) and many neighbouring countries have introduced a substantial volume of **legislation** to protect, preserve and enhance ecosystems and their services. Examples include the Water Framework Directive, the Marine Strategy Framework Directive, the Air Quality Directive, the Habitats and Birds Directives and the Landscape Convention. A wider range of European policies affect natural capital and ecosystem services including the Common Agricultural Policy, the Common Fisheries Policy, cohesion policy and rural development policies.

Investment in GI promotes the protection of natural capital, which in turn ensures healthy, connected and well-functioning ecosystems which can provide long-term services that benefit the development of the society.

The design of a multifunctional and well-connected network of GBIs, having the ecological network as its backbone, is a Key planning tool for the conservation of Natural Capital capable of supplying a wide range of Ecosystem Services underpinning sustainable and balanced territorial development. Furthermore, although controversial, the possibility of assigning an economic value for the restoration and maintenance of ecosystem services provided by green and blue infrastructure could place full value on natural capital in policy trade-offs and land development choices.

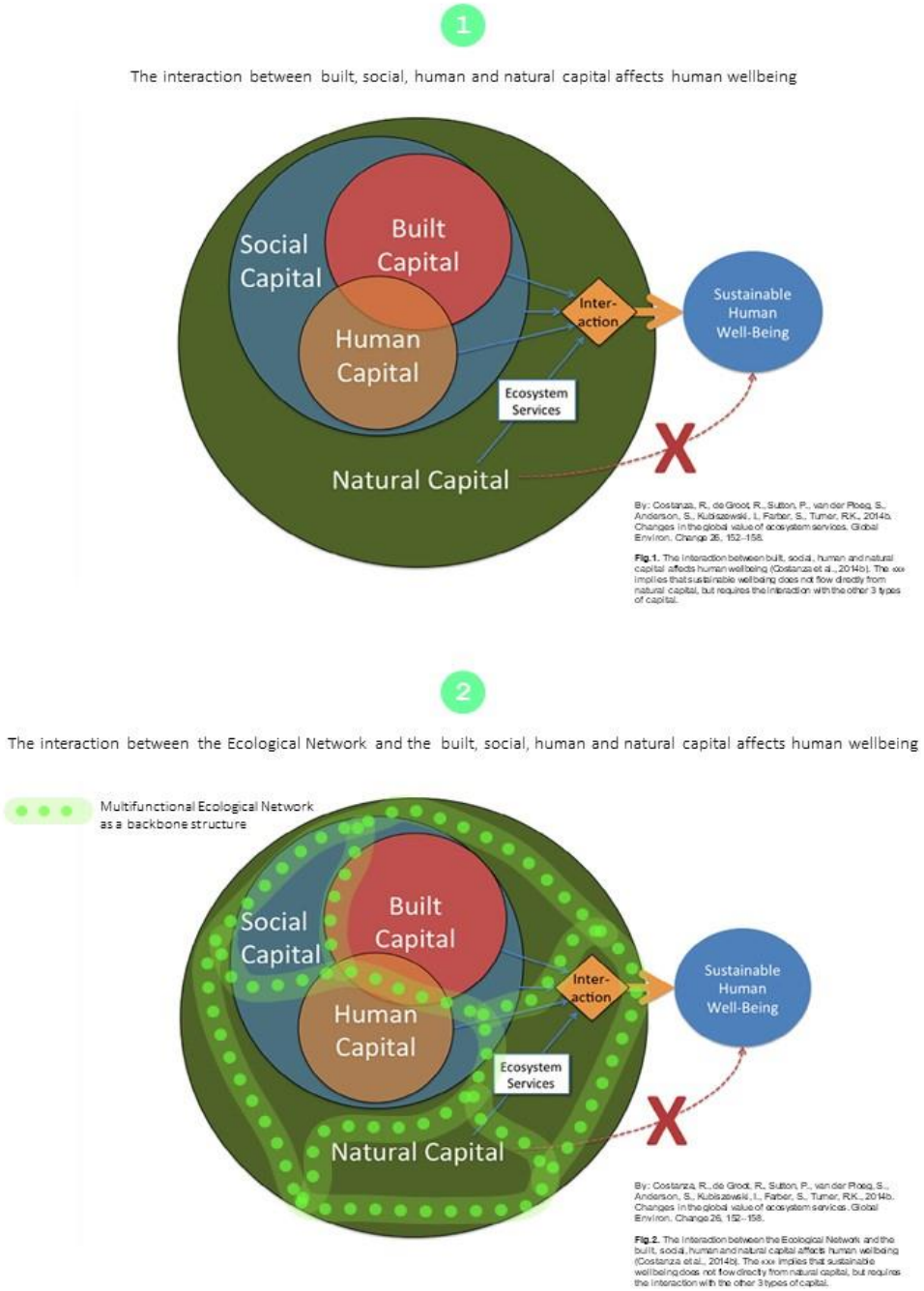


Figure 14: The concept of Natural Capital (source: Constanza et al., 2014)

2.1.3.2 Ecological connectivity, ecosystem services and nature-based solutions

To clarify the relationship between planning of green and blue infrastructure networks, ecological connectivity, ecosystem services, and nature-based solutions, it is useful to present key findings of the 2013 Study “Ecological Connectivity and Nature Based Solutions in the Carpathian Region”. The report by students from the Geneva Graduate Institute was commissioned by UNEP with the purpose of identifying the socio-economic benefits of applying Nature-based Solutions to enhance ecological connectivity in the Carpathian region. The assessment methodology is based on ecosystem service assessments. It focuses on the conservation and restoration of wetland and forest ecosystems to highlight how increasing ecological connectivity through nature-based solutions (NbS) fosters socio-economic benefits in the Carpathians. Most of its findings are relevant for the Alpine Space as well. The following is an excerpt from the report conceptual framework and findings.

Ecological connectivity is characterized by the degree to which landscapes and seascapes allow species to move freely and ecological processes to function unimpeded (UNEP, 2014). Ecological connectivity is crucial for the proper conservation of biodiversity in any ecosystem. By connecting different populations and enabling processes to influence a wider area, problems associated with fragmentation are minimized. Strategies designed to increase ecological connectivity are therefore crucial to prevent environmental degradation.

Ecosystem degradation can lead to major negative consequences not just for the plant and animal species in danger, but also humanity as a whole. To combat degradation, ecological connectivity remains as a key element.

There are consequences to ecosystem fragmentation and degradation that surpass strictly environmental damage and affect human wellbeing and economic activity. In order to understand the true repercussions of biodiversity loss and ecosystem degradation, it is important to comprehend the ecosystem services provided by those ecosystems. **Biodiversity loss, habitat destruction, and ecosystem fragmentation lead to the disruption of ecosystem functions**, **disappearance of ecosystem services** and the **emergence of biological, social, economic and health threats**.

The first part of the research consisted in assessing how the causes of ecosystem fragmentation and biodiversity loss. These threats to wetland and forest ecosystems were found to be triggered by anthropogenic factors (e.g. poor forest management practices, mining, urban development, unsuitable agricultural practices, adverse effects caused by hydroelectric plants). The report found that ecosystem fragmentation translates into the loss of supporting, provisioning, regulating, and cultural ecosystem services offered by the area, which can have devastating socioeconomic consequences for the local and Pan-European region. The loss of supporting ecosystem services has socio-economic consequences. Indeed, it would not only mean the disappearance of native and endemic plant and animal species, but it would also affect agriculture with the degradation of soil formation and nutrient cycling capacities. Moreover, wetland and forest ecosystems provide provisioning services that are essential to human survival such as water and agricultural goods for human consumption. Additionally, the provision of timber, agricultural goods, and hydroelectric

power enable local communities to generate revenue. Moreover, fragmentation and biodiversity loss threaten cultural ecosystem services such as ecotourism or the appeal of historical tourist attractions such as medieval monuments, which also generate revenues for local communities. Lastly, the loss of biodiversity and fragmentation of wetland and forest ecosystems would intensify the release of carbon that had been sequestered in the past by those habitats while simultaneously decreasing those same carbon sequestration capacities of the Carpathian region.

The following are example of ecosystem services linked to biodiversity and natural capital in 2 case studies (Iron Gates and Djerdap National Parks) of the Carpathian region[9].

Table 1: Example of consequences of Ecosystem Services degradation in the Carpathian Region (Source Ecological Connectivity and Nature Based Solutions in The Carpathian Region)

Supporting	Provisioning	Regulating	Cultural
Type of Ecosystem Services Offered in Iron Gates and Djerdap Region			

• Nutrient Cycling
• Soil Formation
• Native habitat for:
  ◦ 5,000 species of invertebrates
  ◦ 14 species of amphibians
  ◦ 17 species of reptiles
  ◦ 205 species of birds
  ◦ 34 species of mammals
	• Wetlands: water (both for consumption and for energy), food (small-scale fishing)
	• Forest Ecosystems: timber and other agro-forestry products, food (hunting and agricultural)
		• Carbon sequestration (both wetland and forest ecosystems)
		• Pollination by wild insects (both wetland and forest ecosystems)
		• Water filtration (wetlands)
		• Waste decomposition
			• Cultural heritage sights of regional and national importance (more than 20 listed)
			• Scientific work and education
			• Wetlands: fishing, tourism
			• Forest: tourism, hunting, historical sites

Consequences of Ecosystem Service Degradation			
Loss of endemic species	• Health hazards through water contamination • Loss of economic activities such as fishing, agriculture	• Increase flooding risks • Increase landslide risks • Acceleration of climate change • Decreased biodiversity and environmental resilience	Loss of recreational activities Loss of cultural patrimony

9 https://www.graduateinstitute.ch/sites/internet/files/2023-06/Final%20Report%20-%20ARP4%20Project%206%20-%20Ecological%20Connectivity%20and%20Nature-Based%20Solutions%20in%20the%20Carpathian%20Region.pdf

Supporting services are the processes that allow the planet to sustain basic life forms (National Wildlife Federation, 2022). Crucial processes such as nutrient recycling cycles and photosynthesis serve as the basis for entire ecosystems and help maintain healthy biodiversity levels (Food and Agriculture of the United Nations, 2022) and underpin the provision of all other ecosystem services. The Carpathian area is a biodiversity hotspot and host a myriad of different habitats, plant and animal species. Many of these have protected status. These habitat and species are part of a collection of complex and endangered ecosystems. As a consequence of ecosystem fragmentation, the existence of these ecosystems is threatened.

Regulating services are benefits provided by ecosystem processes that moderate natural phenomena such as water filtration or pollination of crops by wild insects (National Wildlife Federation, 2022). Forests landscapes, particularly old-growth (older and diverse stands) and virgin (completely or largely untouched) forests, throughout the Alpine region provide essential ecosystem services which are coming increasingly under threat. Mostly or completely undisturbed forest ecosystems with ecological balance and cohesive systems are the most effective forest ecosystem in sequestering and storing carbon long term. High biodiversity forests are also more resilient to natural disturbances and are more likely to naturally adapt to changes in climate and nutrient conditions than managed or single species stands (Konôpka et al, 2019). Encroachment on virgin forests, which contain high volumes of carbon, also threaten to speed the advance of climate change while depriving forest management of valuable tools for best practices within managed areas. Another example are the regulating systems provided by wetlands are characterized by hydrological transfer and flood control, biochemical transfer, nitrogen and carbon cycling, filtering, cleaning, and retention of nutrients (UNEP, 2014: 36). Carbon sequestration is arguably the most important ecosystem service provided by wetland ecosystems. In fact, wetlands have higher carbon storing capacities than any other terrestrial ecosystem (UNEP Freshwater, 2022). Although wetlands make up only 6% of the global surface area, they retain more than 20% of the terrestrially stored carbon (UNEP Freshwater, 2022). This is why the loss of wetland ecosystems not only prevents higher levels of carbon sequestration, it also discharges extensive amounts of carbon into the atmosphere. Wetlands also provide water retention and flood prevention capabilities that can aid massively during periods of heavy precipitation. Additionally, erosion may lead to issues such as hazardous impacts on waterside infrastructure and alterations to riparian habitats. The recovery of natural forest habitats in previously agricultural or managed areas also results in better outcomes for landscape management and safety with corresponding decreases in soil erosion, landslides, water pollution, and species disturbance related to carbon release (Malek et al, 2018)

Provisioning services include any kind of tangible resource that can be extracted out of an environment (National Wildlife Federation, 2022) such as timber, fish, grains, food, water as well as energy (e.g. hydroelectric powerplants) Losing provisioning services would affect economic activities such as fishing, electricity production, logging, and more. Threats to wetland ecosystems also affect provisioning services.

Cultural services are non-material benefits that contribute to the development and cultural advancement of people (such as recreational activities or cultural heritage traditions) (National Wildlife Federation, 2022). Recreation and tourism (e.g fishing, hiking and mountaineering, biking, wildlife watching, water sports, and hunting); Aesthetic and Inspirational Values (e.g. scenic beauty, tranquillity and solitude). Cultural heritage and identity (e.g traditional farming, shepherding and chees making practices that has been passed down from generations, historical sites, castles, monasteries, and other historic structures are integral to the cultural landscape); Spiritual and Religious Significance (e.g sites of spiritual or religious importance, such as pilgrimage routes and mountain shrines, a sense of connection to nature and the divine); Educational and Scientific Value (environmental education and scientific research; Health and well-being (e.g. therapeutic landscapes are opportunities for physical activity contribute to mental, physical health and stress reduction). Losing these cultural services that the area offers would translate into a loss of revenue for local populations.

Research findings show that national governments, municipalities, and private actors can counteract the effects of ecosystem fragmentation by tackling the root causes of ecosystem degradation through an array of NbS. Wetlands can be restored and preserved through NbS such as installations of water treatment facilities, restoration of proper hydrological regimes and river dynamics, floodplain recovery, changes to agricultural practices, and the introduction of buffer zones. NbS for forest ecosystems restoration and conservation included banning illegal logging through economic schemes directed at the population, species' introduction, replication of natural distributions for tree plantation, creation of ecological corridors, and implementation of financial tools aimed specifically at biodiversity conservation.

The main socio-economic benefits of implementing these NbS resulted in flood disaster risk prevention and reductions of monetary losses caused by flood damage, climate change mitigation through the increase of carbon storage capacities, creation of employment opportunities, improved health benefits through the improvement of water quality, and more.

The main policy recommendations for the realization of these outcomes were the following:

- Increasing knowledge production and quantification of the socio-economic benefits of Nature-based Solutions through ecosystem service assessments and more
- Introduction of transboundary agreements in terms of knowledge sharing, legislation, and funding in the Carpathian Convention, etc.
- Creation of financial tools to fund these solutions: establishment of markets with offset mechanisms.

2.1.3.3 Territorial potentials for green infrastructure in Europe

The working paper “Territorial potentials for Green Infrastructure” by ESPON (2018)[10] investigated the effects of GI and ecosystem services on European territorial development, the geographical distribution of GI and associated ecosystem services, and how European cities, regions, and national governments can be assisted in realizing their GI and ecosystem service development potential.

According to the study, In Europe, along with **Land use and spatial development planning** several other **policy sectors** are more explicitly incorporating GI concepts, such as, **Water management, Agriculture, Forestry, and Fisheries, Climate Change Mitigation and adaptation, Environmental protection, and Rural development**. this showed that GI is regarded as encompassing more than just biodiversity protection, as envisioned by the European Green Infrastructure Strategy in 2013. In other policy sectors, GI principles were less prevalent, such as in Finance, Health, and Social Services.

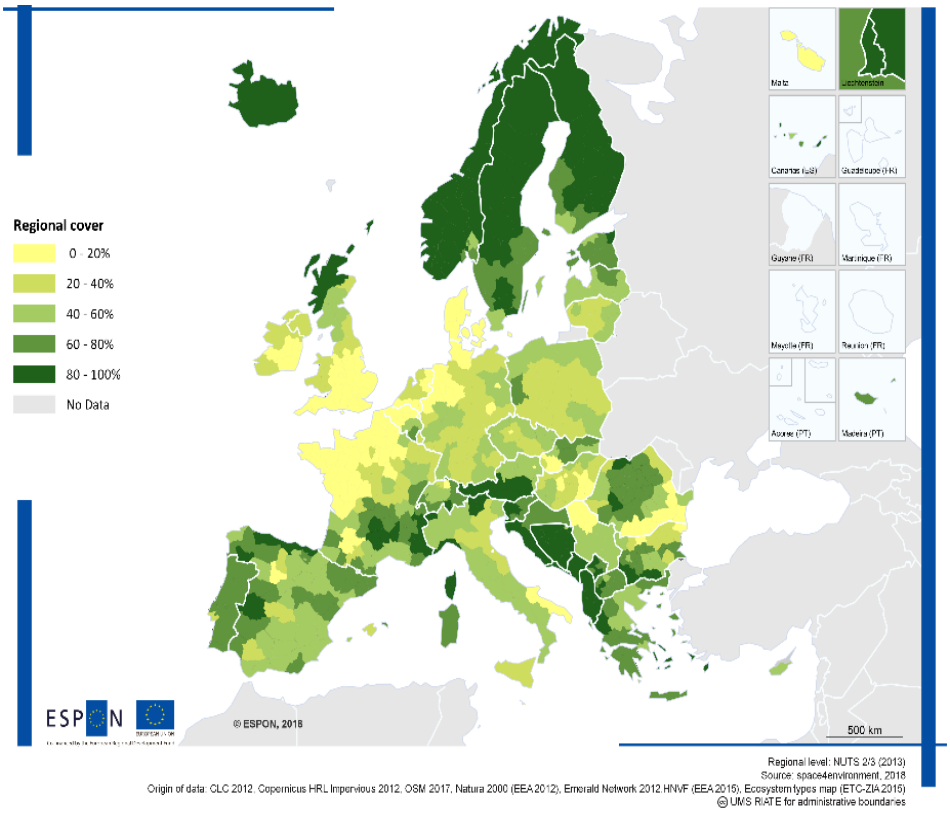


Figure 15: Spatial distribution of GI network at landscape level (source: ESPON, 2018)

[10] https://archive.espon.eu/working-paper-territorial-potentials-green-infrastructure

Mapping the spatial distribution of green infrastructure network potential in European NUTS 2/3 regions revealed two distinct trends:

- a very high percentage of potential GI coverage in the Nordic countries, the Balkan countries along the Adriatic, and the eastern Alpine area.
- a very low percentage of potential GI coverage in the regions of northwestern France and Germany, southeastern United Kingdom and Ireland, and Denmark, which, in a TEN-N idea, act as a transition barrier between northern and southern Europe

The project also found that the potential for ecosystem service provision and the benefits offered by GIs to policies are unevenly distributed across Europe. The number of services offered simultaneously by GIs, as well as the number of policies that benefit from them, are significantly greater in central European regions than in northeaster and southwestern regions.

The ES offered by GIs in most Italian regions, central Germany, and northern France serve many purposes for biodiversity, climate change, and water management (see dark green regions in fig. 15).

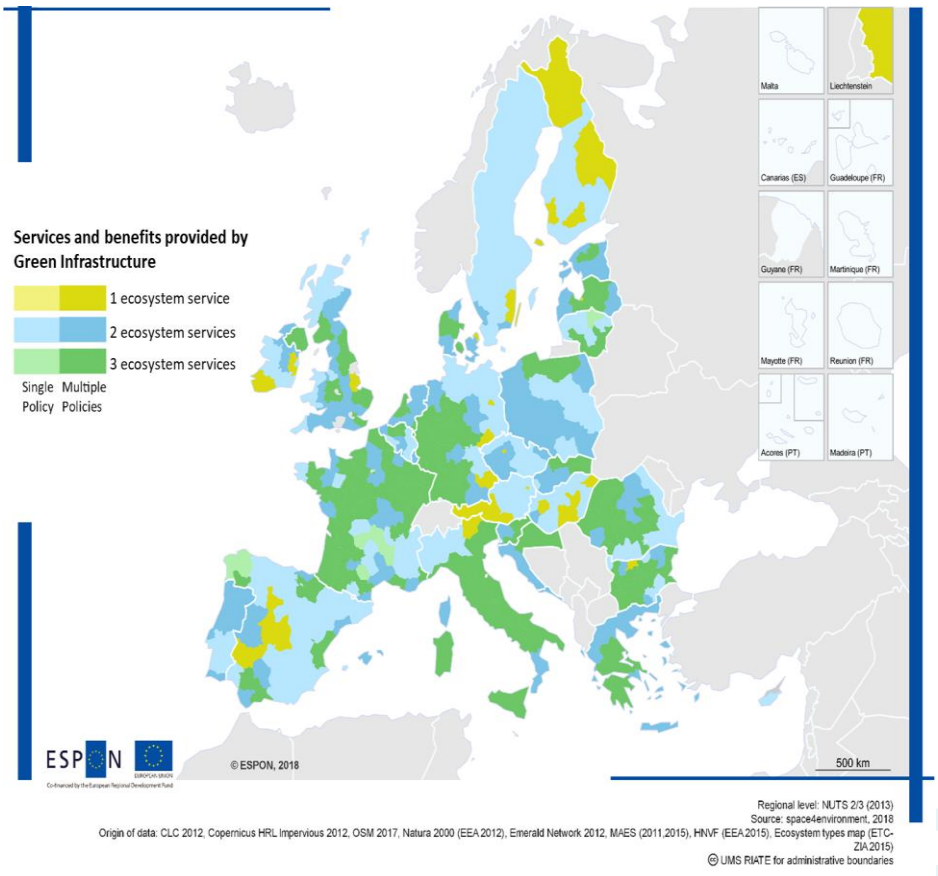


Figure 16: The multifunctionality of Green Infrastructure (source: ESPON, 2018)

2.1.4 Trans-European Network for Nature (TEN-N)

Under the GI Strategy, the **Trans-European Network for Nature** (TEN-N, sometimes called Trans-European Network for Green Infrastructure, or TEN-G) was implemented to create a coherent network of green spaces that enhances connectivity across Europe, complementing the existing Trans-European Network for Transport (TEN-T) and energy networks. It is closely related to the Natura 2000 network, which consists of protected areas designated under the EU Habitats and Birds Directives.

The TEN-N initiative seeks to **establish ecological corridors and green infrastructure networks** that connect key habitats and protected areas, facilitating the movement of species and the preservation of biodiversity. The TEN-N corridors can span various types of landscapes, including terrestrial, freshwater, and marine regions.

Alongside, the concept of Green Infrastructure recognizes the importance of nature and ecosystems in **providing essential services**, such as clean air and water, climate regulation, and recreational opportunities. By integrating green infrastructure into spatial planning and development projects, the EU aims, then, to enhance environmental resilience, support sustainable land use practices, and promote the conservation of biodiversity.

TEN-N will be built on the existing Natura 2000 network **by analysing the potential connectivity between Natura 2000 sites using green infrastructure (GI) landscape elements important for delivering ecosystem services**.

2.1.4.1 'Building a coherent Trans-European Nature Network'

To this regard the EEA published a briefing 'Building a coherent Trans-European Nature Network'[11] based on an integrated assessment developed by the EEA and its European Topic Centre on Urban, Land and Soil Systems (ETC/ULS). The assessment builds on the most recent spatial data and developments in methodology presented in a joint JRC and EEA report on strategic green infrastructure and ecosystem restoration (see box 3) and further analyses the connectivity between protected and unprotected areas, the ecosystem services provided and the conservation status of these connecting areas. It demonstrates that GI has co-benefits for people and for the conservation status of species and habitats. Protecting additional areas in this GI network could potentially boost the delivery of ecosystem services and decrease pressure on species and habitats.

However, natural and semi-natural unprotected landscape elements are also important in determining conservation status, as these areas serve as connectors. High-density landscape features, in particular small woody features, could play a key role in this in agricultural areas, as proposed in the new strategy. The work highlights opportunities for

[11] https://www.eea.europa.eu/publications/building-a-coherent-trans-european

strengthening the existing GI network and its capacity to deliver multiple ecosystem services.

The results of the EEA work suggest that a holistic approach using spatial data to identify, select and manage GI priority areas essential for the networks connectivity will ensure its delivery of multiple ecosystem services. It will also contribute to achieving and maintaining good conservation status of species and habitats. To define the ecosystem services benefiting from this approach we need to specify the composition and needs of species and habitats. Threatened species (those under the nature directives or specified in the International Union for the Conservation of Nature Red List) need healthy ecosystems outside protected areas and rely on habitats not protected by Annex I of the Habitats Directive.
The GI priority areas identified may or may not already have protected status. Depending on its level and type of protection, GI can fall under different types of ownership and have diverse levels of biodiversity or other competing priorities. In these cases, there are various interventions that could be applied:

- Designate the GI element as a protected area to meet the 30 % target of the biodiversity strategy to 2030.
- Restore the area to improve the habitat condition and delivery of ecosystem services
- Create new connecting landscape elements to physically or functionally connect existing GI elements. This can be done as part of environmental and sustainability measures implemented under the common agricultural policy and rural development planning.
- Maintain and manage the area in a sustainable way by defining and implementing targeted conservation measures, which may allow various types of low-impact land uses.

Such interventions should primarily improve biodiversity, but they can also be designed to contribute to other goals, e.g. adapting to climate change and improving human health.

The EU restoration plan is an opportunity to include these interventions in a catalogue of measures for GI priority areas and **provide guidance to MSs on planning measures**. Local and regional conditions need to be considered in decision-making and drawing up recommendations and targeted actions.

Systematic assessment and frequent monitoring of the GI network at the EU level (linked to the assessment of the conservation status of habitats and species and of ecosystem services) could be established under the new plan to create a governance system for biodiversity will enable assessment of the performance of the TEN-N and its GI elements and highlight gaps and remaining needs in terms of natural habitats and species condition.

Box 3 - 'Building a coherent Trans-European Nature Network', EEA Briefing

The integrated assessment maps a GI network of protected Natura 2000 sites and unprotected natural and semi-natural terrestrial ecosystems (including agro-forestry) relevant for the movement of medium-large mammal species at the EU level. Findings (see figure 17) reveals that:

- *around 80% of Natura 2000 sites, dominated by woodland and forest, are connected by natural and semi-natural features in the wider landscape (not part of Natura 200 sites) across 27 EU Member States.*
- *of these sites, more than 50% are connected by unprotected forest and woodland ecosystems.*
- *around 20% of the Natura 2000 sites are disconnected because they are fragmented by urban areas or agricultural land.*
- *breaks in the GI network are most common in the southwestern and eastern regions of Europe.*
- *about 15 % of the disconnected forest and woodland Natura 2000 sites are less than 1 km from mapped GI segments.*

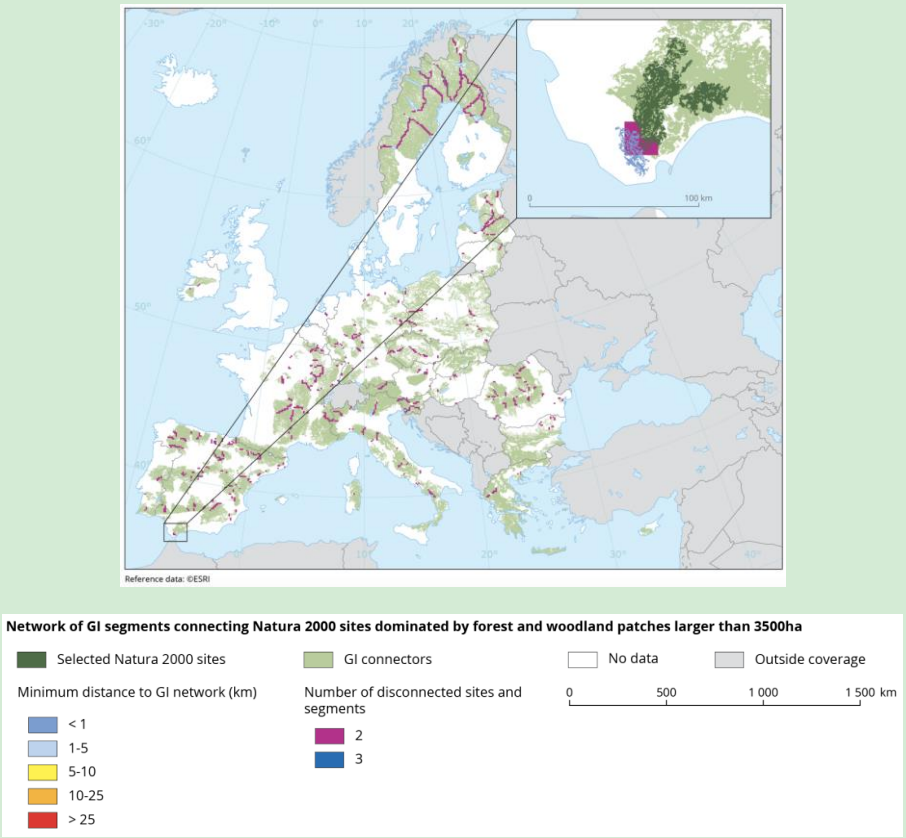


Figure 17: Network of GI segments connecting Natura 2000 sites dominated by forest and woodland patches larger than 3 500 ha (source: EEA)

The assessment analyses the connectivity between protected and unprotected areas, the ecosystem services provided and the conservation status of these connecting areas

Around 70 % of the EU-27 territory is covered by ecosystems providing medium and important service areas, i.e. one or two of the three key services (pollination, flood control and recreation) to people in the same area. However, there are more areas providing no services than those providing three services simultaneously

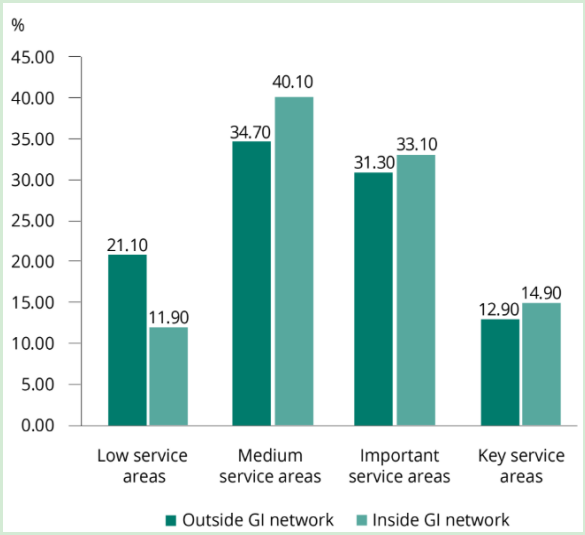


Figure 18: Distribution of multiple ecosystem services in areas outside (a) and inside (b) the GI network mapped in Figure 17 (source EEA)

Figure 18 shows that:

- *the GI network improves the provision of multiple ecosystem services in an area by almost 4 % compared with areas not included in the GI network (Figure 17),*
- *provision of at least one ecosystem service in medium service areas also increases by almost 6 % inside the GI network compared with outside the network,*
- *connected Natura 2000 sites to provide around 10 % more co-benefits to people compared with unprotected and disconnected landscape elements.*

Six prioritisation levels are proposed for conserving existing biodiversity-rich ecosystems in good condition and restoring degraded ecosystems inside and outside the GI network:

- *pressure prevention and/or minimization.*
- *low-level management of pressure.*
- *prompt protection and/or restoration.*
- *active pressure reduction.*
- *urgent protection and restoration.*
- *fast-track management intervention.*

These levels enable to map where GI should be maintained, more effective managed, restored or further deployed inside and outside the Natura 2000 network. The prioritisation framework is based on a decision matrix that estimates the capacity of the GI network to simultaneously supply multiple ecosystem services and secure biodiversity conservation, with a special focus on areas that connect protected Natura 2000 sites (see Figure 19).

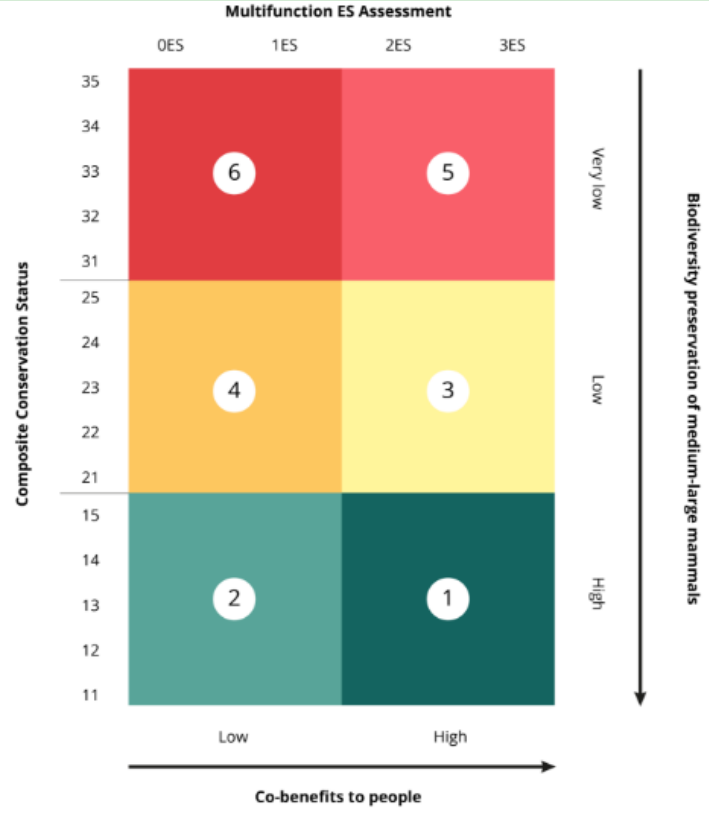


Figure 19: The proposed prioritization framework for measuring biodiversity preservation and the co-benefits of GI (source EEA)

Figure 20 shows that the likelihood of maintain favourable conservation status is very high for selected mammal species inside and outside the GI network (levels 1 and 2). Around 80% of areas classified as levels 1 and 2 outside the network should be able to be included with little or very little management. Areas inside the GI network are subject to less ecosystem pressure (i.e. the percentage of areas under levels 5 and 6 prioritisation) then the areas outside the network. Levels 1 and 2 predominate in Baltic countries, Poland, Slovakia, the Carpathian region, Austria, the Spanish Extremadura region, and the Pyrenees. Monitoring systems are needed to mitigate future pressures on ecosystem conditions and mammal species.

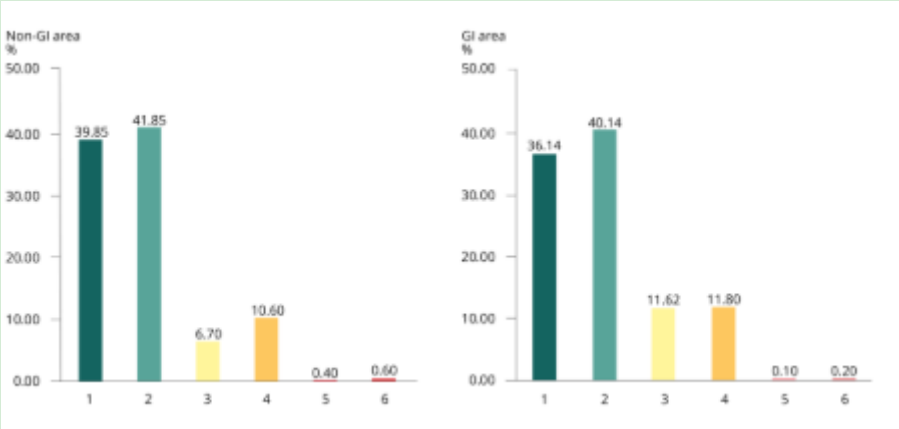


Figure 20: Distribution of priority interventions in areas outside (a) and inside (b) the GI network

Major areas with low ecosystem services provision and unfavourable conservation status within GI network are less than 1%.

The remaining GI segments across the EU-27 territory have a medium capacity to sustain the conservation status of selected mammals and simultaneously provide co-benefits to people by regulating ecosystem services. The ecosystems covered by these GI elements are subject to pressures that need to be identified and reduced to restore their biodiversity and ability to provide multiple ecosystem services.

2.1.4.2 Conceptual framework for the implementation of the TEN-N

The key goal of the EU Biodiversity Strategy for 2030 of establishing a larger EU-wide network of protected areas on land and at sea is essentially the design of a connected '**Trans-European Nature Network**' (TEN-N), having as a backbone structure an enlarged Natura2000 network that helps to build a coherent and resilient network of conserved areas across Europe for nature and people.

To this end the NaturaConnect project[12] is currently working on the development of a conceptual framework for the implementation of the TEN-N. In doing so is undertaking a process of co-design with stakeholders developing narratives on future nature protection in

[12] https://naturaconnect.eu/

Europe using the **Nature Futures Framework** tool (NFF, see box 4). The NFF is based on three major value perspectives: nature for nature, nature for society and nature as culture and intends to inform context- and place-specific policy alternatives.

Providing a number of plausible futures increases the chance that the design of the network will be resilient in the face of different possible changes (in policies, land uses, climate) and can still achieve its objectives under changed environmental and social conditions.

The goal is to **create nature-centred multi-scale scenarios** for a sustainable future while also facilitating cross-scale coordination to monitor and reverse reductions in biodiversity and ecosystem services. Nature Futures scenarios seek to change established approaches of predicting society effects on nature toward nature-cantered visions and routes. These scenarios integrate social-ecological systems, biodiversity, environmental functions, and human well-being.

Among the scenarios Nature for Nature perspective is may be seen as the representation of the backbone structures of the TEN-N project focused on the enlargement of the N2000 network. In the **Nature for Nature perspective**, nature intrinsic value is central to humans. Ideas such as non-management, rewilding (the ecological process of letting nature take its course through reducing long-term management), the improvement of resilience to disturbances and the restriction of extractive uses, are key to this scenario wherever possible**.**

Protected Areas expansion focuses on preventing the extinctions of species, increasing ecosystem integrity and allowing natural processes to take place. They are established in areas where human activities can be minimized, to reduce the impacts on nature. The vision primarily aims to establish large, protected areas that can sustain self-regulated ecosystems, but smaller protected areas also can play a complementary role since they can be part of corridors and stepping-stones between larger areas. The 10% of Protected Areas under strict protection are characterized by no ex-tractive uses and no human intervention and a long-term goal to restore wilderness. Large-scale corridors are integrated in a coherent nature protection network, to support the dispersal and migration of organisms and gene flow.

Green and Blue Infrastructures are planned in areas where they supports the establishment of ecological corridors (e.g., stepping stones, green belts, etc.). As dynamic systems, **wetlands help biodiversity to adjust to climate warming**, and are thus given particular emphasis to support shifts in species communities.

There is a moderate to high tolerance towards **human activities** within protected areas (e.g., hunting, extensive farming). **Precision farming is encouraged** to optimize both agricultural input and output and to reduce extra water consumption during irrigation. **Grazing** would occur as it facilitates sustainably low intensity used landscapes with anthropogenic and natural features. **Forestry** for wood production is also allowed by setting level thresholds for harvesting, to meet the demand sustainably.

Obsolete and redundant infrastructures (such as river barriers, roads, etc.) are removed, especially in areas where they reduce barriers to native species movements. **Energy installations** are allocated in degraded areas and high-intensity agricultural landscapes**. Power lines** are built along already existing infrastructures and can be hidden underground, if possible, to avoid species disturbance.

Transition from exotic tree plantations to native tree plantations and promotion of multi-aged and more diverse stands is promoted while fire-risk is reduced through natural grazing with increased diversity and density of wild ungulates.

Connectivity between urban and rural areas is increased by ensuring continuity of natural habitats between urban parks and important natural habitats beyond the limits of the city.

Box 4 - Nature Futures Framework and NaturaConnect Project

The Nature Futures Framework (NFF) is a framework for creating scenarios and models of ideal futures for humans, nature, and the planet. It tackles the limits of current scenario techniques in biodiversity and ecological services. The NFF is based on three major value perspectives: nature for nature, nature as culture/one with nature, and nature for society. It intends to inform context- and place-specific policy alternatives, contribute to the Convention on Biological Diversity 2050 Vision of 'Living in Harmony with Nature', and promote the Kunming Montreal Global Biodiversity Framework implementation.

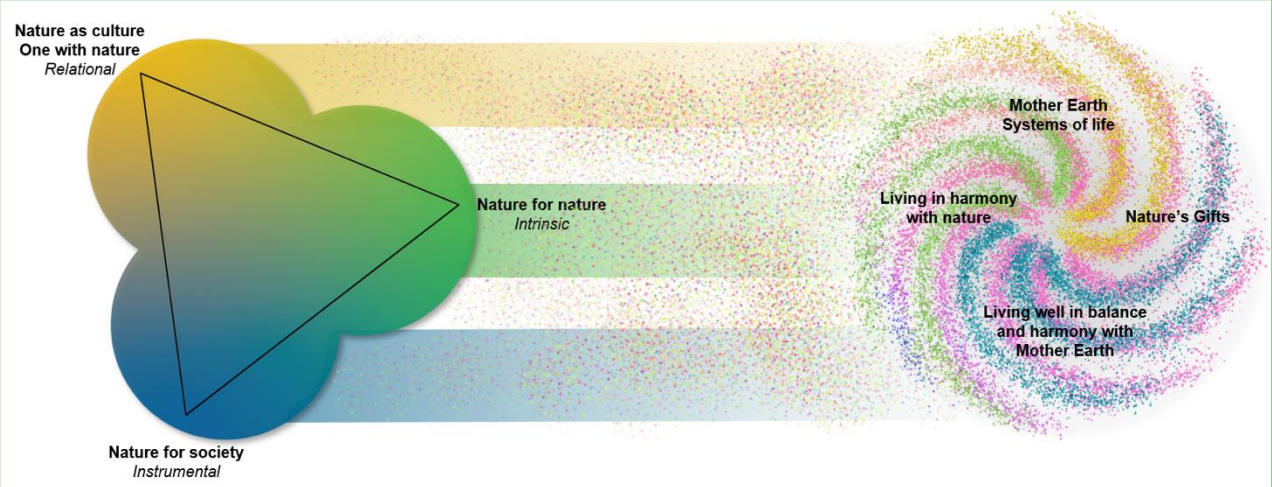


Figure 21: The Nature Futures Framework (source: https://www.ipbes.net/scenarios-models)

The NaturaConnect project, through a process of co-design with stakeholders, is developing narratives on future nature protection in Europe using the Nature Futures Framework (NFF). These narratives present contrasting perspectives and priorities for seven themes:

- Protected areas,
- Connectivity and Restoration,
- Forestry,
- Freshwater ecosystems,
- Urban system,
- Agriculture,
- Energy

The NaturaConnect Nature Futures narratives are outlined below.

Nature for Nature

The Nature for Nature narrative centres on the intrinsic value of nature, independently of the benefits to people. In this narrative, natural areas under strict protection are set to drastically reduce human intervention in ecosystem processes. By reducing the sprawl of new infrastructures and the demand for biofuel, whose production requires large areas, there is more space for wilderness. Protection of nature primarily aims to achieve the undisturbed functioning of selfregulated ecosystems, instead of seeking to manage nature for material and non-material benefits that people may get. Approaches such as non-management, rewilding (the ecological process of letting nature take its course through reducing long-term management), the improvement of resilience to disturbances and the restriction of extractive uses, are key to this scenario wherever possible.

Nature for Society

The Nature for Society narrative focuses on the utilitarian benefits and instrumental values provided by nature, thus ecosystems are managed to prioritise and enhance the provision of Nature's Contributions to People (NCP). Natural areas are integrated with a matrix of human land use, and multifunctional and multiscale landscapes are sustainably managed. Green infrastructure and ideas such as Nature-based Solutions are key components of cities and other landscapes. Protected areas emphasise both biodiversity conservation and ecosystem service delivery. Society pursues sustainable development, adopting win-win solutions for nature and people.

Nature as Culture

The Nature as Culture narrative focuses on the relational values between nature and people's culture (e.g., sense of place, participation, stewardship, spirituality, reciprocity), strengthening the personal connection that humans have with nature. Emphasis is given to traditional land use practices and experiences that connect people to specific landscapes (e.g., Farm to Fork

initiatives, wine routes, transhumance of livestock, biodiversity-friendly farming, pilgrimage routes, hiking and enjoyment of nature); consequently, the belief systems and behaviours adapt to a society where nature centred education and lifestyles are a priority. The connection that people feel towards the environment is strengthened by an increase in community-based management initiatives. Emphasis is given to the heterogeneity of cultural landscapes across Europe. Overall, the land sharing principle prevails more than in the other perspectives, by integrating nature within human managed systems.

Figure 22: The Nature for Nature/Nature for Society/Nature as Culture approaches in the NaturaConnect Project

The narratives will serve as a basis to investigate how land use and nature conservation scenarios can be integrated to achieve the NaturaConnect aim of designing a coherent TEN-N for nature and people

The narratives will be used by NaturaConnect also ***to develop specific settings for connectivity in terms of priorities for conserving and restoring functional and structural connectivity****, and* ***priorities for connecting protected areas (PAs****), in the three corners of the NFF. For example, the conservation and restoration of structural connectivity will prioritise roadless areas in the Nature for Nature TEN-N, the development of Green and Blue Infrastructure connecting peri-urban landscapes in the Nature for Society TEN-N, or enhancing landscape mosaics and hedgerows in the Nature as Culture TEN-N.*

Considering Translation of narratives into scenario settings and indicators, “NaturaConnect” will use existing **scenario simulations** with global scale economic models to depict the broader macro-economic changes that occur due to radical changes in sustainable consumption or increased technological efficiency. The Natura-Connect project will make use of the spatial land use model “CLUMondo”, to **simulate plausible scenarios** of land use change outcomes based on the NFF storylines for Europe.

CLUMondo (Asselen and Verburg, 2013; Schulze et al., 2021) is a spatially explicit land use allocation model that simulates land use changes over large areas using process representation and empirically quantified relationships between land use and its driving factors or demands. CLUMondo can simulate plausible scenarios of land use outcomes based on each of the Nature Futures Framework (NFF) storylines.

The goal of the project is to design a TEN-N that is also resilient to more extreme climate and land use change scenarios. For CLUMondo, the focus is to understand how different **targets or priorities** would affect potential land use change in terms of distribution and area per land use system. Once the model has been run, maps with land use outcomes in each NFF are generated. These outcomes would then indicate different opportunities and constraints for the development of the TEN-N under a specific NFF vision.

The project will make use of Systematic Conservation Planning (SCP) as approach to identifying priority areas which would best contribute to the protection of species or habitats at a regional or global level, including the conservation of multiple species (Margules and Pressey, 2000; Nicholson et al., 2019) or Nature Contribution to People (Jung et al., 2021; O’Connor et al., 2021). SCP is a structured approach to locating and designing PA networks that achieve set objectives. This organized strategy aims to identify and prioritize conservation sites to successfully protect biodiversity and ecosystem services. Setting defined objectives, assessing conservation values with scientific data, and de protected area networks using spatial planning tools are all part of the process. SCP seeks to ensure that conservation activities are efficient, cost-effective, and consistent with larger environmental and socioeconomic goals. Defining aims, prioritizing regions, taking measures, and monitoring outcomes are all critical processes for adapting and improving tactics over time.

2.2 Funding Mechanisms to implement GBI and ecological connectivity

EU funding and national funding sources relevant for financing projects focusing on biodiversity and nature protection provides support for projects that promote sustainable spatial development and ecological connectivity.

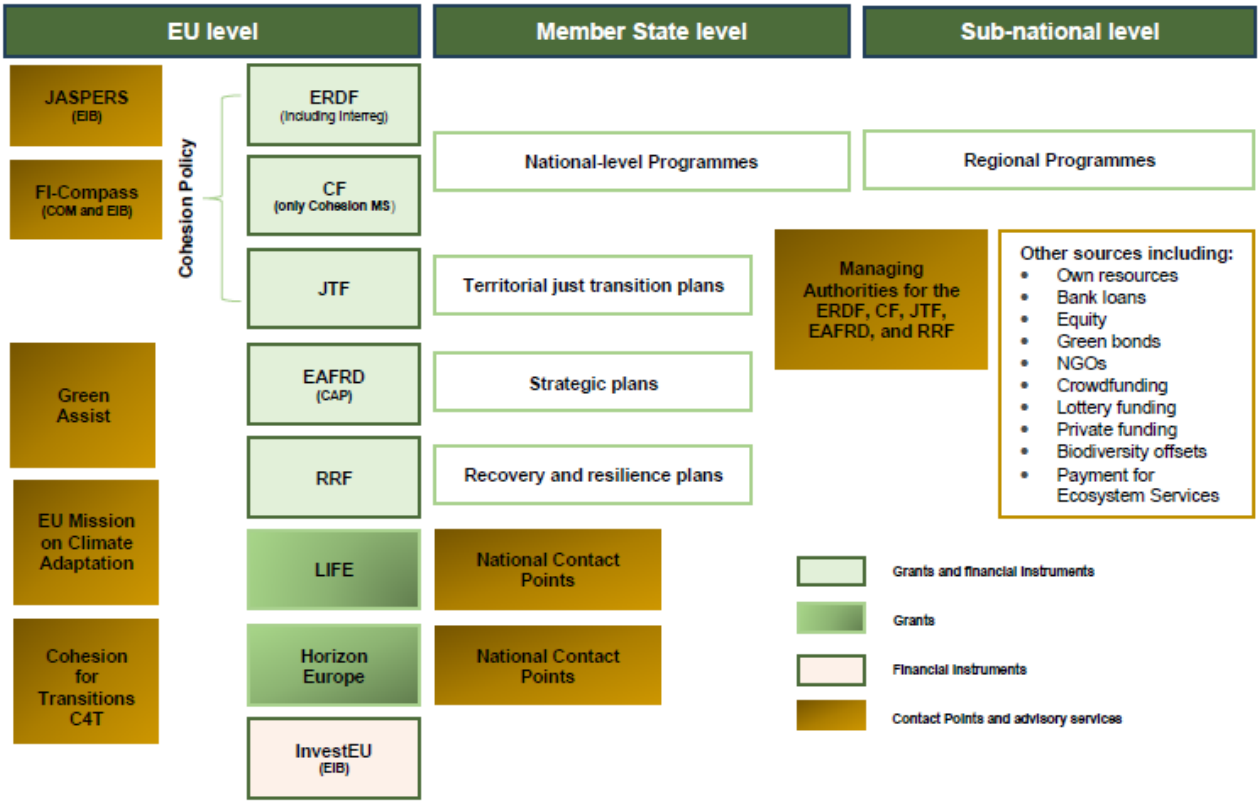


Figure 23: Typology of funding sources (source financing guide 3 billion's tree pledge[13])

This includes funding for green infrastructure, habitat restoration, and biodiversity conservation projects and cross border cooperation. Additional types of funding instruments include international (other than EU) funding, and innovative funding sources, which may be used both in national and international contexts.

13 https://op.europa.eu/en/publication-detail/-/publication/c216e918-d646-11ee-b9d9-01aa75ed71a1/language-en/format-PDF/source-308529914

2.2.1 EU funding

The EU Cohesion Policy, supported by structural and investment funds, provides financial support for projects that promote sustainable development and ecological connectivity. This includes funding for green infrastructure, habitat restoration, and biodiversity conservation projects. The main **funds** under the Cohesion policy include:

- **European Regional Development Fund** (ERDF, member state specific funding and Interreg funding), which finances projects that enhance ecological connectivity through the creation and maintenance of GI, restoration of natural habitats, and establishment of ecological corridors. Examples include urban green spaces, river restoration projects, and the creation of wildlife corridors.
- **Cohesion Fund:** Target Member States whose Gross National Income (GNI) per inhabitant is less than 90% of the EU average, may supports large-scale infrastructure projects, including those related to the environment and climate change adaptation. It funds initiatives that improve ecological connectivity, such as wetland restoration, floodplain reconnection, and sustainable water management practices.
- **Just Transition Fund (JTF)**, which aims to mitigate the social and economic impacts of the transition towards a climate-neutral economy focusing on the regions most affected by this transition. The JTF can finance projects that restore degraded land and support biodiversity, thus contributing to ecological connectivity. This includes reforestation, land rehabilitation, and the creation of green spaces.
- **Horizon Europe** is the EU instrument supporting the development of innovative projects, including projects aimed at tackling climate change and promoting sustainable development.
- **Recovery and Resilience Facility** (RRF) is a building block of the NextGenerationEU, the EU's plan to recover from the COVID-19 pandemic. The RRF supports green transition, including biodiversity goals. 37 % of the financial allocations of the recovery and resilience plans, which are guiding the spending in each Member State, should encompass measures that effectively contribute to green transition.
- **Invest EU** supports sustainable investment, is divided into four 'policy windows' with the 'Sustainable Infrastructure' window being the most relevant for ecological connectivity Annex II of the Invest EU Regulation lists areas eligible for financing, which encompass 'the enhancement and restoration of ecosystems and their services including through the enhancement of nature and biodiversity by means of green and blue infrastructure projects' and climate adaptation
- Also, the **Agricultural Fund for Rural Development** (EAFRD) could be considered a possible economic source in this sense.

Specific Initiatives and Programs Supporting biodiversity and ecological connectivity include:

- **LIFE Programme**, Two of the four LIFE sub-programmes are the most relevant "Nature and Biodiversity" and "Climate Change Mitigation and Adaptation" that directly supports the realization of EU environmental policies and legislation, including those that enhance

ecological connectivity. This includes habitat restoration, species conservation, and the development of green infrastructure.

- **European Agricultural Fund for Rural Development** (EAFRD). is a part of the Common Agricultural Policy (CAP), with the main objective to support EU farmers and populations living in rural areas: it will deliver measures to support biodiversity and ecological connectivity, such as:
    - **Eco-schemes** (voluntary for farmers) Under the new CAP (2023-2027), eco-schemes offer payments for agricultural practices that are beneficial to the climate and environment, encouraging farmers to adopt sustainable practices.
    - **Agri-environmental Schemes** (voluntary for farmers) These measures support farmers who commit to practices that go beyond mandatory requirements, such as water management, organic farming and habitat conservation, including maintaining hedgerows, buffer strips, and other landscape features that act as ecological corridors.
    - **Greening Payments**: Farmers receive additional payments for practices beneficial to the environment, such as crop diversification, maintaining permanent grassland, and creating ecological focus areas (EFA). Under the CAP, farmers with more than 15 hectares of arable land are generally required to allocate at least 5% of their arable land to EFAs. However, the specific requirements can vary by country, as each EU member state has some flexibility in implementing the rules. EFAs can take various forms, and farmers have a range of options to fulfill their EFA requirements. Some common types include, hedges and woodland Edges, buffer strips, Cover crops, fallow land, pond and ditches, terraces, agroforestry.
    - **Green infrastructures**: It also funds projects that restore and connect natural habitats in rural areas.

2.2.2 Innovative funding sources (other than EU)

Innovative funding sources relevant to biodiversity and connectivity include primarily financial incentives, sustainable land management practices, green bonds and crowdfunding:

- **Payments for Ecosystem Services (PES**), which are a potential method to conservation and sustainable resource management because they provide financial incentives for the supply of ecological services. By integrating economic and environmental goals, PES can help to conserve biodiversity, mitigate climate change, and promote sustainable development. To ensure long-term and meaningful results, successful implementation necessitates thorough planning, consistent funding, good monitoring, and fair participation.
- **Carbon farming**, is a whole farm strategy to improving carbon capture on functional landscapes which refers to a set of land management practices that enhance the uptake and storage of CO2 in plant matter and/or soil organic matter. This PES-like funding

source is regarded as essential for the efforts to mitigate the effects of climate change, improve soil quality, and diversify farmer's income.

- **Crowdfunding platforms and ESG policies.** Through these innovative tools conservation an renaturation projects can mobilize resources and community support to enhance ecological connectivity, contributing to the overall health and resilience of ecosystems. Example to this regard are the WoW Nature platform of ETIFOR[14] supporting reforestation projects as well as the protection of existing forests companies can mitigate their environmental impacts, activate forms of corporate social responsibility for their employees and integrate reforestation and conservation projects into their environmental, social, and corporate governance policies (ESG policies).

2.2.3 National funding

National funding may take various forms, including aid dedicated to environmental programmes and funds, support to afforestation and land management programmes, funding provided by regional and municipal governments, by non-governmental organisations and foundations or even donors. National-level funding is also needed to complement EU funding, which may provide up to 100 % of funding for individual projects (this is the case for most forest-related interventions under the CAP). An overview of institutional national funding opportunities is provided in the country-specific information provided in section 5 of the 2024 Financing guide of the 3 billion's tree Initiative[15].

[14] https://www.etifor.com/en/services/reforestation-and-forest-protection/

[15] https://op.europa.eu/en/publication-detail/-/publication/c216e918-d646-11ee-b9d9-01aa75ed71a1/language-en/format-PDF/source-308529914

3 Alpine policy framework for Ecological connectivity

3.1 Alpine 2050 spatial development perspective

During the German presidency of the Alpine Convention (2015-2016), the ministers in charge of the territorial development policies in the Alpine Region signed the "**Declaration for sustainable spatial development in the Alps**"[16]. The agreement identified ten main challenges and topics:

1. Climate change, the adaptation to climate change and natural hazards.
2. Demographic changes and organization of work.
3. Transport and connectivity.
4. Settlement structure and land use.
5. Saving, production, supply and storage of energy.
6. Tourism.
7. **Ecosystem functioning, ecological networking and biological diversity.**
8. Vitality of the mountain regions and their small and medium-sized towns.
9. Preservation of cultural and natural heritage.
10. Improving governance, cooperation and organizational needs.

Based on these matters, they realised **common spatial development perspectives** and a vision for the Alpine area were needed to guide policy making and strengthening joint actions towards a common sustainable territorial development in the AlpConv and EUSALP area. The idea of a common vision and the connected spatial perspectives has the ambition to **facilitate and improve harmonized cross-border territorial development**. They also addressed the need for planned and coordinated development in the abovementioned fields identified by the Declaration.

The Alpine 2050 common **spatial perspectives for the Alpine area**[17] consider **ecological connectivity as a critical aspect of biodiversity conservation and sustainable development in the EUSALP macro-region.** This region, characterized by its diverse ecosystems and rich biodiversity, spans across several European countries, including Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia, and Switzerland and hosts various protected areas, including national parks, nature reserves, and Natura 2000 sites. These areas play a key role in preserving biodiversity. Promoting cross-border cooperation among these protected areas enhances their effectiveness by creating a larger, interconnected network of habitats.

[16] https://www.alpconv.org/en/home/topics/spatial-planning/

[17] https://archive.espon.eu/Alps2050

3.1.1 Alpine 2050 Scenarios of spatial development on the environmental perspective

Based on territorial analyses, participatory processes, political agendas and mega-trends of socio-economic development, **Alpine 2050** defined future spatial developments scenarios, covering three perspectives of territorial sustainability:

- 'People & Territories'.
- 'Economy'.
- 'Environment'.

Considering the environmental development perspective, ecological connectivity in future scenarios is considered a crucial issue for both biodiversity and the provision of ecosystem services.

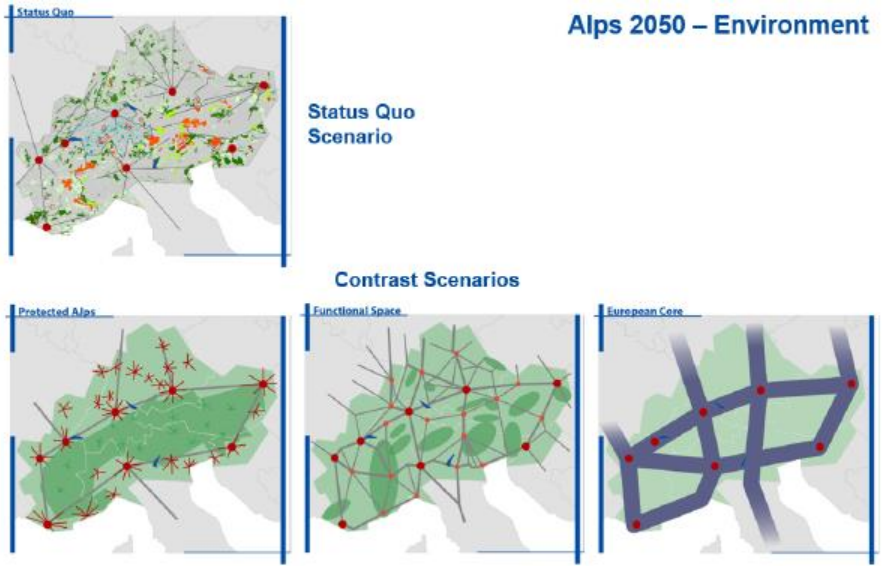


Figure 24: Alps 2050 environment (source: https://archive.espon.eu/Alps2050)

Environment - scenario 1 "the status quo scenario"

The status quo scenario assumes that the hitherto dominant trends will be carried forward. Development paths are mainly based on national, domestic politics that lead to complex spatial patterns, only limited success in achieving sustainable development and strategic spatial development is foreseen.

In the map, we see clear differences between national protection regimes. For example, national parks are much more frequently enacted in AT, FR and IT, whereas DE and CH have fewer **national parks** which are relatively small. Another difference between Alpine countries is the varied implementation path of the EU protection directives that display very different average sizes of protection areas within these countries (going up to 37% protection area in SI). Even if a series of cross-border protection initiatives exists (e.g. Naturpark Nagelfluhkette between Austria and Germany), the potential of cross-border formats is

certainly not yet exploited. In recent years, the question of ecological connectivity came high on the political agenda. The key idea is to ensure sufficiently large functional ecological systems by - ideally - connecting in a way that flora and fauna can inter-exchange. Area protection is just one element of this more comprehensive approach. Against this background, ecological connectivity is hindered by continued construction activities and settlement dynamics that cut across ecological networks and, particularly in hitherto unaffected areas.

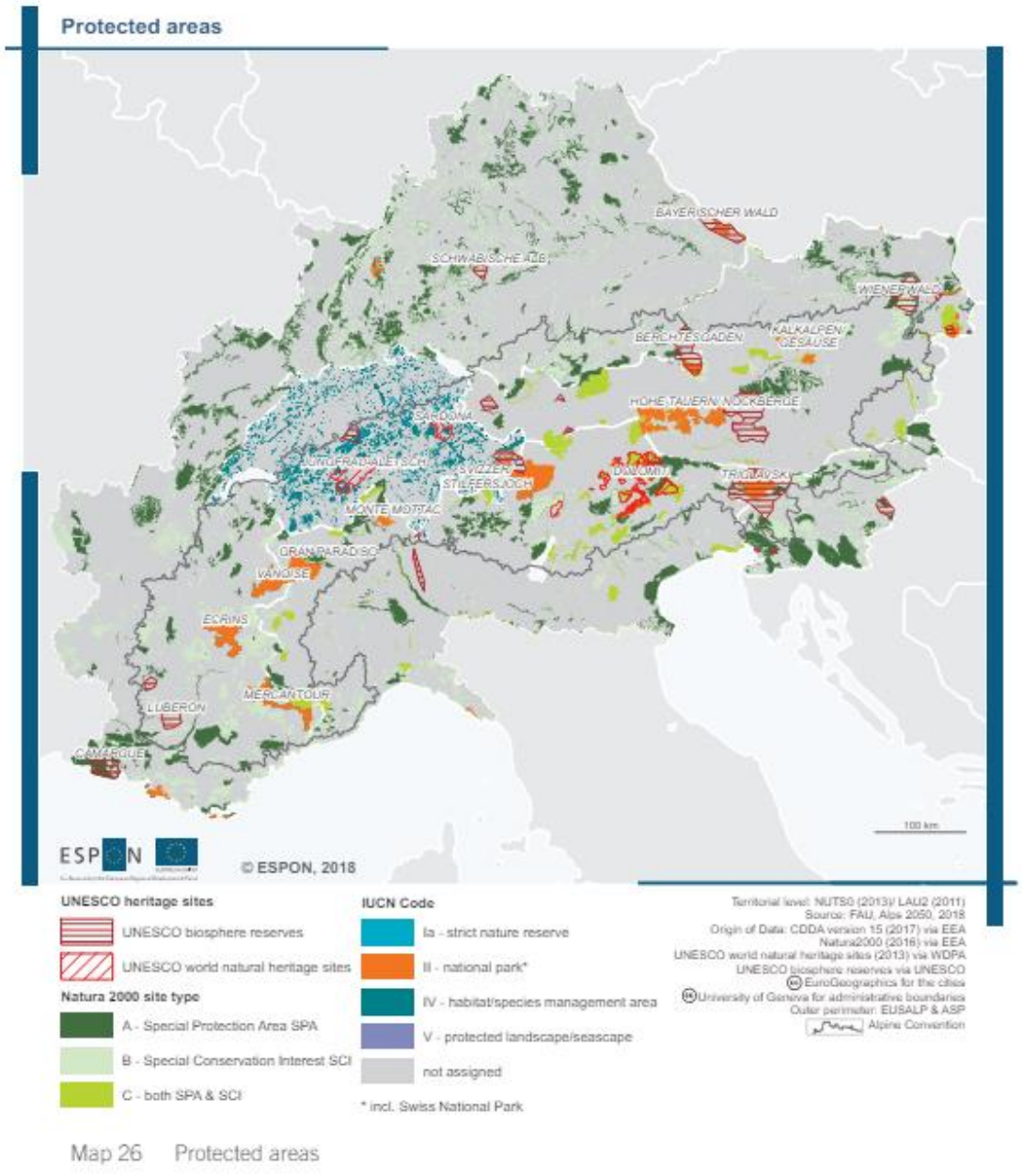


Figure 25: Alps 2050 protected areas (ESPON: The Alps 2050 Atlas)

Environment - Protected Alps scenario

The second perspective underlines the prerequisite of protecting the inner-Alpine mountain areas. The Alpine mountains are a precious and vulnerable natural and cultural heritage. High pressure is affecting the region due to touristic demand, transport needs, settlement growth and other human activities. **Protection regimes** as introduced by the Alpine Convention are more than necessary and are to be further strengthened. The dynamic of the 'metropolitan ring' surrounding the Alps will be organized in a way that does not question sustainable development within the Alps (e.g. about settlement sprawl, transport emissions).

The scenario of the '**Protected Alps**' focusses on the maintenance of the natural and, at the same time, of the cultural heritage. In the Alpine Region, both dimensions are intensely intertwined. Within this scenario, protected areas and tools for ecological connectivity must complement each other where connectivity is a major objective also to reduce soil sealing processes in the vulnerable mountain regions. Connectivity can be insured by smart conceptions of area protection and by a systematic implementation of spatial planning objectives and by sectoral biodiversity policies. The main tools are rooted in spatial planning systems that combine the domestic (national, regional) procedures with a transnational, Alpine wide basis.

Environment - Functional space scenario

The scenario that describes the Alpine Region as one 'functional space' underlines the necessity to improve linkages between the different subregions. Towards 2050, the relationship between mountain inner-Alpine and the more urbanized pre-Alpine parts will be strengthened, and in parallel the cross-border relations will be addressed more intensively. The several borders between the Alpine countries have been diverging for a long time. **Smart spatial development strategies** can overcome existing frictions with innovative political agreements and adequate infrastructure investments. Removing barriers and enhancing functional links is extremely important (e.g. in the labour market, public services but also on natural capital preservation and provision of ecosystem services). The scenario of the 'functional linkages' space focuses on place-based approaches that overcome constrictions and develop synergies and complementarity. Regarding the environmental perspective, in this scenario**, the inner-Alpine region provides a series of ecosystem services to outer-Alpine regions that are linked to the unique natural quality**. These range from leisure facilities and drinking water supply to biodiversity functions. Natural protected areas must be seen as functional areas as they often have an intermunicipal, transregional, or transnational character. Fostering ecological connectivity between natural parks and introducing new connections is important. The Alpine wide protection regimes should be aligned for the areas which are essential at Alpine level (ecological connectivity, river regimes, flood management along cross-border rivers, and so on).

Environment - European core scenario

In this scenario, the Alpine Region is one of the most successful economic spaces in Europe and one of the most attractive touristic destinations worldwide. The Alpine Region has an

important environmental function for Europe. The unique and attractive landscape and natural capital must be safeguarded and developed for touristic and leisure use, drinking water resources, energy supply and energy, storage are major functions that the Alps must fulfil. In times of **biodiversity loss**, the Alpine region has an important role to play for the whole continent. Large scale area protection must be safeguarded (editor note this include improving ecological connectivity) where other land use demand is not conflicting in a too fundamental way. drinking water resources, energy supply and energy storage are major functions that the Alps must fulfil in times of climate change. Providing these tasks - also for other European regions, will be compensated financially (editor note e.g. with payments for ecosystem services). It is important to organize the environmental functions of the Alps in an efficient manner. This means to assign functions to those spaces where conflicts of interest are not expected to be fundamental. For example, biodiversity and protection objectives should be assigned, if possible, to those regions where competing land use needs are not too pressing. As a result, large scale zoning is an important tool.

Instrumental toolbox for implementation of environmental future scenario

Policy measures in the context of transnational cooperation. Independent from the question which scenario is to be favoured, there are certain tools that influence the sectoral domains and the spatial development.

The following table proposes an overview on the most relevant options. In the latter columns, the crosses indicate to what extent the tools ‘fit’ the different environmental perspectives introduced above. Obviously, it depends on the concrete formulation of the proposed tools if they fit to one or the other approach. Still, the indicative assignment shows different possible implementation options.

Table 2: Exemplary measures (source: ESPON: The Alps 2050 Target Analysis)

Relevance for scenarios	Protected Alps	Functional region	European core
III - Environment			
Organising ecosystem services Alpine wide, linking pre-Alpine and inner-Alpine areas	++	+++	+
Organising ecosystem services on European scale (water, biodiversity, etc.)	+	++	+++
Protecting Alpine ecosystem services from high metropolitan demand	+++	++	+
Climate adaptation program	+++	++	+

The examples of the environmental measures show which **implications** the different scenarios have on the instrumental side: the Alpine-protection scenario prioritizes measures to limit strong demands from outside the Alps, the functional-area scenario focuses on trans-Alpine flows, and the European-core-scenario prioritizes the large-scale interrelations.

3.1.2 An Alpine spatial development vision on environment

The objective is to achieve a sustainable spatial development process that goes beyond domestic regimes but that develops potentials on a cross-border and transnational scale, a **common definition of priorities and complementariness** was created to facilitate a spatial development that addresses common challenges.

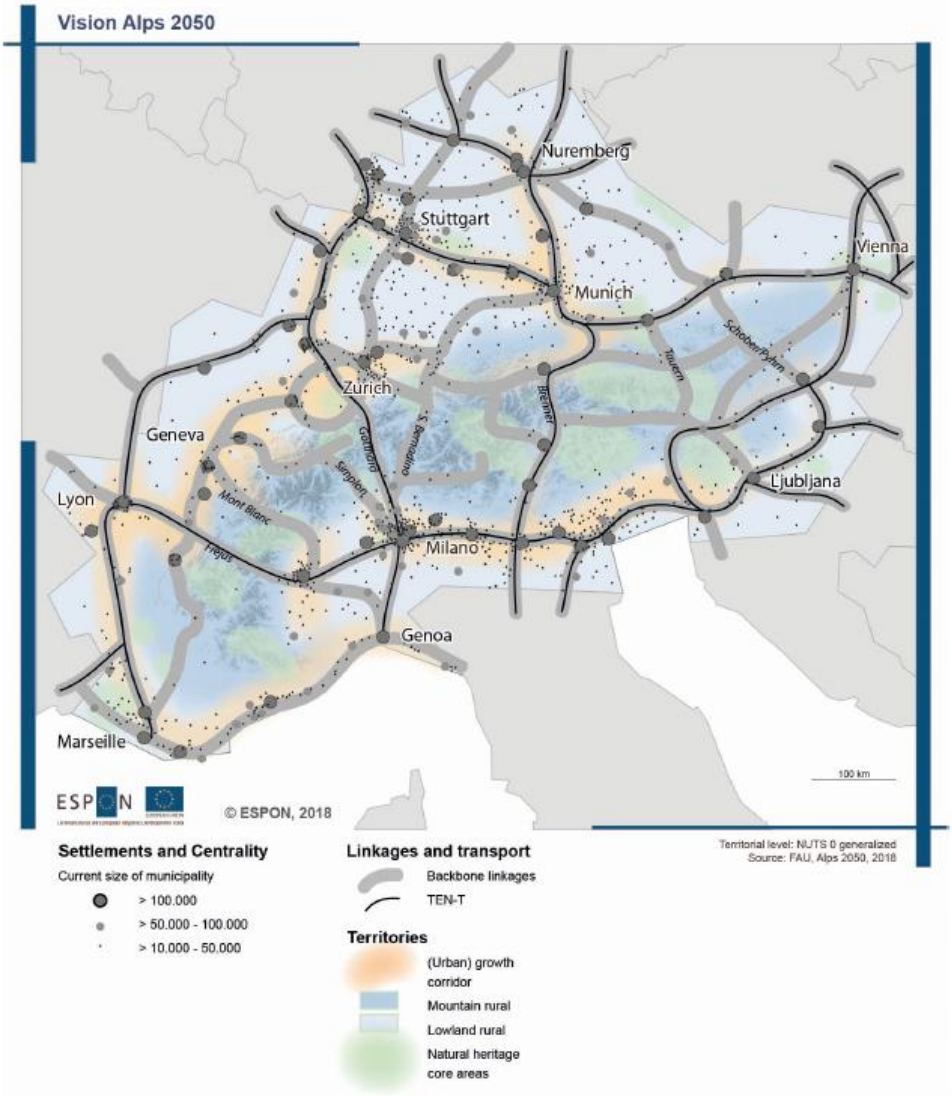


Figure 26: The territorial structuring of the Alps 2050 vision (source: ESPON: The Alps 2050 Target Analysis)

From the environmental perspective, this involved all key principles of ecological development, including limitations to soil sealing and settlement sprawl, and ecological connectivity by means of and beyond protected areas. Climate change mitigation and adaption measures are crucial. To address the much accelerated and particularly dangerous threat, the implications of climate change must be addressed mostly on the Southern side of the Alps. Adaptation strategies embrace risk management, including mountain forest management, and water resources management. Measures of sustainable mobility, new construction modes and energy systems contribute to climate change mitigation.

Protected areas are an important facet of environmentally sound development. The following map is not meant to show the exact protection regimes but illustrates a spatial category that **prioritizes action** to protect and develop natural heritage, considering touristic potentials wherever reasonable (in the map based on existing UNESCO sites and national parks).

Political Action calls for Cross-border protection regimes: the hitherto established protection areas are predominately selected and restricted to national boundaries. Strengthening the cross-border dimension is very promising, considering the primary challenge of ecological connectivity.

Regarding juridical instruments, the scope is limited. On the European level, the mandates for **spatial planning** are rather weak, and this is also true for the transnational level. Against this background, soft tools of spatial development, including cooperation processes, strategy formulation processes, monitoring etc. play a key role. A series of INTERREG projects has often helped to initiate and foster these elements. Spatial development cannot be based on soft instruments alone, but they must be embedded in binding development strategies. Now, the binding elements are mostly located on the domestic level (e.g. spatial planning, transport system development) and on the European level (e.g. Habitats directive). The intergovernmental treaty of the Alpine Convention is binding among the Parties who have ratified it, including the Protocol on Spatial Planning and Sustainable Development.

3.1.3 Political context and cross border cooperation on spatial planning, ecological connectivity and green and blue infrastructures

About cross-border protection regimes, the hitherto established protection areas are predominately selected and restricted to national boundaries. Considering the primary challenge of ecological connectivity strengthening the **cross-border dimension** is very promising. The existing platforms on the transnational level (the EUSALP action groups and the Alpine Convention working bodies) are without a doubt a good basis for developing Inter-regional policy processes and cooperation among its member countries to address ecological connectivity on a macro-regional scale. This includes joint projects, knowledge sharing, and harmonizing policies and practices.

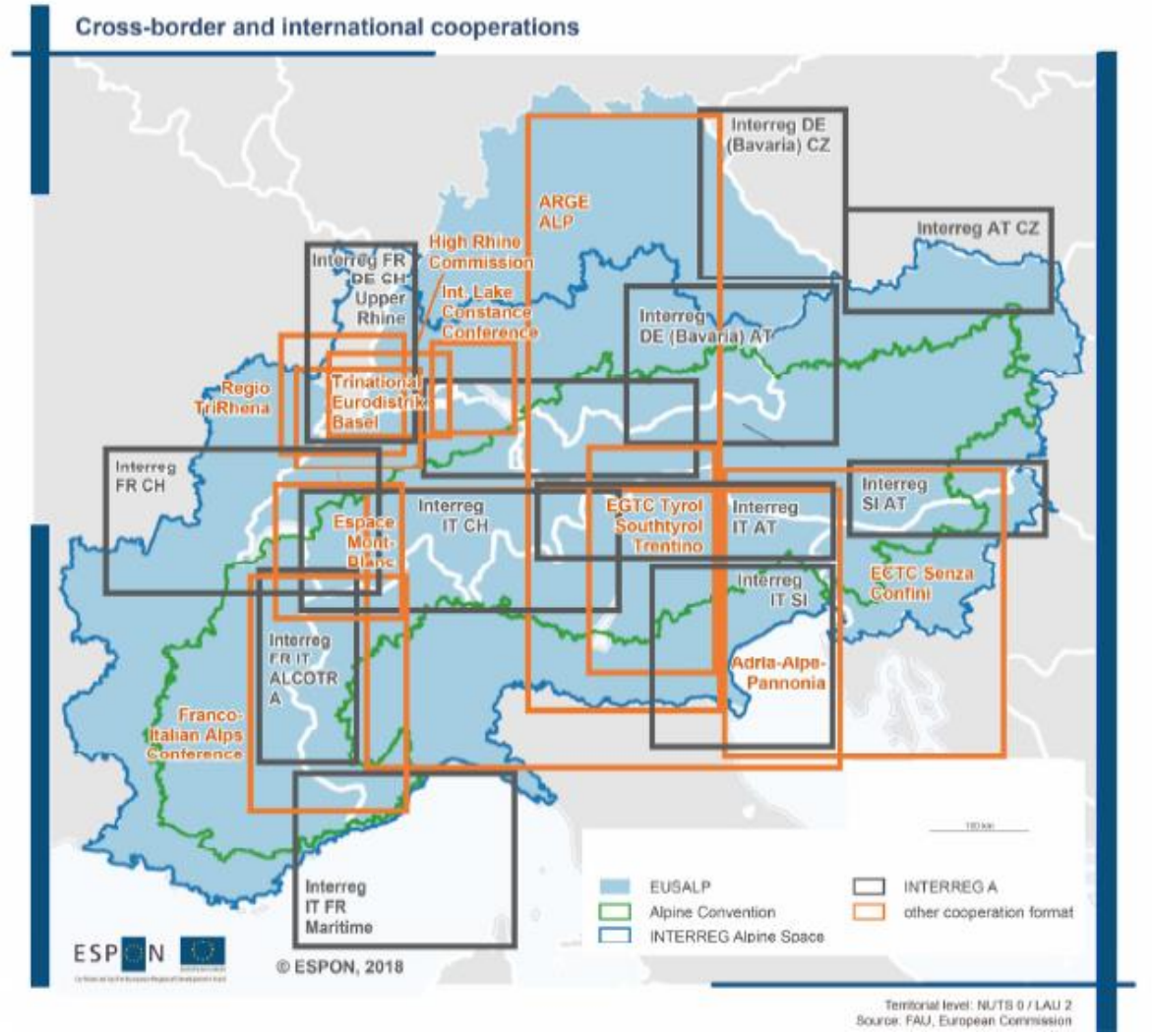


Figure 27: Cross-border and international cooperation in the Alpine area (source: ESPON: The Alps 2050 Target Analysis)

Within the EUSALP political context, initiatives like the Alpine Convention and the Alpine Space Programme support **collaborative efforts** to improve ecological connectivity. The table below shows the links between EUSALP action groups, Alpine Convention working groups and Alpine Space Specific objectives regarding ecological connectivity and spatial planning in the Environmental perspective.

Table 3: EUSALP policy framework per objectives (source: ESPON: The Alps 2050 Target Analysis)

EUSALP objectives (action groups, AG)	Alpine convention protocols (working bodies)	INTERREG Alpine Space priorities (specific objectives, SO)
Environment	Prot. Spatial planning and sustainable development Prot. Nature protection and landscape conservation Prot. Energy Prot. Soil conservation	Low carbon Alpine Space Liveable Alpine Space
ì	Alpine Climate board	
	Ad hoc Expert group on Spatial planning	
Energy (AG8)		Low carbon policy instruments (SO2.1)
Green Infrastructure (AG7)	Ecological Network Platform Mountain forests working group	Ecological connectivity (SO3.2)
Resources (AG6)	Water Management in the Alps Platform	Cultural and natural heritage (SO3.1)
Risk governance (AG8)	Natural hazards platform PLANALP	
	Large Carnivores, Wild Ungulates and Society platform WISO	

SECTION 2

ECOLOGICAL NETWORKS IN THE ALPINE SPACE: MOSAIC OF NATIONAL AND REGIONAL CONNECTIVITY CONCEPTS

4 Ecological networks planning

The pan European biological and landscape diversity strategy (PEBDLS)[18] was developed under the auspices of the Council of Europe in order to achieve the effective implementation of the convention of biological diversity (CBD) at the European level. A key element of PEBLDS has been the development of the Pan European Ecological Network (PEEN) as a guiding vision for coherence in biodiversity conservation. PEEN has been developed in three subprojects: Central and Eastern Europe, completed in 2002; South-eastern Europe, completed in 2006; and Western Europe, also completed in 2006. The methodology of the development of the three maps has been broadly comparable but data availability, differences in national databases, technical developments and geographical differences caused variations in the detailed approach.

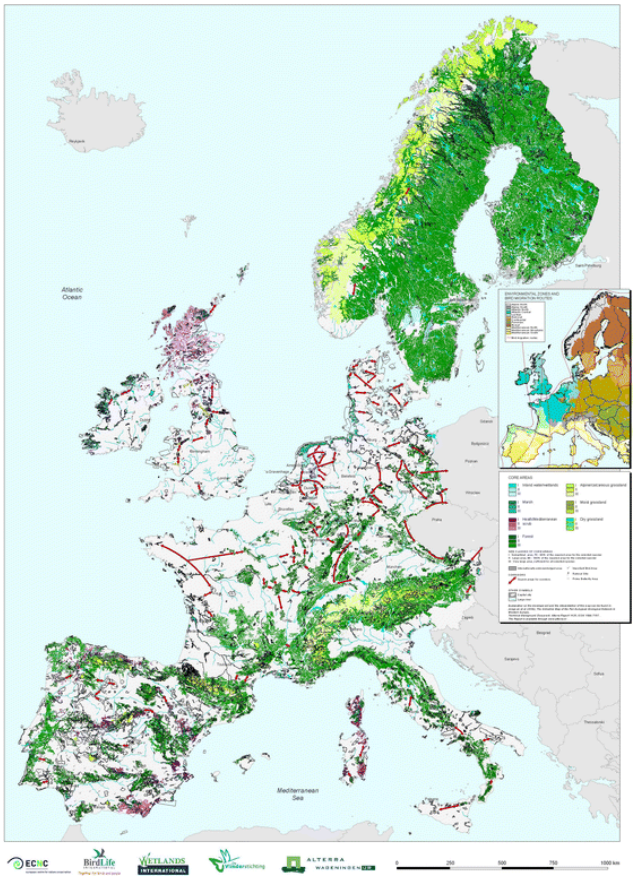


Figure 28: The map of Pan European Ecological Network for Western Europe (source: Jongman et al. 2006a)

[18] https://www.eea.europa.eu/policy-documents/pan-european-biological-and-landscape

This section of report has compared and analysed the state of art on Ecological Network planning in the Alpine Space territory highlighting issues of coherence, comparability, data availability, differences in national databases, technical developments and geographical differences with the intention to identify main potential areas of inconsistences across national and regional borders and provide recommendation for cross-border cooperation in the framework of an Alpine Planning Strategy for Ecological Connectivity.

4.1 The current mosaic of Alpine ecological network concepts

Following paragraphs contains the description of the current mosaic of national and regional ecological network concepts in the Alpine space. The overall mosaic is represented in the GIS map below

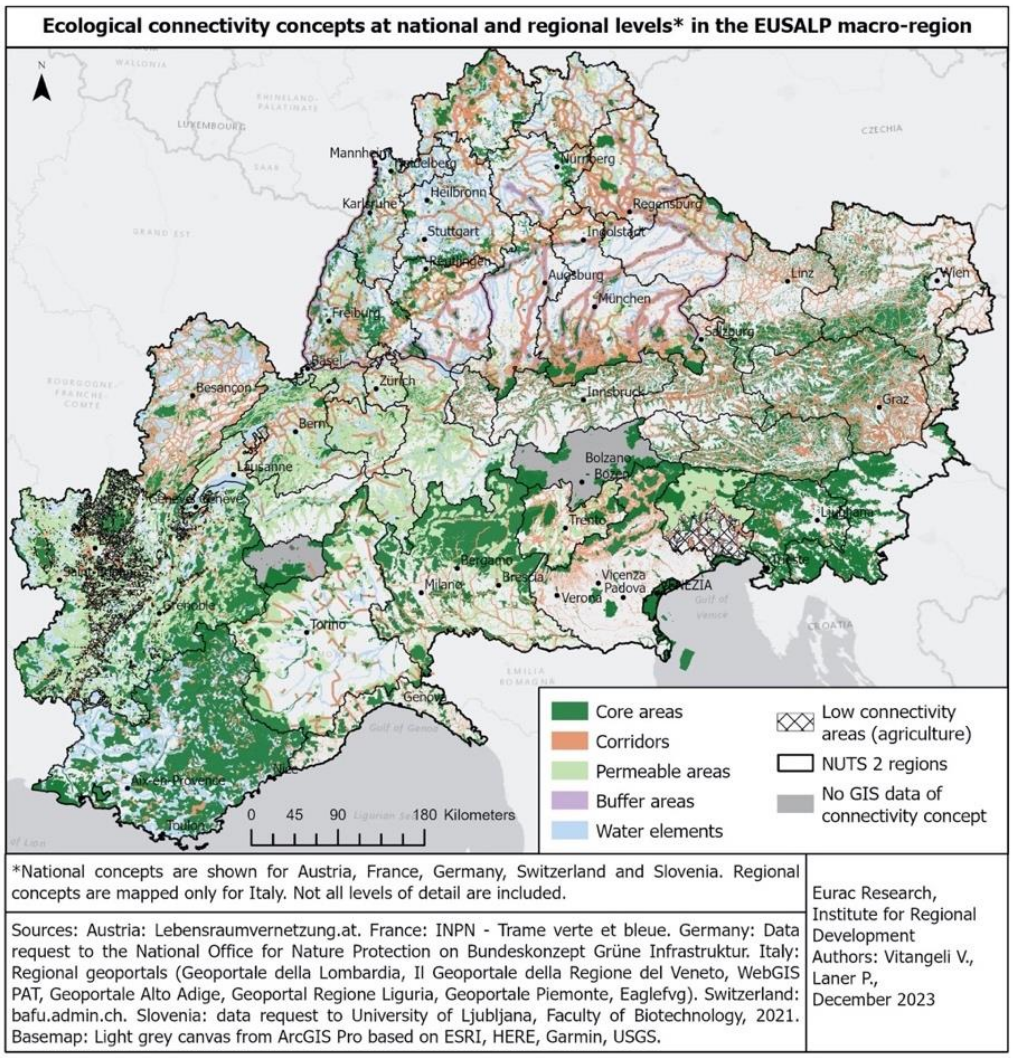


Figure 29: Ecological networks mosaic (source: EURAC)

4.1.1 Connectivity planning approaches in the Alpine Space

In terms of ecological networks, functional and structural ecological corridors are critical components of landscape planning for preserving and improving ecological connection, that should be considered as multiscalar and multifunctional concepts, to be adapted at differ.

Functional corridors are intended to aid the migration and distribution of specific species or groups of species. These corridors accommodate for the target species behaviour, habitat requirements, and migration patterns. Species-Specific Design is intended to meet the needs of specific species or groups of species. For example, a corridor for amphibians may include wetland habitats, but a corridor for large mammals may include forested areas. Behavioural considerations contemplate species daily, seasonal, or life-stage-specific movement habits. The Habitat Quality approach ensures that the habitats inside the corridor provide adequate resources like as food, shelter, and breeding places.

Structural corridors, on the other hand, emphasize the physical qualities of the environment that promote connectedness. They are more concerned with habitat physical continuity than with species specificity. Physical continuity ensures that natural or semi-natural habitats extend over the area. Considering Landscape elements, structural can connect existing landscape elements, such as hedgerows, rivers, and mountain ranges. For a broad applicability of the concept, this approach is intended to assist a diverse variety of species by preserving habitat continuity and reducing habitat fragmentation.

Functional and structural corridors are essential for preserving biodiversity and ecosystem health. Effective landscape planning frequently includes both types of corridors to achieve complete biological connectedness. Functional and structural ecological corridors play critical roles in landscape ecology and conservation planning. By keeping landscapes connected, these corridors help to maintain biodiversity, support ecosystem services, and boost the resilience of both natural and human systems in the face of environmental change.

4.1.2 Methodological aspects, objectives and network structures

The **methodology** for creating ecological networks in Austria, Germany, Slovenia, Switzerland, France, and Italy varies depending on the region.

In **Austria**, a landscape model was created, calculating optimal habitat corridors using GIS, and validated through a participatory project with stakeholders. In **Germany**, the BKGI approach focuses on protecting natural and cultural landscape heritage diversity, materialist functions, and immaterialist functions. **Slovenia** Green infrastructure network scheme uses a structural approach to preserve wildlife habitat connectivity, with linkages derived from ‘Least-cost path’ analysis and monitoring of species transitions.

In **Switzerland**, the Three Directions for the Development of a Functional Ecological Infrastructure (EI) aims to ensure the quality of existing areas, use existing processes for quantitative expansion, and supplement areas to close gaps. In **France**, the ecological

continuity network of the Trame verte et bleue (TVB) is defined by the hydrographic network and does not differentiate between biodiversity reservoirs and ecological corridors.

In **Italy**, the Po Valley covers the Alps and Apennines, encompassing the Adriatic and Tyrrhenian seas. Ecological Networks models are created by 6 Ordinary Regions and two Special System Authorities, with most designs regionally determined and integrated by Provincial and Municipal plans. The **Ligurian** Ecological Network was constructed using geometries from the Liguria Region Land Use Map, while the Life+ T.E.N. project aimed to design an ecological network in **Trentino**, Italy.

The **Veneto** Region Ecological Network was constructed by analysing environment conditions, identifying ecologically homogeneous areas, and defining the framework based on naturalistic characteristics. The Regional Ecological Network in **Friuli Venezia Giulia** is structured into three levels: structural, functional, and project.

Passing to **objectives and network structures**, this is the Alpine Space framework that emerges from the analysis.

The **Austrian** Biodiversity Strategy 2020+ aims to preserve species and habitats by establishing a functional biotope network and considering biodiversity and ecosystem services in spatial planning and transport. The network focuses on clean air, water, food timber, recreational space, water retention, climate regulation, and genetic resources. It consists of modelled corridors that connect large and slightly fragmented core habitats and Natura 2000 sites. The networks consider thematic aspects of terrestrial green habitat connectivity, but not those of wet or dry habitats.

In **Germany**, the BKGI focuses on protecting ecosystems and their services, aiming to simplify coordination with neighbouring states, integrate existing nature conservation concepts, and concrete spatially relevant targets. Its concept focuses on spaces and elements in nature and landscape that are remarkable in their qualitatively seldom or extraordinary characteristics and therefore not replaceable. The network consists of three main categories: habitat, species, and territorial systems.

The Spatial Planning Strategy of Slovenia 2050 (2023) focuses on ecological, environmental, climatic, economic, and social objectives. The ecological network objective is to maintain connectivity of wildlife habitats, particularly forest habitats, to maintain wildlife species that use these corridors to move between habitats. Slovenian green infrastructure network consists of core areas, including large geographical units, protected areas, and natural landscape elements. The strategy aims to ensure connectivity between these areas through natural linear and punctuated landscape elements. The network also focuses on ecological function by linking ecologically important landscape features across national borders, removing barriers, and improving natural ecosystem conditions. Core areas include nodes being habitats for brown bear (forests), red deer (grassland/forest), vultures (gliding birds), aquatic birds (wetlands), and migratory fish species.

The **Swiss** Biodiversity Strategy Action Plan translated these goals into actions through initiatives and environmental legislation. It aims to promote biodiversity, create links between

the Confederation biodiversity policy and other policy areas, and raise awareness among decision-makers and citizens about the importance of biodiversity. The Federal Council extended the first phase of the Plan until the end of 2024 and directed the FOEN to develop an Action Plan for the second phase, running from 2025 to 2030.

The Swiss Landscape Concept (SLC) defines the preservation and networking of valuable habitats as a quality objective, requiring sectoral policies from the Confederation and cantons to contribute to the creation of its ecological infrastructure. As of 2020, Switzerland has 304 wildlife corridors of supra-regional importance, linking fragmented ecosystems or suitable habitats and are essential for species.

The Ecological Infrastructure (EI) in Switzerland is related to protected areas and other priority areas, including biotopes of national, regional, and local importance, such as floodplains, amphibian breeding sites, marshes, dry meadows, pastures, and reserves of international and national importance for waterfowl and migratory birds. Interconnection zones are essential for long-term biodiversity protection, ensuring connectivity to priority areas beyond cantonal and national borders.

In **France**, the TVB objectives are enunciated on national guidelines and aim to contribute to the preservation and restoration of ecological continuity to prevent biodiversity loss. Planning documents must follow national guidelines and focus on reducing fragmentation, conserving, and connecting areas important to biodiversity conservation, implementing water quality and quantity objectives, facilitating wildlife biology, and improving landscape quality and diversity. It consists of two main elements: core areas with rich biodiversity and natural habitats that function properly. These reservoirs include protected areas, watercourses and canals, wetlands, and ecological corridors. Ecological corridors provide connections between these reservoirs, offering species favourable conditions for movement and completing their life cycle.

In **Italy**, waiting for the National Ecological Network project to be developed, the Environmental legislation led to the identification of several national parks in the 1980s and the creation of a legislative framework for parks in 1994. In 2010, Italy preserved areas covered 10.50% of the national territory and were divided into 24 national parks, 147 national natural reserves, 27 marine protected areas, 134 regional natural parks, and 171 other protected areas.

The regional law in **Piedmont** outlines procedures for biodiversity conservation and management of protected areas, including Piedmont system of protected areas, contiguous areas, Special Areas of Conservation (SAC), Sites of Community Importance (SCI), Special Protection Areas (SPA), natural protection zones, ecological corridors, and other important land features.

In **Liguria**, the main purpose of the regional ecological network is to preserve natural resources important for the conservation, migration, geographic distribution, and genetic exchange of wild species. The objectives of the network include maintaining ecosystem functionality, ensuring ecological coherence, avoiding environmental fragmentation, and

fostering ecological connectivity among species of community interest. The Ligurian Natura 2000 Network consists of 126 Special Areas of Conservation (SAC/SIC), 27 marine sites, and 7 Special Protection Areas (SPA), representing 29.1% of the territory. The network includes all three bio-geographical regions in Italy: Alpine, Continental, and Mediterranean. Ligurian resources and natural assets have been preserved through the establishment of a system of protected areas on a regional scale. The system includes three state Marine Protected Areas, one in the process of being established, and the Marine Protection Areas of two regional protected areas. The Alta Via of Ligurian mountains and the Excursion Network of Liguria (REL) represent a model of sustainable accessibility to protected areas.

The main network purposes in **Lombardy** are the conservation, recovery, and valorisation of natural and environmental assets, considering local interests in economic and social development. The system is governed by the Regional Protected Areas Plan, which includes one national park, 24 regional parks, 101 parks of supra-municipal interest, three national nature reserves, 67 regional nature reserves, 33 natural monuments, 246 Natura 2000 Network sites, 147 CIS, 67 SPZ, and the Regional Ecological Network. The RER scheme was approved with the Regional Act n. 8/10962/2009, which includes directives for avoiding land and soil transformations, first-level elements, and transformation areas.

The Autonomous Province of **Bolzano** spatial planning law focuses on protecting and enhancing landscape and natural resources. The future Provincial Strategy Plan aims to increase the provincial protected area to at least 30% by 2030, including strategic areas for ecological connectivity. The law also includes ecological functions to counteract climate change. Protected elements include lakes, rivers, mountain areas, glaciers, Stelvio National Park, nature parks, forests, wetlands, and archaeological sites. Municipal landscape plans define areas covered by landscape protection, with ‘natural monuments’, nature parks, biotopes, and protected landscape elements being the most important for ecological connectivity. Protected landscapes and landscape respect zones indirectly contribute to ecological connectivity but are less important for large-scale ecological connectivity. A provincial dataset maps all landscape elements, but there is no explicit prioritization for GBI protection.

The Provincial Urban Plan of the Autonomous Province of **Trento** aims to ensure ecological connectivity, promote sustainable development, and define a reference framework for community and municipal planning. The plan includes a map of ecological and environmental networks, identifying areas suitable for interconnecting spaces and natural resources to ensure ecosystem functionality and biodiversity conservation. The objectives align with the European Biodiversity Strategy 2030, but do not explicitly include the guarantee of ecological processes/functions/services. The ecological and environmental networks include water resources, wells and springs protection, lake and river protection areas, high naturalness areas, and high integrity areas. Specific provincial provisions apply for the protection and use of these areas.

The Regional Ecological Network in **Veneto** was created to address the environmental and natural changes caused by human activities, such as industrialization, land use changes, road construction, and urbanization. The network aims to ensure adequate habitats for

species survival, sufficient connectivity, protection from edge effects, maintenance of primary ecological processes, balance between ecosystems and human activities, ecosystem continuity, and greater sustainability of settlements. It covers 40% of the Veneto region, with Belluno having the highest percentage of mountain core areas. The network consists of core areas, continuous or widespread linear ecological corridors, and caves. Additionally, 46 Biodiversity Priority Areas are identified, with three in mountainous areas and 43 in hilly and lowland areas. These areas are crucial for ecological processes and are in areas where the conflict between nature conservation and anthropogenic development is higher. The network also includes the pilot area of 'Caorle Lagoon' and the Estuary of the Tagliamento River.

The Ecological Network in **Friuli** aims to conserve nature and preserve biodiversity within the Regional Landscape Plan (RPP). A study was conducted to identify ecological connection routes, focusing on the distribution of target habitats and species in urbanized landscapes and mountain and lowland areas of the Friuli Venezia Giulia region. The network defines specific goals for different areas based on characteristic threats. The main objectives include the conservation of Alpine and pre-alpine areas, hill systems, high plains, lower plains, sedimentary coastal systems, and karst. The Friuli Venezia Giulia Region is divided into ecotopes, each with a predominant function. These categories include core areas and buffer strips, connective categories, discontinuous connectives, and areas of poor connectivity. Core areas maintain target populations of flora and fauna, buffer strips protect sensitive habitats, connective categories encourage biological population dispersion, discontinuous connectives support mobile organisms, and areas of poor connectivity reduce movement and relationships among terrestrial wild-life species.

4.1.3 Regulatory and legislative aspects

In terms of **regulatory and legislative aspects**, the Alpine Space Ecological networks have a varied background.

The **Austrian** Habitat network is a national concept commissioned by the Ministry of climate, environment, energy, mobility, innovation, and technology. It aims to legalize habitat networking, exchange knowledge, coordinate habitat connectivity criteria, provide a contact point for questions, and provide current planning bases. Although **not legally binding**, the network is harmonized on federal and national boundaries and partially integrated into federal GIS systems. It is available as a nationwide data set for spatial planning and sectoral planning in various contexts.

The BKGI is a national concept in **Germany** that aims to integrate national conservation targets with spatial planning targets, such as minimizing spatial usage conflicts, establishing large open space networks, creating cultural landscapes, reducing land use, adapting to climate change, and regulating renewable energy development. It aims to harmonize different planning sectors in the EU Biodiversity strategy. **The BKGI is an informal concept** that combines existing spatial plans for eco-system protection and is only available as a

national concept. It has been applied to all federal states, but implementation is still early in Bavaria.

The Federal Green Infrastructure Concept (Nature Conservation Foundations for Plans Adopted by the German Federation) faces inconsistencies in data, knowledge, and methods used to assess content. There is still much development work needed on topics like landscape diversity, the Blue Belt program in Germany, and marine environment. These concepts are in preparation and will be integrated into the Federal Green Infrastructure Concept in the future. The Federal Nature Conservation Act mentions the protection of natural and cultural landscapes as an aspect of national conservation, and their importance for engagement with nature and recreation. The main objective is to develop a nationally significant inventory of significant landscapes, which is crucial for planning-relevant decisions and quality improvement.

The German Federal Government Blue Belt (BBD) program aims to promote the renaturation of watercourses and floodplains along federal waterways. This includes reviewing and potentially renaturing the 2,800-km-long network of secondary federal waterways, restoring shallow water areas, levelling banks, and developing damp and wet meadows. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety emphasizes measures such as removing bank reinforcements, restoring floodplain habitats, promoting extensive uses, and reducing bottom erosion. The program is currently in an intensive phase of development.

The Action Plan for Protected Areas, jointly developed by the German Federation and the Länder, aims to safeguard the significant contribution of protected areas to biological diversity conservation and develop their role to address current and future challenges. The research and development project involves a nationwide study of protected area representation, management, and integration into landscapes, as well as flagging up options for further development up to 2030.

The German Federation competence in the German Exclusive Economic Zone (EEZ) in the North Sea and Baltic Sea provides it with specific functions for marine conservation. However, local protection measures alone are insufficient to ensure good environmental status and favourable conservation status. Additional spatial measures are necessary to ensure connectivity between marine protected areas and make measures mandatory outside protected areas. The Federal Agency for Nature Conservation is developing concepts to spatially implement measures under the Marine Spatial Planning Directive (MSFD). Marine spatial planning is crucial for establishing spatially operationalizable measures that are compatible with conservation targets. The Federal Agency for Nature Conservation is working towards updating these objectives and principles through research and development projects. An ecosystem approach is being used to strengthen networking structures in marine areas and implement an ecosystem-based methodology for human activities in the sea.

The Federal Green Infrastructure Concept in Germany, then, aims to enhance the conservation of biological diversity and ES by integrating data on endangered animal and

plant species. The concept will be used in various fields, including transport infrastructure planning, power grid expansion, and spatial planning. The Federal Transport Infrastructure Plan includes roadbuilding and waterways projects, assessed from a nature safeguard perspective. The Federal Green Infrastructure Concept will provide fundamental data for parties involved in these projects, ensuring legal security and addressing nature protection problems. The 2016 Federal Regional Planning Act emphasizes the protection of biodiversity in regional planning, and the Federal Green Infrastructure Concept will be included in the Standing Conference of Ministers Responsible for Spatial Planning (MKRO) models and strategies for action on spatial development in Germany. The concept will also be incorporated into the German Federation spatial development plans, ensuring a solid data basis for new functions.

The German Federal Government aims to reduce daily new land take for settlements and transport to 30 hectares minus x per day by 2030, focusing on upgrading infrastructure in undesignated areas and land-saving treatment of inner-urban areas. The Green in the City paper commits to improving green amenities in towns, cities, and communities, with urban green infrastructure being of equal value to other concerns. The Nature Conservation Campaign 2020 emphasizes nature-friendly agricultural policy and support. The Federal Concept describes priority areas and topics for green infrastructure conservation, aiding decision-making on federal funding instruments. The European Union supports the development of trans-European networks in transport, energy, and telecommunications sectors, requiring aggregated data on natural amenities. The safeguarding and development of green infrastructure will require cooperation with other federal departments and the German Federation, the Länder, and municipalities.

The Spatial Planning Strategy of **Slovenia** 2050 (2023) defines green infrastructure as a strategically designed network of natural and semi-natural areas, including green spaces in settlements and coastal areas. It aims to conserve biodiversity, increase resilience to climate change, improve ecosystems, and benefit the population in terms of health, safety, quality of life, and spatial identity. **Green infrastructure** is planned at regional and local levels and **is legally binding** as a strategic content. However, it needs more detailed definition at regional and local levels. Slovenia Forest Service developed the Methodology to protect corridors at national level: the currently pro-posed corridors should be checked and respected (from 2023 on) in any spatial plan adoption or changes procedure (municipal, regional or national), where the opinion (or terms) on the compatibility of interventions is requested (by the Spatial Management Act). The document is now legally binding (statutory framework). It should be used on any level of spatial planning (not cascading).

The **Swiss** Constitution mandates cantons to protect nature and landscape as federal goals. The Confederation safeguards landscapes, historical sites, and cultural monuments, and supports conservation efforts. Federal regulations cover fauna, flora, endangered species, and special beauty wetlands. The Ecological Infrastructure (EI) is a national binding project. cantons are responsible for planning ecological infrastructure, with the Federal Office for the Environment developing a guide to define priority areas. The Swiss Landscape Concept (SLC) defines the preservation and networking of valuable habitats as a quality objective. It

requires that the sectoral policies of the Confederation and the cantons contribute to the creation of its ecological infrastructure. As of 2020, Switzerland has 304 wildlife corridors of supra-regional importance. They link fragmented ecosystems or suitable habitats and are essential for species. The main structure of the Ecological Infrastructure (EI) is related to protected areas and other priority areas, which include biotopes of national, regional and local importance.

The Trame verte et bleue - TVB (green and blue infrastructure) is the ecological network framework **in France**, it was introduced by the Grenelle I (2009) and II (2010) laws to reduce the fragmentation of natural and semi-natural habitats and to take better account of biodiversity in spatial planning. This legal framework which al-so includes decrees and other legal provisions, define the main lines of action of the ecological network, objectives, concepts, the role, and orientations of three territorial levels in the implementation (national, regional and local). Urban planning documents at local levels must consider the Regional Ecological Coherence Scheme (SRADDET) and national guidelines. The national TVB is created using geographical data from regional-scale ecological networks, restitution of regional ecological continuities at the national level. The national map serves as a tool for planners and practitioners.

Table 4: The Alpine Space framework of ecological networks

Country	Kind of network	Planning level	Mandatory or not	Specific regulations
Austria	Other: project 'Habitat Network'	NUTS 0	no	no
France	Ecological network plan (Trame verte et bleue)	NUTS 0	yes	yes
Germany	Other: German Federal Green Infrastructure Concept	NUTS 0	no	no
Slovenia	Other: Green infrastructure network Ecological network plan: "Corridors to maintain wildlife habitat connectivity" by Slovenia Forest Service	NUTS 0	yes/yes	no/yes
Switzerland	Ecological network plan (Ecological Infrastructure)	NUTS 0	yes	yes
Bolzano	Protected area network Informal studies on Ecological connectivity (2022 ASP project LUIGI, 2015 EURAC)	NUTS 2 and 3	Yes/no	Yes/no

Friuli Venezia Giulia	Ecological network plan	NUTS 2	yes	yes
Liguria	Ecological network plan	NUTS 2	yes	yes
Lombardy	Ecological network plan	NUTS 2	yes	yes
Piedmont	Ecological network plan	NUTS 2	yes	yes
Trento	Protected areas network “Trentino Multipurpose Ecological Network”	NUTS 2 and 3	yes/no	yes/no
Veneto	Ecological network plan	NUTS 2	yes	yes

In Italy, Law No. 349 of 1986, which established the Ministry of Environment and included the idea of environmental damages in **Italian national legislation**, was the first law in the country to define the environment as a diffuse value in a modern sense. Although several national parks, such Gran Paradiso (1922), Abruzzo (1923), Circeo (1934), and Stelvio (1935), were established and recognized decades earlier, Italy introduced a fundamental framework for natural parks with law no. 394 of 1991. After Sweden, Switzerland, and Spain, Italy was the fourth nation in Europe to establish two natural parks.

By now, no national unified concept was enforced yet, as the National Ecological Network project, promoted by the Ministry of the Environment and Protection of Land and Sea, is a practical tool for orienting and scheduling territorial planning and natural resource usage at the national level. The national Ecological Network Project in Italy could be a significant initiative aimed at enhancing ecological connectivity and biodiversity conservation across the country. This project involves various strategies and methodologies to create and manage ecological networks that mitigate habitat fragmentation and support the movement and survival of species. Several models of ‘networks’ have been built under this project, conceived as a global network that contemplates all vertebrate species existing in Italy, a specialized network for each taxonomic category[19].

Considering **Ecological Networks and Territorial Planning**, the Italian Institute for Environmental Protection and Research (ISPRA) has contributed significantly to research on land fragmentation and ecological connectedness. The initiative aims to create interconnected habitat systems including core regions, buffer zones, and corridors to enable species interchange and lower the danger of extinction. Its initiatives include producing

[19] https://www.mase.gov.it/pagina/rete-natura-2000

guidelines and practical instruments to support territorial policies and planning, ensuring that ecological connection is included into local and regional frameworks.

Overall, promoting a national unified Ecological Network design in Italy could be a comprehensive attempt to include biodiversity conservation into land use planning and management, resulting in a more sustainable and resilient environment.

Being Environmental protection and **Spatial planning topics** that are managed by both the National and Regional legislative levels, most of the planning concepts in terms of ecological networks were defined at regional levels, with Landscape Regional Plans having a primary role in their definitions. Several Italian Regions have incorporated ecological and landscape networks into their planning efforts.

In Italy, at the national level, there is also the **2030 National Biodiversity Strategy**[20], which pursues two goals:

1. Build a coherent network of terrestrial and marine Protected Areas with the goal to establish 30% of protected areas on land and sea, and 10% strictly protected areas,
2. Restore terrestrial and marine ecosystems, reaching a restoration of the 30% of the conservation status of habitats and species, particularly through the activity conducted at the regional scale about the objectives and conservation measures of Network Natura 2000 sites.

18 actions are formulated to achieve these targets. Read more on this topic in 2030 National Biodiversity Strategy, Ministry of Environment and Energy Security (mase.gov.it).

E.g., **Piedmont, Lombardy, Tuscany, and Puglia** have created regional landscape plans that emphasize their landscapes' ecological importance and ecosystem services. These plans aim at maintaining and increasing ecological connection by identifying biodiversity aspects, ecological corridors, and restoration areas. The regional tools usually entail the construction of a green system that mixes ecological aspects with historical and cultural assets to promote a multifunctional and sustainable landscape.

The implementation of these tools is mostly **multiscalar**, with Provinces, Municipal Authorities, Park Administrations and other NUTS3/4 level bodies being entitled of the detailed design and accomplishment of the Regional goals and concepts. Some of these plans include extensive measures to preserve biodiversity and control land take, highlighting the importance of soil protection and the preservation of ecological continuity within urbanized areas.

Piedmont Region developed the Regional Ecological Network through the Regional Law no. 19 of 2009 - Con-solidation Act on the Protection of Natural Areas and Biodiversity - identifying within it the Regional System of Protected Areas as a fundamental network

[20] https://www.mase.gov.it/pagina/strategia-nazionale-la-biodiversita-al-2030

component. It consists of national parks, state nature reserves (for the part falling within the regional territory), and protected areas under regional, provincial, and local man-agement (NUTS 2). As in the Lombardy region, in Piedmont the elements that make up the ecological network are subject to pro-tection by the competent authorities. For ecological corridors included in urban and territorial instruments at any level, the authority responsible for plans or interventions' approvals affecting ecological corridors defines the interventions necessary to compensate for any negative effect.

The Liguria region has developed a Regional Ecological Network Project based on the Natura 2000 Network ex-tended by functional ecological linkage areas. It has not introduced the Green and Blue Infrastructures con-cept. The Regional Ecological Network (RER) is the framework for the construction of Ecological Networks of local administrations: Metropolitan City of Genoa, Provinces, Municipalities and for other institutions involved in land planning and management..

The **Lombardy** region Protected Areas Network, established in 1983, regulates the management of natural reserves, parks, and monuments, as well as areas of special environmental importance. The network is governed by the Regional Protected Areas Plan, which includes national parks, regional parks, and natural monuments. The network is part of a cascading planning system, with specific plans implemented at the municipal level. The Regional Territorial Plan (PTR) assumes the Regional Ecological Network (RER) as a main green infrastructure, integrating it with other green system components and open spaces.

The Autonomous Province of **Bolzano**, a NUTS 2 and NUTS 3 region, lacks a legally binding ecological network concept. The new provincial spatial planning law recognizes existing GBI elements in the landscape, but there is no spatial planning document to take over existing analysis. The Provincial Strategy Plan (PSP) is in phase of review and approval, which may include ecological connectivity as a main objective under the macro-topic of 'Biodiversity'. However, most legally binding ecological network elements are included in municipal landscape plans and have protective functions. A study about the current state of structural ecological connectivity was conducted in 2022 in course of the Interreg Alpine Space LUIGI project by the Institute for Alpine Environment of Eurac Research and another one about local wildlife passages in 2015 by the Provincial Office for Landscape Planning, but without legal binding. By March 2024, informal studies regarding ecological connectivity at provincial level are considered by spatial planning offices for municipal development programs or by Impact and Strategic Environmental Assessments. Some municipalities are elaborating in-depth landscape analyses on voluntary basis, with 38 out of 116 municipalities choosing specific topics for in-depth landscape analysis.

The Autonomous Province of **Trento** (Provincia autonoma di Trento, PAT) is a NUTS 2 and NUTS 3 region with over 620,000 hectares, with over 30% protected. The concept of ecological networks is referred to in legislation on protected areas and territorial governance. The Trentino Multipurpose Ecological Network includes all parks, sites of the Natura 2000 Network, and territorial areas of ecological integration. The Life+ T.E.N. project was launched in 2012 to define a Provincial Ecological Network, which is now part of the Provincial Urban Plan (PUP) and 16 Community Territorial Plans. The Ecological Network

is also considered in the Provincial Urban Plan (PUP) and is part of the 16 Community Territorial Plans.

The **Veneto** Region in Italy has a Regional Ecological Network scheme (RER) as part of the Regional Territorial Coordination Plan (PTRC). The RER aims to preserve, protect, and enhance biodiversity, improving ecological connectivity in the territory. It integrates nature conservation in Protected Areas (parks and nature reserves) and Natura 2000 sites, while enhancing biodiversity and widespread naturalness in man-made territories. Italy has no National Ecological Network framework, but several protection models exist, including National Parks, Natura 2000 sites, and UNESCO Biosphere Reserves. The 2030 National Biodiversity Strategy aims to build a coherent network of terrestrial and marine Protected Areas and restore terrestrial and marine ecosystems. The RER is part of a cascade system, with regional, provincial, and municipal levels coordinating the design, actions, and measures to protect, build, and restore ecological connectivity in the Veneto Region.

In **Veneto**, the regional level defines the overall scheme, the nodal points on which the network is based, and the main connectivity routes (corridors). It also defines the tasks for the lower administrative levels. The provincial level, crucial for ecological network construction in Veneto Region, develops a detailed design aligned with regional schemes, while outlines directions and actions for municipal implementation. the municipal level incorporates the directions of the higher administrative levels and is responsible for developing the local design, actions, and measures to protect/build/restore ecological connectivity.

The Regional Ecological Network (REN) of **Friuli** is aimed at ensuring connectivity to natural and semi-natural ecosystems, based on the assumption that not isolated ecosystems ensure landscape quality and the functioning of eco-system services. The Regional Ecological Network identifies natural, semi-natural, rural, and urban land-scapes for the purpose of conservation, improvement and increase of landscape quality and ecological connectivity of the regional territory. The ERN relates to the entire regional territory, which is divided, classified, and described according to ecological functionality. The Regional Ecological Network is one of the contents of the Regional Landscape Plan. The planning is addressed at improving the eco-logical connectivity of the network, therefore, it provides different degrees of intervention depending on the degree of connectivity between ecotopes and the need to connect them.

4.1.4 Methodological aspects and design approaches

In terms of **methodologies**, the heterogeneousness of Ecological Networks concepts in the Alpine space and the project reference context is even wider.

In **Austria**, the methodology involved creating a landscape model, calculating optimal habitat corridors, and analysing corridor sections using GIS. It integrated large core habitats, Natura 2000 sites, and green bridges. The corridors were validated through a participatory project with stakeholders.

The BKGI approach in **Germany** aims to analyse three main objectives: protecting natural and cultural landscape heritage diversity, materialist functions, and immaterialist functions. The research attempted to identify distinct corridors and spaces for biotope linkage (including on an international level) while focusing on various protection zones, ecosystems, and species. Maps first illustrate these subjects, then an investigation of bottlenecks-that is, areas vulnerable to settlement and traffic infrastructure-comes next.

The Green infrastructure network scheme in **Slovenia** is based on structural approach (habitats and landscape matrix). The Slovenia Forest Service has established corridors to preserve the connectivity of wildlife habitats. These corridors are based on a structural approach, involving the selection of 13 significant forest inhabitants. The linkages are derived from the 'Least-cost path' analysis, and they are verified by precise data obtained from the monitoring of species transitions, including species-specific connectivity, hunters' associations, and reports of road accidents involving wildlife. The structural and species approaches are combined in the network and corridor design.

In **Switzerland**, the Three Directions for the Development of a Functional Ecological Infrastructure (EI) aim to ensure the quality of existing areas, use existing processes for quantitative expansion, and supplement areas to close gaps. EI operations involve renovating and developing core and networking areas, while quantitative expansion involves using existing processes and programs. Supplementing EI includes adding cantonal protected areas under national planning principles. EI is crucial for enhancing landscape quality, promoting sustainable use, and biodiversity conservation. It includes protecting animals and plants, allowing natural site conditions, and promoting sustainable land use.

The ecological continuity network of the Trame verte et bleue (TVB) in **France**, is defined by the hydrographic network and does not differentiate between biodiversity reservoirs and ecological corridors. The 'Trame verte' consists of biodiversity reservoirs, permeable spaces, and ecological corridors. The method used to distinguish reservoirs and corridors varies between regions, relying on the identification of protected areas, threatened species ranges, and natural habitats. For the Rhone-Alpes region, biodiversity reservoirs were identified using existing perimeters, such as protected areas, sites managed by the Conservatoire du littoral, and breeding habitats. The identification and drawing of ecological corridors consider artificialized spaces, fragmenting elements, and points of punctual or linear conflicts.

The Po Valley in Northern **Italy** covers the Alps and Apennines, encompassing the Adriatic and Tyrrhenian seas. Ecological Networks models are created by 6 Ordinary Regions and two Special System Authorities. Most designs are regionally determined and integrated by Provincial and Municipal plans, following regional guidelines. Italian regions have regional laws establishing park and protected areas, aiming to create a national ecological network. This project aims to plan, program, and use resources, with models including global, specialized, and threatened 149 Italian animals networks.

The network in **Piedmont** was defined using a structural approach, identifying primary and secondary nodes, connections, project areas, and environmental regeneration areas. The

network was identified using a technical-scientific methodology based on the regional cartographic database, using fauna and vegetation indicators and modelling tools to identify areas of ecological value and ecologically permeable areas. This approach ensures the dynamics of biological population dispersion between nodes, supports the recovery and mitigation of connectivity and discontinuity stretches.

The **Ligurian** Ecological Network was constructed using geometries from the Liguria Region Land Use Map, published in 2011. Surveys were conducted to verify correspondence between environments and the Map Corine Biotopes/EUNIS categories. In-depth studies were conducted for the province of Savona, ensuring homogeneity throughout the region. Some categories were converted to anthropized settings, while others were verified through orthophotos and attributed to Corine Biotopes codes. Surveys were conducted to determine environments in natural areas.

For the **Lombardy** region Ecological Network, a structural definition of the network elements is made. Based on a continuous comparison between the various parties involved (the Lombardy Region Green Systems and Landscape DG, the technical working group, the Protected Area management bodies), the entire process of determining the PRAP (Regional Protected Areas Plan) was supported by the technical working group and the technical-scientific support of the Lombardy Environment Foundation. This was done in accordance with a method that provided for technical-scientific analysis and assessment phases alternating with participatory approach.

The Landscape Planning Office is largely responsible for creating landscape plans at the municipal level. The identification of landscape elements in these plans begins with an examination of aerial photographs. Site visits are used in a second stage to verify, validate, and assess these studies. Here, a structural approach is mainly taken. Hedgerows, stream channels, tree groups, riparian forests, chestnut orchards, dry grasslands, and wetlands are examples of landscape features that are protected. Nevertheless, the provincial nature protection statute exclusively protects marshes and dry grasslands. Other GBI components are customarily considered in landscape planning even though they are not legally defined. Nothing close to a functional approach is done.

The Life+ T.E.N. project aimed to design an ecological network in **Trentino**, Italy. In 2012, an extensive ecological database was developed, leading to the creation of 14 ‘Homogeneous Territorial Ambits’ (ATOs) to prioritize connectivity. These areas, involving different municipalities, serve as a ‘hatchery’ for establishing new Networks of Reserves. The project also developed a provincial-specific inventory of active protection and connectivity reconstruction actions, defining guidelines for active conservation inventories. This resulted in a provincial General Inventory, which outlines the framework for active protection and restoration of ecological connectivity actions. The first unofficial ecological network was identified after an in-depth analysis of the territory. Distribution and abundance models were developed for valuable species and distribution areas with the greatest environmental suitability for them and their associated biological communities.

The Ecological Network of the **Veneto** Region was constructed by analysing the environment condition, identifying ecologically homogeneous areas, and defining the framework based on naturalistic characteristics. The backbone areas are Natura 2000 Sites, Protected Areas, Nature Reserves, and Biodiversity Priority Areas. The network aims to conserve residual nature through maintaining ecological connections and reconstructing multipurpose ecosystem units. Corridors are identified based on environmental units' characteristics and status, ensuring connectivity between core areas and corridors.

The Regional Ecological Network in **Friuli Venezia Giulia** is structured into three levels: structural, functional, and project. Structural level categorizes ecological elements, functional level identifies functional ecotopes, and project level outlines specific conservation, strengthening, and restoration projects for each ecotope.

4.1.5 Inconsistencies in the ecological connectivity concepts at national and regional borders in the EUSALP macro-region

The report moved from the reconstruction of the ecological network's mosaic to determine the possible discrepancies between the actual concepts of the 6 considered countries

France - Italy

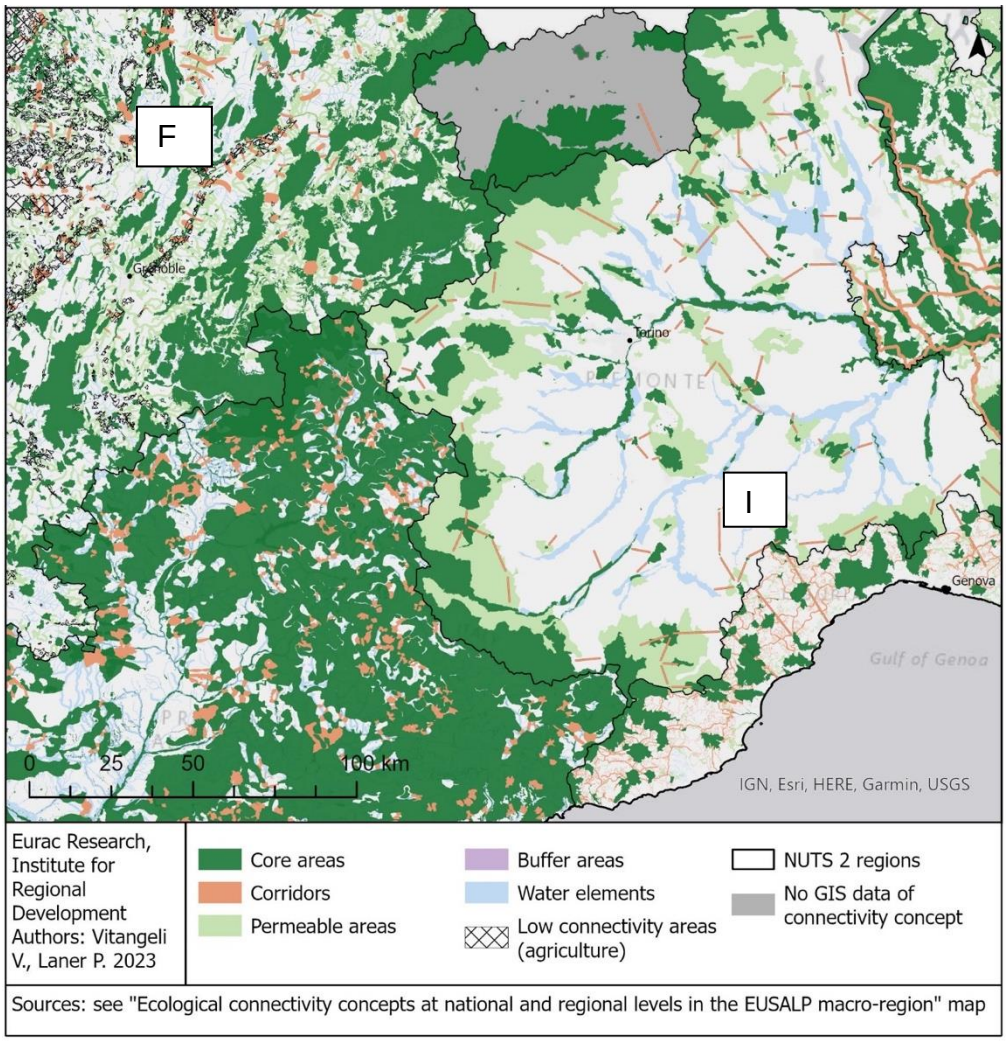


Figure 30: The map of ecological connectivity concepts between France and Italy (source: EURAC)

The border between France and Italy is relatively coherent but presents inconsistencies between core areas in France and permeable areas in Italy. This is particular evident between the French core area corresponding to the Natural Regional Park of Queyras, and the Varaita Valley, defined as permeable area in the Piedmont region. Also, between the National Parc Vanoise (FR) and the Italian Susa valley a harmonization of EC concepts would be needed.

France - Switzerland

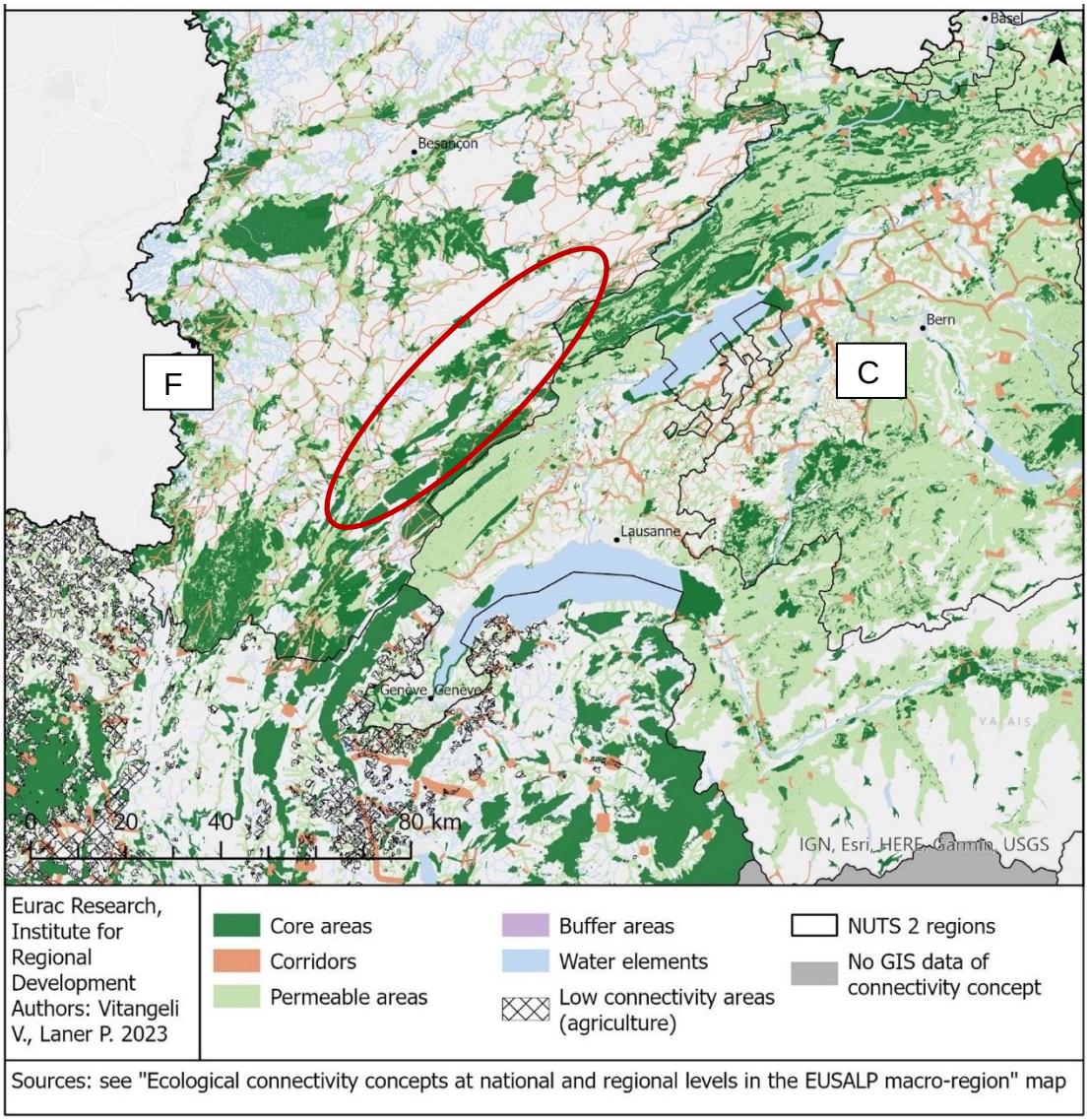


Figure 31: The map of ecological connectivity concepts between France and Switzerland (source: EURAC)

The first problem in the network coherency between France and Switzerland arises between the Provence-Alpes-Côte d'Azur region, where the presence of agricultural areas is interpreted as problematic for connectivity, while on the side of Switzerland, in in the south of Geneve they are classified as 'permeable landscape'. In addition, a great part of the border between Auvergne Rhône-Alpes and Switzerland has inconsistencies in the definition of core areas and permeable areas. Cross-border corridors are present and coherent among nations.

Austria - Germany

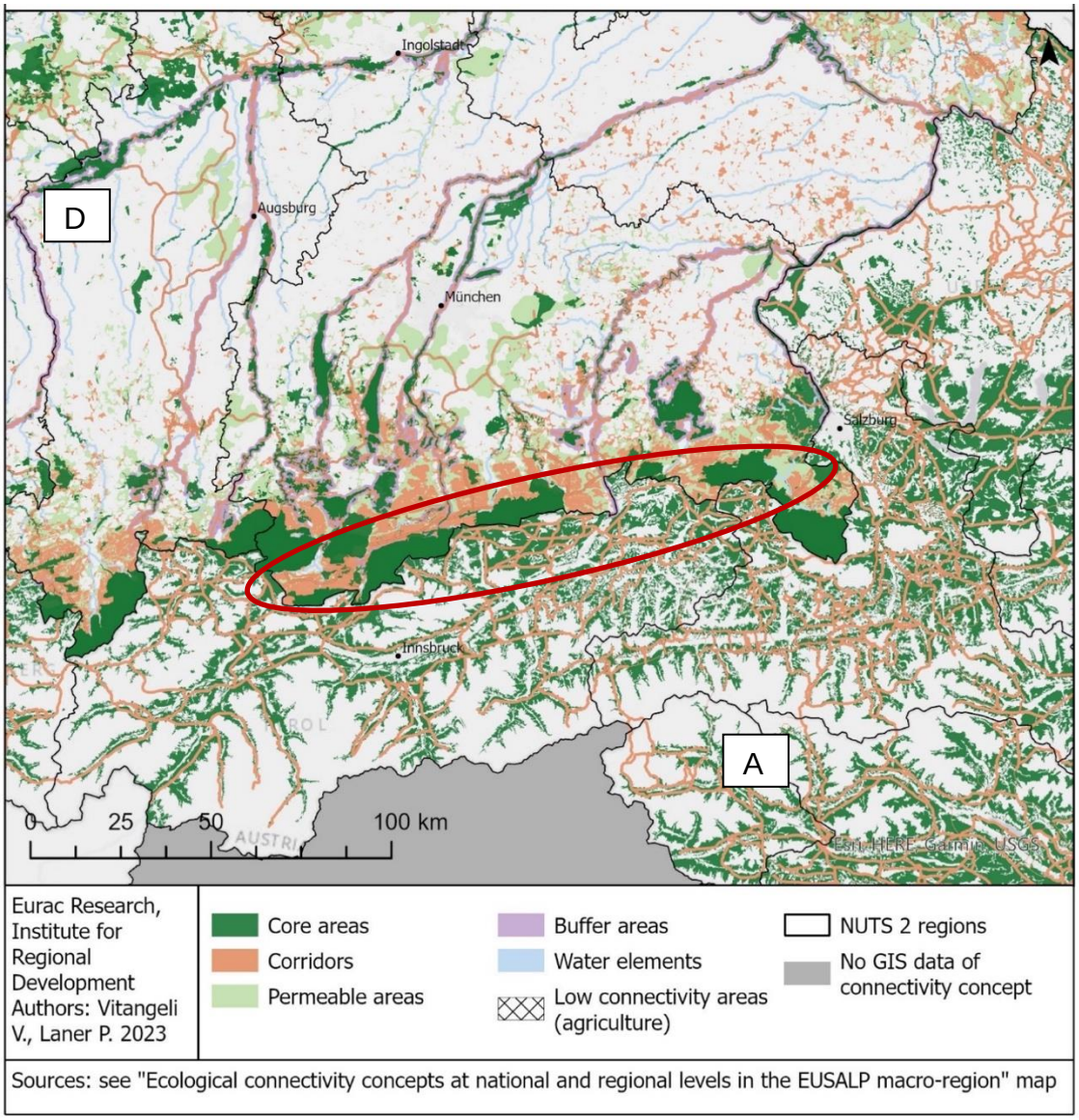


Figure 32: The map of ecological connectivity concepts between Austria and Germany (source: EURAC)

Germany and Austria have noticeable different methodologies in addressing core areas, as it can be noticed not only along borders but also within the national territory. This results into wide portions of terrain considered as core area by Germany which are then converted into thin areas or even the absence of any ecological network element in Austria. Indeed, whether the former considers protected areas as core areas independently on their functionality, the latter has modelled these areas on species specific needs (i.e. ungulates).

Austria - Italy

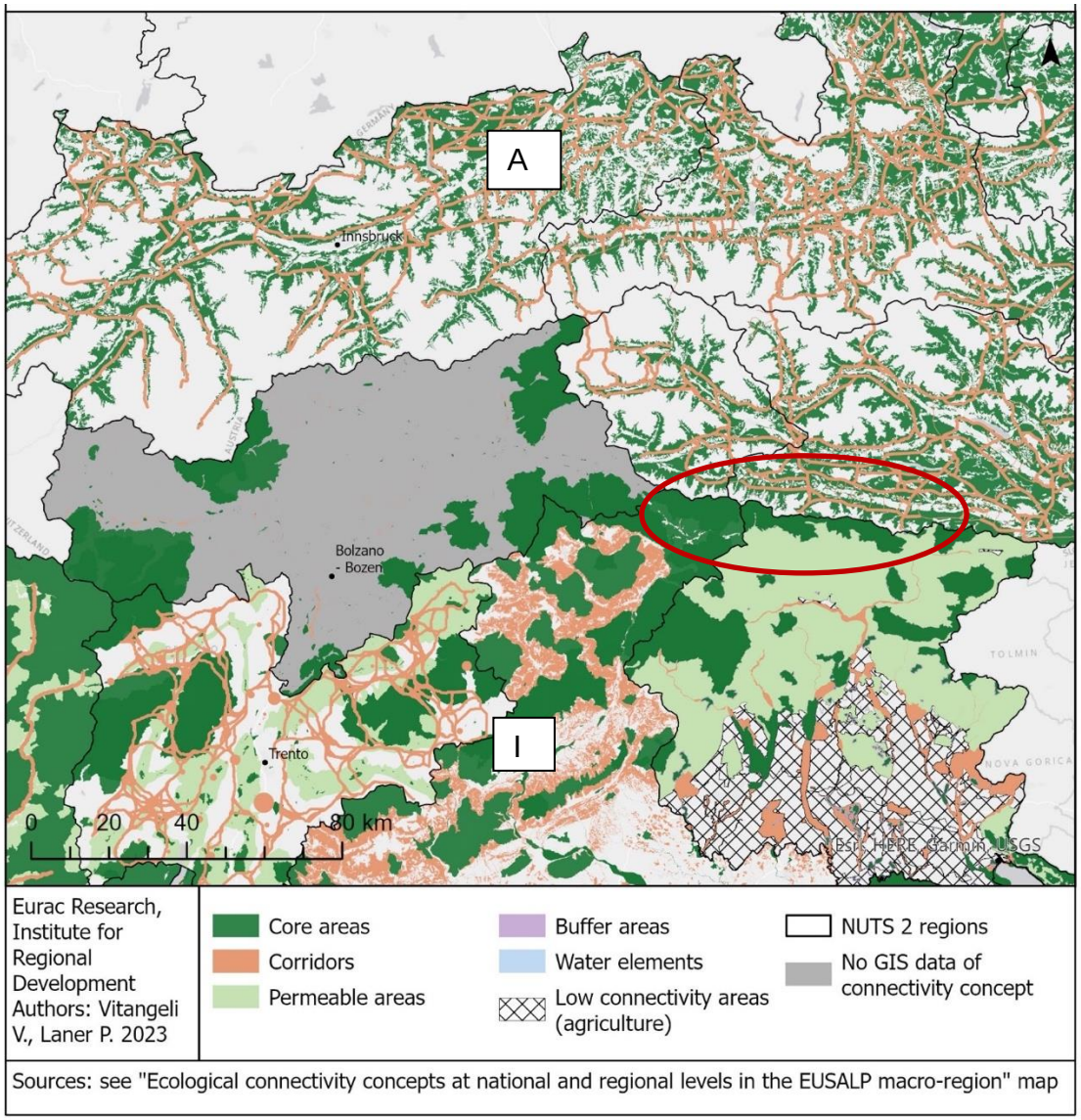


Figure 33: The map of ecological connectivity concepts between Austria and Italy (source: EURAC)

As for the German-Austrian border, the different conceptualization of the ecological connectivity network between Italy and Austria results into a discrepancy among core areas. Whereas for Italy (Friuli-Venezia Giulia and Veneto regions) core areas are identified starting from protected areas, the methodology of Austria does not consider important transnational connectivity areas, as there are some corridors which do not reach Italy. However, there would be a big potential for cross-border connectivity areas at the Austrian side, as Italy defines core areas and permeable landscapes touching the border to Austria.

Switzerland - Italy

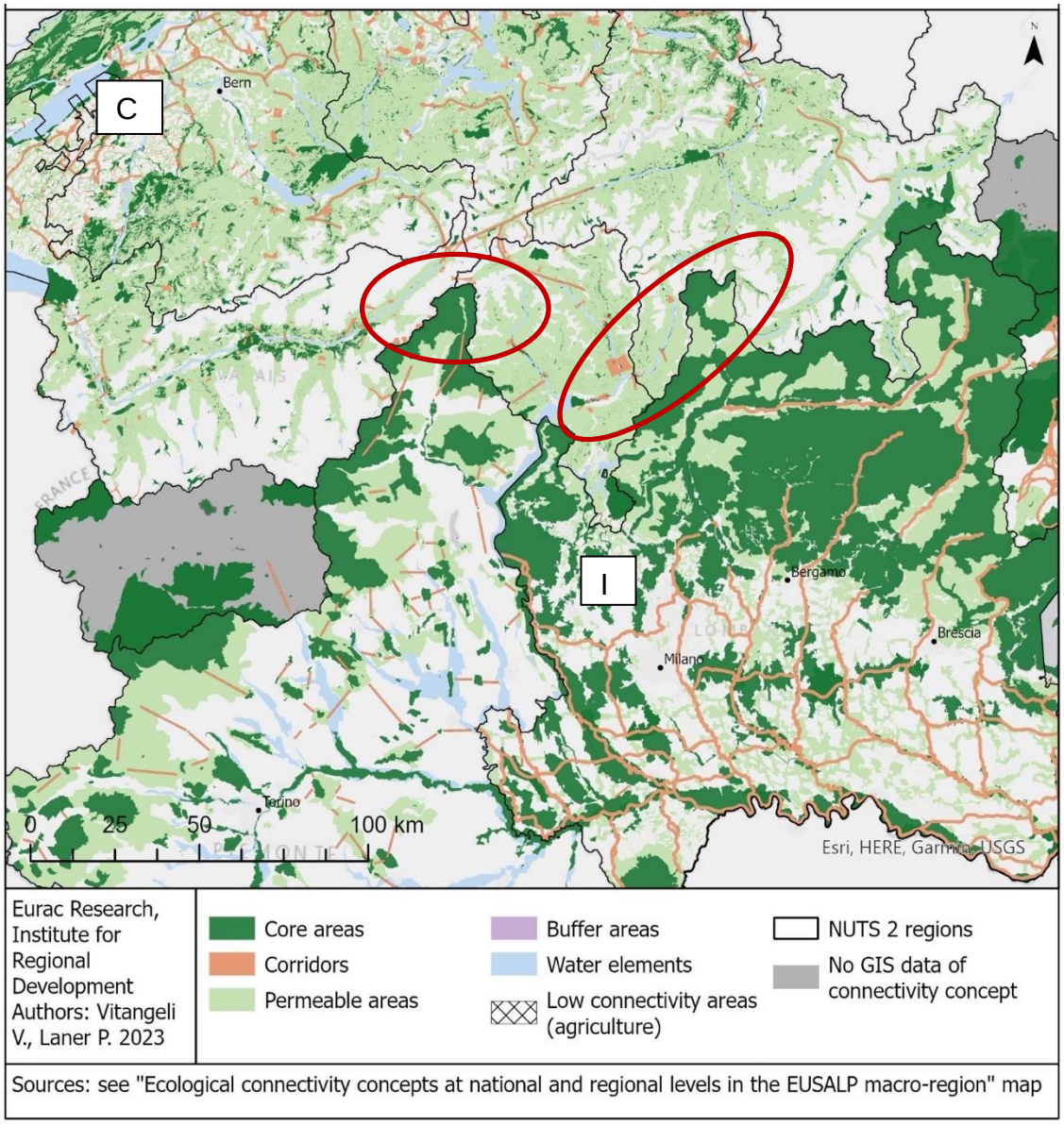


Figure 34: The map of ecological connectivity concepts between Italy and Switzerland (source: EURAC)

This border presents noticeable inconsistencies due to a different classification of core areas or permeable areas. The northern part of Piedmont is mainly classified as core area, whereas the Switzerland has conceptualized the nearby area as a permeable one. Some cross border corridors exist between the two states, even though Piedmont and Lombardy have separate concepts. Not all of them are aligned.

Switzerland - Germany (including Switzerland - Austria)

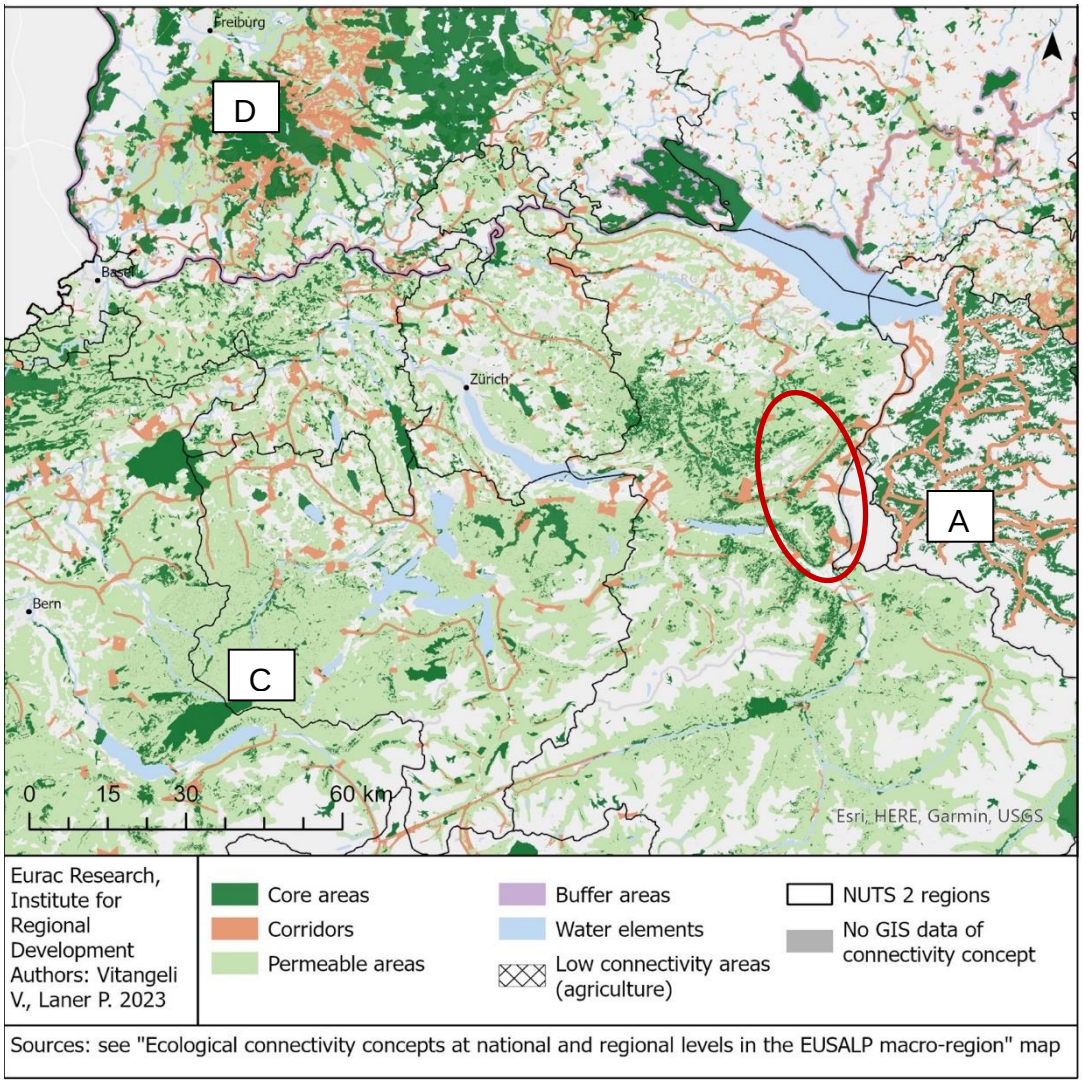


Figure 35: The map of ecological connectivity concepts between Germany and Switzerland (source: EURAC)

The border between Switzerland and Germany presents one inconsistency in the northern part of Costanza Lake, where the Wollmatinger Ried - Untersee - Gnadensee natural reserve is, constituting a core area for the German concept, whether on Switzerland the nearby area is not included in the ecological network. However, the presence of buffer areas along almost the whole border ensures the transition between the two networks. The Switzerland - Austria border, though, presents a major misalignment, also because apparently an ecological connectivity concept in Liechtenstein is still missing. Nonetheless, there are some cross-border corridors from Switzerland towards Liechtenstein that could be connected to the Austrian core areas.

Slovenia - Austria (including Slovenia - Italy)

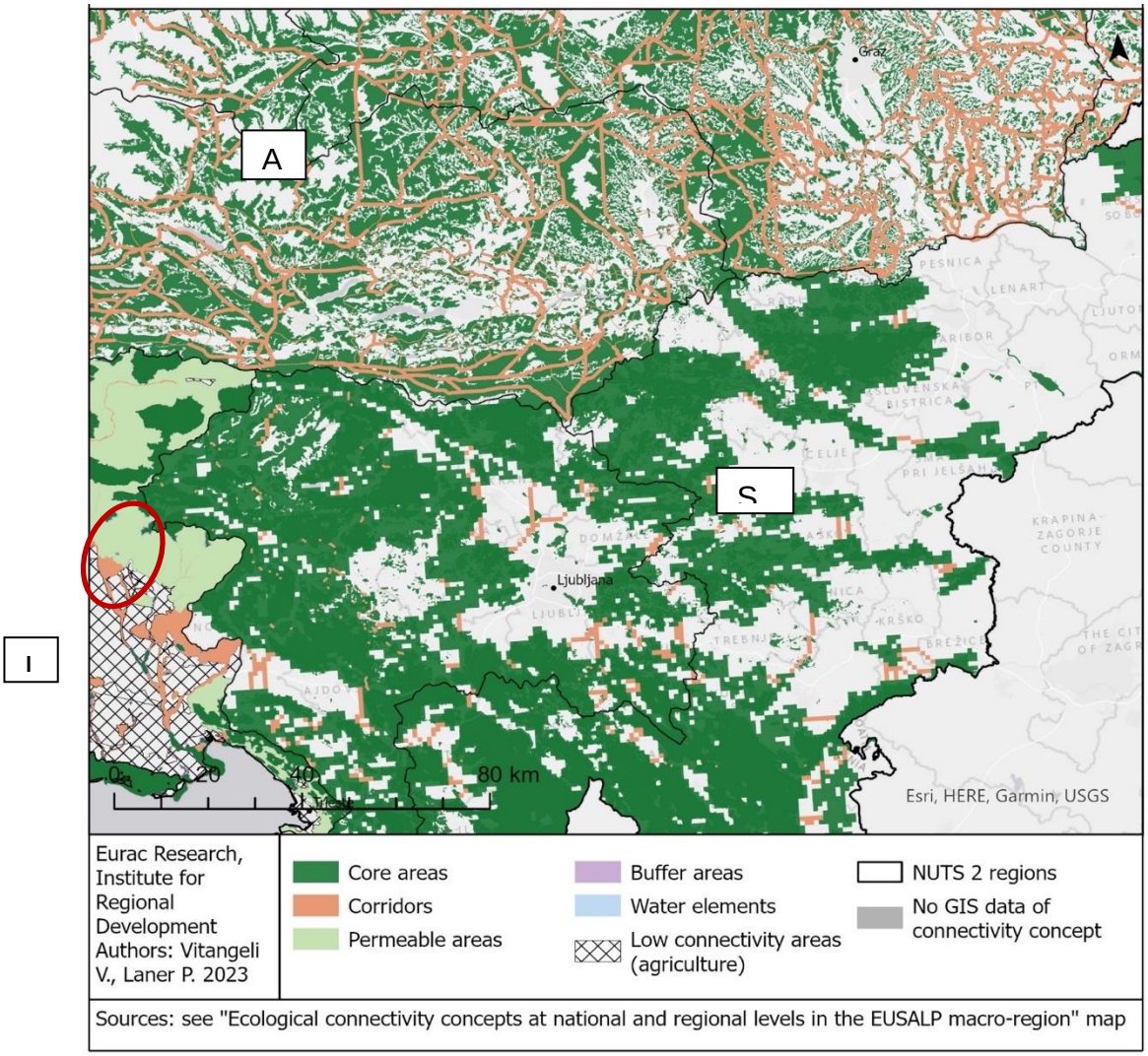


Figure 36: The map of ecological connectivity concepts between Slovenia and Austria (source: EURAC)

Whether the western side of the border between Austria and Slovenia are well harmonized, the eastern side contains a major inconsistency: In the north-eastern part of Slovenia, there is an array of corridors approaching the border from the Austrian side, which do not see any core area or permeable area on the Slovenian side, causing lack of functionality. On a more detailed level, a transboundary corridor in the eastern side of Maribor, directly pointing towards the Slovenian territory, does not reach any area included in the ecological connectivity concept. On the Italian-Slovenian side, there are no major inconsistencies, if not the huge part in Slovenia classified as core area which is conceptualized as permeable area by the Friulian side.

Details - inconsistencies among Italian regions

As for the real structure, the majority of Italian Regions have a regional law that establishes the parameters at various levels for regional parks and protected areas. This law aids in the construction of a national ecological network, which is now only being pushed as a future initiative. An operational tool for national territorial planning, programming, and resource usage is the National Ecological Network project. Numerous 'networks' models have been created within this **framework**: a global network encompassing all Italian vertebrate species, a specialized network for each taxonomic category (i.e., group of species), and finally a network for all 149 Italian animals that are threatened with extinction.

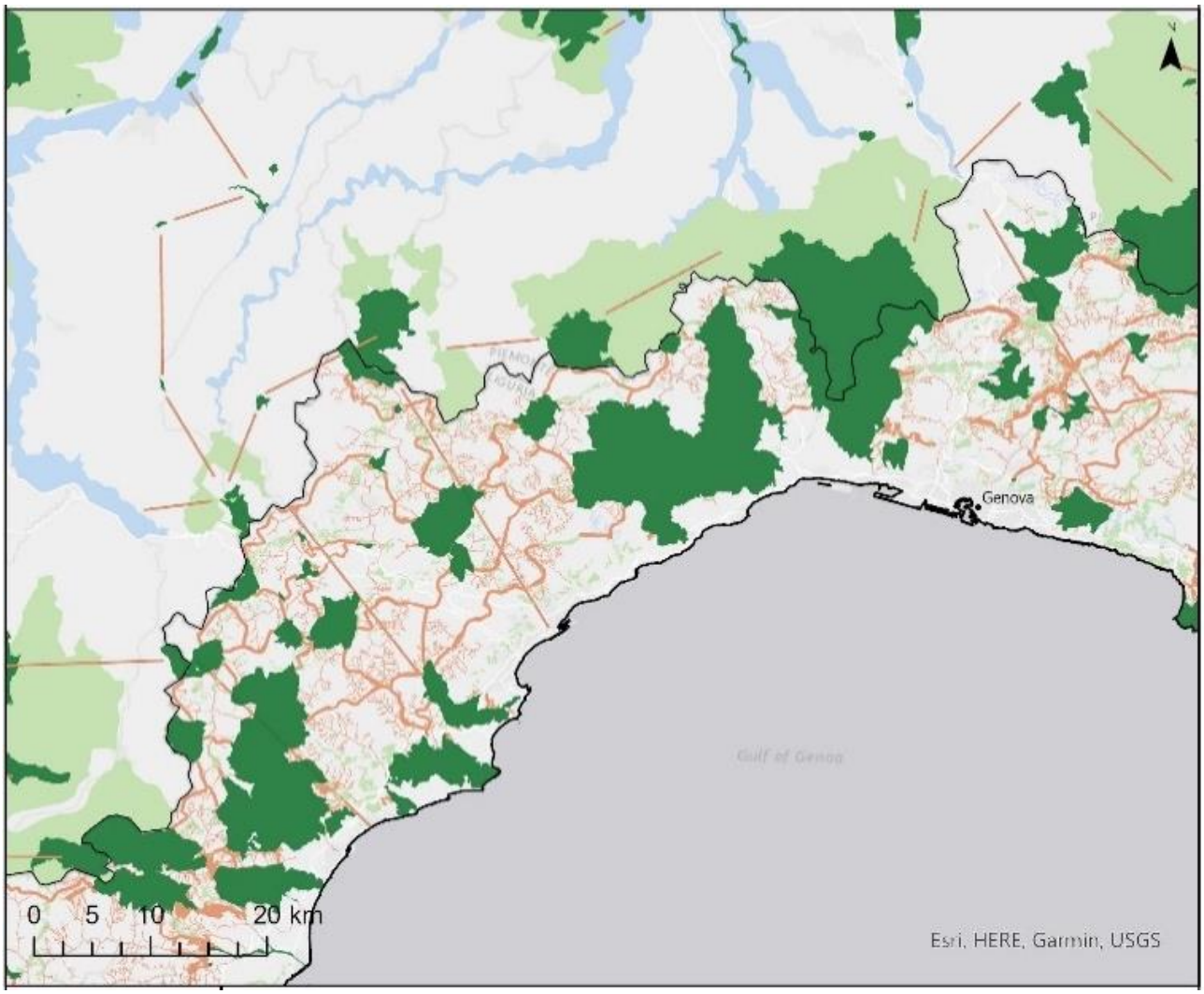


Figure 37: border between Liguria and Piedmont (source: EURAC)

The border between Liguria and Piedmont does not present major inconsistencies if not for the more extensive use of permeable areas on the Piedmont territory.

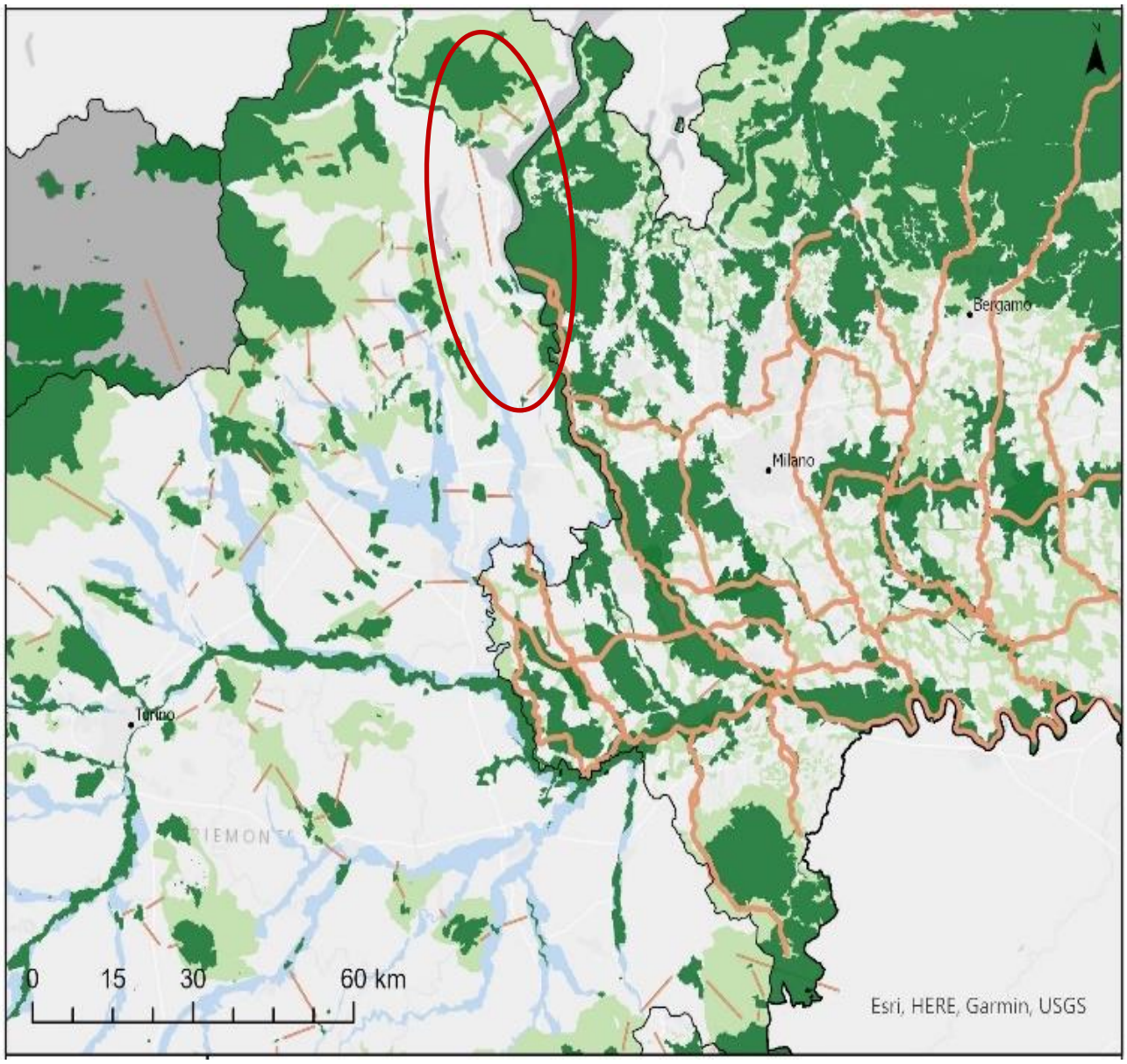


Figure 38: border between Piedmont and Lombardy (source: EURAC)

While Lombardy has designated the vicinity of its regional border as a core area, Piedmont has not incorporated the nearby area into its network. This is particularly noticeable at the northern area, surrounding Lake Maggiore. Such inconsistencies may lead to a risk of functionality, particularly regarding the corridor along the border, which terminates in a poorly defined corridor by the Piedmont regional framework.

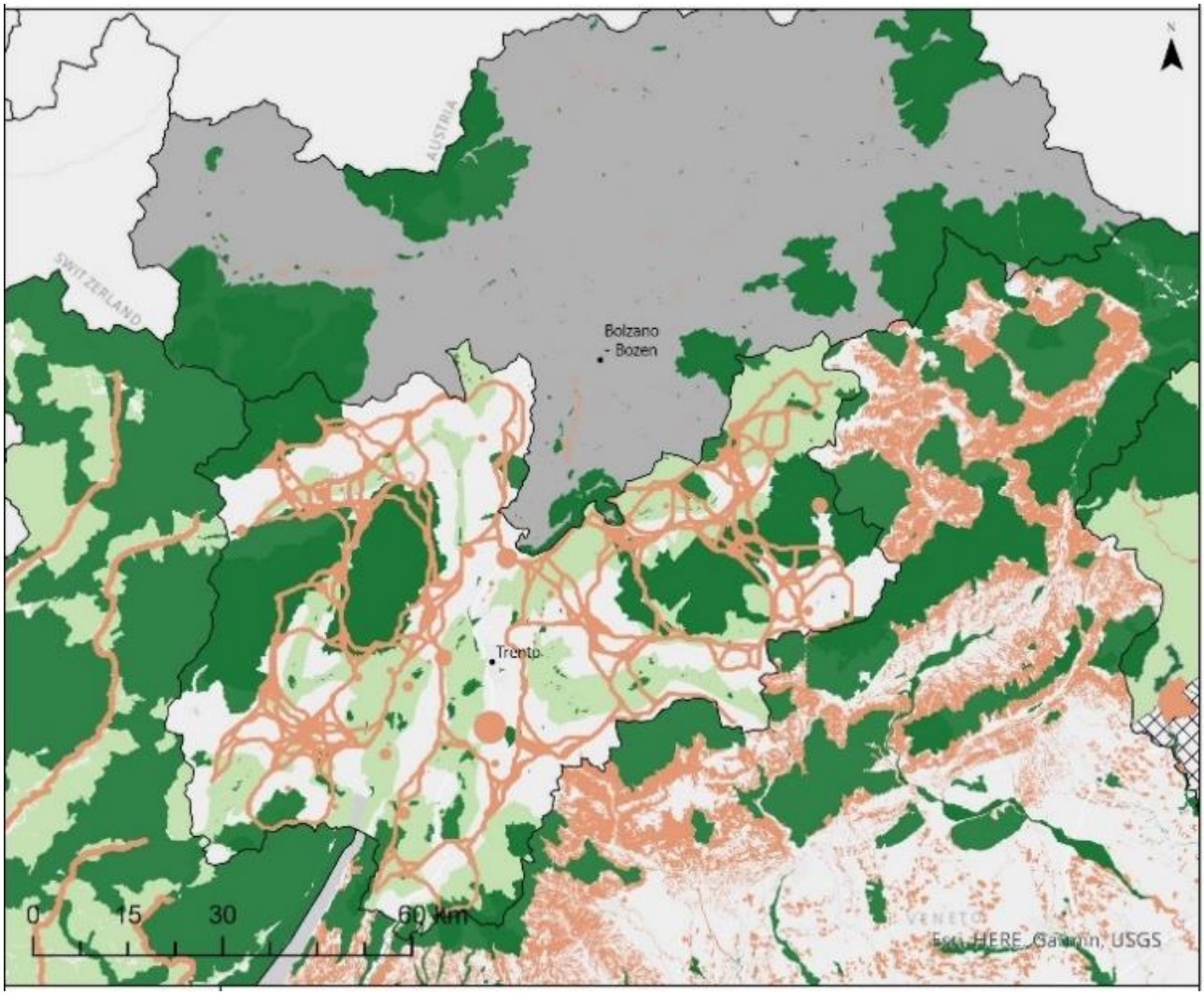


Figure 39: border between Lombardy and Veneto (source: EURAC)

A slight difference is present among the classification of core areas between Veneto region and Trentino, whereas no major inconsistency occurs between Trentino and Lombardy.

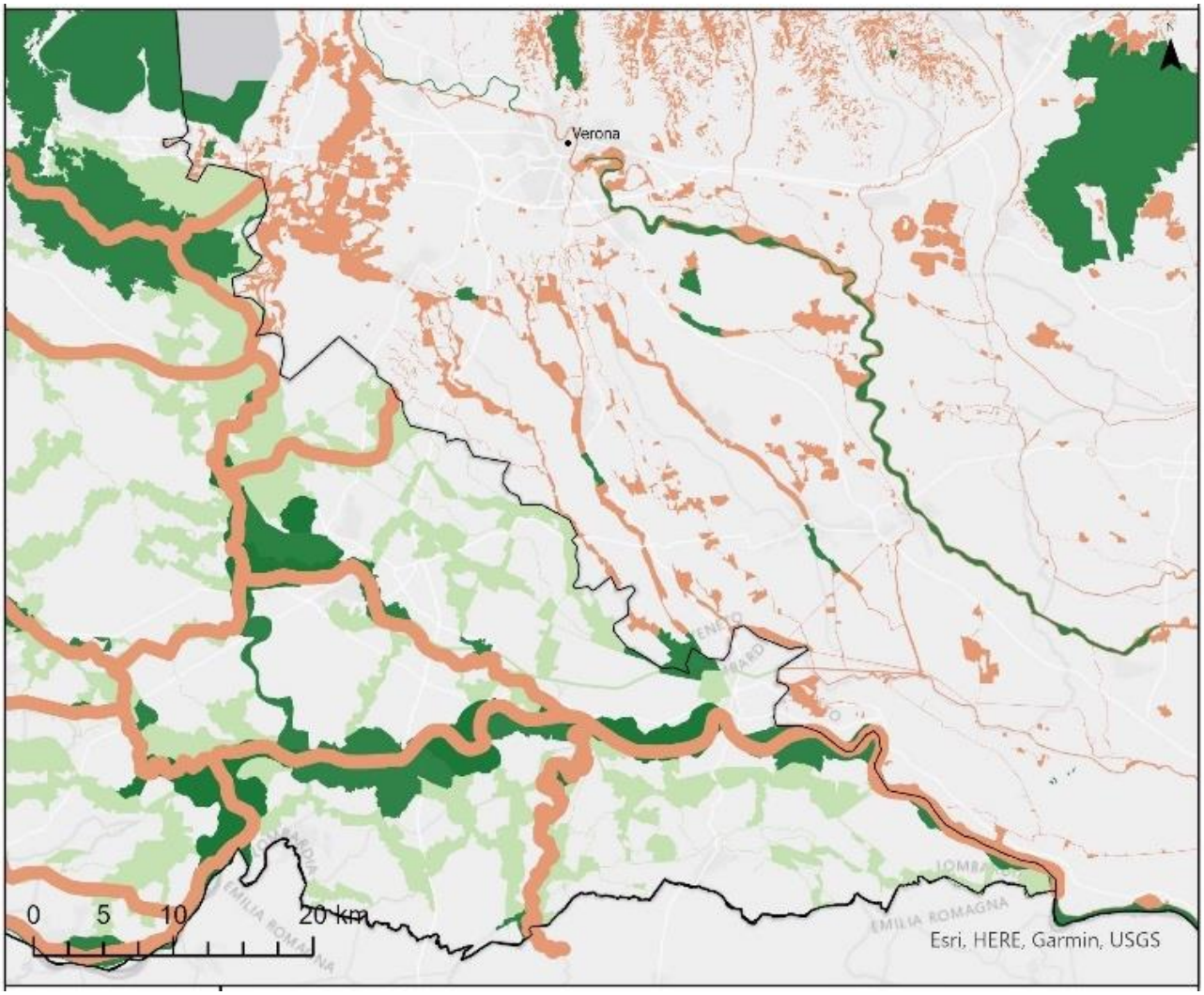


Figure 40: border between Veneto and Lombardy (source: EURAC)

The regions Veneto and Lombardy do present quite different ecological connectivity concept as the first one does not include permeable areas in its network. On the other hand, there are some functional corridors that are connected to transboundary core areas or permeable areas.

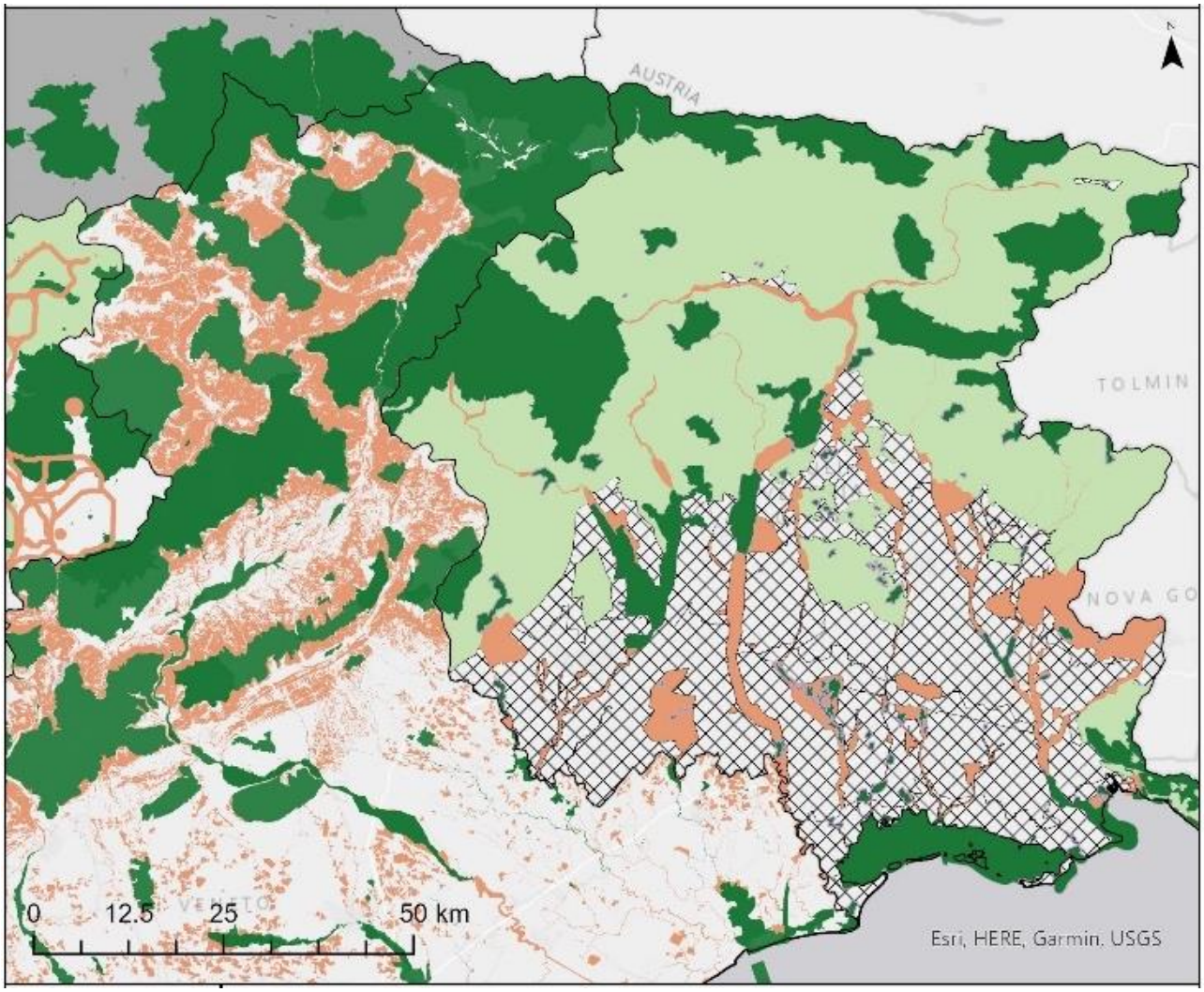


Figure 41: border between Veneto and Friuli-Venezia Giulia (source: EURAC)

The border between Veneto region and Friuli-Venezia Giulia is coherent, if not for the area in the north-west Friulian side, which is conceptualized as a permeable area. The Natura 2000 area 'Dolomiti del Cadore e del Comelico, which can be interpreted as a core area, begins just behind the regional border.

4.1.6 Challenges and opportunities

If we consider **strengths and weaknesses**, some interesting elements emerge.

- The **Austrian** federal level handling of spatial planning and wildlife conservation complicates the implementation of habitat corridors, while **Germany** national law for nature protection lacks detail. **Slovenian** Green Infrastructure Network strategic outline requires more detailed definition of links and barriers, relying heavily on intersectoral cooperation. Switzerland has granted funding to close implementation gaps in national biotopes, with cantons contributing to the network.
- The **French** TVB ecological network cartography varies across SCoTs, impacting territorial challenges identification. The Kunming-Montreal Global Biodiversity Framework aims to address ecological connectivity by 2027. Italy regional planning system faces challenges in designing regional and provincial ecological networks at the local level, including conflicting economic interests with environmental conservation goals, land availability, high fragmentation of private property, and financial resources.
- Corridor planning in **Bolzano** Province faces challenges such as individual municipalities drawing landscape plans, recording protected landscape elements, and not coordinating environmental compensation measures. Implementation challenges include political will and lack of resources for the Office for Landscape Planning. Provincial strategy plans could define important objectives and upgrade existing tools like the GeoBrowser, and guidelines for new spatial planning instruments should consider ecological connectivity at the local level. In **Trentino**, large human infrastructure barriers hinder the execution of initiatives aimed at enhancing permeability, strengthening connections within the network, and devising comprehensive programs involving local economic stakeholders. The description of network terminology in **Veneto** is inconsistent between maps, reports, and regulations, causing difficulty in understanding.
- In **Friuli Venezia Giulia**, artificial causes fracturing natural habitats contribute to the decline in biodiversity. Future drafting of the Landscape Plan may include the new outline of the regional GBI, guidelines for its implementation, and the development of goals, actions, and tools defined by the National Biodiversity Strategy.

In terms of future **challenges**, other interesting factors emerge from the comparative reading of the actual situation in the Alpine Space.

- Both spatial planning and wildlife conservation are handled at the federal level in **Austria**. This complicates the process of implementing the habitat corridors as stipulated by the laws of the nine federal states. However, efforts to incorporate the contents into the corresponding federal laws are still underway.
- The **German national law** for nature protection lacks detail, with federal and local governments implementing conservation measures. Construction management is

legally binding, except for regional planning. The BKGI and evaluation document highlight the need for further development to support planning sectors and integrate future conservation concepts. The BKGI offers connectivity opportunities by presenting non-fragmented, low-traffic-impact spaces, allowing planners to access relevant data for traffic, energy transmission line, spatial, settlement, and infrastructure planning.

- In **Slovenia**, spatial planning documents related to the Green infrastructure network strategic outline must define links (as well as barriers, voids, and inconsistencies) in more detail. In-depth network planning and execution depend heavily on intersectoral cooperation. Open communication and information exchange are essential, particularly with municipalities, practitioners of spatial planning, etc. In-depth network planning and execution depend heavily on intersectoral cooperation.
- To close implementation gaps in national biotopes in **Switzerland**, the Federal Council granted funding in 2016 for quick actions in the areas of nature conservation and forest biodiversity. The Confederation and the cantons have program agreements that include these resources, which are well utilized. Contributions are augmented by cantons. Investing in biodiversity is beneficial because it creates jobs, increases the value of products, and adds value to forestry and agriculture in outlying regions. The network is still being developed, and the first cycle of assessments that determined the effectiveness of measures in terms of economic and environmental sustainability will need to be considered for the new program (2025-2030).
- The ecological network cartography precision in the **French** TVB varies across SCoTs, impacting territorial challenges identification. Opportunities include articulating planning documents, facilitating dialogue between different levels, and developing actions to reinforce the TVB. The Kunming-Montreal Global Biodiversity Framework objectives address ecological connectivity, with four concrete actions to implement by 2027: reducing discontinuities, setting fragmentation targets, restoring watercourse continuity, and accelerating dark infrastructure implementation.
- Ecological networks are planned and developed at the regional level in **Italy** because, as per Italian legislation (Art. 117 of the Constitution, as in the formulation of the Constitutional Law of Reform no. 1 of 2001), planning is a sector that can be managed both at national and regional levels. The Constitutional law No. 11 (11 February 2022) has only recently added the environment to the list of values contained in Article 9, just as originally drafted.
- The **Piedmont** region has witnessed a growing use of supra-local planning tools, including as regional and provincial territorial plans and natural park plans, to address the integration of ecological networks. In contrast, a weak operational viewpoint is still present at the local level, which is necessary for urban development focused on protecting natural areas, fostering ecological connectedness, and safeguarding the landscape. In fact, it is rare to find local projects with explicit actions and regulations for network construction and management that follow the programmatic principles established for ecological networks.

- The inability to compare the areas of the various provinces with one another and then apply the same analytical or evaluative criteria to the entire regional territory that can consistently describe the region habitat conservation and, consequently, the effectiveness of the Ecological Network is due to the lack of methodological homogeneity in the Ecological Network construction. The conceptual differences between the approaches taken by different provinces in defining the boundaries of ecological corridors, buffer strips, renaturation areas, and high naturalness areas were discovered in 2021 during an additional study aimed at harmonizing the databases of municipal land use plans. These differences are most noticeable at many provincial boundaries.
- The **Lombard** multi-level planning system faces challenges in designing regional and provincial ecological networks at the local level. The design often emerges from regulatory compliance rather than local projects, requiring interconnected urban and extra-urban open spaces and green infrastructures. Challenges include conflicting economic interests with environmental conservation goals, land availability for network realization, high fragmentation of private property in mountain areas, and the availability of financial resources for network project implementation. Preliminary identification of measures to finance interventions is crucial for successful implementation.
- Corridor planning in the **Bolzano** Province faces challenges such as individual municipalities drawing landscape plans, recording protected landscape elements based on their existence, and not coordinating environmental compensation measures. Municipalities are starting to plan their own networks, risking losing the chance to create a coherent regional ecological network. Implementation challenges include political will and lack of resources for the Office for Landscape Planning. To improve the ecological network, the provincial strategy plan could define important objectives and upgrade existing tools like the GeoBrowser. Guidelines for new spatial planning instruments should consider ecological connectivity at the local level and create a provincial potential ecological network that is legally binding for municipalities. This network could be useful for coordinating compensation measures and ensuring a coherent ecological network.
- In the P.A. **Trento** large human infrastructure barriers like the railway network, the freeway and main road network, and the primary agricultural landscape with significant added value for the local and national economy are the main causes of the implementation issues with the provincial ecological network in Trentino. These hurdles genuinely impede the execution of initiatives aimed at enhancing the permeability of regions, strengthening connections within the network, and devising comprehensive programs involving many local economic stakeholders. Furthermore, the ecological corridors are merely an indicative study that is widely employed by provincial offices; they are not mentioned in any laws or provincial plans.

- The description of the Network terminology in **Veneto** is inconsistent between maps, reports, and regulations, causing difficulty in understanding. The report mentions elements like Priority Areas for Biodiversity but lacks clarity on how they are incorporated into the network. Provincial plans have developed their ecological network consistently with regional directions, but different methods in different territories may result in different structures and elements. A paradigm shift from the Ecological Network to the Green and Blue Infrastructure paradigm could lead to a holistic approach that considers the whole territory and ecosystem functions, including anthropogenic ecosystems. The future drafting of the Landscape Plan may include the new outline of the regional GBI, guidelines for its implementation, and the development of goals, actions, and tools defined by the National Biodiversity Strategy.
- In **Friuli Venezia Giulia**, one of the main reasons for the decline in biodiversity is the process of artificial causes fracturing natural habitats. The process that leads to a progressive decrease in natural environments and an increase in their isolation is known as fragmentation. As a result, natural surfaces become increasingly isolated and spatially separated fragments within a spatial matrix with human origins.

To wrap up the actual situation of the Ecological networks mosaics in the Alpine space, some of the most important **challenges** could be identified as follows.

- In terms of **legislation**, Austria, Germany, France, Slovenia, Switzerland and Italy all have national laws for nature protection, having different levels of details depending on the specific legislative model of each country. E.g., in Germany, the national law for nature protection is not detailed, with both federal and local governments responsible for conservation measures. In Italy, Ecological networks are planned regionally due to national and regional jurisdiction over planning (Article 117 of the Constitution) and the Environment has become a constitutional value to preserve only recently (Constitutional law No. 11-2022), being previously mostly related to the legislative concept of Landscape. In Austria, implementing habitat corridors could be complex due to different federal laws in its nine states and efforts to integrate connectivity concepts into consistent federal laws are ongoing.
- Considering the **Governance** factors, the fact that both spatial planning and wildlife conservation are managed at the federal level in Austria, Germany, France and Slovenia can be a possible positive factor, though that could determine some discrepancies passing to local management levels. Switzerland and Italy, having a more decentralized structure (managed by Cantons and Regions), can have a more efficient concept design, though the lack of a general national vision could represent a problem in term of overall connectivity and harmonization of the local provisions.
- With regard to **Planning** tools, Germany, France, Slovenia and Austria seem to have an efficient general framework to drive regional and local policies and planning decisions at different levels. E.g. the BKGI (Bundesweiter Konzept zur Grünen Infrastruktur) was able to identify low-traffic-impact spaces for planners, supporting traffic, energy, spatial, and infrastructure planning. Green infrastructure network plans

in Slovenia are called to detail links, barriers, voids, and inconsistencies in the two national existing frameworks. In Italy, instead, the lack of methodological homogeneity and conceptual differences in defining ecological network components across Regions is, for sure, one of the most urgent problems too address to harmonize the general existing concepts.

- In terms of **horizontal and vertical integration**, in most of the considered countries, successful network planning and implementation rely on intersectoral cooperation and open communication, especially with municipalities. This leads to the consideration that further development is needed to support planning sectors and integrate future conservation concepts, mostly in Slovenia and Germany. The lack of cooperation and unitary standards reflects also in some technical issues, mostly in cartographical terms, which, as an example, in France determine the fact that the precision varies across SCoTs (Schéma de Cohérence Territoriale), impacting the identification of territorial challenges.
- Despite that, several **opportunities** can be featured by an improved articulation of planning documents, facilitating dialogue, and reinforcing the National and Regional concepts. As investing in biodiversity can create jobs, enhance product value, and promote forestry and agriculture.

4.1.7 Data sources of the Ecological networks mosaic

For a more detailed description of the Ecological Networks provisions at National and Regional level for each country, please, refer to Annex 1. The sources used to build the map of the Ecological networks mosaic, developed by EURAC, are the following:

- *Austria*

  Lebensraumvernatzung.at (2022). Geodatenkatalog Lebensraumvernetzung. LRVA-2022: Aktuelle Version der Lebensraumkorridore Österreich (Version 2022-10-16). https://lebensraumvernetzung.at/de/geodata

- *France*

  Inventaire National du Patrimoine Naturel, (2023). La Trame verte et bleue. Layer “couche nationale des corridors surfaciques”. https://inpn.mnhn.fr/programme/trame-verte-et-bleue/donnees-srce

- *Germany*

  National Office for Nature Protection, (2023). Data request to the National Office for Nature Protection of Germany (Bundesamt für Naturschutz). Bundeskonzept grüne Infrastruktur. BKGI_2023.

- *Italy*

GeoCatalogo Alto Adige (2023). Ricerca per categoria. Dati di base e pianificazione. Pianificazione e catasto. http://geokatalog.buergernetz.bz.it/geokatalog/#!

Regione Autonoma Friuli-Venezia Giulia, (2023). Catalogo dei dati ambientali e territoriali. PPR - Aree interesse Regionale RER - DATASET - dataset. https://irdat.regione.fvg.it/consultatore-dati-ambientali-territoriali/search

Regione Liguria, (2023). Opendata. Biodiversità - Rete Ecologica. Version: Martedì, 01 Gennaio 2008. https://www.regione.liguria.it/homepage-opendata/item/7065-biodiversita-rete-ecologica.html

Regione Lombardia (2011). Geoportale della Lombardia. Metadati. Rete Ecologica Regionale (RER). https://www.geoportale.regione.lombardia.it/metadati?p_p_id=detailSheetMetadata_WAR_gptmetadataportlet&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&_detailSheetMetadata_WAR_gptmetadataportlet_identifier=r_lombar%3A6c25a13d-e6e2-4fc0-9538-9866145908b0&_jsfBridgeRedirect=true

- *Slovenia*

Penko Seidl, N., Bevk, T., Golobič, M., Jerina, K., Bordjan, D., (2021). Definition of ecological corridors at SI level as a support for spatial development planning and management of nature and other resources - final report. University of Ljubljana - Biotechnical Faculty. Data request 2023.

- *Switzerland*

BAFU, (2023). Biodiversität: Geodaten. REN (Nationales ökologisches Netzwerk, 1:100’000), Wildtierkorridore Überregional. https://www.bafu.admin.ch/bafu/de/home/themen/biodiversitaet/zustand/karten/geodaten.html

4.2 Harmonization process

4.2.1 Key findings

Given the variability of spatial planning systems in the Alpine states, the need for harmonizing current design of Ecological networks in cross border areas is evident.

Cross border inconsistencies between ecological network concepts in the Alpine Space can be summarized as follows.

- The border between France and Italy is relatively coherent but presents inconsistencies between core areas in France and permeable areas in Italy. The same inconsistencies between core and permeable areas have been detected in Italy, France, and Switzerland. Core areas misalignments have been highlighted also between Italy and Slovenia.
- On the other side, the different conceptualization of the ecological connectivity network results into a discrepancy among core areas definition in Germany/Italy and Austria.
- The border between Switzerland and Germany presents one inconsistency in the northern part of Costanza Lake, however, the presence of buffer areas along almost the whole border ensures the transition between the two networks. The Switzerland-Austria border, though, presents a major misalignment, also because apparently an ecological connectivity concept in Liechtenstein is still missing.
- Despite the western side of the border between Austria and Slovenia are well harmonized, the eastern side contains some major inconsistencies.

It is useful to consider that despite the different models of Ecological Networks are based on different principles, a comprehensive Network of Ecosystem can be traced. The different models are summarized as follows.

- The Austrian modelled corridors are connecting fragmented core habitats and Natura 2000 sites as well as the German Network is focused on different protection areas, habitats, species, trying to identify specific corridors and spaces for biotope connection.
- The Swiss Ecological Infrastructure EI structure consists of protected areas and priority areas, including national, regional, and local biotopes, Swiss National Parks, peri-urban nature parks, and international and national bird reserves connected by corridors in a cascading system of planning.
- It relevant to notice that the French Ecological Network is defined by the hydrographic network and does not differentiate between biodiversity reservoirs and ecological corridors. The TVB consists of biodiversity reservoirs, permeable spaces, and ecological corridors.
- The Slovenia Forest Service created the national corridor protection methodology, which states that starting in 2023, any procedure involving the adoption or modification of a spatial plan at the municipal, regional, or national level must be checked and respected to protect the currently proposed corridors. Slovenian Network includes large geographical units, hills, larger forest complexes, karst fields, karst area as core areas and stepping stones.

- With regard to Italy, most Italian Regions have a regional law defining the framework for regional parks and protected areas at different levels, contributing to the definition of a national Ecological Network, which has only been promoted as a future project by now.

4.2.2 Harmonization process

Data and outcomes from the analysis of national and regional concepts has been already used to refine potential regional ecological linkages mapped by EURAC on the base of GIS analysis in the Mapping report of priority connectivity areas for spatial planning and GBI typology catalogue (figure 41).

Resulting Alps-wide connectivity maps produced by EURAC could be then used as reference for evaluating mapped inconsistencies between the ecological networks of different countries and initiate a harmonization process.

Cross-border priority connectivity areas for spatial planning identify by the project PlanToConnect and mapped inconsistencies in the ecological connectivity concepts across national and regional borders in the EUSALP macro-region (see paragraph 5.1.5) could be used as basis to identify and promote cooperation initiatives.

The transnational working group on Ecological Connectivity established by the project PlanToConnect under the AlpPlan network could promote cross border processes and the exchange with existing stakeholders' platforms.

The establishment and development of stakeholder platforms to facilitate trans-national cooperation on different topics, as well as the exchange of experience and application of lessons learnt across stakeholders in the countries involved are important tools to support GI projects and in turn address inconsistencies in ecological connectivity planning across national and regional borders. There are already inspiring examples such as the supra-national corridor in the Alpine and Carpathian Mountain ranges, the creation of a GI continuum along the Danube River basin and the urban greening policy in urban and peri-urban areas.

Certain initiatives could also be revitalized or renewed in other forms like the platform 'Ecological Network' of the Alpine Convention (2006), the Ecological Continuum Initiative ("Catalysing and Multiplying Alpine Connectivity") started by four active Alpine network organisations (2007) in the framework of the ECOCONNECT project ("Restoring the web of life") project (2008-2011).

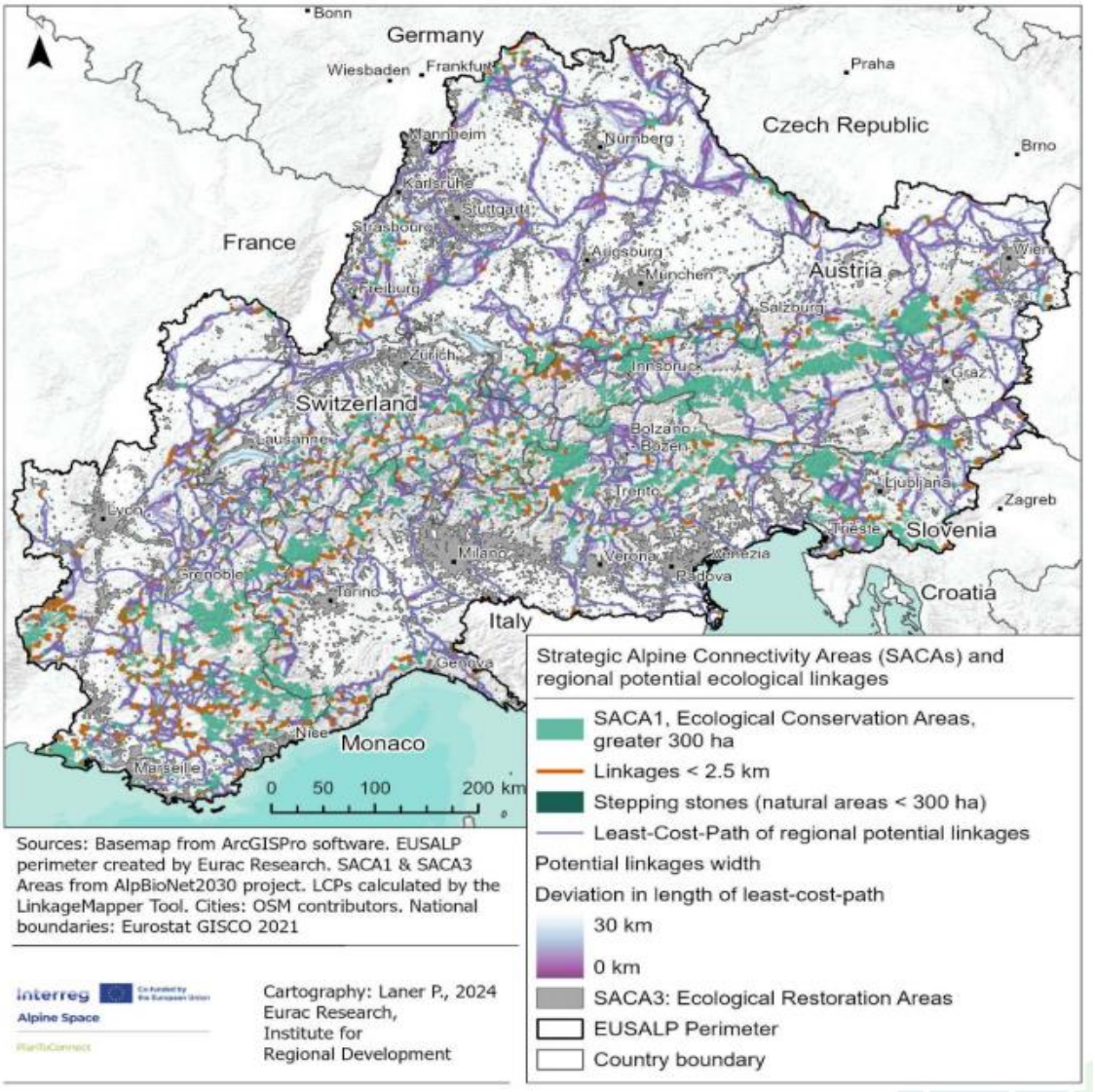


Figure 42: Potential Ecological network (PlanToConnect)

SECTION 3

CONCLUSIONS:
INPUTS FOR PROJECT ACTIVITIES AND AN ALPINE PLANNING STRATEGY FOR ECOLOGICAL CONNECTIVITY

5 Conclusions

5.1 Policy framework for the Alpine planning strategy for EC

Alpine and EU environmental policies and spatial development perspectives analysed in the previous chapters provide a good framework for the development of a spatial planning strategy for ecological connectivity in the Alpine Space. Their aims are to connect natural habitats, facilitate biodiversity conservation, and enhance ecosystem resilience, with member states responsible for implementing related policies. Some synthetic conclusions about this framework are presented as follows.

Synergies between environmental policies promoting ecological connectivity are:

- Common Goals: all initiatives aim to conserve or restore ecosystems, enhance biodiversity, and build resilience against climate change.
- Integrated Approach: The Nature Restoration Law provides a legal framework with binding targets that operationalize the broader goals of the Biodiversity Strategy.
- Mutual Reinforcement: The targets and actions outlined in the Nature Restoration Law will directly contribute to the objectives of the Biodiversity Strategy, such as increasing protected areas and enhancing ecological connectivity.
- Holistic Implementation: By aligning restoration efforts with biodiversity goals, the EU ensures a coordinated and comprehensive approach to environmental sustainability.

Implementation of Ecological Connectivity according to the EU and Alpine spatial development perspective should include:

- Green Infrastructure and ecosystem services: Member states are fostered to develop and implement strategies for green infrastructure, i.e. networks of natural and semi-natural areas designed to deliver a wide range of ecosystem services, including habitat connectivity. That should mean that we need tools to estimate the ecosystem services performances.
- Land Use Planning, strategic environmental and impact assessment (SEA, EIA): Integrating ecological connectivity into land use planning at all levels is essential. This involves ensuring that developments do not disrupt key ecological corridors and considering connectivity in the design and placement of new infrastructure, (SEA and EIA). In a wider perspective, it is necessary to develop approaches that are not limited to replace what has been disrupted, but that understand the ecosystem network needs, and then take opportunities from the transformations to increase the ecosystem functions and improve landscape. As it was underlined by the nature restoration law initiative: it is fundamental not to minimize the negative impacts but maximise the positive ones.
- Ecological connectivity, Nature Based Solution (NbS) and Restoration Projects: Restoration of degraded habitats and creation of new habitats can help enhance connectivity. Projects may include reforestation, wetland restoration, and creating wildlife corridors.

Practical Examples of Nature based solutions (NbS) could be:

- River Restoration: Restoring river ecosystems to enhance connectivity for aquatic and riparian species and NbS for Water Flow Disturbance to restoration of hydrological regimes and river dynamics. E.g. removing barriers like dams or weirs that hinder fish migration and restoring floodplains by reconnecting riparian ponds. Beside improving biodiversity, the risk of flooding is vastly reduced and might become an attractive spot for fishing and ecotourism, improving the local economy.
- Hedgerow Networks in agricultural plains: Managing and planting hedgerows in agricultural landscapes to provide connectivity for birds, insects, and small mammals and enhance landscape qualities improving the provision of supporting and cultural services (e.g. identity, sense of place, attractiveness, tourism).

Challenges and Considerations in the field:

- Balancing Development and Conservation: Ensuring that economic development does not compromise ecological connectivity requires careful analysis on the ecosystems network, and functions and needs, a careful planning and a monitoring program for verify the expected results. The use of Ecosystem Services in planning connectivity network should be recommended.
- Cross-Border Coordination: Ecological connectivity often requires coordination between neighbouring countries, especially where species migration routes across national borders.
- Monitoring and Adaptation: Continuous monitoring of ecological connectivity is necessary to assess the effectiveness of implemented measures and adapt strategies as needed.

5.2 Conceptual framework for the Alpine planning strategy for EC

In line with recent developments in the European and Alpine policy framework presented in the previous chapters, the project is developing an “Alpine Planning Strategy for Ecological Connectivity” that promotes multifunctional Green and Blue Infrastructure networks (GBI) and Nature-based Solutions (NBS) as a reference for the conservation and restoration of ecological connectivity in the Alps.

The Alpine planning strategy built on the Alpine 2050 spatial development perspective further developing its vision on environment and providing strategic directions with regard to connectivity and GBI networks planning.

At alpine level, the planning strategy defines and identifies “transnational priority connectivity areas for spatial planning” as areas where specific provisions aimed at preserving or re-establishing ecological connectivity should be included in national and regional spatial plans to avoid the isolation of Alpine biodiversity and enable ecosystem adaptation to climate change.

At the local level, within these areas, specific natural and semi-natural landscape elements will need to be conserved and, if necessary, new artificial ones created as part of a multi-purpose, multifunctional network of GBI to conserve and improve ecological connectivity between "core alpine conservation areas".

In the planning of such networks, the design and implementation of “connectivity conservation and restoration areas” outside the protected areas is particularly challenging and typically includes: the protection of "gateways" still free of infrastructural development, defragmentation actions to overcome existing infrastructural barriers, interventions to improve the quality of habitats and actions to counter the spread of invasive species.

To ensure their long-term implementation, "conservation and connectivity restoration areas" should then become an integral part of the spatial plans of the concerned territories as "a clearly defined geographical space, outside protected areas, that is governed and managed in the long term to maintain or restore effective ecological connectivity". Appropriate Impact Assessment procedures should be applied to all works and plans that may affect the functionality of these areas. The design of “connectivity conservation and restoration areas” in “transnational priority connectivity areas for spatial planning”, their integration in spatial plans of concerned authorities and the definition of appropriate cross-border governance arrangements for their implementation is therefore also a topic of the Strategy.

5.3 Integration of ecological connectivity in spatial planning

5.3.1 Integrating Ecological Network and Green and Blue infrastructure concepts

According to the EU *Green infrastructure has been defined as “A strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a* ***wide range of ecosystem services****, while also enhancing biodiversity.” Such services include, for example, water purification, improving air quality, providing space for recreation, as well as helping with climate mitigation and adaptation. This network of green (land) and blue (water) spaces improves the quality of the environment,* ***the condition and connectivity of natural areas****, as well as improving citizens’ health and quality of life. Developing green infrastructure can also support a green economy and create job opportunities.* ***The Natura 2000 network of protected areas constitutes the backbone of the EU’s green infrastructure***

Considering the evolution of the strategic framework on the environment, the spatial development perspectives in the EU and Alpine Space, and the concepts of ecological network and Alpine Space analysed in the previous chapters, it can be seen that the concept of ecological network in spatial planning, initially based on the Habitats Directive's concept of Natura 2000 network (see paragraph 2.1.1: protected areas in Art. 3 and corridors and milestones of Art. 10), with the entry into force of the GI strategy (see paragraph 2.1.3) is evolving into a holistic green and blue infrastructure network concept where the Natura 2000 network forms the backbone of the EU green infrastructure (EC 2021). This is confirmed by

the conceptual framework for the implementation of the TEN-N adopted by the current NaturaConnect project (see paragraph 2.1.4).

Evolving current ecological network concepts at national and sub-national levels into the backbone of GBI network concept could benefit planning and design of connectivity conservation and restoration areas and their integration in spatial planning and sector policies.

Spatial planning in the Alpine Space should considers ecological corridors in the context of green systems and green infrastructure and the goal of rational sustainable spatial development, which is aimed at placing development activities in space in such a way as to preserve its natural qualities.

The European Union is concentrating efforts on **building Green and Blue Infrastructure** (GBI) networks to better integrate them into planning tools with a structural approach. In ecology, this involves creating multifunctional landscapes that enhance biodiversity, mitigate climate impacts, and improve ecosystem services. By incorporating GBI into spatial planning, the EU aims to foster resilient and sustainable environments. This strategic integration is supported by the Biodiversity Strategy for 2030 and the Nature restoration law which promote systematic investments in nature-based solutions and healthy ecosystems.

Green and blue Infrastructure network is then to be considered **the evolution of the original concept of Ecological network** that could be implemented after the Habitats and Birds Directives, being a network of healthy ecosystems that provides benefits to the natural balances and socio-economic interests of populations. GBI is also aimed at ensuring that the quality of ecosystems is maintained or restored by connecting natural areas with each other, allowing nature to continue to provide human communities with the vital services they need, such as clean air and water, food supply chains, flood prevention, crop pollination, carbon storage, the health and well-being of citizens, and, at the same time, allowing living species to thrive in their natural habitat.

The concept of '**infrastructure'** depends on the spatial scale, being a multiscale concept, and it is widely used when considering the connectivity and distribution of green areas in a territory, or analysing existing elements in the landscape, such as protected natural areas, wooded areas circumscribed in rural areas, riverbanks and riverways of valley bottoms that define the essential joints of green infrastructure. Urban sprawl and the construction of road and energy infrastructure degrade and divide valuable ecosystems that damage habitats, species and reduce the spatial and functional coherence of the landscape.

By improving Green Infrastructure connections, it is possible to maintain or recreate **valuable natural and landscape elements**, which contribute to the provision of ecosystem services and are valuable for biodiversity.

Preserving or restoring ecosystems to a healthy **status** and maintaining the long-term provision of multiple ecosystem services within a well-connected GBI framework supports the objectives of many EU policy areas, such as cohesion policy, water, energy, transport, agriculture, climate and biodiversity. This policy is one of the elements of a real '**resilience**

strategy' that can cope with potentially changing conditions of human populations in the future, thus contributing to the European Union 2050 vision of living well within planetary boundaries, that includes at least the White Paper on 'Adapting to climate change: Towards a European framework for action' (COM(2009) 147 final), the Resource Efficiency Roadmap (COM(2011) 571 final), the EU Water Blueprint (COM(2012) 673 final), the Urban Agenda and the Amsterdam Agreement (2016), the European Green Deal (COM(2019) 640 final), and the European Strategy for Biodiversity - 2030 (COM (2020) 380 final). This log-term commitment to connectivity and biodiversity preservation has also been recently renewed through the European Restoration law.

As well, the EU environmental legislation, the backbone of ecological connectivity actions in Europe, established since the 1970s, is largely determined by its **implementation at national, regional, and local levels**. The European Union environmental policies have shifted from a primary focus on ecological interconnection to a more comprehensive **concept of multifunctionality**.

This shift seeks to include diverse ecosystem services into urban and rural development, supporting Green and Blue Infrastructure (GBI) networks that not only **benefits** biodiversity but also addresses climate change, natural risk reduction, and human well-being.

The conceptual change since the 1970s in this field, which intensified from 1992 to 2030, is significant: the European contextual overlook moved from an approach including connectivity at the heart of Ecological Infrastructures Planning to the concepts of multifunctionality, that have included **Ecosystem Services** and the shift from connections for protection to the active measures of the Restoration Law and the most recent virtuous practices, as described in the previous chapters. Multifunctionality emphasizes the importance of multiple natural systems, such as mixed forests and urban green areas, in delivering a range of advantages. These include flood mitigation, climate regulation, recreation areas, and wildlife habitat.

The **EU plans and strategies**, such as the Green Infrastructure Strategy and the Biodiversity Strategy for 2030, emphasize the necessity of incorporating GBI into spatial planning as well as agriculture, forestry, and urban development. This approach is supported by a variety of EU policies and activities that promote nature-based solutions and include ecosystem services into decision-making processes. These programs seek to build synergies between environmental protection and socioeconomic rewards, supporting sustainable development across Europe.

This path can be identified both in the legislative tools, that recently addressed more complex issues, while until the **Green Deal** they tended to tackle only specific issues (such as the Natura 2000 policies, the Directive on soil, the Directive on water, etc.) and in **planning practices**, in which we have moved from the planning of Ecological Networks to Green and Blue Infrastructures, pushing us to increasingly research/rediscover the urban-rural relationship including 'urban' nature and agroecosystems (see the Nature Restoration law) as well.

The transition from Ecological Networks to Green and Blue Infrastructures (GBI) in EU environmental planning indicates a **more comprehensive and integrated approach**. Initially, ecological networks emphasized biodiversity and habitat connectedness. The move to GBI today includes many environmental services such as climate change mitigation, natural risk reduction, human well-being, and biodiversity. GBI aspires to develop multifunctional landscapes that give social, economic, and environmental advantages by incorporating nature-based solutions into urban and rural design to promote sustainability and resilience across Europe.

5.3.2 Priority connectivity areas as backbone of the TEN-N in Alpine Space

The definition and mapping of priority areas by the PlanToConnect project for planning ecological connectivity at national and transnational level already offers a methodology, based on GIS analysis, to identify and assess potential natural and semi-natural GBI connectivity elements (and barriers) in priority areas to be included in national and regional spatial plans. The resulting network is the potential backbone structure for TEN-N project in the Alpine Space territory to avoid the isolation of Alpine biodiversity and enable ecosystem adaptation to climate change.

Threats to biodiversity from the fragmentation of habitats, both within and between protected areas is one of the focus of PlanToConnect analysis. To support sustainable land use planning, critical areas for defragmentation are identified based on connectivity analysis and can contribute to the mapping of GI (see Staccione et al., 2022).

5.3.3 Planning and design of connectivity conservation and restoration areas

Current ecological network concepts drafted at national and subnational levels in the Alpine Space analysed in this report, should be considered as starting point for the definition of National and subnational Green and Blue infrastructure concepts as part of the EU TEN-N project having connectivity as crucial element to prevent ecosystem degradation and disruption of ecosystem functions that sustain life on earth and provide social and economic benefits to the communities.

The integration of Ecological networks into the Green and Blue infrastructure concept allow to qualify and quantify ecosystem services provided by nature thus offering an anthropocentric and a human-nature reciprocity perspective that is very functional for the integration of the connectivity theme into spatial planning tools whose aim is to allocate space for land uses and reconciliate (often) conflicting interests.

Developing guidance for the upgrade of current ecological network concepts in the Alpine Space as the backbone structure of green Infrastructures concepts at all planning levels could offer the key for the better integration of ecological connectivity into spatial planning systems overcoming current gaps and inconsistencies in network design and implementation. Definitely to improve the expected benefits to biodiversity, adaptation and landscape qualities.

PlanToConnect should address:

- Policy Integration: Building on the strategic and spatial development perspectives of the Alpine Space, the spatial planning and nature conservation protocols as well as sectoral protocols and strategies in the Alpine Space should be upgraded to include ecological connectivity and NbS as a cross-cutting topic, thus integrating connectivity concepts with GBI and provision of ecosystem services. Current ecological network concepts present at the national and subnational levels should therefore be considered not as purely nature protection plans, but as the core structure of the holistic nature project carried out within the TEN-N project and the green infrastructure strategy.
- Planning and design methodology of connectivity areas that considers territorial challenges and potentials: Broaden the scope of connectivity areas by planning and designing them not only for the benefit of biodiversity but also to restore locally relevant ecosystem services that may have been lost and that support key ecological processes underpinning the preservation of the natural capital, community well-being and wealth (e.g. timber supply, clean water, cultural values, tourism economy, climate regulation, etc.). (see paragraph 2.1.3.2)
- Funding and Investment: promote the coordination of existing funding opportunities and encouraging further and innovative investments involving, financial institutions, SMEs and businesses in funding of nature-based solutions and green infrastructure (e.g. payment for ecosystem services, carbon farming, environmental, social, and corporate governance policies) (see paragraph 2.2)
- Cross-Sector Collaboration: encourage collaboration among different sectors to produce multifunctional landscapes. Primarily spatial planning, water management, Agriculture and Rural Development, Forestry, and Fisheries, Climate Change Mitigation and adaptation, Environmental protection that already are more explicitly incorporating the concept of Green Infrastructures but also finance, health and social and cultural sector. Developing narratives on future nature protection in the Alps using the Nature Futures Framework (NFF) could be an helpful resource to initiate collaboration (see box 4 Nature Future frameworks, paragraph 2.1.4.2)
- Multi-Level Governance: promote a multi-level governance approach that involves local, regional, national, and Alpine Space actors in planning and implementing measures to enhance ecological connectivity. The AlpPlan working group in Ecological connectivity could address relevant EUSALP and Alpine convention working groups on this topic and develop a specific project proposal to be funded under Priority 4, “Cooperatively manged and developed alpine region” of the Alpine Space program. At local level guidance on integrated planning of connectivity conservation and restoration areas based on PlanToConnect case studies would promote a process of co-design with stakeholders and the use of voluntary agreements (e.g. river contracts, ecological contracts, conservation easements), the process could potentially aim to the fulfilment of OECM criteria (see paragraph 21.2)

- Cross-Border Cooperation: encourage cross-border cooperation to address ecological connectivity challenges that span over national borders. This includes joint projects and strategies to address transboundary ecological corridors. Relevant transboundary cooperation areas could be selected based on mapped priority connectivity areas for spatial planning (see PlanToConnect mapping report D1.1.1) and the analysis of inconsistencies between ecological network plans of different countries presented in this report (see paragraph 4.1.5)
- Guidelines and Tools for policy makers: provide guidance and resources to help planners and policymakers in the Alpine Space to integrate connectivity and GBI into decision-making processes. The following commission documents published on the EC webpage on "green Infrastructure" could be helpful resources[21] :
    - "Guidance on supporting the deployment of strategic EU level green and blue infrastructure" encourages a more strategic and integrated approach to scaling-up investments.
    - "EU guidance on integrating ecosystems and their services into decision-making" (Summary, Part 1, Part 2, Part 3) highlights the wide range of benefits that flow from nature to people, and possible ways to take better account of these benefits in policy, planning and business investment decisions.
    - The guidance document is complemented by an overview and progress report of "Natural Capital Accounting in the European Union" (2019).
    - Factsheet on nature's role in climate.
    - Discussion Paper Towards a Strategy on Climate, Biodiversity and Ecosystem Services.
- GBI mapping methodology: With regard to GBI mapping and integration into spatial plans (A1.4 activity) PlanToConnect strategy could encompass the development of an **analytical framework for spatial prioritization**, which include the following elements:
    - restoration, maintenance or enhancement of biodiversity (priorities for conserving species/genetic diversity/habitats/ecosystems);
    - spatially explicit information on pressures, and on ecosystem services (or the underlying natural capital from which they are derived); and
    - system properties (e.g. through measures of connectivity, naturalness, and vulnerability)

[21] https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en

The JRC EEA mapping approach for GBI (see box 2, “Strategic Green Infrastructure and Ecosystem restoration” paragraph 2.1.3) and the related prioritization framework for measuring biodiversity preservation and the co-benefits of GI could be a reference for this work (see box 3 ‘Building a coherent Trans-European Nature Network’, EEA Briefing, paragraph 2.1.4.1)**.**

5.3.4 Cross-border cooperation, relevant policy context to address

About vertical and horizontal integration and governance, different policy sectors affect how to plan, implement and evaluate connectivity and GIs. This makes the involvement of stakeholders from different sectors (e.g. forestry, agriculture, industry, etc.) at the appropriate scale (e.g. local, regional, national and European) very important, for connectivity measures to optimized.

Figure 43: Green and Blue Infrastructure in the Alps (source: EUSALP)

The establishment and development of **stakeholder platforms** to facilitate trans-national cooperation on different topics, as well as the exchange of experience and application of lessons learnt across stakeholders in the countries involved are important tools to support GI projects, cross border harmonization of ecological networks plans and in turn ecological connectivity. Along with **the transnational working group on Ecological Connectivity (TCWG)** established by the project PlanToConnect under the AlpPlan network there are already inspiring examples such as the **supra-national corridor in the Alpine and Carpathian Mountain ranges** for the creation of a GI **continuum** along the Danube River basin and the urban greening policy in urban and peri-urban areas.

TCWG could benefit from the exchange with such stakeholders' platforms. With regard to the Alpine space policy context, to promote the implementation of the PlanToConnect Alpine Strategy and progress in both the integration of connectivity in spatial planning systems and in the cross-border harmonization of current ecological network plans. TCWG should address the following bodies and policy instruments:

- **Key transnational bodies to address**: EUSALP Action Group 7 (AG7), Alpine biodiversity board (ABB), (particularly its ongoing process towards an Alpine Spatial Planning Perspective), Mountain agriculture and mountain forestry working group, Large Carnivores, Wild Ungulates and Society platform WISO, Soil protection working group.
- **Other relevant bodies**: if we consider the benefits and threats to a well-connected Alpine GBI infrastructure, the related provision of Ecosystem Services, relevant stakeholders are to be found as well in Risk governance (AG8), Natural hazards platform PLANALP, Alpine Climate board, Resources (AG6), Energy (AG8).
- **The Key policy instrument to address** is the Alpine Convention protocol for spatial planning and sustainable development.
- **Other relevant policy instruments** are the protocols on nature protection and landscape conservations, energy and soils conservation. If we enlarge the scope to well-connected Green and Blue infrastructures, then water management and natural hazards platform applies as well.
- **Key past and current cooperation projects** to consider are primarily those supported by AG7[22], including Econnect, AlpBioNet2030, and Green Alps (on connectivity), LOS_DAMA! and AlpES (on landscape and ecosystem services), but also the AG6 Spare project (Strategic Planning for Alpine River Ecosystems) and the AG8 AlpGov (Alpine governance) project, even though their scope and goals are different. Key ongoing project are:
    - The "NaturaConnect project" Building a resilient ecological network of conserved areas across Europe for nature and people" (see paragraph 2.1.4.2)
    - "Nature-based solutions in the Alpine region: using ecosystem functions to promote climate mitigation and adaptation measures. Creating new nature-centred governance mechanisms across sectors and policy levels", commissioned by the German Federal Environmental Agency to CIPRA Int/ifuplan.
- **Other relevant cooperation projects** to consider are DinAlpConnect and the case study on the EUSALP macro region led in the framework of the ESPON project GRETA ("Green infrastructure: Enhancing biodiversity and ecosystem services for territorial development")[23].

[22] https://alpine-region.eu/topics-action-groups/detail/green-infrastructure

[23] https://archive.espon.eu/sites/default/files/attachments/GRETA_Alpine_Macro_Region.pdf

Table 5 updated EUSALP policy framework for cooperation per objective

EUSALP objectives (action groups, AG)	Alpine convention protocols (working bodies)	INTERREG Alpine Space priorities (specific objectives, SO)
Environment	Prot. Spatial planning and sustainable development Prot. Nature protection and landscape conservation Prot. Soil conservation Prot. Energy	Climate resilient and green alpine region Carbon neutral and resource sensitive Alpine region
	Alpine Climate board	
	Spatial planning and sustainable development working group	
Energy (AG9)		Promoting energy efficiency and reducing greenhouse gas emissions (SO2.1)
Green Infrastructure (AG7)	Alpine biodiversity board Mountain agriculture and mountain forestry working group Large Carnivores, Wild Ungulates and Society platform WISO	Enhancing protection and preservation of nature, biodiversity and green infrastructure, including urban areas, and reducing all forms of pollution (S01.2)
Resources (AG6)	Soil protection working group	Promoting the transition to a circular and resource efficient economy (SO2.2)

Risk governance (AG8)	Natural hazards platform PLANALP	Promoting climate change adaptation and disaster risk prevention, and resilience, taking into account eco-system based approaches (SO1.1.)

5.3.5 The Alpine Convention protocols on spatial planning and nature protection

The Alpine Convention is an international treaty aimed at **promoting sustainable development in the Alpine region**. It involves the eight Alpine countries (Austria, France, Germany, Italy, Liechtenstein, Monaco, Slovenia, and Switzerland) and the European Union. The Convention goals include protecting the natural environment, promoting sustainable economic development, and preserving the cultural heritage of the Alps.

The Alpine Convention stresses that making the Alpine region available as a place with functions of broad interest to the whole of Europe, especially those of protection and those related to ecological balance, and as an area of tourism and recreation, can justify appropriate supporting measures, aimed at harmonizing land use with ecological needs and objectives (AlpConv, 1991). In particular, spatial planning and sustainable development policies should reconcile economic interests with environmental protection, aiming to restore ecological balance and biodiversity in the Alpine region.

Ecological connectivity, protected areas, and open spaces are not linked to territorial or administrative entities, but must be treated in a broader, cross-border context. at the national and international levels frequently target land take reduction in cross-border contexts in specific border regions. Natural hazards are also important themes for cross-border collaboration, depending on the territory.

The **main goals** of the Convention are:

- Balanced growth: ensuring that spatial growth in the Alps is balanced and sustainable, while contemplating ecological, economic, and social factors.
- Environmental protection, which refers to the preservation and protection of the Alps natural environment, landscapes, and biodiversity.
- Sustainable Land Use: the efficient and bearable use of land and resources to reduce environmental impact.
- Integrated Planning, promoting integrated and cross-border spatial planning to address shared issues and possibilities in the Alpine region.

These objectives led to a **Spatial Planning and Sustainable Development Protocol**[24], which is one of the key initiatives of the Alpine Convention. It outlines the principles and measures for spatial planning and sustainable development in the Alpine region. The Main Provisions of this protocol are related to:

- Zoning and land use planning, developing standards to guarantee that development is compatible with environmental and cultural values.
- Urban Development, encouraging sustainable urban development and limiting sprawl.
- Infrastructure and Transportation, creating infrastructure and transportation systems that reduce environmental impact and promote sustainable mobility.
- Cooperation, encouraging collaboration among various levels of government and stakeholders to facilitate the efficient implementation of spatial planning policies.

Considering implementation, the accomplishment of the Spatial Planning Protocol entails a variety of initiatives, including **Regulatory Frameworks**, creating and unifying regulatory frameworks for spatial planning in Alpine countries, and Monitoring and reporting, implementing procedures to measure progress and guarantee compliance with the protocol objectives. Another significant outcome of the protocol is **Public Participation**, which is aimed at including local communities and stakeholders in the planning and decision-making processes, to ensure that their needs and opinions are reflected.

In terms of possible **benefits to ecological connectivity**, environmental sustainability, as one of the main goals of the Convention, entails preserving natural habitats, landscapes, and biodiversity in the Alpine region. Also, Cultural preservation is an important advantage, as it refers to preserving the Alpine community's cultural heritage and traditions. Regional collaboration is surely another plus in the Convention outcomes, strengthening collaboration and coordination among Alpine countries and regions to address shared challenges and opportunities. **Economic Development** supported by the Spatial Planning Protocol, though being a potential threat to ecological connectivity, can be turned in another possible positive effect, by advancing sustainable economic activities that are consistent with the Alps environmental and cultural values.

The Alpine Convention and its Spatial Planning Protocol are to be considered **important tools for fostering long-term development and environmental conservation** in the region. These two elements can combine growth needs with environmental and cultural preservation through the promotion of integrated and cross-border spatial planning.

The "Assessment study: Cross-border spatial development in the Alpine Convention area" (2022) highlights among topics for stronger cross-border cooperation on protected areas, open spaces and ecological connectivity:

[24] https://www.alpconv.org/fileadmin/user_upload/Convention/EN/Protocol_Spatial_Planning_EN.pdf

- Cartographies and common rules for the elements of the ecological network with transboundary value
- Establishment and management of border-crossing protected areas
- Securing of transnational large-scale ecological corridors
- Economic usage of open spaces for renewable energy production (PV, solar, biomass)

5.3.6 Cornerstones for the integration of ecological networks into green and blue infrastructures and spatial planning systems

To turn the GBI concept into an operational tool, existing ecological networks should be translated into fundamental elements of Green Infrastructure, to be seamlessly integrated into spatial planning systems, enhancing ecological connectivity and promoting sustainable development. The **Green Infrastructure** (GI) approach is related to some main concepts, that could be summarized as follows:

Ecological Networks

- Definition: a system of interconnected natural areas and green spaces that provide habitat for wildlife, maintain natural processes, and support biodiversity.
- Current Status: existing ecological networks include protected areas, nature reserves, and corridors that facilitate wildlife movement and ecological processes.

Green Infrastructure

- Definition: A strategically planned network of natural and semi-natural areas designed to deliver a wide range of ecosystem services, such as clean air and water, climate regulation, and recreational spaces.
- Cornerstones: core areas (protected lands), buffer zones, corridors (linking habitats), agricultural lands or even landscapes, hydrological network and sustainable land-use practices.

Ecological Connectivity

- Importance: ensuring that different habitats and ecosystems are connected allows species to migrate, adapt to climate change, and maintain genetic diversity.
- Challenges: Urban development, infrastructure projects, and land-use changes often disrupt these connections, leading to habitat fragmentation.

Spatial Planning Systems

- Integration: incorporating ecological connectivity into urban and regional planning to ensure that development projects consider and maintain ecological networks.
- Tools: planning regulations, land-use planning, environmental impact assessments, and green space requirements.

Benefits of Green Infrastructure are related to Biodiversity Conservation, through enhanced habitat connectivity supports a wider range of species and ecosystems, Ecosystem Services, as GI provides essential services such as flood mitigation, air and water purification, and recreational opportunities, Climate Resilience, connected green spaces help urban areas adapt to climate impacts by regulating temperatures and managing stormwater, and Quality of Life, thanks to increased access to green spaces improves physical and mental health for urban residents.

5.4 Spatial planning approaches and tools for conservation and restoration of ecological connectivity

There are several **Technical implementation tools** that can help improving ecological connectivity, including physical mapping of components, techniques to strengthen the connectivity of ecosystems and enhance biodiversity and nature preservation (prioritising measures for defragmentation and restoration) and methods to ensure the multifunctionality of ecosystems for the long-term delivery of ecosystem services, which could include climate change mitigation, sequestration (greenhouse gases, air pollution) and recreation. In this complex prospect of techniques, methods and tools, Nature based solutions (NBS) seem to be the most popular ones in the actual planning scene.

The European Union is supporting and promoting **mapping tools for Green infrastructure** to improve the deployment if GI in rural landscapes, urban areas, and ecosystem services. GI is being implemented in rural areas to prioritize conservation, restoration, and defragmentation measures and to mitigate the impacts of agricultural intensification and road infrastructure on species movement. Tools for urban mapping assess territorial and ecological coherence between urban and peri-urban areas. GI is also being explored for enhanced biodiversity and ecosystem service delivery through spatial modelling of land use change. Another relevant element being assessed for prioritization measures and the benefits of GI for society is the related costs, with GI projects being considered **cost-efficient alternatives** to grey infrastructure or greening measures. To increase the efficiency of GI solutions, the mapped components should also be integrated in planning tools at different scales, to highlight fragmentation patterns and connectivity of recommended landscape components and to drive decisions in planning towards an integration and harmonization of the existing networks.

5.4.1 Polycentric Spatial Development and connectivity

Polycentric Spatial Development refers to the strategy of promoting multiple centres of growth within a region or country rather than concentrating development in a single metropolitan or urban area. This planning strategy can contribute to better balanced territorial development, counteracting excessive concentration by strengthening secondary

growth poles thus supporting more sustainable land use patterns and reducing environmental impacts by preventing urban sprawl and territorial fragmentation.

In the TEN-N perspective GBI should be considered as the ordering principle of sustainable land use planning, in which ecological connectivity is the structuring element for the organization of a balanced territory. The green and blue infrastructure should therefore become part of an overall strategy for sustainable land use planning based on a polycentric organisation of the territory. In this perspective, the various elements making up these infrastructures make the limits to urban expansion tangible (green belt), they accompany the polycentric organisation by formalising breaks (green infrastructure) and provide amenities and ecosystem services in the densest part of the agglomeration, which contribute to improving the quality of life.

Integration of ecological connectivity as strategic element of Polycentric Spatial Development could contribute to the integration of environmental sustainability into urban and regional planning by preventing urban sprawl, reducing fragmentation from linear infrastructures and related land degradation patterns thus ensuring that natural habitats and green spaces are interconnected, benefiting both human and nature.

At the level of regional and inter-municipal planning among the key aspects of a polycentric spatial development strategy that truly supports more balanced spatial growth and sustainable land use patterns, **PlanToConnect's Alpine planning strategy should recommend explicitly including**, in parallel with the development of efficient transportation networks to connect the various urban centres and facilitate the movement of people and goods, **the development of a green and blue infrastructure network** for the preservation and restoration of ecological connectivity in order to support genetic, material, and energy flows related to the basic ecosystem functions that sustain natural capital essential for sustainable economic growth and the well-being of populations. The following are key points for the PlanToConnect strategy with regard to promote a truly polycentric spatial development:

- *Multifunctional corridors (ecosystem services)*
  - As described in the previous chapter, are the backbone of the future European spatial development perspective with regard to green growth, environment, climate mitigation and adaptation in Europe.
- *Multi-level Governance*
  - Coordination: Collaboration among local, regional, and national authorities to ensure cohesive planning and management of ecological networks and green and blue infrastructures.
  - Policy Integration: Embedding ecological connectivity objectives into spatial planning policies at all governance levels.
- *Sustainable Land Use*
  - Planning Regulations: Implement land use planning that preserves and enhances natural habitats and green spaces.

    - Urban Development: Encourage compact and mixed-use development to minimize urban sprawl and habitat fragmentation.
- *Stakeholder Engagement*
    - Involvement: Engage communities, NGOs, and private sector stakeholders in planning processes to ensure inclusive and effective solutions.
    - Awareness: Raise awareness about the importance of ecological connectivity for sustainable development.

Integrating ecological connectivity into polycentric spatial development in the EU assures that economic and urban growth do not compromise environmental sustainability. By **encouraging green infrastructure**, sustainable land use, and collaborative governance, regions could be supported in achieving balanced growth that benefits both people and nature. This approach not only protects biodiversity and ecosystem services, but it also improves the resilience and quality of life in communities across the EU.

In terms of **implementation of connectivity**, the following is to be considered by PlanToConnect's Alpine strategy:

- *Regional Planning Frameworks*
    - Develop comprehensive regional plans that prioritize ecological connectivity.
    - Identify and protect critical habitats and corridors within polycentric regions.
- *Ecological Corridors*
    - Establish and maintain ecological corridors that connect core natural areas, facilitating wildlife movement and genetic exchange.
    - Utilize existing natural features (rivers, ridges) and Nature based Solutions (NbS) to create new corridors (urban greenways, wildlife overpasses).
    - To develop a draft network of ecological corridors for pollinators and develop a plan of measures for its implementation
    - Identifies threats to connectivity within and between water bodies, such as dams, weirs and other physical barriers, in river basin management plans (RBMPs) and re-establish free movement of water, sediment and biota between different habitats.
- *Green Infrastructure Projects and NbS*
    - Define the relative weight of the biodiversity versus ecosystem services objectives when designing connectivity corridors (e.g. non-native vegetation makes no difference for some specific ecosystem services - e.g carbon sequestration - but might not serve as suitable habitat for many species). Involving stakeholders from different sectors is crucial to determine priorities ecosystem services to be addressed and expected benefits to nature and society.
    - Promote reforestation, habitat restoration projects and other large-scale green infrastructure project in rural areas.
    - Invest in projects that enhance urban green spaces, such as parks, green roofs, urban forests and nature-based solutions to connect urban centres.
- *Monitoring and Evaluation*

- Implement monitoring systems to track the effectiveness of connectivity measures and adapt strategies as needed.

Use GIS and other technologies to map and analyse ecological networks and GBI not only physically but also in terms of provision of key ecosystem service (see next paragraph 5.4.2).

5.4.2 Assessment tools in spatial planning (SEA and EIA)

Evaluations and assessments are important procedures to integrate connectivity strategies into spatial planning systems at regional and local level and should be considered by PlanToConnect in both the development of the Alpine Planning strategy and a key point to address in the case studies' technical proposal for spatial planning authorities in pilot areas.

Environmental Impact Assessment (EIA) the EU Guidance on Screening in EIA (Directive 2011/92/EU as amended by 2014/52/EU) in coherence with Art.6 of the habitat directive (see paragraph 2.1.1) requires member states to assess the potential environmental impacts of public and private projects, including infrastructure developments that may affect connectivity function of the ecological corridors outside of protected areas. The aim is to ensure that such projects are carried out in a manner that minimizes adverse effects on biodiversity.

Strategic environmental assessment (SEA) in Europe is also crucial in this sense. Governed by Directive 2001/42/EC, known as the SEA Directive, this tool requires an assessment of the environmental implications of certain plans and programs before they are implemented. The goal is to incorporate environmental issues into the formulation and implementation of these plans to promote sustainable development. The SEA Directive covers a wide range of sectors, including land use, transportation, energy, waste, and agriculture.

Strategic environmental assessment (SEA) and Environmental Impact Assessment (EIA) can support decision-makers in constructing more sustainable plans, programs, and policies (PPPs) and projects. **PlanToConnect Strategy,** to be more coherent with new frontiers of sustainable territories**,** should promote that PPPs and projects would need to include specific connectivity conservation and restoration objectives for preserving or restoring natural capital, biodiversity and connectivity to increase ecosystem service (ES) strategies.

As presented in previous chapters Ecosystem Services (ES) represent the human benefits derived from a combination of biophysical structure and ecological functions (including connectivity) that characterize the landscape and can be conditioned from the method and purpose for which humans use the land. Ecosystem Services should then be included in decision-support procedures, such as strategic environmental assessments (SEAs) for public plans or programs and environmental impact assessments (EIAs) for individual projects affecting connectivity areas and their importance for the preserving ecosystem function and related ecosystem services essential to safeguarding people's well-being.

Currently, the decision support processes in SEA and EIA do not consider GI/NbS-based ecosystem service assessment. This is an important gap requiring action to clarify the feedback between the built environment, GI, ecosystem functions (including connectivity) and human well-being during planning to find the best solutions to achieve territorial sustainability.

PlanToConnect could investigate this topic further by building on existing studies such as the case study of a peri-urban development plan in the municipality of Gallipoli, in Southern Italy (Semeraro, 2020)[25].

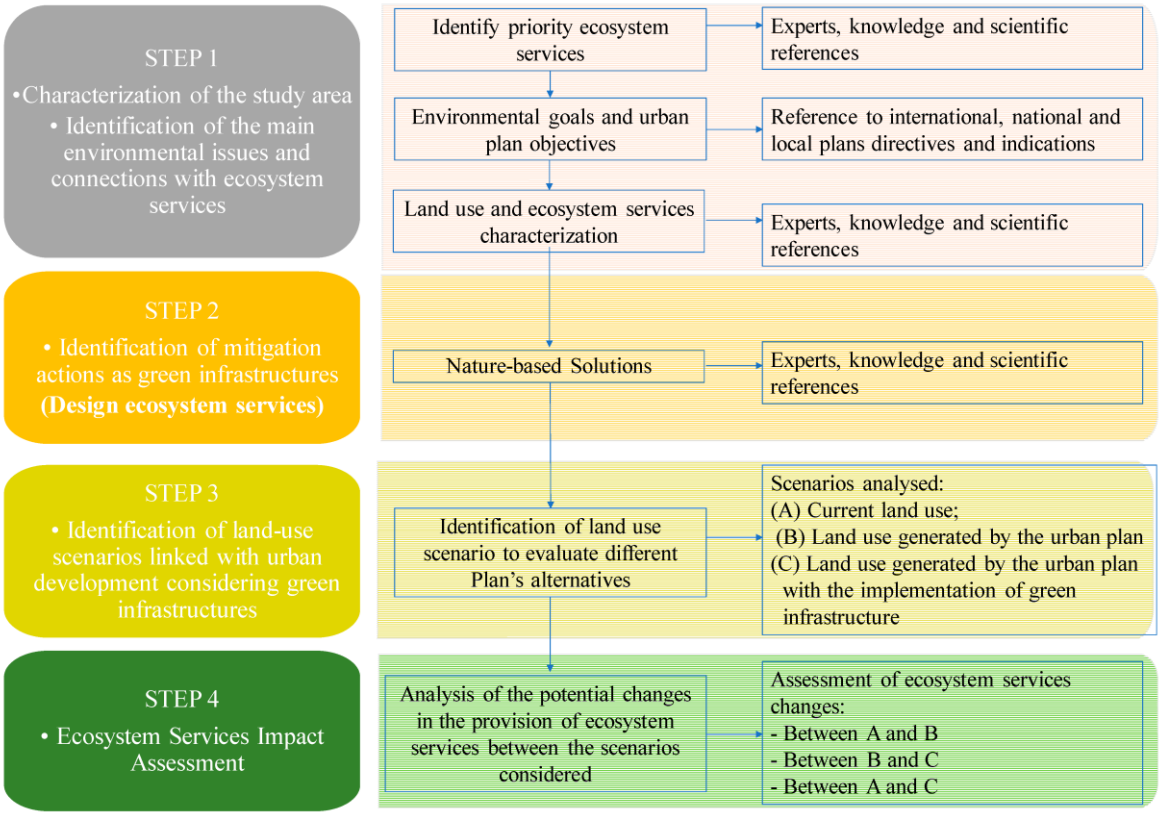


Figure 44 Ecosystem Services in SEA and EIA, scheme of the methodology modified considering Therivel, UNEP, Geneletti, and Vasquez et al.

[25] https://www.mdpi.com/2071-1050/13/1/122

The methodology proposed in the case study is inspired by the UNEP guidelines, and is based on the definition of priority ecosystem services along with the environmental objectives of a given territory, and can be useful for incorporating the concept of ecosystem service into all stages of the SEA process, creating an interconnected workflow between the SEA process and the inclusion of ecosystem services in spatial plans.

For the purpose of conserving connectivity, the ES habitat quality (see paragraph 2.1.3.2) could be included among other priority Ecosystem service selected on the base of territorial vocations, environmental objectives and climate vulnerabilities (e.g. provision of timber for forest ecosystems, of food for agri-ecosystems, water purification and flood control for wetland-ecosystems etc.). Then following the assessment of priority ES the design of mitigation actions like green infrastructure and NBS is identified, which could be implemented in the spatial plan to benefit connectivity, natural capital, territorial resilience and human wellbeing. The capacity to develop green infrastructure in SEA processes could configure the SEA as a tool for ecological landscape design that is integrated with spatial planning.

5.4.3 Nature based solution

Nature based solutions are an important implementation tool in the definition of connectivity conservation and restoration measure to be considered in PlanToConnect strategy and in case study implementation**.**

Nature-based Solutions (NbS) are defined by the European commission as "*Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*".

NbS for the ecological connectivity are major measures in the European Union environmental policies, that aim to improve biodiversity and ecosystem resilience, while mitigating the effects of climate change. NBSs are actions that use and enhance nature to address societal concerns, benefiting both biodiversity and human well-being. Examples of NBSs are the restoration of wetlands to improve water quality, the establishment of green urban spaces to prevent heat islands, and reforestation efforts to sequester carbon and boost biodiversity.

Benefits to connectivity related to NbSs start from Biodiversity Conservation, as they help to protect and restore ecosystems, which in turn increases biodiversity. The increasing in biodiversity is not the only result. In fact, biodiversity is a goal but also an indicator of the functionality, or the health, of the ecosystems. In other words, biodiversity is the key for the ecosystems to provide different kinds of services. That is why the support **Ecosystem Services**, linked to habitat provision, pollination and so on, are considered as the fundamental ecosystem services able to maintain all the others. We couldn't have climate mitigation and so on without functioning ecosystems.

Climate Mitigation and Adaptation benefits of NbSs are related to improving carbon sequestration and ecosystem resilience, as NBSs help to mitigate climate change and allow people to adapt to its consequences. In terms of Economic and social advantages, NBSs can provide cost-effective alternatives to traditional infrastructure, support sustainable livelihoods, and improve human health and well-being. Strategies for Enhancing Ecological Connectivity related to NbSs can help improving Corridors, creating connections suitable to wildlife, that connect isolated habitats to enable species mobility. NbSs can be used also to mitigate the impact of barrier, identifying and reducing the negative effects on species movement of highways, dams, and fences. Habitat restoration, another positive factor to ecological connectivity, is the process of restoring degraded areas to improve their ecological function and connection. For sure, integrating connectedness into Land Use Planning tools can ensure that all levels of land use planning incorporate and emphasize ecological connectivity in their actions.

Figure 45: Simultaneous multiple benefits of nature-based solutions (source: networknature.eu)

NbS and Green Infrastructures enhancing ecological connection are **key planning tools for attaining the EU environmental and climatic objectives**. By incorporating them into policy and planning processes, the EU aim to foster a more resilient and sustainable future for both nature and people.

NBSs require thoughtful attention and consideration in terms of **design** and implementation. Three design stages must be considered: planning, execution, and delivery. For PlanToConnect NbS for ecological connectivity the following should be considered:

- dynamic solutions must be proposed, as they are designed around dynamic ecosystem functions that can change over time,
- multiple benefits should be created, i.e., not only addressing ecological connectivity (e,g. habitat quality) but also other benefits (e.g carbon sequestration, climate regualtion) that should be mitigated primarily, but also other territorial priorities (e.g. production of timber, food, attractiveness etc.)
- to address the same challenge, there may be several solutions; therefore, NBSs must follow the multiple designs principles,
- adaptive maintenance is a goal, as NBSs may need to be adjusted over time for new challenges

5.4.4 The NaturaConnect connectivity network design framework

With regard to the design and implementation of GBI connectivity network in PlanToConnect case studies the recently issued "Guidelines for connectivity planning in Europe"[26] NaturaConnect project outlines a set of five key steps for practitioners to design connectivity framework that could be a useful reference to project activities in pilot areas. They are the following:

(1) Scoping and Problem Assessment: Conduct a comprehensive analysis of the entire landscape to identify potential threats, connectivity actions, and impact of those actions, identify all relevant stakeholders and build an interdisciplinary collaboration team for connectivity analysis, communication, and implementation. Establish the general spatial extent at which your study will take place.

(2) Setting of Objectives: Use the assessment of the connectivity problem to establish spatial and temporally explicit objectives and targets that will help mitigate the identified problem. Determine the appropriate width and characteristics of corridors and stepping stones based on the target species and landscape characteristics. Finalize the spatial extent and needed data resolution.

(3) Analysis Selection and Data Preparation: Determine the correct model or models to analyse ecological connectivity. Given the model and your objectives collect and produce all the necessary data and spatial layers necessary to run the spatial analysis.

(4) Assessment of connectivity: Use connectivity metrics and models to determine the most effective design for a connectivity network that integrates with the current network of protected areas. Present draft results to stakeholders, iterate new models, and prioritise corridors and stepping stones; and

[26] https://preprints.arphahub.com/article/129021/

(5) Implementation, Monitoring and Evaluation: Develop a comprehensive management and monitoring plan for the ecological corridor and/or stepping stones. This includes activities such as habitat restoration, invasive species

Figure 46 Framework for the design and implementation of ecological connectivity projects

Further strategic and operational guidance on planning, mapping and implementation of green and blue infrastructure networks for connectivity is provided by the NaturaConnect guidelines and should be considered as a valuable input for the Alpine connectivity planning strategy and project activities.

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