Interreg Alpine Space

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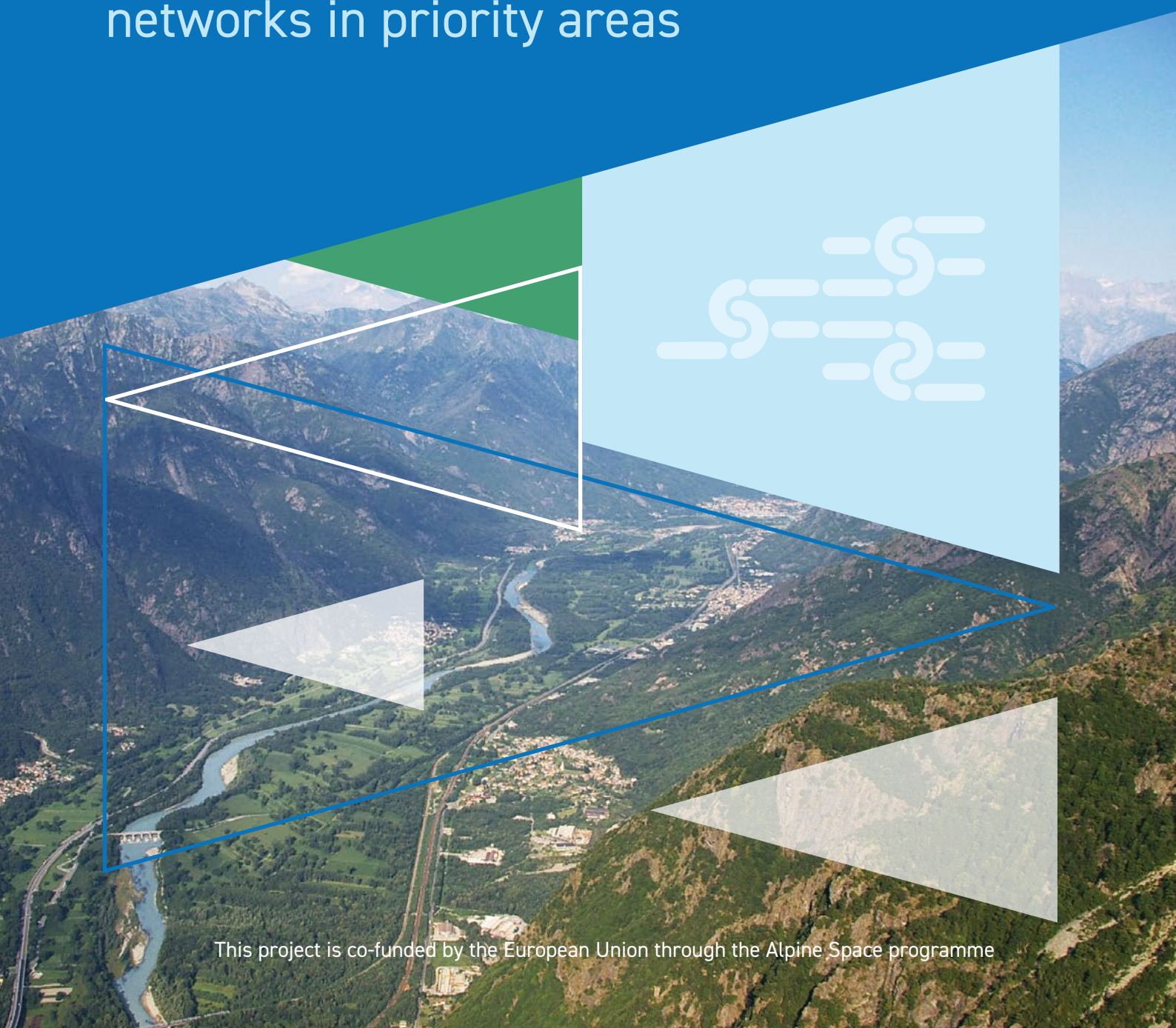
PlanToConnect

ALPINE PLANNING STRATEGY FOR ECOLOGICAL CONNECTIVITY

Harmonized and integrated planning of green and blue infrastructure networks in priority areas



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Harmonized and integrated planning of green and blue infrastructure networks in priority areas

Alpine planning strategy for ecological connectivity
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Glossary of abbreviations

ARL	Academy for Territorial Development in the Leibniz Association
CAP	Common Agricultural Policy of the European Union
EEA	European Environment Agency
ERDF	European Regional Development Fund
ES	Ecosystem Services
GBI	Green and Blue Infrastructure
INU	Istituto Nazionale di Urbanistica – National Urban Planning Institute of Italy
ISPRA	Italian Institute for Environmental Protection and Research
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
ÖROK	Österreichische Raumordnungskonferenz - Austrian Conference on Spatial Planning
SACA	Strategic Alpine Connectivity Areas, developed in the AlpBioNet2030 project
TEN-N	Trans-European Nature Network
TEN-T	Trans-European Transport Network

01

INTRODUCTION

Ecological connectivity is a fundamental component in the protection of biodiversity, yet it remains insufficiently integrated into spatial planning systems across the Alpine region. The existing protected areas have been established to preserve biodiversity and ecosystem functions but, to be truly effective, they need to be linked through an ecological network. As long as it is not implemented, harmonized and managed by the Alpine countries, this structure of ecological connectivity will be threatened by the effects of human presence, anthropogenic infrastructures, and climate change, as is currently the case.

The necessity of integrating ecological connectivity into spatial planning

Spatial planning plays a crucial role in managing territorial development and balancing land-use interests coming from different sectors. One of its key tasks is to counteract unbalanced soil consumption and landscape fragmentation, especially outside protected areas, which is directly linked to ecological connectivity.

Ecological network elements are highly place-specific and require a certain amount of physical space. When analysing ecological networks, this can be specified by indicators like species dispersal distances, minimum sizes of core areas, minimum corridor widths, disturbance distances, and buffer zone distances around protected areas. The spatial dimension is therefore clearly given, and the public interest in maintaining ecological networks derives not only from the EU level (e.g. Biodiversity Strategy 2030), but also from a spatial planning perspective. To counteract landscape fragmentation and to preserve ecological functions of the landscape are core objectives of the spatial planning discipline reflected in spatial planning laws of many Alpine countries (see section 4 on legislative aspects). From a spatial planning perspective, the prevention of landscape fragmentation becomes relevant for infrastructure planning, including settlement development, as well as development of transport and energy infrastructure. For instance, counteracting fragmentation by inner development of existing settlements is an avoidance measure for interventions in the open landscape and ecological networks. Reducing fragmentation is a widely accepted objective, of significance not only for conserving natural habitats and biodiversity, but also for landscape protection, protection of soil functions, reduction of transport distances and routes, as well as of infrastructural costs for municipalities. However, among these aims, the spatial and landscape planning disciplines recognize the maintenance of ecological networks and landscape protection as a key contribution to sustaining biodiversity.

Another reason for integrating ecological connectivity into spatial planning concerns the cross-sectoral management of land use interests. The *GUIDELINES on How to Use Spatial Planning Tools in Integrative Management of Ecological Corridors* for the Danube basin, an output of the Interreg Danube ConnectGREEN project, highlight the need for managing ecological corridors and potential anthropogenic land use conflicts through spatial planning procedures (Finka et al., 2021). For the management of ecological networks, which are site-specific, a cross-sectoral coordination of spatial requirements is needed. Also, in local, provincial and regional administrations, the competence for ecological connectivity is not assigned to a single administrative office. Spatial planning is a cross-sectoral and integrative discipline, and it has the task to coordinate the spatial needs arising from different sectoral policies. Therefore, spatial planning could make a significant contribution to the coordination of tasks and spatial requirements among various sectors for the designation and management of ecological corridors. According to Austrian experts (Leitner et al., 2014), only an integration of ecological networks in regional and local spatial planning can guarantee evaluation procedures of infrastructural projects. For maintaining the functionality of the designated ecological network, permeability of each ecological corridor should be checked in the case of a planned project.

Furthermore, from the administrative point of view, nature protection administrations primarily manage protected areas. In some regions of the Alpine Space, landscape planning offices have the task to tackle the problem of fragmentation and to guarantee ecological connectivity between protected areas.

Therefore, the Interreg Alpine Space PlanToConnect project elaborated tools, technical implementation

proposals in pilot sites, and recommendations in the form of two guidelines to mainstream ecological connectivity into spatial planning systems of the Alpine Space. The project thus contributes to the inclusion of ecological connectivity and biodiversity into spatial planning tools and policies of the Alpine countries and to the enhancement of a coherent network of green and blue infrastructures throughout the Alps.

The need for a spatial planning strategy for ecological connectivity

As ecological networks are intrinsic to natural areas, planning for ecological connectivity does not stop at administrative boundaries. It would therefore be necessary for the Alpine countries to follow a coordinated approach with a shared vision, objectives and priorities for the establishment of a coherent ecological network.

A shared strategy is needed to:

- establish a common vision and objectives for joining forces and concentrate on shared priorities for the establishment of certain ecological network elements at the Alpine level
- apply common tools (e.g. databases) that facilitate connectivity planning
- bring all countries to the same status of connectivity planning
- harmonize ecological networks between the countries and avoid different regulations at national boundaries
- reduce administrative and legal barriers
- emphasize the public interest of preserving ecological functions of the landscape.

Target groups of the strategy

This strategy is aimed primarily at stakeholders operating at higher administrative levels, namely the regional, national and transnational. It addresses decision makers, technicians, and informs non-governmental organisations on options for improving the Alpine ecological network by spatial planning procedures. As ecological connectivity is a cross-sectoral topic, stakeholders from nature conservation, wildlife management, spatial planning, territorial development, infrastructure development, especially for transport, as well as the agricultural sector are addressed. The forestry sector is only considered for specific regions (see section "Most important anthropogenic pressures"). In the following, examples of target groups at different levels are listed.

At transnational level:

- Action group 7 "Green infrastructure" of the EU strategy for the Alpine region (EUSALP)
- the Permanent Secretariat and thematic working bodies of the Alpine Convention, such as the Spatial Planning and Sustainable Development Working Group
- CIPRA as an "*independent non-governmental and non-profit umbrella organisation, committed to the protection and sustainable development of the Alps*" (cipra.org).

At national level, the strategy should inform ministries for spatial development and planning, nature protection, transport, agriculture, as well as national institutions or networks in these fields. Some examples:

- ARL (Academy for Territorial Development in the Leibniz Association)
- ISPRA (Italian Institute for Environmental Protection and Research)
- INU (*Istituto Nazionale di Urbanistica* – National Spatial Planning Institute of Italy)
- National bodies of professional associations of engineers-architects-planners in Italy (Consigli nazionali di ingegneri, architetti, paesaggisti, pianificatori), and other similar bodies related to professionals involved in the spatial planning process
- ÖROK (*Österreichische Raumordnungskonferenz* – Austrian Conference on Spatial Planning)
- Agence nationale de la cohesion des territories – ANCT in France
- Institute of the Republic of Slovenia for Nature Conservation
- Ministry of Natural Resources and Spatial Planning of the Republic of Slovenia.

At the regional and provincial levels, technicians in administrative offices and decision makers in the named sectors are addressed, e.g. provincial and regional spatial planning offices, offices for nature protection, wildlife management, transport infrastructure and agriculture.

Regional associations and institutions, including the Alpine Clubs, chambers of architects, spatial and landscape planners, chambers of civil engineers, as well as regional and provincial farmers associations, should be informed about the content. These actors can provide a valuable contribution to implement options for improvement of ecological networks.

Structure of the document

Following a description of the workshops and institutions involved in elaboration of this document (section 2), the spatial planning strategy provides an overview of the conceptual framework of ecological connectivity (section 3) and legislative aspects regarding ecological connectivity at European and regional level (section 4). It gives recommendation for harmonizing landscape elements worth protecting (section 5) and describes the current situation of ecological connectivity in the Alpine region (section 6). After these descriptions of the current situation, the strategy provides a common vision, mission and objectives for strategic planning, as well as a spatial scenario of priority connectivity areas in the Alpine region (sections 7 and 8). The scenario contains the existing corridors that should be protected and potential corridors to be developed and is interlinked with a tool to visualize and download geographic data. The latter can be a starting point for harmonizing corridors across national boundaries and for setting priorities. The vision and objectives are separated into the main spatial and landscape planning fields for developing ecological networks and conclude with country-specific recommendations (section 9).

02

METHODOLOGY

The Alpine planning strategy for ecological connectivity as output O1.1 of the work package *Knowledge base for green and blue infrastructure (GBI) connectivity planning* was elaborated based on the results of various activities. These was firstly the "definition of priority areas for ecological connectivity planning at national and transnational level" and the elaboration of a GBI typology catalogue (activity 1.1), where an alpine-wide structural connectivity model was developed. Secondly, the identification of the main compatible and incompatible anthropogenic uses posed to different GBI network elements in priority connectivity areas (activity 1.2), and thirdly the assessment of major emerging threats posed to GBI ecological networks (activity 1.3) contributed to the knowledge base. The results were brought together to develop guidelines for elaborating a network design and their integration into spatial planning instruments (activity 1.4).

The planning strategy was elaborated in collaboration with all project partners. Active participation was required especially on the mid-term workshop on the 26th of November 2024 together with project observer, but also in the PlanToConnect project partner meetings from the 15th to the 17th of April 2024 in Klagenfurt (AT) to discuss target groups and structure, and between the 14th and 16th of April 2025 in Annecy (FR) to elaborate country-specific recommendations.

To create a vision for 2050 and objectives for 2040, as well as first steps to create enabling conditions, a transnational workshop was conducted. The mid-term transnational workshop was held in Obergurgl, Tyrol, on the 26.11.2024. The methodology to create a vision for ecological connectivity for the Alps and to elaborate first objectives it was decided to conduct a future laboratory and to apply the back-casting method. Four different tables with different sectors were created that are important for spatial planning and which can strongly influence ecological connectivity and landscape fragmentation:

- Ecological networks and connectivity planning from the point of view of nature protection and protected areas
- Ecological connectivity in the light of infrastructure planning, mainly considering transport, energy and tourism infrastructure
- Protection of ecological linkages by land-use planning, focusing on settlement development
- GBI network planning in agricultural areas as part of landscape planning

The lessons learned from pilot sites will be incorporated in the main recommendations.

Stakeholders from the following institutions were involved in the workshop:

- ALPARC – The Alpine Network of Protected Areas
- Permanent Secretariat of the Alpine Convention
- Mountain Research Initiative - MRI, Mountain Governance Working Group - MGWG

- BOKU University of Life Sciences Vienna (AT)
- Salzburg Institute for Spatial Planning and Housing (AT)
- Private office for geography and research on spatial development, RaumEval e.U., Salzburg (AT)
- National Environmental Agency Austria - *Umweltbundesamt* (AT)
- Office of the Government of the Federal State of Tyrol - *Amt der Tiroler Landesregierung* (AT)

- Swiss Federal Research Institute – WSL (CH)

- German Centre for Integrative Biodiversity Research (iDiv) (DE)
- *Verwaltung für Ländliche Entwicklung, SG „Landespflege", Bayern* – Bavarian Administration for Rural Development, Landscape Management (DE)
- State and Regional Planning sector from the Government of Upper Bavaria (DE)
- University of Würzburg (DE)
- Private office for environmental planning - ifuplan (DE)

- ISPRA - Italian Institute for Environmental Protection and Research (IT)
- Veneto Region, Spatial Planning Directorate (IT)
- Politecnico di Milano, Department of Architecture and Urban Studies (IT)

- Provincial Office for Landscape planning of the Autonomous Province of Bolzano-South Tyrol (IT)
- Provincial Office for Municipal Planning in the Department for Nature, Landscape, and Spatial Development of the Autonomous Province of Bolzano-South Tyrol (IT)
- University of Udine (IT)
- Eurac Research (IT)

- Urban Planning Institute of the Republic (SI)
- Slovenian Forest Service (SI)

Picture 1: Future Lab workshop at the PlanToConnect mid-term event

03

CONCEPTUAL FRAMEWORKS FOR ECOLOGICAL CONNECTIVITY

3.1 Key green and blue infrastructure principles

Ecological connectivity became increasingly important in the context of the ongoing landscape fragmentation and biodiversity loss in Europe. The EU's Green Infrastructure Strategy therefore aims at developing a strategically planned network of natural and semi-natural areas. This network should enhance ecosystem services (ES) and connect protected areas (PAs), thereby supporting multifunctional landscapes (Hermoso et al., 2020). The European Commission defines green infrastructure (GI) 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.*" (European Commission, 2013 & 2021). 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).

Key concepts related to green infrastructure are:

- connectivity
- ecosystem services
- spatial planning
- natural capital
- nature-based solutions
- ecological functionality
- multifunctionality
- nature conservation
- landscape ecology
- landscape management
- multi- and transscalarity
- anti-fragility.

Of these concepts, spatial planning and connectivity are among the most important ones, along with multifunctionality. The social and ecological benefits of green and blue infrastructure (GBI) depend to a large degree on ecological connectivity (Moreira et al., 2024), because it is "the unimpeded movement of species and the flow of natural processes that sustain life on Earth" (UNEP - CMS, 2020).

Ecological connectivity

Ecological connectivity is defined as "the unimpeded movement of species and the flow of natural processes that sustain life on Earth" (UNEP - CMS, 2020).

Spatial planning

Spatial planning refers to the methods used by the public sector to influence the distribution of people and activities in spaces at various scales as well as the location of the various infrastructures, recreation and nature areas. Spatial planning activities are carried out at different administrative or governmental levels (local, regional, national), while activities of cooperation in this field are also implemented in cross-border, transnational and European contexts (CEMAT, 2007).

Landscape

"Landscape" means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors (Council of Europe Landscape Convention, 2000).

Landscape planning

"Landscape planning" means strong forward-looking action to enhance, restore or create landscapes (Council of Europe Landscape Convention, 2000).

Ecosystem services

The benefits that human populations derive via goods and services, directly or indirectly, from ecosystem functions (Constanza et al., 1997 in Ferraro et al., 2025). The European Environmental Agency distinguishes between

providing services like crops, timber or fresh water, regulating services like pollination, temperature regulation, flood regulation, and cultural services, i.e. recreation, aesthetic and cultural identity (EEA, 2023). In other definitions, supporting services are included, that describe the processes allowing the planet to sustain basic life forms (National Wildlife Federation, 2022 in Chiapparini et al., 2024). Crucial processes such as nutrient cycles and photosynthesis serve as the basis for entire ecosystems and help maintain healthy biodiversity levels (Food and Agriculture of the United Nations, 2022 in Chiapparini et al., 2024).

Multifunctionality

Multifunctionality of green and blue infrastructures (GBI) refers to designing networks that not only benefit biodiversity but also address climate change, natural risk reduction, and human well-being. In this perspective connectivity is seen as a proxy to maintaining fundamental ecological process linked to biodiversity that underpin the provision of multiple benefits (ecosystem services) (Chiapparini et al., 2024).

Anti-fragility

Anti-fragility is an approach to spatial planning that promotes the adaptation to changes related to disruptions caused by several kinds of events or stress factors, finding new, improved balances after them. It comes from the theories of Taleb (2012) about systems.

Protected areas

"A protected area is a clearly defined geographical space, recognised, dedicated and managed through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (IUCN definition, 2008).

3.2 Functions of ecological networks, analysis and mapping approaches

In recent decades, many different analysis and mapping approaches have been developed, which can be used to identify important areas that should be re-connected and defragmented. Earlier methods and tools focus on the provision of landscape structures that meet specific requirements of certain species to move (functional connectivity) or on the landscape permeability in general (structural connectivity). A more recent approach is the perception of connectivity areas that beyond benefits for ecological connectivity also provide other ecosystem services, i.e. the green and blue infrastructure concept. Such multifunctional approach should gain more acceptance among planning authorities and the public.

The approaches depicted above were applied in different combinations within the PlanToConnect pilot sites, while on the Alpine level, the structural approach was used to reduce complexity.

3.2.1 Structural approach

Structural connectivity, also called landscape connectivity, refers to physical conditions of the territory (space/landscape), physical connexions that facilitate or impede species movement and is influenced by factors like land use, topography, level of fragmentation, and the presence of infrastructure (Godron and Forman, 1983, Taylor et al., 1993, and Pierik et al., 2016 in Favilli, Hoffmann, Ravazzoli, 2017).

The IUCN Guidelines for Ecological Connectivity describe structural connectivity more in detail as "*a measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances, and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment*" (Hilty et al., 2020). The basic assumption for modelling structural connectivity is that low levels of human interference and anthropogenic infrastructure indicate a low degree of human disturbance – to which species can be sensitive – and therefore a high landscape permeability (ibid.). The structural approach is assessing the connectivity of natural or semi-natural ecosystems irrespective of any species-specific habitat requirements (Laner, Rossi et al., 2024). "*Linear areas that provide connectivity, such as river corridors, ocean currents or linear forest fragments, can be identified and prioritised for conservation (e.g., Rouget et al., 2006)*" (Hilty et al., 2020).

The example of the PlanToConnect project trilateral transboundary pilot site situated in Austria, Italy and Slovenia shows the importance of forest for structural connectivity. The pilot area is mainly forested (by different types of forest) and can be considered as highly permeable. Large forest areas can be found on the

mountain ridges. Forest is protected by the forest law and is normally not removed for development projects without assessing the forest functions and compensation measures. Therefore, it can be cautiously considered as "continuous". The valley floors, however, consist mainly of structured meadows with hedges and single trees, and wetlands; the latter are fallow lands with high connectivity value. The aim of the case study is to keep these structural connectivity areas free from human development, which is continuously growing. As long as the existing corridors remain permeable, they offer both structural connectivity areas and good habitat quality for a variety of species. The latter depends on the respective forest quality, forest age, density of forest roads and the forestry practices applied.

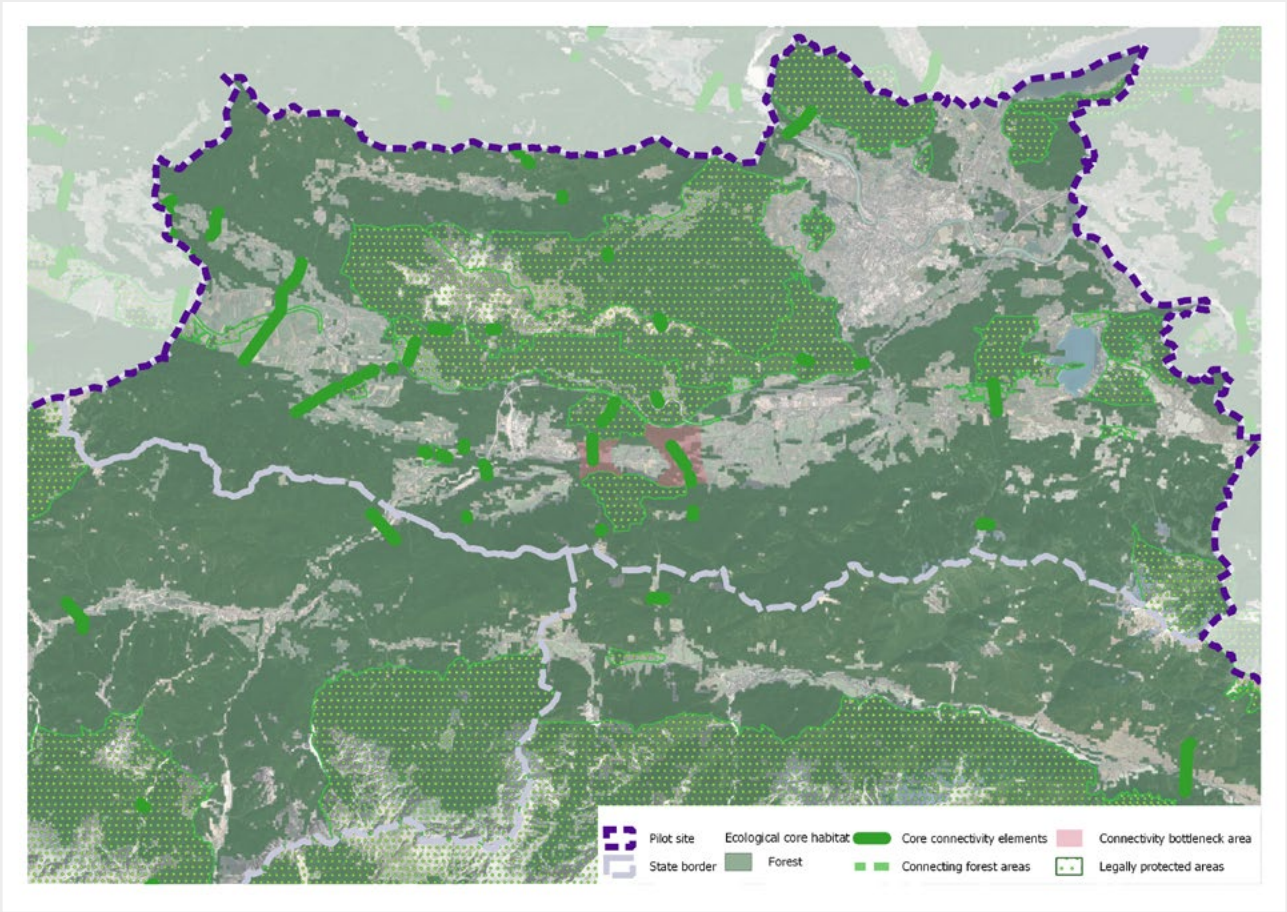


Figure 1: The situation of the border area between Austria, Italy and Slovenia. In the Gail valley in Austria a bottleneck for connectivity exists on two of the mayor corridors.

Picture 2: Example of wetland area on ecological corridor bottleneck in Austria. Photo: Susanne Glatz-Jorde

A second aspect of structural connectivity is the existence of legally protected areas. In the trilateral pilot site large, protected areas exist, however not in the corridor areas. Establishing a protected area encompassing the corridors would be a strategic step to ensure connectivity also for the future.

In the case study encompassing the South of Lake Annecy, the method of analysis with habitat differentiation was chosen to analyse the landscape based on three major types of fauna movements: through warm temperature sensitivity (open land habitats), through vegetation's concealing capacity (bushes and forested habitat) or through water (blue infrastructures). They represent the main habitats that fauna will seek to pass through when moving from one place to another. This approach allows to gather under the same type of habitat several species and to target within the landscape common key thresholds or corridors potentially used for a large range of species.

A suitable method is also to use geographic information system (GIS) for a spatial analysis with models, applying tools like "Graphab" which was used for the pilot site analysis.

However, as Philip D. Taylor et al. (2006) mentioned, this approach has some drawbacks mostly because it does not take into account the behaviour of species dispersal and focusses only on a "passive, physical process" which is not in phase with reality when studying living-beings.

Also, the view from a structural approach is limited by a restricted scale of human perception that misses the point to different range of scale's perception from species (from beetle to hare to red deer). A combination of both structural and functional approaches is highly recommended to solve this issue (John A. Wiens, 2006).

In the South of Lake Annecy case study the structural approach was chosen as a way to summarize places and habitats at stake within the territory, in order to focus the attention of local politics on specific places that could be restored, managed or better connected. The issues related to a species-specific approach can be easily overlooked, whereas a combination of species with different interests for the territory is a stronger defence to politics for corridor improvement.

3.2.2 Functional approach

Functional connectivity, also termed species-specific connectivity, refers to the behaviour of the investigated species in response to environmental conditions. It is influenced by ecological necessities of the species and

their behaviour. "*Functional connectivity describes how well genes, gametes, propagules or individuals move through landscapes*" (Hilty et al., 2020). In some cases, indicator or umbrella species (e.g. Capercaillie or Lynx) with large habitat requirements are used to identify connectivity areas for a wider range of species.

The concept was introduced in the 1980s and developed by a high number of scientific studies. "*Species-specific approaches have been used in several transnational European projects (Kohler et al., 2009; Walzer et al., 2011; Favilli et al., 2015) and were applied in support of biodiversity conservation and landscape and urban planning (Modica et al., 2021; Tarabon et al., 2020).*" (Laner & Rossi et al., 2024)

Some examples show that functional connectivity analysis can be used for elaboration of ecological network designs and for integration into planning documents: Functional connectivity analysis was done for red deer species to integrate green corridors at the regional level in the Development Programme of the Federal State of Salzburg (Austria). In the Landscape Plan of Friuli Venezia Giulia (Italy), the ecological network is based on three levels. The structural level defines the overall hierarchy of landscape elements, while the functional level identifies elementary spatial units of the landscape with homogeneous functional ecological characteristics, called "ecotopes", and specifies their role within the regional ecological network. The ecological network concept of the Autonomous Province of Trentino (IT) contains wildlife corridors and passages, which are based on umbrella species.

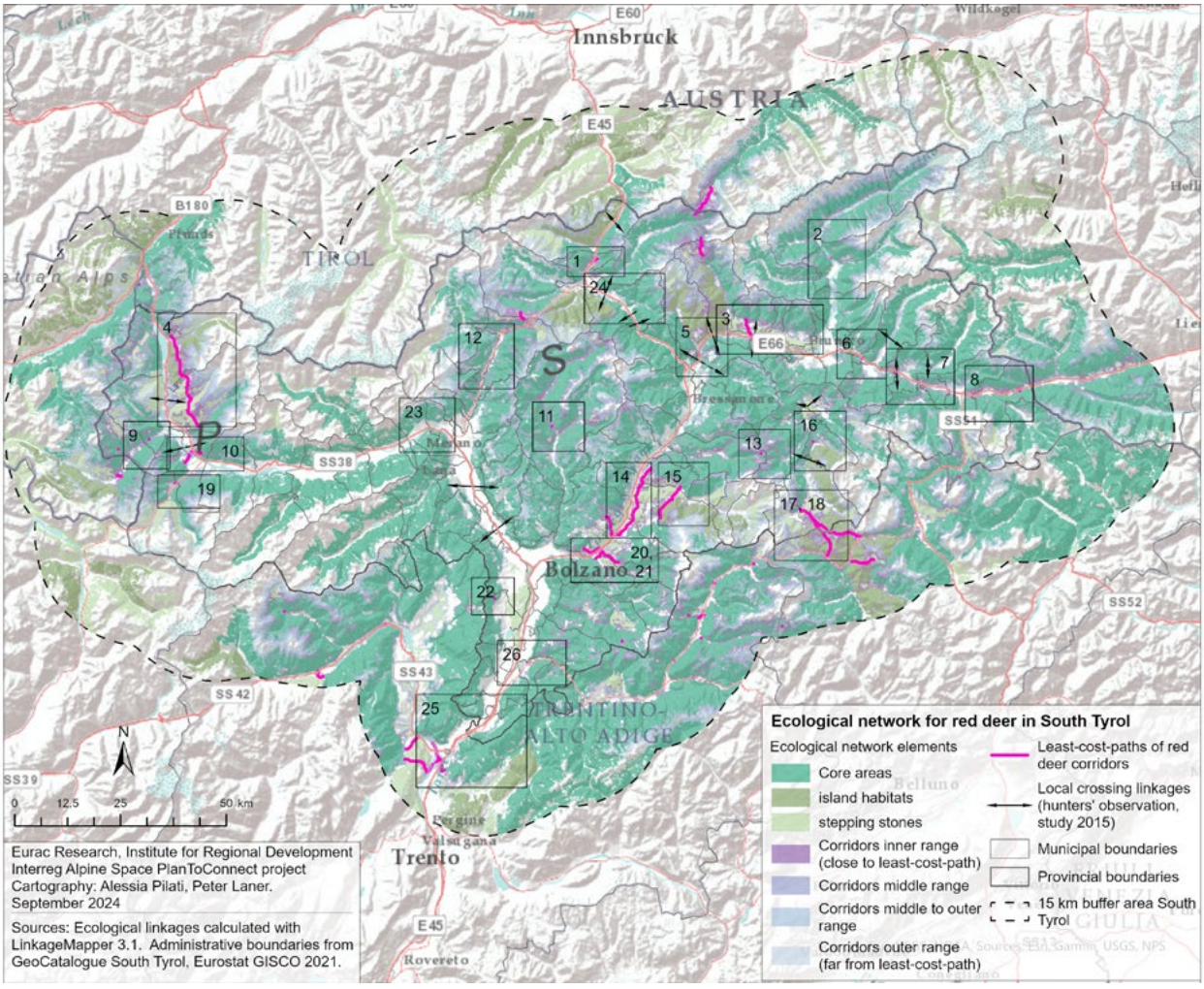


Figure 2: Ecological network for red deer in South Tyrol

3.2.3 Ecosystem services-based approach

The approach is based on the 2019 JRC and EEA report *Strategic Green Infrastructure and Ecosystem Restoration. Geospatial methods, data and tools.* The report shows how two complementary mapping approaches (physical and ecosystem based) could provide guidance for the strategic design of a well-connected, multi-functional, and cross-border green infrastructure.

The physical mapping approach focuses on identifying and spatially delineating landscape features that make up the green and blue infrastructure (GBI) network, such as green and blue elements (e.g., the "Trame verte et bleue" in France), with the aim of supporting and enhancing nature, natural processes, and natural capital within a given region.

This method has a cartographic and descriptive nature, defining which landscape elements qualify as part of the GBI network regardless of their ecosystem functions. It is a scale-dependent concept, widely used in both urban and rural areas — for instance, in evaluating the share of urban green spaces or when using pre-existing landscape elements such as hedgerows and small woody features in rural contexts as core connectivity elements of the GBI network (see structural and functional approaches in the paragraph before).

The ecosystem service-based mapping approach assesses the capacity of the land to provide ecosystem services. Unlike 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 GBI elements are expressed in terms of ecosystem services they deliver.

The aim of the approach is to define a strategic design for a multifunctional green and blue infrastructure network. This design is aligned with the transalpine ecological network framework promoted by the PlanToConnect project, and with the objectives and strategic guidelines set out by the main territorial planning instruments that regulate, at regional, provincial, and local levels, the issues of ecological connectivity, biodiversity, and environmental degradation.

The design of the green and blue infrastructure network is based on the mapping and assessment of ecosystem services within the context of spatial and landscape planning. The objective is to identify ecosystem vulnerabilities and performance levels, to which targeted actions, strategies, and nature-based solutions can be applied to maintain or enhance the overall environmental quality of the area.

The aim is to integrate social, biotic, abiotic, and cultural aspects into the ecological network's functions, thus fostering the sustainable development of environmental and landscape-related activities across the network. The network design is supported by a knowledge base developed through the creation of mapping tools for evaluating ecosystem performance.

This approach investigates a wide range of factors, including habitat quality, soil erosion conditions, hydraulic risk, agricultural soil yield and quality, as well as the distribution of cultural and recreational services. Overlaying and jointly analysing these datasets provides a multi-systemic interpretation of the territory, highlighting both its vulnerabilities and valuable features.

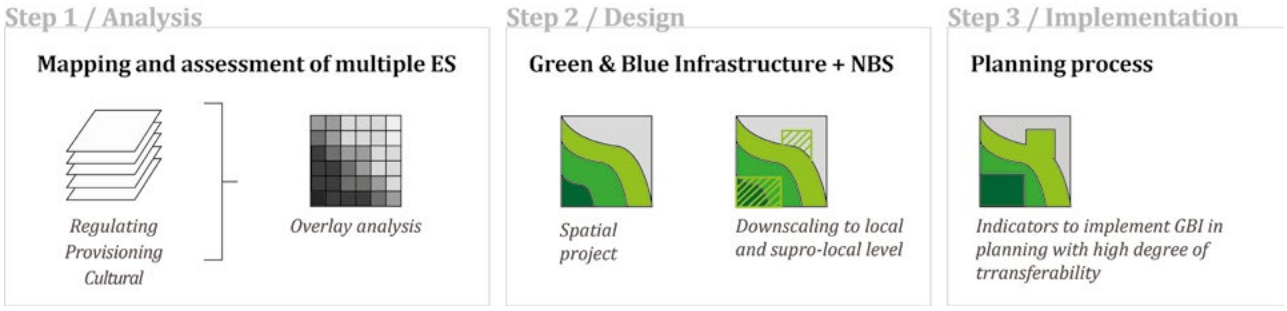


Figure 3: Methodological framework for the definition of the multifunctional green and blue infrastructure network (Developed by LabPPTE, DAStU – Politecnico di Milano)

These elements will collectively shape the structure of the multifunctional network design, that aims to preserve and strengthen existing connections and ecological nodes while rehabilitating degraded areas - also through the application of nature-based solutions. Within this framework, green and blue infrastructure planning aims to integrate rehabilitated areas with existing ecological corridors into a coherent and interconnected system, while simultaneously supporting the continuity of traditional land-use practices and promoting the sustainable use of the territory. The case studies carried out in the Province of Sondrio (by Fondazione Politecnico di Milano) and in the Caorle Wetland System (by the Veneto Region) are two examples of this approach.

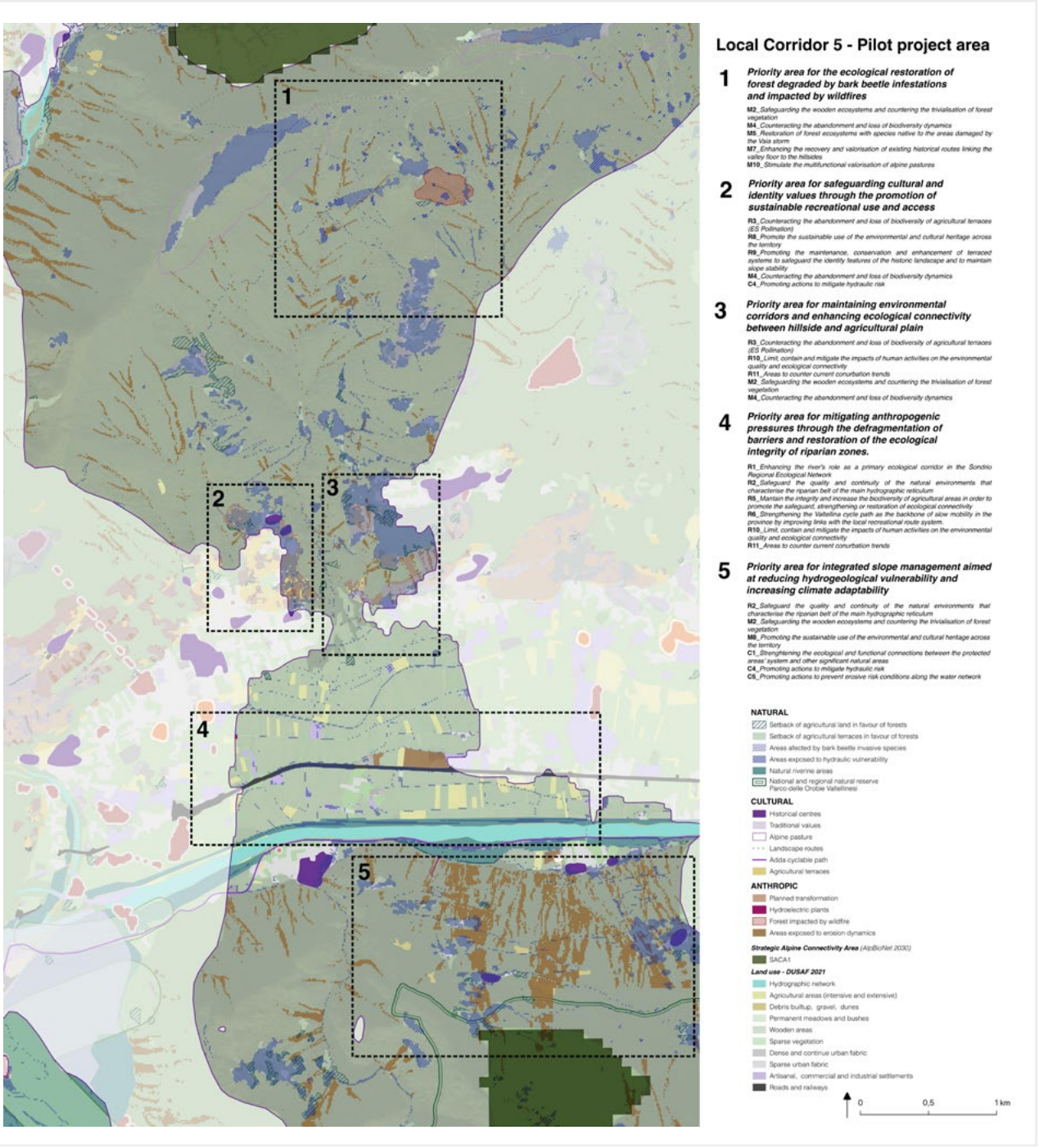


Figure 4: Multifunctional GBI for the Province of Sondrio – Ppilot project: Local corridor 5 (Developed by LabPPTE, DAStU – Politecnico di Milano and FPM)

A strategic framework for designing green and blue infrastructure networks through ecosystem services can provide a structured approach for designing green and blue infrastructure (GBI) networks that leverage ecosystem services to enhance ecological connectivity, biodiversity, and territorial resilience while supporting socio-economic development. By adopting an ecosystem service-based strategic framework, planners can create functional, resilient, and transboundary GBI networks that integrate nature, economy, and society in a sustainable manner.

Mapping ecosystem services is essential for integrating natural capital into spatial planning, conservation, and decision-making. Various methodologies and tools help quantify, model, and visualize these services across different scales. By integrating biophysical, socioeconomic, participatory, and GIS-based approaches, spatial planners, conservationists, and policymakers can effectively manage and enhance ecosystem services to support sustainable development.

Ecosystem services (ES) can be seen as the missing link between nature and economy, since they can connect the value of resources to economic values, being relevant tools to manage conflicts in the actual society. Economy in this approach should be linked to its original meaning of efficient management of resources, far from the concept of 'chrematistics', which represents the modern conception of many economical approaches. In this sense, the values that can be elicited through the ES mapping and evaluation include many of the dimensions of the 'total economic value' that could be identified for natural resources (e.g. the existence and the bequest values, or the option values, which includes also intangible and transcendent values). ES can then become the approach that can make explicit the role and the links to natural resources in the actual settlement development and management process, turning them into a cultural vision of preservation that changes the approach of spatial planning towards an equitable and sustainable progress. Such an approach is fundamental for the cultural transformation of the society and to engage people in decisional processes, pushing them to elicit their own values against the ephemeral values promoted by the actual system of communications, becoming a crucial element for the correct resources management. This new concept of value is crucial also for participation approaches, eliciting direct and indirect needs from citizens through a decision-making process, having a fundamental role in increasing the shared knowledge and awareness on the actual problems of our planet and the need for a real green transition, in its evolutive meaning.

Being a multiscalar process involving also monitoring steps, it is important that datasets and knowledge bases are built in a homogeneous approach. The same semiology should possibly be used, at least for land use at different scales, with a more precise categorization than CORINE. Further, integrated legend structures should be applied, which start from the local and more defined level and arrive to the territorial scale, where detailed information is grouped.

The choice of technical methodologies and tools depends on the:

- scale of analysis (local, regional, or global),
- type of ecosystem services (provisioning, regulating, cultural, or supporting),
- available data (spatial, economic, participatory inputs).

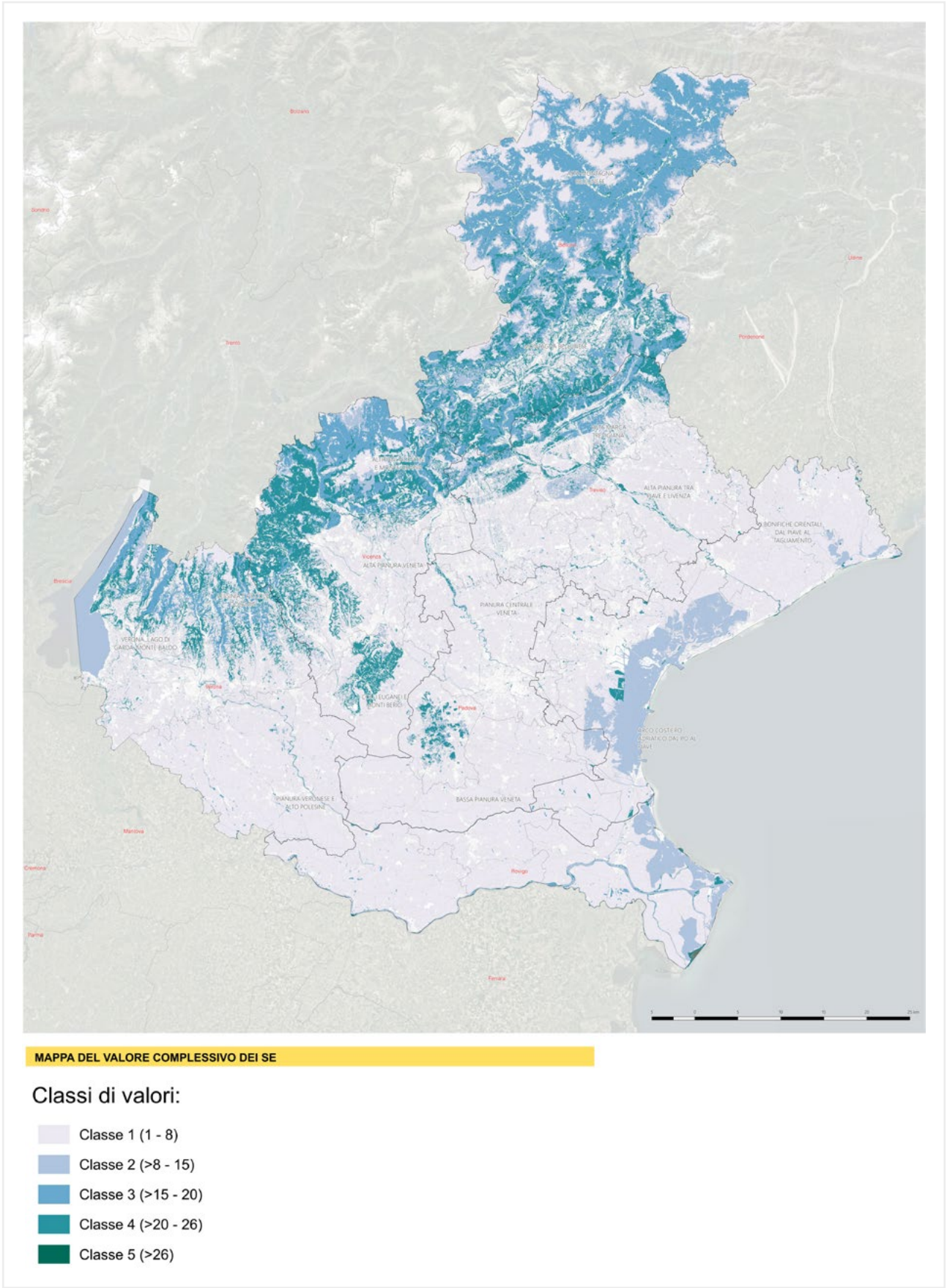


Figure 5:Total value of ecosystem services in Veneto (Source: Veneto Region)

04

LEGISLATIVE ASPECTS REGARDING ECOLOGICAL CONNECTIVITY

4.1 European and transnational level

4.1.1 United Nations Convention on Biological Diversity

During the fifteenth meeting of the Conference of the Parties (COP 15) held in December 2022, the Kunming-Montreal Global Biodiversity Framework was adopted, defining among others the following objectives at international level:

Target 1: *Ensure that all areas are under participatory integrated biodiversity inclusive* ***spatial planning*** *and/or effective management processes* **addressing land [...] use change, to bring the loss of areas of high biodiversity importance [...] close to zero by 2030 [...]**.

Target 2: *Ensure that by 2030 at least 30 per cent of areas of degraded terrestrial ecosystems are under* ***effective restoration, in order to enhance*** *biodiversity and ecosystem functions and services,* ***ecological*** integrity and ***connectivity***.

(CBD/COP/DEC/15/4)

4.1.2 EU Habitats Directive

Articles 3, 6 and 10 of the Habitats Directive concern the Natura 2000 network. Article 3 specifies that the Natura 2000 network is composed of two typologies of elements: Natura 2000 sites and corridors/stepping stones. Natura 2000 sites are mandatory elements and consist of special areas of conservation and special protection areas (identified under the Birds Directive). Corridors/stepping stones from Article 10 are not mandatory elements. Planning and management of landscape elements outside protected sites, as well as 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, is suggested. Article 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. (Chiapparini et al., 2024).

4.1.3 EU Biodiversity Strategy 2030

The new EU Biodiversity Strategy for 2030 (adopted in 2020) – "*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 Habitats 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.

In terms of strategic goals, the Biodiversity Strategy for 2030 aims 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).
- 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 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.

More specifically, the first target defines the following: "*Legally protect a minimum of 30% of the EU's land area and a minimum of 30% of the EU's sea area, and integrate ecological corridors, as part of a true Trans-European Nature Network.*"

The EU Biodiversity Strategy 2030 obliges the Member States to ensure the integration of ecological corridors into national legislation in order to contribute to a trans-European ecological network. The national biodiversity strategy must therefore create a coherent network of nature conservation areas (see target 3, action 5.)

For the sub-target 1.3: "*Build a truly coherent Trans-European Nature Network integrating ecological corridors on land*", the following indicator was developed in June 2025:

"*This indicator measures the average proportion of connected natural area on land within a local neighbourhood of approximately 50 km² at EU27 level, based on a reclassification of land cover classes in natural and non-natural areas. It considers both average connectivity within the natural area of the EU27 countries (FAD) and average connectivity within the overall area of the EU27 countries (AVCON). Values are calculated and provided every 2 years by the Joint Research Centre.*" (European Commission, 2025)

4.1.4 EU Green Infrastructure strategy

The EU Green Infrastructure Strategy is based on the green infrastructure concept and aligns with the Territorial Agenda 2030 by promoting the development of a network of natural and semi-natural areas designed to provide a wide range of ecosystem services. Thus, it is operationalizing the 2030 Biodiversity Strategy through investments in green infrastructure and its integration into spatial development plans. The strategy supports the creation of ecological corridors, nature-based solutions in agriculture, forestry, climate change mitigation, disaster prevention, energy, transport, health, and research (Chiapparini et al., 2024).

4.1.5 EU 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 implementation of the Biodiversity strategy 2030 and establishes ambitious aims and targets for restoring degraded ecosystems throughout the EU. The **key elements** of the law are:

- It mandates that at least 20% of EU land and sea areas be restored by 2030, with the goal of addressing all ecosystems in need of restoration by 2050. The aim is to enhance the health of habitats and reverse the decline of pollinators, focusing on forest, agricultural, and marine ecosystems, river connectivity, and urban green spaces. Member states must submit National Restoration Plans within two years, and progress will be monitored by the European Environment Agency.
- **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.

Further, the law 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 kilo-

metres 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.

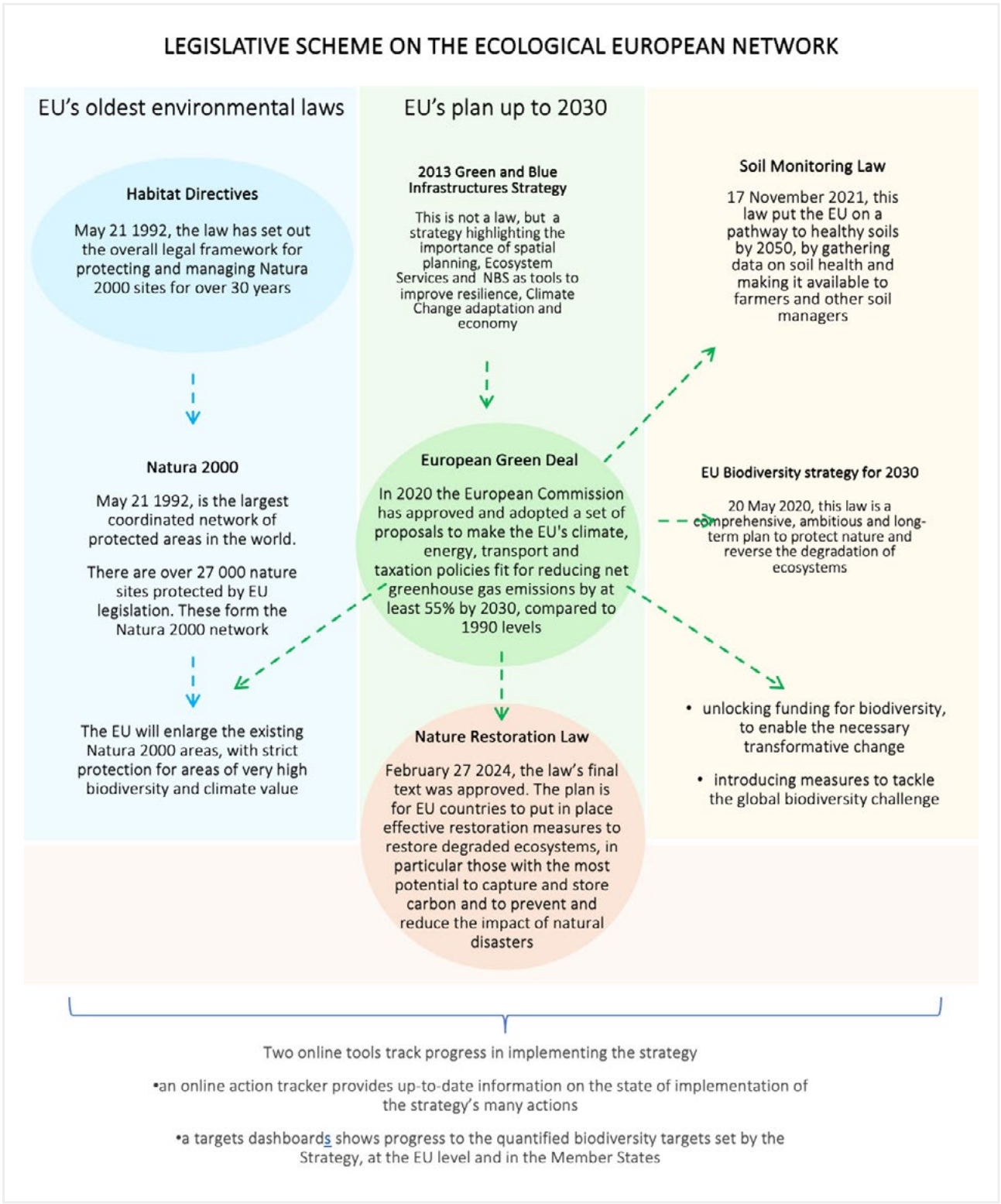


Figure 6: Legislative framework on the environmental strategies for the European Union. Source: Studio Gibelli, PlanToConnect Report on planning instruments and processes for GBI network planning and implementation in the Alps, 2024.

4.1.6 Alpine Convention

Article 12 of the protocol "Nature Protection and Landscape Conservation" of the Alpine Convention is entitled "*Ecological network". It commits the contracting parties to "pursue the measures appropriate for creating a national and cross-border network of protected areas, biotopes and other environmental assets protected or acknowledged as worthy of protection. They shall undertake to harmonise the objectives and measures with the cross-border protected areas.*" (Alpine Convention, 1994)

During the German presidency of the Alpine Convention (2015-2016), the ministers in charge of the territorial development policies signed the "**Declaration for sustainable spatial development in the Alps**" (Alpine Convention, 2025a). The agreement identifies ten main challenges and topics. Among them, the following are mentioned that relate to ecological connectivity:

- **Ecosystem functioning, ecological networking and biological diversity.**
- Climate change, adaptation to climate change and natural hazards.
- Settlement structure and land use.
- Preservation of cultural and natural heritage.
- Improving governance, cooperation and organizational needs.

4.2 Spatial planning legislations at regional level

Counteracting landscape fragmentation and preserving ecological functions of the landscape are topics mentioned in many spatial planning laws of the Alpine space. Such objectives are included in spatial planning legislation which is valid for each of the PlanToConnect pilot sites:

The French Town Planning Code (Code de l'urbanisme) states in Art. L101-2: "*In accordance with the objectives of sustainable development, the action of public authorities in the field of urban planning aims to achieve the following objectives*": ... (6) ***Protection*** *of natural environments and landscapes, preservation of air quality, water, soil and subsoil, natural resources,* ***biodiversity, ecosystems, green spaces and the creation, preservation and restoration of ecological continuity***". Paragraph 6 thus explicitly mentions ecological connectivity and includes natural resources, which refers to the ecosystem services concept.

The Bavarian spatial planning law contains in Art. 6, §2, several objectives that refer directly or indirectly to ecological connectivity: §§ II states that "Urban sprawl in the countryside should be avoided. Settlement activity should be spatially concentrated and prioritised towards existing settlements with sufficient infrastructure. Open spaces should be preserved; a large-scale, **ecologically effective network of open spaces** should be created. Further **fragmentation of the open landscape and forest areas should be avoided as far as possible.**" §§ VIII states that "**the requirements of the biotope network should be taken into account**".

The Carinthian spatial planning law refers explicitly to ecosystem services and to the maintenance of ecologically connected landscapes under Art1, §2, I: "***Areas and spaces which, due to their nature, are able to fulfil ecological functions and enable the use of natural resources (ecosystem services) are to be safeguarded*** *and, where possible,* ***kept free of uses that impair their functionality*** *to a more than minor extent. The open space structure is to be developed with particular regard to open spaces that are to be kept free of development in the long term and* ***to elements connecting them in such a way that the arrangement of open space-related uses is achieved while avoiding mutual interference as far as possible and further fragmentation of contiguous areas is avoided as far as possible***."

The regional spatial planning law of Veneto promotes a "*sustainable and lasting development aimed at satisfying the growth and welfare needs of citizens, without compromising the quality of life of future generations, while respecting natural resources. (lit. a). The territorial structure plan determines, [...] the theoretical parameters of sizing, [...], the limits and conditions for the development of settlements, for changes of use [...] pursuing the integration of compatible functions and uses, the full use of the settlement potential of the existing urban fabric and the* ***containment of soil consumptio****n, also pursuant to the regional law containing provisions for the containment of soil consumption (Art. 13, lit. k). Under "competences of the region*" (Art. 45 ter), it is stated that a landscape plan must be approved and the competences of the regional government (§6) are the promotion of training and refresher activities in the field of landscaping (lit. i), for the halting of settlement dispersion and the consequent containment of soil consumption (§§1), and **the formation of an extended ecological**

network on a territorial scale and the safeguarding of biodiversity (§§2).

The Lombardy Region promotes the objectives of reducing soil consumption and urban and territorial regeneration in its spatial governance tools (Art. 1, §3 bis.). The municipal land use plan should encourage "*urban regeneration projects of high environmental quality, including the enhancement and development of multifunctional green infrastructure, with particular reference to the green and ecological network, in connection with the existing urban and environmental system*" (Art. 8 bis, §b).

The spatial planning law of South Tyrol is stating in Art. 2, §1, that the landscape and natural resources should be protected and valorised (lit. c.). To **avoid urban sprawl**, already developed areas should be used in an efficient way and a compact settlement structure should be promoted (lit. i.).

The spatial planning law of Slovenia is not mentioning ecological connectivity explicitly, but encompasses objectives that are strongly connected with maintaining ecological connectivity: "*limiting dispersed construction and protecting unbuilt areas; ensuring that heating, cooling and lighting of buildings does not further damage the environment.*"

The spatial planning law of Salzburg states, that "*the basic natural resources must be protected and utilised with care in order to preserve them in sufficient quality and quantity for the future. The diversity of nature and landscape must be preserved*" (Art. 2, §1, §§2). The avoidance of urban sprawl is defined as one of the nine planning principles (Art. 2, §2, §§3).

4.3 Conclusion

Considering the international agreements, European directives and strategies, as well as the objectives mentioned in the national and regional spatial planning laws, it can be stated, that the maintenance and restoration of ecological connectivity is considered as public interest, which is the basis for spatial planning decisions.

05

LANDSCAPE ELEMENTS WORTH PROTECTING

List of green and blue infrastructure elements

To define a coherent ecological network for the Alpine region, landscape elements which are worth protecting need to be harmonized among the Alpine countries. The PlanToConnect project made a proposal for basic landscape elements worth protecting, grouped in categories of green and blue infrastructure according to Benett et al. (2011). Land use change in these areas should be avoided at any level and for any reason.

Green and blue infrastructure (GBI) refers to a network of natural and semi-natural areas, features, and green spaces in rural and urban, terrestrial, freshwater, coastal, and marine areas.

GBI CATEGORY	SUBTYPES/FEATURES	TYPICAL EXAMPLES
1. Core areas	Natural and semi-natural ecosystems with high biodiversity value	Alpine pastures, dry meadows, natural forests, bogs, floodplains, lakes, rivers, coastal wetlands, extensive agricultural areas
2. Restoration zones	Previously degraded or abandoned areas with ecological restoration potential	Reforested quarries, rewetted fens, revitalized floodplains, former farmland
3. Anthropogenic use zones	Agricultural or forestry landscapes with retained ecological function	High nature value (HNV) farmland, protection forests, extensive pastures
4. Urban & peri-urban green areas	Vegetated areas within or around cities that provide ecological and social benefits (see urban-rural linkages approach)	Green paths, street trees, allotments, green roofs, urban parks
5. Natural connectivity features	Structural elements that support species movement and landscape continuity	Hedgerows, field margins, ponds, small woodlands, riparian vegetation
6. Artificial connectivity features	Engineered interventions to mitigate fragmentation and restore connectivity	Wildlife overpasses, amphibian tunnels, fish ladders, greened roadside verges

Table 1: GBI categories with subtypes and typical examples (based on Benett et al., 2011)[1]

1 A more detailed list of green and blue infrastructure elements which are worth protecting is available in the PlanToConnect Standardized protocol of GBI network design (Deliverable 1.4.1).

06

CURRENT SITUATION OF ECOLOGICAL CONNECTIVITY IN THE ALPINE REGION AND PLANNING GAPS

To analyse the current state of ecological connectivity in the Alpine region, the PlanToConnect project elaborated a model of potential ecological corridors, focusing on corridors on land. Aquatic connectivity and bird migration routes are not considered. It is a structural model, which means that the corridors connect Ecological Conservation Areas (SACA1 areas) located closest to each other. These are mainly protected areas. SACA1 areas which are not protected have similar characteristics of natural land use, unfragmented landscape patches, low population density and appropriate topographic conditions as the protected ones. The calculated corridors are representing connections with the fewest anthropogenic land uses and barriers with the lowest barrier effect on their path. They represent connections with the highest landscape permeability.

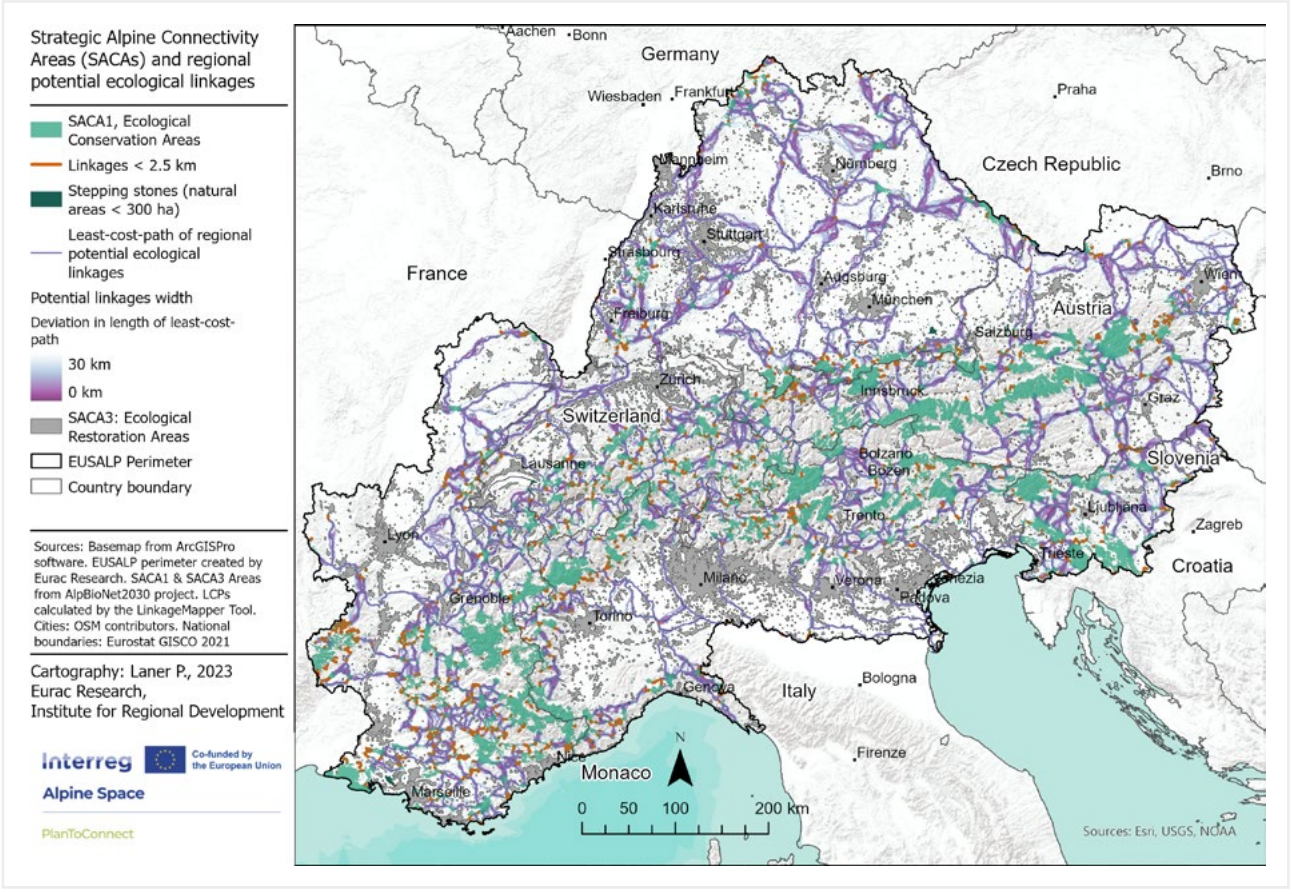


Figure 7: Potential structural ecological network in the Alpine region

6.1 Structural problems of landscape connectivity in the Alpine region

The Alpine region is characterised by some peculiarities in its urban development patterns and transport structures. The spatial arrangement along the valley bottoms is creating specific problems for ecological connectivity.

- **Linear infrastructure development of inner Alpine valleys:** A characteristic problem in the inner Alpine valleys are the infrastructural expansions and agricultural land uses developing in the flat areas along the valleys, which are due to the special topography. Such expansions tend to create linear barriers, interrupting habitat connections between mountain slopes.
- A second characteristic problem is that the Alpine region, especially the Alpine Convention area, is at **risk to become a biological island**, because anthropogenic infrastructure is strongly developing in the outer Alpine Space. It is creating a belt of infrastructure barriers around the inner Alpine Space, interrupting ecological connections between the Alps and other mountain ranges. The Alps, located at the core of Europe, have a high potential for macro-regional connections and therefore play a crucial role in the European context.
- Many national boundaries exist in the Alpine region, and for this reason the **transnational dimension** of ecological connectivity became crucial. Therefore, ecological connectivity planning requires collaborative frameworks.
- **Protected areas** are a key starting point for implementing measures towards ecological connectivity. Currently the Alpine Protected Areas2 cover 30,7% of the Alpine Convention territory (58.581 km²/190.700 km²), around 9,8% of this surface under strong protection according to the ALPARC definition3. Nevertheless, there are important differences regarding the level of protection and role in biodiversity protection between Alpine protected area categories. Even though the biodiversity 30/10 goal is virtually soon to be achieved, there is still room for improvement in terms of extent of protected areas and in the balance of protected areas distribution across the Alpine countries. 3.841 km² of valuable areas for connectivity conservation (SACA1 areas) are not yet protected, most of them in Switzerland. This corresponds to 8,1% of all SACA1 areas.

6.2 Most important anthropogenic pressures

> *"The Alpine region biodiversity hotspots are being constantly threatened. In the valley areas, the increasing infrastructure developments, the impacts of overtourism and the future demands regarding the use of the land and natural resources (e.g. renewable energies) within the region are key challenges to address when elaborating the design of the ecological network for the region".*
>
> (Perrin, Berthrand & Kohler, 2019)

An expert-based evaluation showed that transport infrastructure, urban development and agricultural practices are the top three most important types of anthropogenic pressures in the PlanToConnect pilot sites. This was confirmed by an expert evaluating the whole Alps who rated urban development and transport infrastructure as very strong pressures, and agriculture in general as strong pressure. Forestry related practices and extraction of resources are rated as the weakest anthropogenic pressures on the selected ecological corridors in the pilot sites.

The highest rates among the subcategories of pressures are concerning roads – highways and related infrastructure, the conversion from other land uses to built-up areas, and the use of plant protection chemicals on agricultural land.

In the following, the situation regarding ecological connectivity which emerged after modelling the potential structural ecological network in the Alpine region is described.

2 The protection coverage is calculated based on data from the ALPARC database of Alpine Protected Areas. The data includes the following categories: Nature/Regional parks, Nature reserves, National parks – Core area, Particular protection status, UNESCO World heritage – Natural sites, UNESCO Biosphere reserves – Transition area.

3 Strong protection categories: National parks – core area, Nature reserves and Italian Nature parks.

6.2.1 Settlement development

An analysis of how settlement areas cause problems for ecological corridors shows that, due to settlement development, 309 potential ecological linkages are passing through 972 bottlenecks of less than 300 m width. Linkages which could be threatened by urbanisation thus represent one third of the total number of identified potential linkages.

This result highlights the importance of spatial planning for considering ecological connectivity in settlement development processes. Urbanisation threats appear mainly in the flatland areas of the outer Alpine Space, especially in the Po Valley (IT), in the centre of Slovenia, in the flatland areas of Upper and Lower Austria (AT), around Lyon (FR), and at the border between Austria and Germany. Often, bottlenecks due to urbanization occur along river corridors because settlements were placed on rivers due to their former importance as trade routes. The settlements have historically grown to major cities, creating bottlenecks for potential wildlife linkages nowadays. Green areas along the rivers result as important connecting elements in the Alpine-wide model.

Picture 3: Urban sprawl in the Rhine Valley (AT). Photo: Guido Plassmann

6.2.2 Transport infrastructure barriers

The PlanToConnect project modelled 155 ecological linkages, intersecting in 150 locations with motorways placed on ground surface. France and Germany are the two countries with the highest number of identified motorway barriers. In 39 cases, motorway barriers are located within or close to SACA3 areas.

Table 2: Motorway barriers by country

COUNTRY	NUMBER OF MOTORWAY BARRIERS
France	44
Germany	37
Austria	27
Italy	20
Switzerland	13
Slovenia	9
Sum	150

Regarding railway lines, a high number of intersections with potential ecological linkages was identified. Out of 31 intersections of macro-regional corridors with high-speed train lines, only twelve represent a real physical barrier. The others have an underpass or railway bridge nearby. 353 railway intersections with other types of railways must be further investigated, ideally by site visits on the field, to verify if they represent a real physical barrier.

Picture 4: Intensive apple orchards, motorway A22 and railway line in the Adige Valley (Trentino- South Tyrol). Photo: Peter Laner

6.2.3 Intensive agricultural areas

Another result of the potential ecological network model from the PlanToConnect project was that more than half of the Alps-wide potential linkages (489 of 953) are passing through widely intensively used agricultural areas. This highlights the high importance of maintaining patchy and linear woody features or other green linear elements in intensively used agricultural areas. Potential corridor sections of intensive agriculture are on average approximately 470m long. Roughly speaking, most of the mentioned outliers which are corridor distances of more than 3 km passing through intensive agricultural areas are located in the Po Valley (IT) and in Lower Austria. These regions should improve the structure of their agricultural landscape with a high importance.

6.2.4 Forest practices

Although forestry is among the lowest evaluated pressures in the PlanToConnect pilot sites, there is room for improvement in some strategic areas for maintaining ecological connectivity in the Alps:

- Forests in northern Lower Austria, as well as the forests between Freiburg and Kempten and between Nürnberg and Austria are showing a very high pressure. These forests are important stepping stones to guarantee connectivity between the inner and outer Alpine Space and should be managed in an appropriate way.
- Forests in Liguria (IT) have a high overall pressure. This could be a threat for ecological connectivity between the Alps and the Apennines.
- The same is true for the northern Alpine space of France, areas of medium and high pressure are found around Lyon and in the Haut Jura Regional Nature Park. Within them, there are several potential regional connections crossing France and Switzerland, which are threatened by the current situation (Laner et al., 2025).

6.2.5 Energy production

Solar panel fields are a relatively new anthropogenic pressure in the Alpine region. The mapping results are showing that in total 194 potential regional linkages are affected by solar panel fields bigger than 1.000 m². This corresponds to each fifth linkage. Only twenty of them are affected in a serious way, however the trend represents a threat for potential linkages in the future.

Picture 5: Fenced solar panel field in Styria (AT). Photo: Guido Plassmann

Picture 6: Fenced solar panel field in Sulzberg/County of Oberallgäu. Photo: Christina Miller

6.3 Future threats for ecological connectivity

6.3.1 Infrastructural developments

The expansion of transport and energy infrastructures as well as settlement structures present a significant burden on biodiversity and ecological connectivity in the Alps – an issue that will worsen as land consumption and soil sealing continue to increase. Although early-stage planning that incorporates ecological connectivity concepts and subsequent adaptations, such as wildlife crossings and use of roadside strips as habitat corridors, can reduce negative impacts, land consumption remains a central challenge. The loss of habitats through extensive sealing and construction has long-term negative effects on environmental quality and species diversity.

In the field of renewable energies (RE), demands are rising sharply: The expansion of wind, solar, hydropower, biomass, and associated grid connections is essential to meet EU climate goals. At the same time, these installations also affect habitats and ecological connections. In sensitive landscapes like the Alps, where natural resources offer great potential, RE expansion meets a landscape with strict protection statuses, multiple restrictions, and ecological fragility.

A key future problem concerns land-use conflicts: Large parts of the Alpine region are protected areas or nature reserves, severely restricting the installation of wind turbines, ground-mounted photovoltaic plants, or new hydropower projects. Meanwhile, traditional energy sources like hydropower have nearly reached saturation. Projects can cause ecological damage to river ecosystems and require costly ecological compensation measures. Many suitable sites for wind turbines lie within protected zones and wind energy yield in mountainous regions lags behind outer-Alpine sites, limiting expansion possibilities. Forest biomass resources are already strongly used and represent only limited expansion potentials (see Bavarian Wind Atlas and Alpine Convention, 2016), and agricultural biomass may only be used as a supplementary source.

Another challenge arises from difficult construction and infrastructure access in the Alps: Installation, operation, and maintenance of energy facilities often require new

access roads, power lines, or sites, which cause additional environmental interventions into sensitive ecosystems. This increased infrastructural effort raises both costs and environmental impacts.

Social and aesthetic conflicts further complicate matters: Wind turbines and high-voltage power lines, despite relatively low land take, cause visual disturbances, provoking resistance from local populations and conservation organizations.

An analysis of potential threats to connectivity related to renewable energy, transport and settlement infrastructure illustrates the need to differentiate effects. While hydroelectric reservoirs significantly impact both structural and functional connectivity, other types of renewable energy sources are ambivalent in their potential effects: Run-off river power plants, wind turbines, ground-mounted solar panels, biomass or transmission lines on the one hand feature comparably low impacts on structural connectivity. On the other hand, they can have significant impacts on functional connectivity based on barrier/fragmentation effects, collision risks or associated change of land use. In many cases, the impact is a function of the individual installation's size and its cumulative effects. Road and rail infrastructure as well as urban/industrial development are associated with high impacts both on structural and functional connectivity as a consequence of their significant land take, barrier effects, traffic-related wildlife mortality, and noise and other pollutants.

A critical gap is the currently insufficient spatial planning coordination: Environmental impact assessments typically examine only small-scale alternatives, lacking an integrated large-scale strategic planning approach. Particularly for the Alpine region, a supra-national spatial planning framework would be essential to consolidate infrastructure and RE sites, ensure ecological connectivity, and minimize conflicts early. However, the national and regional jurisdictions currently limit comprehensive and coordinated planning efforts.

6.3.2 EU and national legislative developments in selected policy fields

Policies at EU and national level alter framework conditions for ecological connectivity and can ultimately have tangible impacts in a positive or negative sense. The following paragraph outlines selected current legislative developments with potential impacts on ecological connectivity. Obviously, these framework conditions are subject to ongoing policy making and therefore can only reflect the situation at the end of 2024 when the analysis was done.

Energy

The EU has set a binding target for renewable energy to reach 42.5% of the energy mix by 2030, reinforced by successive revisions of the Renewable Energy Directive (RED). Key policy measures include designating renewable energy projects as being of overriding public interest and establishing acceleration or priority areas to fast-track renewables like wind and solar. Tools such as wildlife sensitivity mapping are increasingly used to identify exclusion zones and areas suitable for renewable energy development with minimal impact. Several EU member states and neighbouring Switzerland have introduced emergency regulations and acceleration procedures to expedite renewable energy deployment.

However, challenges emerge in balancing the expansion of renewables with ecological connectivity goals, creating potential spatial conflicts, especially in sensitive areas like high altitudes, wind-prone zones or residual corridors in intensively urbanised areas. Accelerated planning processes risk sidelining environmental concerns, and there is a growing competition for land among renewables, transport infrastructure, food production, biodiversity conservation, and carbon sequestration.

Nature protection

Global and EU-wide environmental goals emphasize habitat restoration and ecological connectivity. The EU Biodiversity Strategy 2030 commits to legally protect 30% of land, strictly protect at least 1/3 of the EU's protected areas and enhance ecological corridors. The EU Nature Restoration Regulation mandates restoration on at least 20% of land areas by 2030, aiming for 90% restoration by 2050, targeting agricultural habitats, forests, and river connectivity. These measures are supported by national examples, such as Bavaria's enhanced nature protection law committing to establishing spatially connected biotope networks on at least 15% of non-forested area by 2030. A law on natural area requirements such as the "Nature-Land Law" proposed for Germany would facilitate the protection of large, interconnected areas and create the conditions for successful implementation of Germany's biodiversity commitments. Restoration efforts are also part of regional plans in Austria,

France, Italy, and Lombardy, emphasizing connectivity and multifunctional protected area networks.

Transport

EU transport policies under the TEN-T framework promote accelerated permit and approval procedures for core and comprehensive transport networks, including corridors crossing the Alps. While these acceleration measures aim to modernize and extend transport infrastructure, there is concern about negative impacts on ecological connectivity as a consequence of e.g. expanding infrastructure capacities and retrofitting railway infrastructure for higher travel speeds.

Climate protection

Apart from renewables expansion, the EU Green Deal's Fit for 55 package includes an ambitious target of net land-based carbon removal of 310 million tonnes CO2-equivalent in the land use sector by 2030. Current monitoring indicates the EU is off track, necessitating increased efforts ranging from conventional carbon sink measures such as sustainable forest management or peatland rewetting to new approaches such as carbon farming. National strategies, such as Italy's national strategy for adaptation to climate change, consider restructuring protected areas to facilitate species migration in response to climate change.

Spatial planning

Renewable energy expansion targets have led to revisions of national spatial planning frameworks to expedite renewables deployment, especially wind power, through amended laws and zoning criteria. For example, Germany is tightening timelines for designating wind energy priority zones.

On the other hand, Slovenia's Spatial Development Strategy 2050 assigns a strategic role to green infrastructure as a planned system of functionally connected and diverse landscapes that enables healthy, safe, climate resilient and multifunctional spatial development in the long term.

Summary

Summarising, two major developments are simultaneously unfolding in regard to the policy framework affecting ecological connectivity: efforts to accelerate permit-granting procedures for renewable energy and grey infrastructure in general – with potential, but not yet verifiable negative impacts on ecological connectivity – on the one hand. On the other hand, ambitious and binding targets have been introduced, most notably in the Nature Restoration Regulation in the framework of the EU Biodiversity Strategy for 2030. Spatial planning will have to play a key role in reconciling these potentially conflicting policy objectives.

6.4 Gaps in ecological connectivity planning across borders

Missing harmonisation processes between ecological network plans in and between neighbouring EU countries have been identified:

1. Several administrative regions in the Alpine Space have not yet elaborated a regional ecological connectivity concept that would feed spatial planning procedures.
2. Italian regions in the Alpine Space cannot refer to a national ecological connectivity concept and to a national set of laws and tools promoting connectivity as a value in spatial planning. Only Natura 2000 is a general reference framework.
3. Existing ecological connectivity concepts are not formalized and legally binding in all countries. Some existing concepts are considered during spatial planning procedures, but it is not mandatory.
4. National and regional ecological connectivity concepts are not harmonized across the national and regional boundaries in terms of spatial coherence.
5. Ecological connectivity concepts are not harmonized in terms of methodological approaches. Due to the federal systems in some Alpine countries, the high number of different planning systems, and the high number of possible approaches to analyse connectivity, there is a high variety of methodologies used.

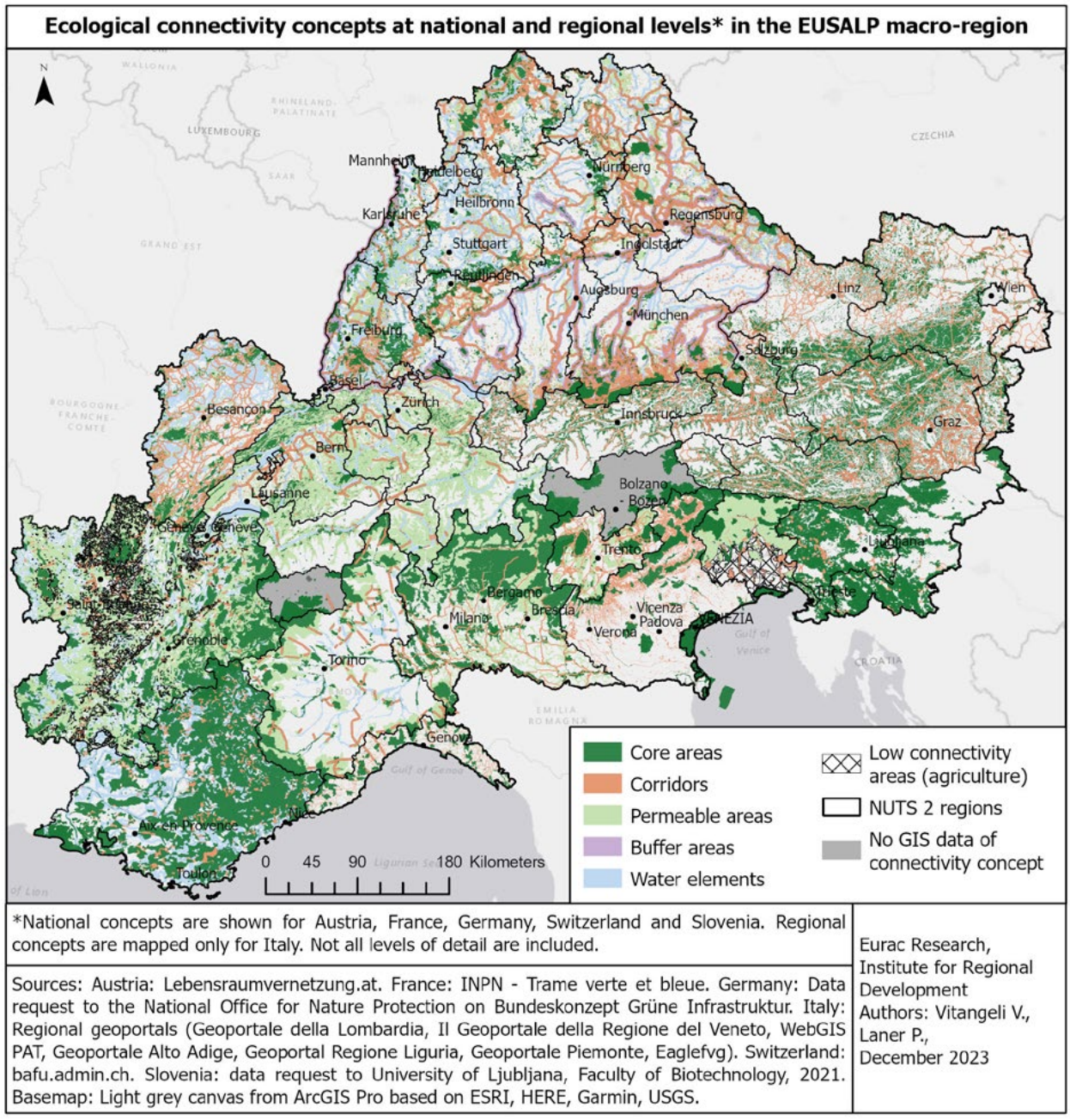
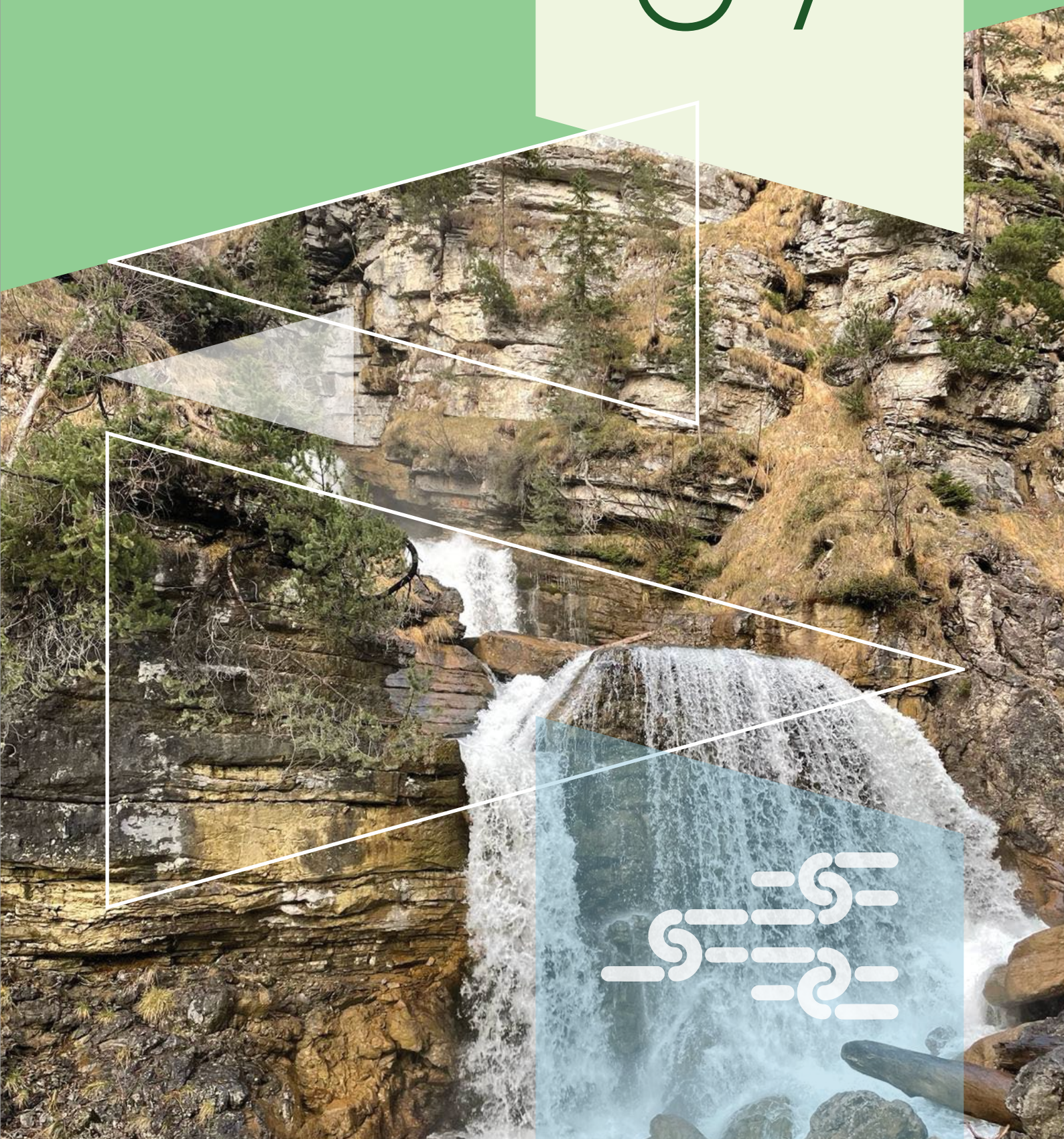


Figure 8: Ecological networks mosaic (Eurac Research, 2023)

07



MISSION AND VISION

In the previous chapters, the general and conceptual aspects of ecological connectivity planning are delineated. In the following, the strategy is structured into four fields of competence: protected areas, infrastructural planning, land use planning, and landscape planning. This should correspond with frequently given structures in the political-administrative systems at the national and regional levels in the Alps. The above-mentioned sectors are sometimes separated in several administrative offices with different competences.

In the context of this planning strategy, we refer to "protected areas" when speaking about protected areas for nature conservation with a higher protection status, which are mostly in the competence of nature protection administrations. Protected landscape areas outside protected areas, on the other hand, often have lower protection status and responsible for them are landscape planning administrations.

In this document, "landscape planning" refers to the sector which is responsible for the proactive sectoral planning of nature and landscape preservation (Schmidt, 2018). It is concerned with conservation and development of landscapes outside existing protected areas and urban development areas with prevailing agricultural land use and forested land cover.

"Land use planning" in the context of this planning strategy is seen from an anthropocentric point of view, especially from the perspective of planning settlement expansion.

"Infrastructure planning" in this document concerns development of linear infrastructures, especially for transport and energy transmission.

7.1 Mission statement

The PlanToConnect project partnership is composed of administrative bodies, research organisations, NGOs, and spatial and environmental planning offices, located within the Alpine region (Alpine Space or EUSALP area), that want to contribute to the integration of ecological connectivity in the spatial planning systems. The project consortium is interlinked with the AlpPlan Network of spatial planners, and EUSALP Action group 7 that aims at preserving and sustainably valorising the Alpine natural and cultural heritage. The partnership is in contact with the Alpine Convention Working Group on Spatial Planning and Sustainable Development, as well as with the Alpine Biodiversity Board.

In general, the PlanToConnect project provides joint solutions, strategies and tools for harmonizing spatial planning processes and promoting cross-border collaboration, with the aim to foster an ecological network across the Alpine region, thus ensuring the preservation of biodiversity.

Specifically, in this strategy, recommendations on how to integrate important ecological linkages into spatial planning instruments are provided for stakeholders and decision makers as well as public administrations at the national and regional levels.

In other project activities, local communities, stakeholders, and policymakers were engaged in a participatory approach to ecological connectivity conservation, and guidelines provided to reduce physical anthropogenic barriers, as well as administrative barriers for ecological connections. Education and awareness were promoted to disseminate knowledge about the effects of landscape fragmentation on ecological networks and possible solutions. NGOs were supported with knowledge and good practice examples.

7.2 Vision 2050 and detailed explanation

7.2.1 Vision 2050

In the year 2050, ...

... for the protection of biodiversity, each region in the Alpine Space has an official and politically approved ecological connectivity concept, which is harmonized at the

regional and national boundaries. The concepts are used by planning offices, regions, provinces and municipalities in spatial planning procedures, to reduce landscape fragmentation and protect existing ecological linkages, connect the inner Alpine Space (Alpine Convention area) with the outer Alpine Space (EUSALP area beyond Alpine Convention), and connect the Alps with the surrounding macro-regional areas that are rich in biodiversity.

... the Alpine regions ensure wildlife gene flow across the Alps through balanced management of nature protection and human activities.

... urban development is compliant with (multi-scale) green networks, development of compact urban areas contributes to safeguarding ecological quality and ecosystem services. The regions are acting in accordance with existing principles, like compact development, resources used sustainably, and with awareness. Planning for ecological connectivity follows a logic transcending the scales.

... all obsolete infrastructures in the Alps have been "removed" and the infrastructural sufficiency achieved. The infrastructures are designed and implemented as multipurpose (regionally adapted/place-specific), seamlessly aligned with environmental requirements regarding ecological connectivity and with a strong legal framework.

... extensive agriculture and close-to-nature forestry are well established in priority connectivity areas in the Alps. Intensive agricultural practices have been replaced by them in localities important for the continuity of natural areas. Fields with a high diversity of types of crops are separated by hedgerows and forest strips in former degraded agricultural areas. Farmers and their representatives are aware that preserving biodiversity is not against their interests, and farmers have a good income. The Payment for Ecosystem Services (PES) is part of it.

7.2.2 Detailed explanations of the vision 2050

7.2.2.1 Conceptual and administrative planning aspects

For the protection of biodiversity, each administrative area within the Alpine region can refer to an ecological connectivity concept at regional or national level to reduce landscape fragmentation, protect existing ecological linkages, and enable vertical and latitudinal exchanges to allow species to respond to climate change. The ecological connectivity concepts are formalized, legally binding, and/or strongly considered in spatial planning procedures. They are harmonized across national and regional boundaries, while each connectivity concept maintains its character to consider the local characteristics of the territory.

The countries and regions within the EUSALP macro-region are considering information about priority areas for ecological connectivity provided on respective data platforms. A transnational concept for a potential ecological network is used to prevent bottlenecks from getting closed by urbanisation, to dismantle motorway barriers, and to create permeable landscape features in intensively used areas. The concept identifies the most important inner-Alpine connections, as well as priority areas that connect the inner with the outer Alpine Space, and with surrounding macro-regional areas that are important for biodiversity (see section 8.1).

Ecological connectivity networks in the Alpine Space are multifunctional, following the green and blue infrastructure network approach, including benefits for people (recreation, hazard risk reduction, benefits for agricultural practices etc.).

Regional and provincial administrations have sufficient knowledge about the future threats to ecological connectivity and to consider macroregional priority areas for restoration and preservation. Spatial planning administrations and planners have the capacity to consider priority areas from the macroregional level when it comes to local implementation. Planners are well connected through the AlpPlan network at the Alps-wide level and through dedicated working groups on regional level. Responsibilities and collaboration procedures for implementation of ecological connectivity are well defined among the sectoral administrations and planning levels.

7.2.2.2 Protected areas

In terms of protection of landscapes, in 2050 there are large-non fragmented areas (with IUCN protection of III/IV) that can ensure the genetic flow of species across the Alps. So, it is the permeability of landscape that is assured for any species (and not the possibility for one species), to move freely from Slovenia to France. To reach this state, landscapes have been well-managed, with a balance between protected area policies, mainly around and between protected areas, and economic activities.

Protected areas' management bodies have sufficient funds to ensure a continuous monitoring of the species and habitats and monitor the impact of tourism using the same standard methodology for the whole Alps.

In 2050, 30% of the EU territory is effectively protected, at least in IUCN category IV. There are a higher number and increased extent of strictly protected areas, and the access of motorized vehicles is prohibited.

Protected areas are in charge of a more horizontal communication, and of an increased presence outside the areas, to promote awareness and education in schools. The local population feels a sense of belonging and recognizes the protected areas' role as a reference for the whole community, sustaining also their continuous funding. Protected areas, and their benefits, are recognized by farmers and hunters, who also contribute to the habitat and species protection, and to reducing the impact of tourism.

7.2.2.3 Infrastructure planning (transport, energy, tourism)

All infrastructure in the Alps that is no longer in use, underused, or environmentally harmful is systematically identified and removed or renatured. This includes disused railways, roads, ski facilities, cableways, military installations, and abandoned buildings. The removal of such structures restores landscape permeability, reduces habitat fragmentation, and improves the functionality of ecological corridors.

Connectivity considerations are embedded in all phases of infrastructure development, from planning and environmental impact assessment to design, construction, and maintenance, especially for intersections between corridors of the Trans-European Nature Network (TEN-N) and the Trans-European Transport Network. Transport and energy infrastructure has no longer characteristics of a barrier but is developed as a component of a connected ecological network. Ecological corridors and artificial green infrastructure (like green bridges) are integrated into infrastructure concepts as standard practices.

7.2.2.4 Land use planning

Priority of ecological decisions over economic ones

In 2050, ecological decisions are given higher priority than economic land use decisions and consideration of soil functions are integrated at all planning levels. Land take policies are considering the value of agricultural soil based also on soil fertility (organic carbon component) and not only on productivity (arable land). The Nature Restoration Law has been established as an effective tool to implement local restoration actions within territorial scenarios/plans (both in urban and natural contexts). It is possible to integrate mandatory greening measures in development plans.

Changed urban planning approaches

A more mindful approach to tourism, developing settlements for locals and not primarily for tourists, has led to multifunctional instead of monofunctional settlements. A different understanding of "how much space do we need?" with less space/person and more space/species and ecosystem services has led to compact, densely built settlements. Green and blue infrastructure will be seen as a driver for territorial and urban planning instead of considering them as residual areas of little value.

International framework respected by lower planning scales

A strong AlpPlan network and transnational institutions have created additional databases and knowledge: A comprehensive database and knowledge on the quality of natural/near-natural areas and their connections (existing/favourable) is established. A transnational planning tool for green infrastructure with connectivity scenarios is integrated. The framework of the Alpine ecological corridors has found its way into the regional legislation for settlement development. Ecological corridors are generally mainstreamed into regional development plans/programmes (approx. 1:20.000) designating corridors. The new green and blue infrastructure plan has been integrated into urban and territorial planning tools (see section 9 – country-specific recommendations) to ensure climate resilience as well as to improve habitat continuity in coherence with the overall ecological network project.

7.2.2.5 Landscape planning in agricultural areas

Landscape structure

From a structural point of view, agricultural landscapes are highly diversified; crops are mixed with fallow fields. Smaller cultivation plots are separated by hedgerows and forest strips. Traditional farming, especially mountain farming still exists, and farms with intensively used land in the Alpine valleys have integrated a network of

ecological stepping stones within their fields and use a wide variety of diverse grassland. Agriculture has reduced monocultures, uses fewer pesticides, and has incorporated various landscape structures such as hedgerows and forests that connect valleys, creating ecological corridors. Ecological connectivity is a side result, not the main aim. Agriculture has adapted to climate change and deals with increased temperatures and reduced water availability. The agriculture sector has become an ecosystem service provider for nature and society. All over the Alps, the landscape is covered/provided with forest corridors and natural forests, that are officially protected, and where the change of land use for infrastructural anthropogenic uses is not possible. Farmers are able to sustain their livelihoods from this type of land use.

Framework

An agreed framework on landscape structure, agriculture and management/close to nature forest is followed and guidelines on how to manage forests within corridors are elaborated and respected. Restoration areas for connectivity are mapped and included in nature restoration plans.

The different regional sectors involved in the planning and management of connectivity in agricultural areas are working together and sharing the same objectives in their different plans and policies. Farmers and their representatives are aware of the importance of preserving biodiversity, which is not against their interests (awareness). They collaborate with other stakeholders and a spirit of collaboration between different sectors has been established.

With a market driven change, extensive agriculture substitutes intensive agriculture.

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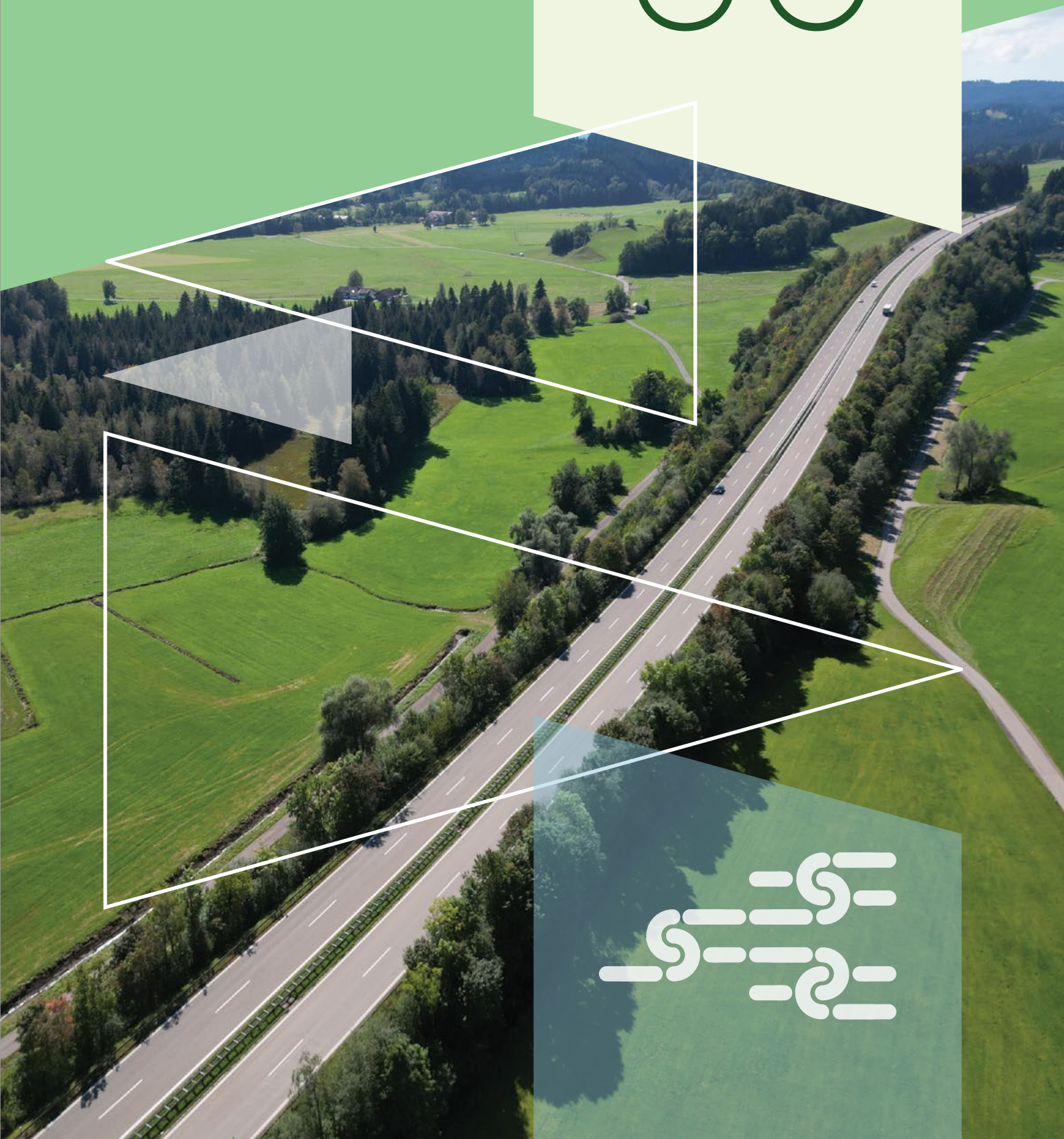

OBJECTIVES FOR CONNECTIVITY PLANNING

8.1 Spatial scenario of priority connectivity areas in the Alpine region

The European Alps are a key hub for a resilient transnational conservation network to be established under the COP15 Global Biodiversity Framework and the EU's Biodiversity Strategy for 2030 targets (30-x-30 target): *"In the face of global changes, the future European reserve network will need to ensure strong elevation and latitudinal connections to complementarily protect multifaceted biodiversity across national borders"* (Chauvier-Mendes et al., 2024). A coherent and coordinated transnational reserve network is required for the Alps, including increased connectivity between protected areas (ibid).

The spatial model developed in the PlanToConnect project categorizes the potential ecological corridors by their importance for network coherency and by the risk that they get lost through urbanisation processes.

In the model, the most important infrastructural barriers on the designed potential linkages are analysed, focusing on bottlenecks of settlements, motorways intersections, and intersections with areas of strong anthropogenic land uses and fragmentation in general (SACA3 areas).

The results are published on the platform of the Joint Ecological Continuum Analysing and Mapping Initiative 2.0 – JECAMI. Data are downloadable in the download section and can be used for ecological connectivity projects.

https://www.jecami.eu/ptc/

8.1.1 How to use the model

- The model should be used to identify priority areas for preservation and restoration of connections between highly natural areas in the Alps and between the Alps and their surrounding natural areas.
- It is a scenario of important green connections, which are harmonized on an Alps-wide scale, and therefore can represent a basis for harmonization processes. Member states and regional authorities can align their spatial ecological network concepts based on the proposed model, to create a true ecological network. Disconnected areas due to missing transnational harmonization processes could be restored.
- The regional linkages should be visualized in combination with the Natura2000 network, which in some cases completes the structure of important linear habitats, contributing to the general ecological connectivity.
- The identified priority areas should not be used as an argument for soil sealing or infrastructure development on other green areas which are not defined as a priority.
- The model of potential linkages can be used as a basis for local connectivity projects and further analysis of functional connectivity based on certain habitats or species in the corridor area, or green and blue infrastructure elements based on ecosystem services, like it was done in the PlanToConnect project. For the exact corridor implementation, more detailed studies should be conducted.

Example of the PlanToConnect pilot site "Illertal" in Bavaria

The structural corridor from the Alps-wide model gives a framework to analyse the connectivity of existing habitats in this area in more detail.

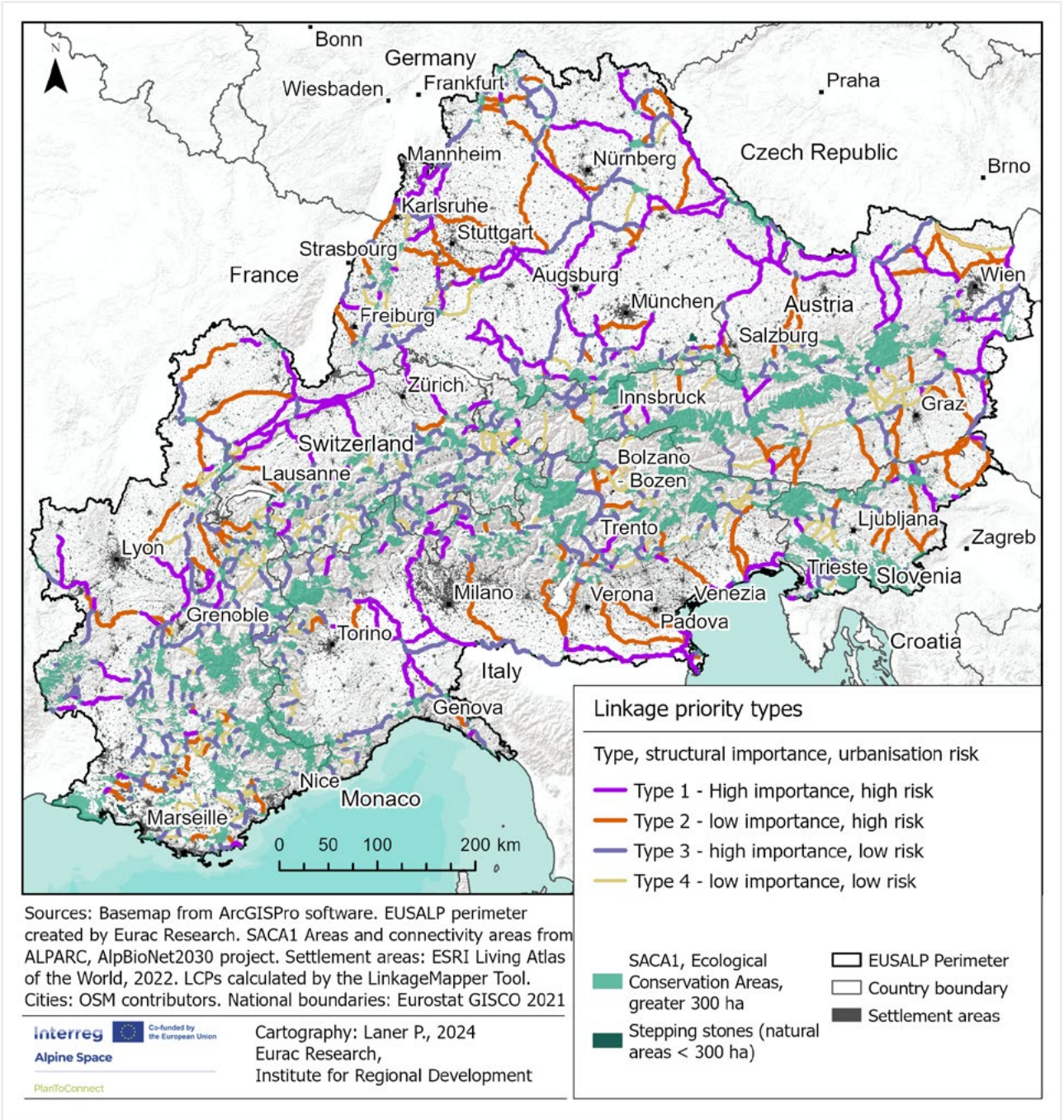

Figure 9: Potential ecological linkages in the Alpine region by priority type

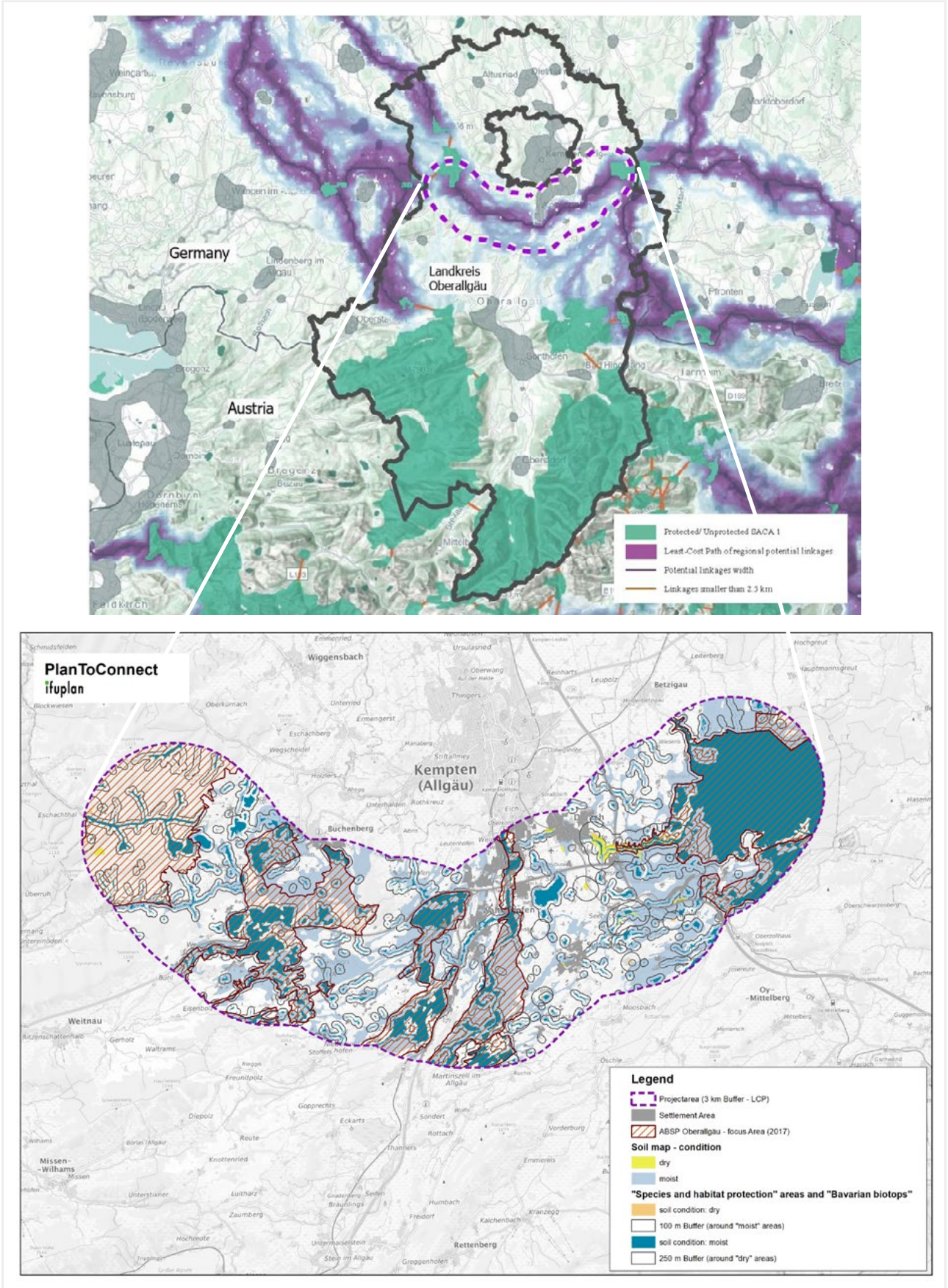

Figure 10: Upper map: Selection of a corridor with high priority at the Alps-wide scale as the project area. Lower map: Analysis of existing habitats and distances on the selected macroregional corridor

8.1.2 General recommendations for harmonization procedures and setting priorities for improving the Alpine ecological network

- Protection and restoration of buffer areas of 2.5 km that are (potentially) connecting two SACA1 areas is a prerequisite to guarantee that regional potential linkages of the elaborated structural network are functioning. From a structural point of view, there are 25 buffer areas to protect as soon as possible from further urbanisation and six to restore or to clarify alternative routes (see report D.1.1.1).
- Restoration measures should be implemented on:
  - corridor sections passing through SACA3 areas which in general have a high barrier effect,
  - at identified motorway barriers, and
  - additionally at bottlenecks due to urbanization processes.

  Linear corridors, stepping-stone or landscape corridors should be implemented on the prioritized potential regional linkages.
- For spatial planning administrations which have the capacity to protect the identified linkages from urbanisation and to prevent the loss of linkages, the priority should be on Type 1 and Type 2 linkages.
- For administrations which can contribute to dismantling of motorway barriers, like transport infrastructure offices, the focus should lie on Type 1 and Type 3 linkages to create a coherent and functioning network.
- Administrations which can contribute to expanding of protected areas on the modelled potential linkages should also focus on Type 1 and Type 3 linkages to create a coherent network, to keep it together and to connect the inner Alpine arc with major wildlife areas outside the Alps.
- Expansion of solar panel fields or installation of agrivoltaic systems on potential linkages should be monitored in respect to ecological connectivity.

8.1.3 Further prioritisation possibilities

Political circumstances sometimes require a selection of pilot projects which are reduced to a restricted number of specific measures to optimize the allocation of resources. Therefore, it is proposed to focus on the conservation and restoration of ecological linkages that are important for the network coherency. The map which is highlighting these linkages is e.g. used in the Policy Brief of the Alpine Biodiversity Board (Alpine Convention, 2025b).

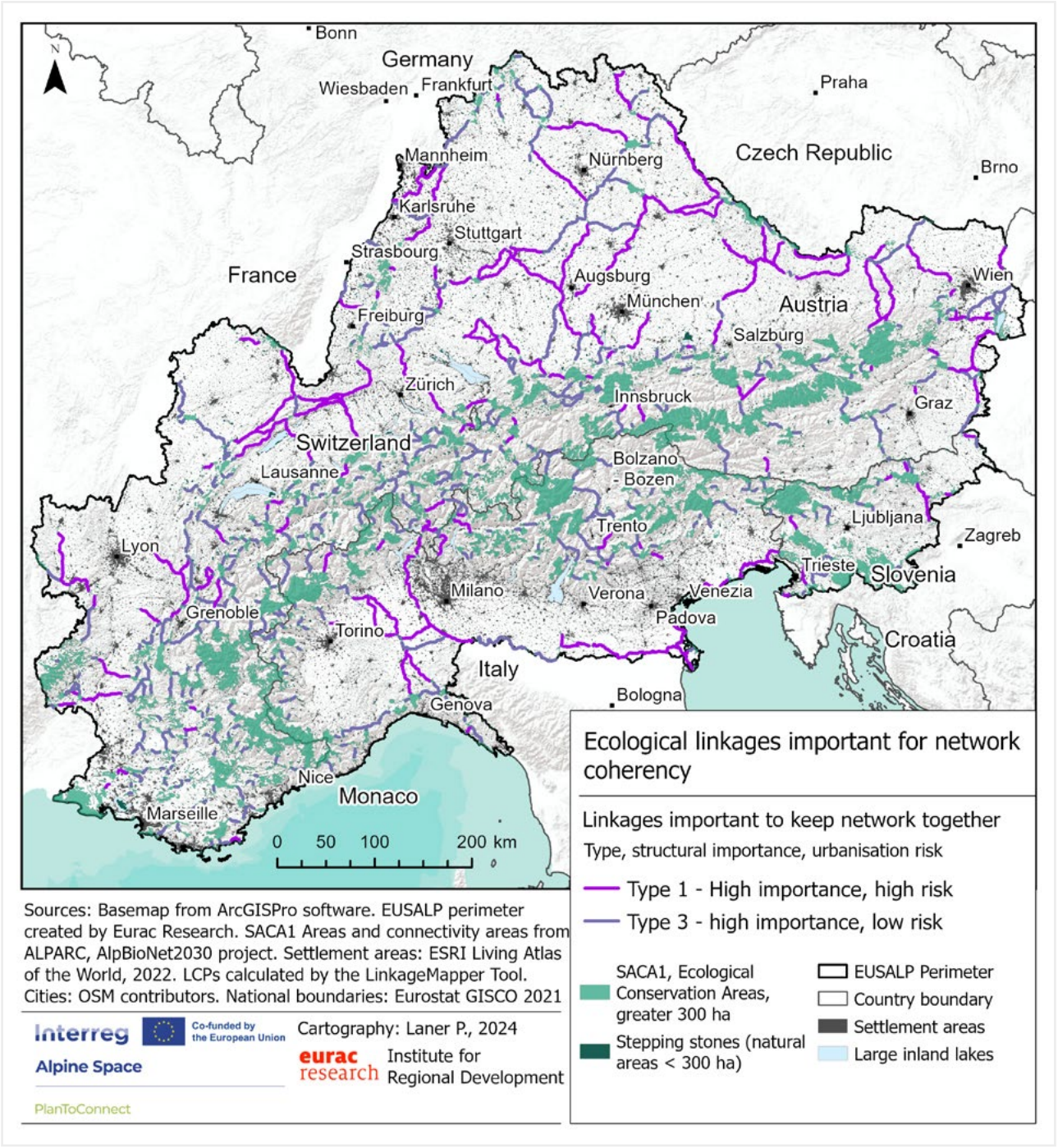

Figure 11: Potential ecological linkages, important for network coherency

To further prioritize ecological linkages in the Alps, it is recommended to focus on those that connect the inner Alpine region with its surroundings.

Below it is shown which priority areas connect the inner Alpine Space (Alpine Convention area) with the outer Alpine Space (EUSALP beyond the Alpine Convention area), and the Alps with the surrounding macro-regional areas that are rich in biodiversity. The latter include the mountain ranges Carpathians, Dinaric Alps, Pyrenees, Apennines, and other macro-regional areas like the European Green Belt, and e.g. also the Black Forest in Germany. The above-mentioned areas had been defined by the ALPBIONET 2030 project (see figure 12). The PlanToConnect project revealed the least-cost-paths which specify the linkages with the lowest barrier effects. They are highlighted in violet in figure 12.

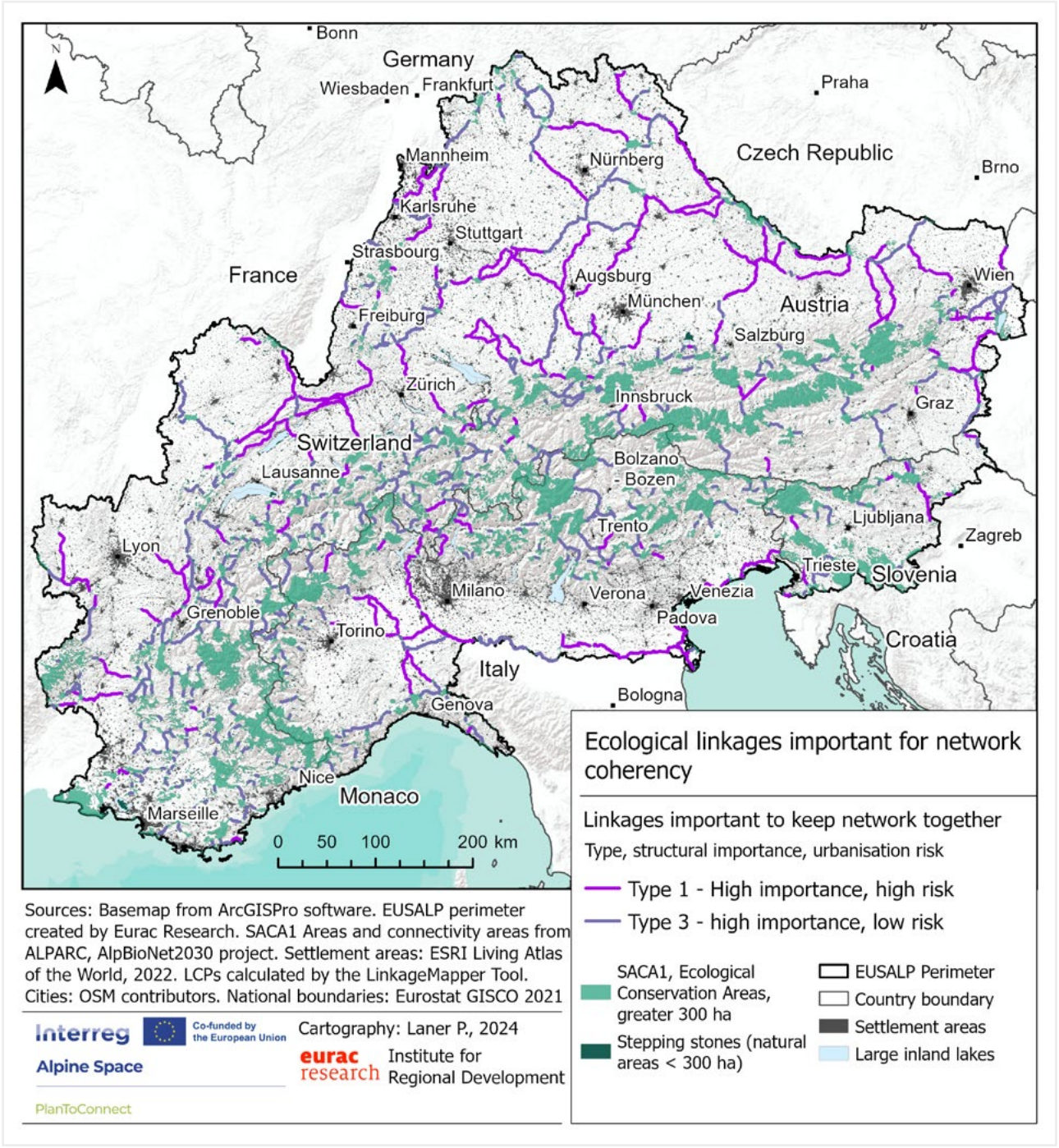

Figure 12: Linkages connecting the inner Alpine areas with the outer Alpine Space

8.2 Objectives for connectivity planning by thematic fields/sectors

8.2.1 Protected areas

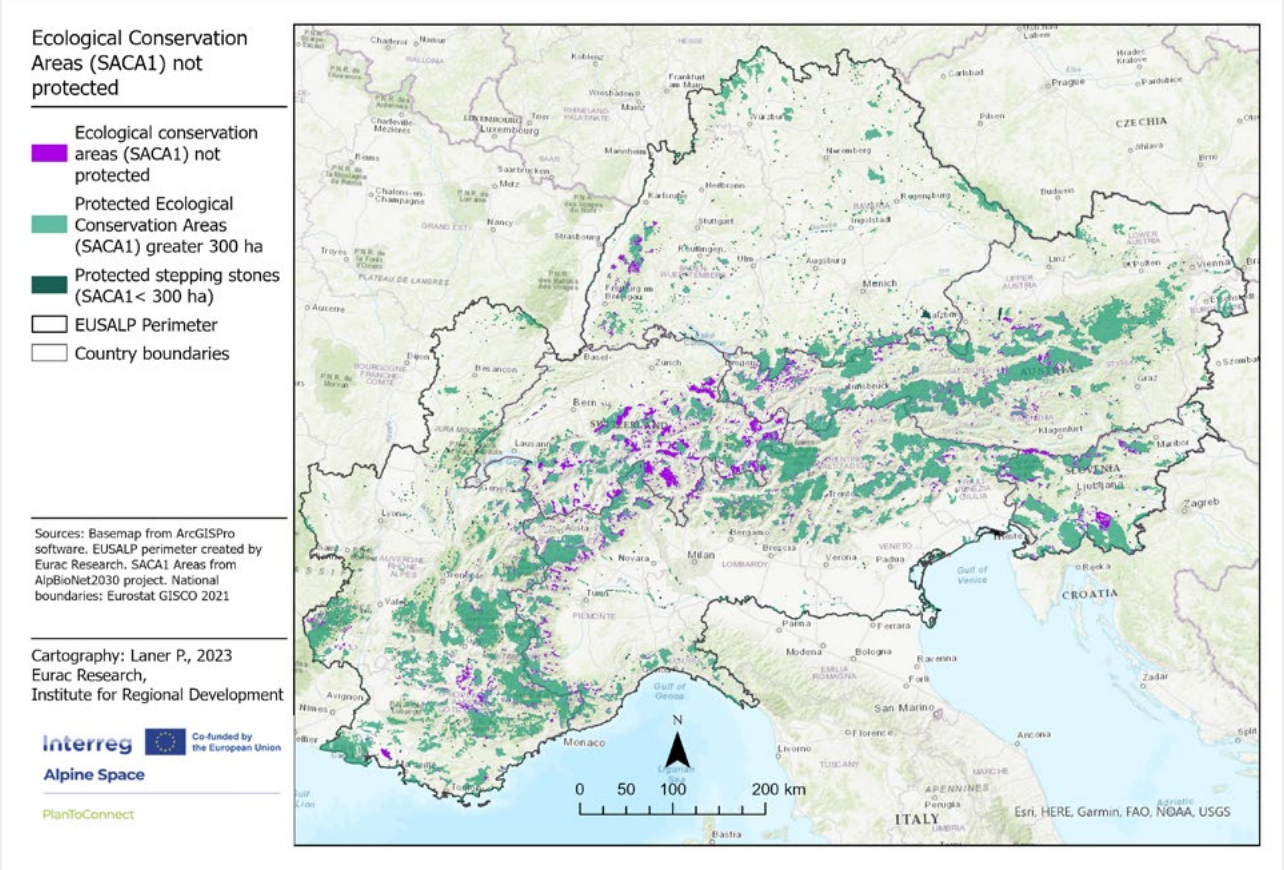

Figure 13: Ecological Conservation Areas (SACA1) which are not protected

Legal protection of nature

Objective 2030

The goal of 30% of effective protection and at least a third of these areas under strict protection in EU is reached, and the objectives of 2030 EU Biodiversity Strategy, and of Nature Restoration Law are fulfilled. Countries define a legal framework to secure the identified ecological network, and the main barriers, mainly administrative.

Objective 2040

A clear definition of nature protection in each country's constitution to guarantee a legal basis at national and EU level.

Stakeholder engagement

Objective 2030

Countries should establish a permanent forum to discuss the solutions to reduce impact of human activities on protected areas, ecological networks and biodiversity. Top-down and bottom-up approaches should be used.

Objective 2040

Ensure that stakeholders are actively involved in the process, with established negotiations and agreements in place.

Other objectives of importance for implementation (not related to planning)

Wildlife species presence and monitoring

Objective 2030

Agreement on monitoring protocols. Projects and studies are in place to know where the main core areas and corridors are located throughout the Alps.
Countries start the process of analysing the impact of agricultural practices and tourism on biodiversity, and on ecological networks (following common protocols).

Objective 2040

Monitoring of wildlife species is done regularly following shared protocols. The aim is improve the knowledge of the wildlife species that live in the Alps and in EU. National plans and strategies are compiled to manage funds.

Funding of protected areas

Objective 2030

Adapt personnel and funding to integrate ecological connectivity into spatial planning, including the payment of public administrations' services for citizens.

Objective 2040

Financial instruments to support protected areas as well as for spatial planning should be established at EU level, allowing all protected areas to define in the same way the ecological network, the corridors, and avoid conflicts.

Education

Objective 2030

Inclusion of nature into students' formation, following the examples of Waldorf and Steiner schools (Alpine school model), with a proper EU certification (label).

Objective 2040

Integrate biodiversity study into the curriculum for primary students, following the principles of early nature education.

8.2.2 Infrastructure planning (transport, energy, tourism)

Picture 7: The green bridge "Bärenbrücke" in the region of Schütt on the motorway (A2) in Carinthia (AT). Photo: ORF.at[4]

Obsolete infrastructure

Objective 2030

Monitoring of infrastructure likely to become obsolete set up, requirements to set aside additional funds established and existing funding and financing mechanisms (e.g. ERDF, LIFE, InvestEU) for dismantling or removal of obsolete infrastructure made known widely.

Objective 2040

First removals of obsolete and particularly invasive infrastructure from the Alps are being implemented, facilitated by:

- A mandatory financial plan and allocation for monitoring and removal of obsolete infrastructure established at the national, regional and local level with support of the EU.
- A European "compensation market" for infrastructure ("no new without old removed/replaced") is running as a support tool for the removals.
- An Alpine strategy for multipurpose infrastructure elaborated and supported by Alpine Space and EUSALP projects. Pilot areas at regional level for multipurpose infrastructures established.

4 https://kaernten.orf.at/stories/3080612/

Alpine connectivity concept as framework for infrastructure planning

Objectives 2030

- Trans-European Network for Nature (TEN-N) formally adopted and coherently considered in infrastructure planning.
- Lobbying for new regulations on Alpine connectivity established.
- A criteria catalogue elaborated to classify the importance and the impact of infrastructure.
- Guidelines for improved decision making on infrastructure planning established, including connectivity effects and demolition costs in cost-benefit calculations for infrastructure. (Cross sectoral and multi-level aspects need to be considered.)
- Financial compensation provided for land needed to improve connectivity to dismantle transport infrastructure barriers.
- Cross-sectoral capacity building pilots for planners and building sector.

Objective 2040

A new regulation for Alpine connectivity is adopted and in place in the EUSALP area.

Infrastructure sufficiency

Objectives 2030

- Infrastructure sufficiency is a priority in relevant funding bodies (e.g. European Regional Development Fund, Connecting Europe Facility for Transport and Energy (CEF, also funding TEN-T), InvestEU and national budgets earmarked for transport, energy and tourism infrastructure)
- A critical review should be done for projects "in the pipeline".

Objective 2040

Mainstreaming of infrastructure sufficiency concept in financial instruments and in the pipelines of infrastructure planning.

8.2.3 Land use planning

Picture 8: Settlements and infrastructure integrated in the Alpine landscapes. Photo: Simon Koblar

Changing legislation

Objectives 2030

- Capacity building and awareness raising for the public, policymakers, and decision-makers regarding the current state and value of ecosystem services.
- Awareness of the significance of ecological connectivity promoted among relevant stakeholders through targeted communication and education strategies.
- Fostering clear, accessible and inclusive communication regarding green and blue infrastructure and ecological corridors on local level using common terminology to actively involve local communities into planning initiatives.
- Facilitate local political dialogue on objectives and benefits of improving the condition of the existing housing stock and to encourage revitalization of vacant buildings and brownfield sites with the aim to reduce consumption of land.

Objectives 2040

- Overall restoration/biodiversity goals on the national legislative level (prioritization).
- Enhancing national legal frameworks addressing land take and restoration efforts.
- Building land contingents introduced.
- Legal and operational coordination of ecological connectivity across the national and subnational jurisdictions, e.g. among states and federal states.

Spatial planning

Objectives 2030

- Policy and legal integration incorporating ecological connectivity into national/regional planning laws, land-use regulations, and sectoral policies (e.g., transport, agriculture, forestry, tourism).

- Spatial planning instruments: Defining ecological corridors and green/blue infrastructure in zoning plans.
- Implementation tools: Developing guidelines, standards and best practices for planners, and setting up financing mechanisms for connectivity measures.

Objectives 2040

- Full integration of ecological connectivity into national, regional, and local spatial planning frameworks, including zoning, infrastructure planning, and land-use regulations.
- Mainstreaming nature-based solutions (NbS) in urban, peri-urban, and rural planning to enhance climate resilience, biodiversity, and ecosystem services.
- Prioritization of land reuse and densification (e.g., revitalizing vacant housing and brownfield sites) over new land consumption to reduce fragmentation and preserve open spaces.
- Cross-border harmonization of planning standards and policies to ensure ecological corridors function across administrative boundaries within the Alpine region.
- Implementation of binding monitoring and evaluation systems, with spatial indicators that measure connectivity, habitat quality, and land-use efficiency.
- Dedicated financing mechanisms embedded in planning processes to support ecological connectivity measures, restoration, and long-term maintenance.
- Strong participatory planning approaches, ensuring local communities are actively involved in shaping and maintaining ecological networks.

Governance

Objectives 2030

- Shared databases, shared knowledge, and shared understanding of ecological network designs among planning practitioners and nature conservation professionals.
- Develop a coherent knowledge database to support planning and management of ecological corridors and landscape connectivity.
- Establish databases and shared knowledge as a prerequisite for coordinated cross-border spatial planning.
- Enhance cooperation and coordination between initiatives and formal governance structures.

Objectives 2040

To establish permanent governance structures with shared knowledge, financing, and related resources.

Funding

Objectives 2040

- Ensure sufficient and reliable financing supported by strong political recognition.
- Promote sustainability by making it convenient through targeted incentives and funding mechanisms.
- Develop and establish improved financing instruments and models.
- Create added value by supporting the reuse and revitalization of vacant housing.

8.2.4 Landscape planning in agricultural areas

Picture 9: Alpine pasture. Photo: Andrej Gulič

Landscape planning and policy

First steps

- Exclude soils of ecological importance from agricultural production (e.g., moors, bogs).
- Digitalize landscape characteristics (features) in agricultural land, important for biodiversity/connectivity, and manage them by Common Agricultural Policy (CAP) funds.
- National Restoration Plans: Prioritize degraded habitats in agricultural and forestry areas situated in ecological connectivity areas, and not only in Natura2000 sites.

Objective 2040

- Cultural and natural heritage sites are integrated in landscape plans.
- Key ecosystem services: Policy coherence for agriculture and forestry should be defined and integrated through green and blue infrastructure concepts in spatial and sectoral plans (e.g. climate and biodiver-

sity plans), as well as in the CAP and Rural Development Policy.
- Hedgerows in agricultural areas which disappeared in the last 20 years should be restored. Concrete measures to realize and restore natural hedgerows in agricultural fields should be established to reach certain thresholds and technical standards. The World Overview of Conservation Approaches[5] proposes a local average length of 36 m of hedge per hectare (the average of the administrative area is 19 m/ha, for details see Pivain and Odienne, 2019), a height between 1.5 m and 20 m, and between 1 and 3 different vegetative strata (herbaceous, bushy, shrubby, tree) (Pivain and Odienne, 2019).

Awareness raising

First steps
- Better promotion of the value of green and blue infrastructure and biodiversity in the society and agricultural sector and that everyone can do something for nature restoration.
- Promoting healthy diets.

Objective 2040
- Meat consumption is reduced.

Other objectives of importance for implementation (not related to planning)

Alignment of Common Agricultural Policy (CAP) with European Regional Development Fund (ERDF)/EU policies

First steps
- Promote measures in the CAP/ERDF programmes and projects to improve biodiversity targets and green networks. Agricultural and rural development policies should be better harmonized with the regional development policy and with nature restoration plans.
- Adjust incentives from CAP in favour of extensive agriculture – this condition needs to be aligned with an appropriate monitoring system.

Objective 2030
Monitoring and effective control system of cross-compliance in relation to CAP implementation. Rules with clear sanctions (for restoration), e.g. no further payments of subsidies when rules are not respected.

Objective 2040
CAP and ERDF are aligned and integrated. A coherence between CAP and ERDF, as well as the Nature restoration law and other European policy instruments has been reached.

Economic interventions in agriculture policy

First steps
Interventions in trade market of agricultural products:
- Introduce higher customs on imported food (which is available in the EU)
- Shorten the chain markets between consumers and agricultural production (farmers closer to consumers), with more competitive small producers.
- Strategic potential of European Investment Bank (EIB): Biodiversity and green infrastructure in portfolio.
- Consideration of the external costs of conventional agriculture and actual transport system.

Objective 2040
Funding:
- Creation of economic marketplaces for diverse agricultural products and payment for ecosystem services.
- Innovative EU funding.
- Public-private partnerships for nature restoration should be established as common financial instruments.
- Certification systems include ecosystem services. In other words, certification of cultivation methods of agricultural products is considering the maintenance of ecosystem services.

5 "The Global Database on Sustainable Land Management (SLM) of WOCAT (the World Overview of Conservation Approaches and Technologies) provides free access to the documentation of field-tested SLM practices from different places in the world and offers practitioners the opportunity to share their own SLM practices."

09

COUNTRY-SPECIFIC RECOMMENDATIONS TO IMPROVE PLANNING AND IMPLEMENTATION OF ECOLOGICAL NETWORKS

Due to the federal legal systems in the Alpine countries and the related large variety of spatial planning systems in the Alps, each country and region has its own way how to deal with ecological network planning. Each of them has different planning gaps and possibilities to improve the network plans. Therefore, specific recommendations are proposed for each Alpine country represented in the PlanToConnect project.

9.1 Austria

Plans/guidelines to be elaborated/updated

- In Austria, spatial planning is regulated at federal state level by nine spatial planning laws. Landscape plans addressing green and blue infrastructure do not exist at this level. It is recommended to elaborate regional landscape plans or concepts with an ecological network design and ecologically valuable areas. Such concepts partly exist, for example in the Federal State of Carinthia (*Freiraumkonzept* – concept for open spaces from the year 2006 which is under revision), but they are intended as advice to planning authorities and are not mandatory. Generally, it is recommended to enhance and strengthen landscape planning in Austria. Some ecological connectivity concepts are integrated in federal development programmes (*Landesentwicklungsprogramme - LEP*), like in the Federal State of Salzburg. However, the example operates only with "should" regulations regarding ecological corridors. It is recommended to give stricter regulations for implementation of the defined corridors.
- The Austrian-wide ecological network concept elaborated by the project "Lebensraumkorridore" is not mandatory. To reach a legally binding character, the network/corridors could be integrated in spatial development plans at the federal state level.
- Spatial planning basically takes place at municipality or local level. Municipalities are obliged to elaborate development concepts and spatial plans. However, those plans predominantly deal with upcoming developments. Green and blue infrastructure elements are shown in the current practice but not analysed and addressed in detail and with regards to their ecological function. It is recommended to include habitat connectivity in development goals, zoning and land use designations in the regional development concepts (*Regionale Entwicklungskonzepte* - REK), as well as in the integrated urban development concepts (*Integrierte Stadtentwicklungskonzepte* – ISEK). ISEKs are elaborated by spatial planners, who advice municipalities as planning bodies. Protected areas are considered, and up-to-date biotope mapping exists. The nature conservation sector should provide respective sectoral base documents showing areas of high natural values including ecological corridors. Proactive nature conservation and spatial planning is recommended for the nature conservation sector to avoid habitat fragmentation. Wildlife corridors are currently provided by the platform lebensraum.at. They are available as layers on the federal GIS platforms. However, it is not mandatory to consider them. It is recommended to integrate these corridors as mandatory into the spatial planning federal laws.
- Habitat connectivity should be addressed at least in the local spatial planning concepts (*Örtliche Entwicklungskonzepte* – ÖEK) and in the land use plans. The instruments "Grünkeil (Green wedge)" or "Settlement boundary" could be used to integrate corridors into spatial plans and programs. Currently, the responsibility for ecological corridors lays in the forest sector and not in the nature conservation sector or spatial planning. It is recommended to establish a governance mechanism for the consideration of ecological corridors.
- The Austrian Programme for the Agricultural Environment (*Österreichische Programm für umweltgerechte Landwirtschaft* – ÖPUL) is a funding instrument for nature friendly agriculture. It is currently not used strategically but rather responds to initiatives

of individual farmers. However, it could be actively used to introduce mechanisms to promote extensive land use in ecological corridors by addressing priority zones matching with corridors identified by the analysis of the national coordination platform on ecological networks "Lebensraumvernetzung" outside the forests and also within protected areas.

- For blue infrastructure, agricultural nitrate regulations currently provide a minimum of three-meter buffer space next to rivers. These spaces function as ecological corridors due to their natural features with trees, hedges and tall forb communities. By enlarging the distance for agricultural activities next to rivers and streams from 3 to up to 10 meters, wide ecological corridors would arise along water courses forming a basic connectivity network. If such areas are actively restored, they would develop as broadleaf forest giving space for a variety of species.
- Corridor contracts (voluntary instrument) between nature parks in transboundary areas could influence territories outside and/or between nature parks.

Platforms to be activated to support the update of plans

The Austrian Spatial Planning Conference (ÖROK) would be an appropriate platform to initiate a working group on ecological corridors in spatial planning at the national level. They should collaborate with the Austrian Coordination Platform for Ecological Networks (Lebensraumvernetzung.at). This platform was launched by the Federal Ministry for Agriculture and Forestry, Climate and Environmental Protection, Regions and Water Management and conducted an Austria-wide analysis on ecological connectivity. Members include experts for forestry, transport infrastructure, wildlife management, nature conservation, but the discipline of spatial planning is not represented (see https://lebensraumvernetzung.at/en/platform). It is recommended to integrate experts for local and regional spatial planning, landscape planning, ecosystem services, and agriculture.

- UNESCO Biosphere reserves with their cross-boundary character could work as facilitators to integrate ecological connectivity. They have no own planning instrument but could influence the elaboration process of municipal development plans and zoning plans.

9.2 France

Plans/guidelines to be elaborated/updated

- Regions in France have elaborated connectivity concepts, however, there is a lack of small-scale analysis besides main corridors. Therefore, it is recommended to update local scale mapping and analysis of corridors.
- It is recommended to widen the analysis of corridors and to integrate more diverse aspects of connectivity, e.g. on black, brown, white or aerial infrastructure. The broadening of range of types of corridors leads to a better assessment of anthropic threats and pressures on the landscape, and how to cope with it.
- Black corridors are paths characterised by darkness and used by species that are not tolerant to human induced nocturnal lights.
- Brown corridors refer to soil connectivity and associated species. It is mostly an issue in urban areas where species dispersal is highly constrained by urban infrastructure.
- Aerial corridors refer to the capacity of flying species to spread in the air without any human induced obstacles (wind turbines, planes, high-voltage lines etc.).
- White corridors refer to human induced noise pollution in opposition to silence. Noise pollution can alter species communication.
- It is recommended to start processes for harmonization between planning documents at different scales (from regional to local levels), and to resolve the lack of harmonisation between intercommunities. Planning instruments addressed are the Local Urban Plan (*Plan Local d'Urbanisme* - PLU) at municipal or intermunicipal level (plan local d'urbanisme intercommunal – PLUI), and the Territorial Coherence Programmes (Schéma de cohérence territoriale - SCoT).
- From experiences in the PlanToConnect pilot sites, a lack of monitoring in urban planning processes by the Departmental Commission for the Preservation of Natural, Agricultural, and Forest Areas (Commission Départementale de Préservation des Espaces Naturels, Agricoles et Forestiers - CDPENAF) is assumed. An improvement of this monitoring is recommended in combination with regular monitoring on ecological connectivity (e.g., by fieldworks and remote sensing). This monitoring should reveal the evolution of corridors.

9.3 Germany

Plans/guidelines to be elaborated/ updated

National level

The existing National Concept for Green Infrastructure (*Bundeskonzept für Grüne Infrastruktur* – BKGI) could be transformed into a legally binding framework plan that needs to be integrated into spatial plans and planning procedures at the federal and regional planning levels.

Federal level

- Biotope Network Concepts are currently in the drafting process (e.g. for Bavaria by the end of 2025) and need to be integrated in the spatial planning system at the federal level. They should be integrated in the land use and landscape plans, to finally achieve the integration into zoning plans. The integration must be considered during the regular renewal processes.
- Cross-border networks should be outlined in the federal biotope network concepts covering border areas.
- Sectoral planning needs to be reviewed to integrate connectivity functions in Forest Functional Plans or River Development Plans.

Regional (intermunicipal) level

From the PlanToConnect pilot sites in Bavaria it was possible to deduce recommendations which apply also to other regions (intermunicipal areas):

- It is recommended to elaborate action plans (timeline, responsibilities, funding) based on federal species and biotope protection programmes (Arten- und Biotopschutzprogramm – ABSP) or similar instruments given by the regional plans for implementation of measures.
- For all regions it is recommended to use existing tools and graphic representation options in regional spatial plans, like the existing biotope network axes and regional green corridors to integrate and formalize ecological corridors. Corridors are also covered by instruments that relate to open space planning and should integrate a multifunctional approach.

Concepts, which need a stronger legally binding character

- The Bavarian species and biotope protection programme (*Arten- und Biotopschutzprogramm* - ABSP)
- Landscape Programme of Bavaria (*Landschaftsprogramm Bayern*)
- Landscape framework plans (*Landschaftsrahmenpläne*)
- Municipal Landscape Plans (*Landschaftsplan*)

Platforms to be activated to support the update of plans

- Regional planning associations
- German Nature Conservation Association (*Deutscher Naturschutzring – DNR*)
- Minister Conference for Spatial Development (*Raumentwicklungs-Minister-Konferenz - RMK*)
- Regional Planning Advisory Council (*Landesplanungsbeirat*)
- Nature Conservation Advisory Board (*Naturschutzbeirat beim StMUV*) at the Bavarian State Ministry of the Environment and Consumer Protection (StMUV), and Nature Protection Advisory Boards at district offices (Naturschutzbeiräte an *Landratsämtern*)
- The involvement of the following institutions is needed:
  - Academies for Nature Conservation and Landscape Management (e.g. in Bavaria the *Bayerische Akademie für Naturschutz und Landschaftspflege – ANL*),
  - Federation of German landscape architects (*Bund Deutscher Landschaftsarchitekten – BDLA*)
  - Academy for Territorial Development of the Leibniz Association – ARL (A*kademie für Raumentwicklung in der Leibniz-Gemeinschaft – ARL*)
  - Trusts such as the Bavarian Nature Protection Trust (*Bayerischer Naturschutzfonds*), *the Heinz Sielmann Stiftung* or the *KulturLandStiftung* of the Bavarian Farmers Association can support the implementation and expansion of local biotope networks.
- Environmental NGOs are important to activate as they feature a strong representation at the local level (*BUND, NABU, Bund Naturschutz, Landesbund für Vogelschutz*) and can raise public awareness and pressure to act.
- As regards on-site implementation measures, a close cooperation needs to be established with Land Care/ Land management Associations (L*andschaftspflegeverbände*). The mandates of Lower Nature Protection Authorities should be supplemented with ecological connectivity planning and coordination tasks.

9.4 Italy

Plans/guidelines to be elaborated/updated

National level:

The National Biodiversity Strategy 2030 (NBS 2030) recalls, among the priorities of the EU Biodiversity Strategy, the establishment of a coherent network of protected areas, including the legal protection of at least 30% of the EU's land area and 30% of its seas, and the **integration of ecological corridors into a genuine trans-European nature network**.

To this priority, the NBS 2030 assigns Strategic Objective A: *Building a coherent network of terrestrial and marine protected areas*.

Within the framework of Strategic Objective A, the NBS 2030 sets Specific Objective A.3: *Ensuring the ecological-functional connectivity of protected areas at local, national, and supranational scales*, and defines the actions for its implementation.

For each of the actions, the PlanToConnect project elaborated the following specific recommendations:

Action A3.1. Establishment of a National Ecological Network of Protected Areas

- Sub-Action A3.1. a) *Definition of a national strategic instrument, in agreement with Regions and Autonomous Provinces, which—building on existing regional ecological networks—aims to identify ecological corridors and other elements of both direct and indirect connectivity among protected areas, the Natura 2000 network, and OECMs. Its purpose is to ensure ecological-functional linkages between them, also harmonizing, for this purpose, the renaturalization of natural corridors formed by watercourses. The National Ecological Network should be integrated into national planning instruments and be functional and effectively connected at the supranational scale for migratory species crossing Italian territory.*
- Sub-Action A3.*1.b) Definition and/or possible updating of regional ecological networks in line with the national strategic instrument referred to in point A3.1.a, and their integration into territorial planning instruments, particularly in Regional Landscape Plans.*
- Sub-Action A3.1.c) *Support national programs and system-wide policies provided for under Article 1bis of Law 394/91 (instruments for institutional cooperation among the state, regions, local authorities, and park authorities).*

To date, Italian regions and autonomous provinces cannot refer to a national ecological connectivity concept, because in Italy the task was given to the regions and autonomous provinces to be implemented in regional and provincial landscape plans. Led by the Italian Institute for Environmental Protection and Research – ISPRA, a process of harmonization is taking place and foresees an update of the current guidelines for ecological connectivity planning of 20036. At national level, five thematic workshops with participants from all Italian regions were held in 2025 regarding approaches for connectivity planning, the relationship with spatial planning instruments, technical instruments for analysis of GBI, implementation and governance. The Italian partners of the PlanToConnect project participated in the working groups and contributed with the gained knowledge.

To support this action, the PlanToConnect project recommends elaborating national priority areas for ecological connectivity, to define them geographically, and to give them implementation guidelines (*norme di attuazione*) which should be adopted by the regional level. The scenario of priority areas for connectivity and the methodology developed by the project for their identification and analysis of green and blue infrastructure, barriers and threats in the Alpine Space as presented in this document could be a useful reference for this task.

Beside supporting the national instruments for institutional cooperation under Article 1bis of Law 394/91, PlanToConnect recommends providing support for the establishment of "voluntary agreements for the preservation of natural capital" within the framework of the National Table of River Contracts. These agreements could play a key role in implementing green and blue infrastructure in priority connectivity areas, helping to identify and map ecological corridors, engage local stakeholders, and coordinate actions across multiple administrative levels and policy sectors.

6 https://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida/Gestione-delle-aree-di-collegamento-ecologico

Action A3.2. Promoting investments in green and blue infrastructure and Nature-Based Solutions

- *Sub-Action A3.2.a) Implementing EU guidance documents on the financing and implementation of green and blue infrastructure and Nature-Based Solutions, incorporating them into spatial planning, landscape planning instruments, and national financial programming documents.*
- *Sub-Action A3.2.b) Adoption of a package of fiscal measures to support investments in green and blue infrastructure and Nature-Based Solutions.*
- *Sub-Action A3.2.c) Inclusion, within the 2023–2027 National CAP Strategic Plan, of a specific eco-scheme for the maintenance of green infrastructure and rural development interventions for their enhancement, setting the target of 10% of agricultural land dedicated to biodiversity conservation and the creation of ecological networks*

To ensure an effective implementation of this action, PlanToConnect recommends integrating the concept of ecological network into spatial and landscape planning with a complementary analysis and mapping of the supporting green and blue infrastructure. This approach enables the proper identification and management of landscape elements that need to be conserved or restored to ensure ecological-functional connectivity between core areas. In this analysis, two complementary mapping approaches (physical and ecosystem-based) were developed and tested in Veneto and Lombardy cases studies and could provide guidance for the strategic design of a well-connected, multifunctional, and cross-border green and blue infrastructure network for connectivity in Italy as part of the trans-European nature network. Green infrastructure 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 and possible scenarios involving all sectors (see Chapter 3.2.3).

<u>Regional/provincial level:</u>

- South Tyrol should adopt a provincial ecological network concept. Currently it is the last region in the Alps which cannot refer to a national concept, and which has no formal or informal ecological connectivity concept. Therefore, an anchor for spatial planning to integrate ecological corridors in municipal landscape plans or municipal development programs is missing and must be elaborated.
- Mismatching ecological networks at regional borders should be aligned with each other, with the help of the new guidelines for ecological network planning at the national level. Cross-border issues should be resolved, and methodological differences harmonized, following the new guideline. It is recommended to focus on creating coherence in the design across borders, among technical norms for corridor elements, and to harmonize labels/keys among various network designs.
- Regional landscape plans are equipped with ecological network concepts, but the analyses should be updated and results integrated into the plans to assure coordination and synergies with other key sector policies, strategies and plans:

Table 3: Plans to be elaborated

COORDINATION OF SECTOR POLICIES	GREEN AND BLUE INFRASTRUCTURE PLANS PHYSICAL/ ECOSYSTEM SERVICES
Climate adaptation	Climate regulation services
Habitat quality (Biodiversity)	Habitat quality
Natural/cultural landscapes	Cultural, leisure
Agriculture, forestry	High nature value agriculture and forestry

- It is recommended to prioritize corridors in the existing ecological network designs (transnational value) of Italian regions and improve the related technical norms.

Platforms to be activated

- ISPRA has taken over the topic of ecological network planning in Italy and acts as the coordinating platform.
- Regional and provincial authorities, as well as research organisations, are formally involved in the preparation of national guidelines for the ecological network. The Italian National Institute for Urban Development and Spatial Planning - INU is involved. A draft of the guidelines is expected by the end of 2025.

9.5 Slovenia

Plans and guidelines to be developed or updated

Currently the concept of ecological connectivity is not recognized as a key binding element within the spatial planning system at the local, regional, or national level. To increase visibility, the concept of ecological corridors should be included under the principle of 'ecosystem connectivity' in the Spatial Planning Act.

A national ecological network should be integrated into the national spatial planning concept, with clearer spatial definition, as well as implementation regulations. A concept for the spatial plan of Slovenia is in preparation (UIRS et al., 2025-2026).

Ecological corridors could be integrated into the green system, with the Ministry of Natural Resources and Spatial Planning - Spatial Planning and Construction Directorate as the main actor. Ecological connectivity corridors should be based primarily on the corridors proposed in the PlanToConnect project. At the regional and local levels, it is necessary to examine the possibilities for harmonizing them with the proposals for functional corridors identified by the Slovenian Forest Service.

Slovenia is in the process of reinforcing the regional level of spatial planning and improving the intermunicipal cooperation. This presents an opportunity to incorporate ecological networks in the upcoming regional spatial plans. The topic could then be included in the municipal spatial plans. Additionally, landscape plans are an appropriate instrument for defining and implementing ecological corridors, as they cover functional or coherent landscape areas and are mostly interregional, or at least intermunicipal in character.

Recommendations for integration of green and blue infrastructure networks into spatial planning instruments: Protection of ecological corridors should not necessarily involve strict conservation measures. Their multifunctional value should be recognized and appropriate measures identified and implemented.

- Identification of ecological corridors should be based on the public interest principle. The Institute of the Republic of Slovenia for Nature Conservation could lead the process; however, appropriate instruments need to be defined.
- Ecological corridors could be included in management plans of the existing protected areas.
- Due to their cross-sectoral nature, implementation of ecological corridors requires coordinated action across departments. However, interdepartmental collaboration remains a major challenge in Slovenia's spatial planning system, with limited operational mechanisms in place. The agricultural sector in particular tends to function independently, hindering alignment with spatial and environmental planning objectives essential for corridor integration.
- By presenting good practices (from abroad), the realization of ecological linkages could be supported in Slovenia.
- Spatial definition of ecological corridors must be refined at the local level to ensure alignment with territorial conditions and land-use realities. This process should be embedded within preparation of municipal spatial plans, enabling integration of corridor delineations into statutory planning instruments with appropriate zoning and regulatory provisions.

Platform to be activated

- The Ministry of Natural Resources and Spatial Planning, particularly its Directorates for Nature and for Spatial Planning and Construction, are actively engaged in the topic of Alpine ecological connectivity and biodiversity conservation.
- Collaboration with/between public service, academic and research institutions should be strengthened, including among other (list not exhaustive):
  - Slovenian Forest Service, which has experience in the analysis and implementation of forest corridors in Slovenia,
  - Institute of the Republic of Slovenia for Nature Conservation as the main national professional organization in the field of nature conservation,
  - Agricultural Institute of Slovenia (AIS) as a partner in several (transnational) projects on ecological connectivity,
  - University of Ljubljana - Department of Landscape Architecture as a partner in research projects on ecological corridors,
  - Urban Planning Institute of the Republic of Slovenia – UIRS, which can support integrating of ecological connectivity into spatial and landscape planning instruments. UIRS could also foster setting up a network of experts and leveraging the existing knowledge of nature conservation professionals.
- It is recommended to establish a Slovenian Coordina-

tion Platform for Ecological Networks/Connectivity[7]. This platform could serve as a vital tool for bringing together existing knowledge, expertise, and resources to support integrated ecological connectivity planning across sectors and governance levels.

9.6 Switzerland

The PlanToConnect project had no partner organisation from Switzerland and was therefore not focusing on this Alpine state. Given the project findings, one recommendation can nevertheless be made:

Being the country with the widest areas where connectivity is still working (SACA1 areas) but without protection, Switzerland should focus on the evaluation of them to safeguard natural areas that have a high potential for nature protection.

7 using the example of Austria (Lebensraumvernetzung.at)

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CONCLUSIONS

Ecological connectivity is important for seed dispersal, movement of wildlife species to find food, to reproduce and escape from predators. It creates gene flow and is consequently important for the maintenance of biodiversity and functionality of ecosystem services.

Objectives to promote ecological connectivity and to improve the ecological network are coming from the European strategies and the European Habitat Directive and therefore need to be implemented on the national, regional and local levels.

Ecological connectivity can be achieved by counteracting fragmentation of the landscape, which is one of the core tasks of the spatial planning discipline. Spatial planning also has appropriate legal instruments to fulfil such objectives. Avoidance of landscape fragmentation by settlement development (urban sprawl) is mostly among the most important objectives in regional and national spatial planning laws and therefore reaches the public interest. Spatial planning laws of the PlanToConnect pilot sites even mention ecological connectivity and the maintenance of ecosystem services among the most important objectives to follow. Moreover, these objectives need to be pursued to avoid land use conflicts, in this case the conflict between anthropogenic land uses and nature conservation goals. Spatial planning should coordinate various land use claims. Cross-sectoral coordination is needed to deal with the variety of aspects regarding ecological connectivity. Spatial planning professionals, administrative officers and involved decision makers thus have the responsibility to steer infrastructure development and anthropogenic land uses to counteract fragmentation of the natural landscape and to mainstream ecological connectivity in spatial planning instruments and processes.

The current situation of ecological network planning in the Alps is characterised by several gaps that need to be closed. Harmonisation problems at regional and national boundaries, missing ecological connectivity concepts and weaknesses in legal enforcement of ecological network plans are among the most prominent. One of the biggest challenges might be harmonization because there exist different views, approaches and possible methodologies to define an ecological network. The many methodologies used in the Alpine Space create a high amount of harmonization problems at the regional and national boundaries.

Therefore, this planning strategy document provides:

1) a tool for prioritizing and harmonizing structural ecological linkages between existing protected areas and highly natural areas (SACA1 areas), as well as
2) a vision, accompanied by long-term and short-term objectives to guide the improvement of the Alpine ecological network.

The above-mentioned tool proposes potential macro-regional linkages which are strategically important to create a coherent ecological network on the Alpine region level. For concrete implementation, the macro-regional linkages need to be further studied and concretized at the regional and local level. It is a tentative to create a basis for spatial planning professionals and decision makers to allocate resources in an efficient way to improve the Alpine ecological network.

The vision and objectives are structured in four different thematic fields, including settlement and infrastructure development, but also agricultural areas and areas for nature conservation. While most of the defined objectives are intended for spatial planning, ecological connectivity needs to be considered also in sectoral policies like agriculture, forestry, or infrastructure development, for which classical land use planning has little competence. To improve ecological networks effectively, landscape planning must be considered e.g. in close connection with landscape management and landscape maintenance, and it must consider additional instruments outside of the classic landscape conservation thematic. The listed objectives therefore go beyond the classical planning instruments.

Specific recommendations for each Alpine country were further elaborated to close the gaps of ecological connectivity planning and to mainstream the topic on various planning levels. Concrete planning instruments are named which need to be introduced, improved or harmonized. These recommendations should be understood

as potential concrete actions to mainstream ecological networks in spatial planning instruments.

In most of the Alpine countries, platforms for ecological connectivity or spatial planning experts already exist and enable exchanging knowledge and starting harmonization processes. It is time to bring experts from these two disciplines together, so that biologists/conservationists and planning experts can join forces for improvement of ecological network planning. Additionally, the platforms can foster exchange among countries and (transnational) organizations. One example where this has already been realized is the exchange between the Alpine Biodiversity Board and the Spatial Planning and Sustainable Development working group of the Alpine Convention. This could be a good example for other exchanges to establish ecological network planning all over the Alps.

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PlanToConnect
Mainstreaming ecological connectivity in spatial planning systems of the Alpine Space

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Alpine planning strategy for ecological connectivity
Harmonized and integrated planning of green and blue infrastructure networks in priority areas

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