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PlanToConnect

Guide on procedural steps for integrating GBI networks into planning

Guidelines for implementing Green and Blue Infrastructure (GBI) networks for spatial planners

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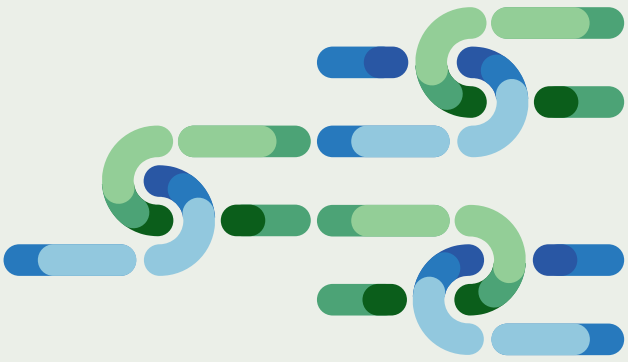

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Guide on procedural steps for integrating GBI networks into planning

Guidelines for implementing Green and Blue Infrastructure (GBI) networks for spatial planners

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Glossary

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).

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

Protected area

"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)

SACA1 - Ecological Conservation Areas

SACA1 areas were the basis for ecological connectivity modelling in the PlanToConnect project. The term was developed in the ALPBIONET2030 project and is defined as “areas, that still have considerable space for connectivity with non-fragmented surfaces and where connectivity should be conserved”. According to Plassmann et al. (2019), currently 61% of the Ecological Conservation Areas within the Alpine Convention perimeter are located in protected areas, which means there is a big potential for protection of these areas.

SACA2 - Ecological Intervention Areas

The main focus in the PlanToConnect project lies on areas for possible interventions to improve ecological connectivity. The ALPBIONET 2030 project simulated such areas with very large extension and developed the term “Ecological Intervention Areas”. These are areas “with a high potential for connectivity in which larger, more or less natural non-fragmented zones could be created, especially by connecting protected areas, Natura2000

sites or other precious biotopes. Ecological connectivity is currently working to some extent in these areas but would benefit from enhancements" (Plassmann et al. 2019).

SACA3 - Connectivity Restoration Areas

"They are areas where fragmentation has already progressed so far that realizing (sic!) interlinked habitats and a permeable (sic!) landscape matrix is no longer a realistic option using reasonable, viable interventions, and solutions would entail extreme financial and political effort. They represent important barriers between Ecological Conservation Areas" (Plassmann et al. 2019). The realization of punctual interventions at very targeted locations to mitigate negative barrier impacts is recommended (ibid.).

1. Introduction

Green-Blue Infrastructure (GBI) implementation demands practical, data-driven steps that translate strategic designs (described in D1.4.1) into tangible outcomes on the ground. This document outlines necessary aspects to consider for the integration into spatial planning processes and documents, supported by the experiences made within the PlanToConnect pilot sites to ensure that GBI measures enhance ecological connectivity, foster biodiversity, and provide lasting socio-economic benefits. By focusing on the integration of connectivity concepts and approaches from barrier removal to funding, partnerships and capacity building, these guidelines complement the *conceptual and strategic planning* foundations set in the guidelines for GBI network design (D1.4.1).

Purpose of the Guide (technical, On-the-Ground):

- Empower local authorities and planners by providing clear instructions on the practical steps for GBI network creation and maintenance.
- Build on the standardized protocol for GBI network design (D.1.4.1) by offering implementation details to realize the policy alignments discussed in D1.4.1.
- Highlight funding and partnerships by presenting mechanisms that support the financial viability of GBI projects over the long term.

Relation to the Standardized protocol for GBI network design (D1.4.1) - Design vs. Implementation:

Where the Standardized protocol for GBI network design (D1.4.1) focuses on why GBI matters and how to integrate it into broader spatial strategies, D1.4.2 gives the hands-on methods for carrying out those plans. Readers should use both documents together for a holistic perspective - D1.4.1 for overarching policy and design principles, D1.4.2 for day-to-day technical guidelines for implementation into spatial planning instruments and procedures.

For the creation of guidelines and a transnational procedure for implementing priority areas for ecological connectivity into spatial planning, it is essential to address multiple scales from general to local (national, regional and local) while fostering cooperation across borders and sectors. These guidelines should promote the conservation and restoration of ecological connectivity and ensure that the knowledge of multi-purpose ecological networks is embedded in all levels of spatial planning. It gives indications for stakeholder engagement, barrier removal, funding, monitoring, and provides an implementation checklist.

2. Strategic integration of GBI into planning frameworks

The successful implementation of GBI networks requires multi-level governance, legal anchoring, integration in robust legal instruments, involvement of key stakeholders and cross-border coordination to embed ecological connectivity into regional, national, and international planning processes.

2.1. The role of multi-level governance in GBI planning, alignment with European policies

Ecological networks span municipal, regional, national, and transnational boundaries. Coherence across these levels is essential:

- Transnational Level: Cross-border frameworks (e.g., EU Green Infrastructure Strategy, Alpine Convention, transnational protected areas) ensure connectivity beyond political borders.
- National Level: Embedding GBI in national spatial planning strategies and guidelines, environmental policies (biodiversity strategy), and sectoral strategies (e.g. transport, agriculture).
- Regional Level: Embedding the importance of GBI networks in regional spatial planning laws. Coordination of larger-scale GBI strategies, balancing conservation with socio-economic development.
- Local Level: Municipalities integrate GBI into urban and peri-urban planning, manage land-use, and engage local stakeholders.

EU policies and local needs:

It is not for lack of stated EU policies that progress in establishing ecological networks is slow. “The EU Policy Landscape” makes clear, EU strategies and policies contain ample references to the need to ensure connected networks of natural areas to protect biodiversity. At a higher level, policy and planning-based measures for protecting ecosystem services would comprise the strengthening of legal frameworks and enforcing environmental laws, such as Natura 2000, Water Framework Directive, and the Habitats Directive. There are initiatives to promote green infrastructure as one of the pieces in the connectivity puzzle. But national implementation of EU policies in general is not on target. One may wonder, then, whether this is because recommended policies are clashing with local needs. EU policies are not created in a vacuum; they are voted on by representatives of national governments in the European Parliament, so on the whole they should be expected to conform to national priorities. But do they also reflect local needs?

In translating EU policies to a local level, care has to be taken to ensure communication is not only open and regular, but also in a format that can be understood by everyone. In an attempt to simplify the connectivity concept.

It is rarely easy to balance conservation needs with local development needs, but policies must mirror local needs, or they are doomed to failure. Development decisions should be based on a dialogue between the grass-roots level and the top level, a combination of the bottom-up/ top-down dichotomy. This is not to advocate that all decision making be based on popular demand coming from the community level – there is a danger in this too, as local needs also often originate from the interests of particular individuals or companies. What is needed from the top down is a strategic concept – in this case covering the requirements for connectivity on a larger scale.

Local interests can then be compared to larger-scale strategies, and compromises must be found. If people realize that everyone is contributing to conserving unfragmented landscapes, their willingness to do so will increase as well. But it must become an important aspect of daily policy discussions.

Development should therefore be seen as a process of continuous exchange between different policy levels and the communities that are being asked to undertake certain activities, and the process should be managed as a natural organic process rather than according to plans, goals, objectives, targets and schedules. Goals and targets may change, and there should therefore be a degree of flexibility in projects.

(modified after greenAlps project, 2014)

None of this is new or surprising, and none of it runs counter to strategies that promote biodiversity conservation and ecological connectivity. It is, rather, symptomatic of government policies that undervalue nature, despite statements to the contrary. Governments must define clear goals that prioritize ecosystem connectivity and conservation in a trans-sectoral context, but that also meet the needs of communities and common European interests. A vision of conservation and connectivity has to be developed on a larger scale but including the views of local people who must then also participate in implementing concrete measures.

(modified after greenAlps project, 2014)

2.2. Integrating GBI into regional and national spatial planning laws

GBI implementation is addressed in different frameworks elaborated on European, regional, national and local levels. While not exclusive for the Alps, there are EU and international initiatives aiming to protect biodiversity and enhancing ecological connectivity, the creation of the Emerald network in 1989, followed by the adoption of Habitats and Birds directives addressed the need to develop a broader approach to protect valuable habitats (Jongman, 2004). The EU Biodiversity strategy 2030 and the Nature restoration law, mention the importance of promoting green infrastructure, as well as the maintenance and restoration of habitats and corridors in order to enhance connectivity.

The European Union macro-regional strategy – EUSALP enhances cooperation among Alpine countries around different subjects including biodiversity. The strategy includes a dedicated Green Infrastructure (GI) action group, promoting the integration of GI elements into spatial planning, encourages best practices and supports the development of a “planned network of natural-and semi-natural areas”. (EUSALP, 2025)

The Alpine Convention also addresses the subject of ecological connectivity. The Convention stresses the importance of maintaining ecological corridors and green infrastructures to facilitate species movement. The "Nature Conservation and Landscape planning Protocol", Article 12, mentions *“The contracting parties [to] take adequate measures to establish a network of existing national and transboundary protected areas, of biotopes and other protected elements or those to be protected. They commit themselves to harmonize the objectives and applicable measures in transboundary protected areas.”*

Making GBI a Mandatory Element of Spatial Planning

> Ecological connectivity must not be treated as an optional add-on. Instead, it should become a binding requirement in land-use and spatial development regulations, ensuring GBI principles shape urban growth and infrastructure projects from the outset. Where Strategic Environmental Assessments (SEA) are employed, GBI design should align with both national and regional planning frameworks, embedding corridor and buffer-zone considerations at every stage.

Embedding ecological connectivity within national/ regional frameworks entails:

- Policy integration: Align GBI goals with national environmental strategies (e.g., EU Biodiversity Strategy 2030).
- Legal mandates: Require municipalities and regions to incorporate GBI in zoning and urban planning guidelines.
- Standardization of connectivity planning: A unified methodology ensures consistent application across various landscapes.
- Monitoring & enforcement: Regulatory mechanisms track compliance and ensure active promotion of corridors.

2.3. Legal and policy instruments supporting GBI implementation

The task of spatial planning and sectoral land management practices is to safeguard habitats and reduce land-use conflicts in areas outside and between strongly protected areas, before fragmentation by anthropogenic infrastructure becomes irreversible. Due to the strong spatial relevance of ecological networks, spatial planning and sectoral land management instruments represent the appropriate framework for anchoring ecological connectivity in legal and policy documents at various levels.

The political – administrative systems can contribute significantly to the establishment of a coherent Alpine ecological network by integrating connectivity requirements **early** in transboundary, regional, (provincial), intermunicipal, and local spatial development plans and programs, zoning regulations, infrastructure planning, and environmental impact assessments. Ecological linkages which are potentially at risk by anthropogenic infrastructure should be considered with priority regarding protection measures to prevent infrastructural interventions into nature and landscape. Corresponding to the hierarchy of reducing the impact of infrastructural interventions, protection measures should be complemented by minimisation and limitation, mitigation, restoration and finally by compensation measures (Johnson & Mayfield in Dodd et al. 2024).

Robust legal instruments create a structured framework for safeguarding ecological corridors, regulating land use, and enabling long-term GBI funding:

- Zoning & land-use regulations:
- Integrating GBI networks into spatial and land-use planning by defining protected areas, buffer zones, and corridors
- Ensuring ecological corridors are preserved in urban and rural development plans: It should define what is allowed and what is not allowed in a corridor or buffer zone, and what landscape elements should be maintained.
- Conservation easements & nature reserves: Even though it became a difficult political question, it should be mentioned that the expansion and improved management of protected areas and the implementation of legally restrict conservation measures in key ecological zones can be an option for improving ecological networks. The designation of new conservation areas became an important topic with the EU Biodiversity strategy for 2030, which defines, that aims to establish protected areas for at least 30% of land and 30% of sea in Europe (EC, 2025)
- Environmental assessments (SEA & EIA): Require connectivity considerations for major infrastructure projects. Defragmentation should be incorporated into Strategic Environmental Assessments (SEA) and supported by legal frameworks that allow for the reclamation of fragmented landscapes. Such policies ensure that defragmentation efforts become a core component of land-use planning rather than a secondary consideration.
- Biodiversity offset mechanisms: Mandate developers to compensate for ecological damage.

Good practice examples:

- The Sondrio Province (Italy) integrated GBI objectives into regional land-use policies, aligning connectivity measures with EU biodiversity goals.
- Salzburg (Austria) embedded GBI principles in regional development plans, preserving ecological networks in high-growth areas.

Integration into legal framework

Each infrastructural intervention into the landscape typically requires environmental permits, engineering feasibility studies, and alignment with local regulations. Early stakeholder engagement, including transportation authorities, municipalities, and landowners, streamlines approval processes.
In early processes of urban planning, outcomes of the planning documents can be drawn up by concerned stakeholders. It is at this stage that requirements for ecological connectivity integration can be settled for the document.
To help standardize these requirements, Asters CEN74 created a grid to analyze the integration of ecological connectivity into planning documents. It gives grades of fulfillment of connectivity integration based on existing legislative tools, exemplary planning documents, and national goals. The grid helps then to give consistent feedback during consultation phases of planning documents with concrete goals and requirements for ecological connectivity integration.
It also allows to compare the difference of integration of ecological connectivity between planning documents, to raise awareness to local policy about possible decision drawbacks and to give feedback for a better harmonization between planning documents of adjacent territories.

Criteria for assessing the consideration of ecological connectivity		Integration into planning documents		
		Yes	Partially	No
	The planning document summarizes the issues of ecological connectivity (GBI network mapping, textual elements, ...)			
2	The consideration of ecological connectivity is coherent with the ecological connectivity network of neighboring territories (across administrative boundaries)			
3	The barriers of connectivity are identified and located (urban areas, fences, roads and railways, energy infrastructure, ...)			
4	The fragmentation of aquatic and terrestrial natural areas on the territory is analyzed			
5	The planning and layout projects are justified			
6	The planning document presents objectives for preservation, restoration and/or creation of ecological connectivity			
7	The planning document presents objectives to limit urbanization			
8	The priority planning areas for ecological connectivity appear as areas to be preserved in the zoning plan			
9	The planning document presents rules for land uses, not only considering urbanization issues, but also other pressures and uses, affecting ecological connectivity, like e.g. the installation of fences, installation of energy plants, sustainable agriculture, etc.			

Table 1: for integration of the ecological networks in local planning documents

2.4. Key stakeholders involved in GBI network planning

Successful GBI networks emerge from the active involvement of diverse stakeholders. A well-functioning Green and Blue Infrastructure (GBI) network requires a multi-level, cross-sectoral, and transboundary approach. Planners should involve local populations in restoration and conservation projects to foster stakeholder and community engagement. Key stakeholders include government authorities, research institutions, private sector actors, civil society, and international organizations.

- Government authorities: National, regional, local bodies set policies, enforce regulations, and provide administrative support.
- Environmental agencies: Oversee biodiversity monitoring, protected area management, and adherence to environmental targets.
- Urban & regional planners: Integrate GBI principles into land-use designs across urban and rural settings.
- Community organizations & NGOs: Offer local insights, champion sustainable practices, and contribute to public consultations.
- Private sector partners: Developers, investors, and businesses increasingly recognize the long-term benefits of ecological infrastructure.
- Research institutions: research institutions contribute with profound scientific evidence of ecological corridor modelling, and verifications to provide scientific-based arguments for policy makers to implement protection, mitigation and compensation measures.

The success of improving biodiversity conservation and therefore the success of projects aimed at meeting this objective depends not only on the work of project partners, experts, and administrations.

It also depends heavily on the support of the population and various stakeholder groups. In order to gain their support or at least approval for complex issues of global importance such as ecological connectivity and the sustainable use of renewable energy, these subjects must be communicated in an understandable manner (after greenAlps project, 2014).

The success depends also on intersectoral collaboration between administrative offices, experts and agencies. Ecological connectivity is an interdisciplinary topic that tackles transport infrastructure, settlement development (including housing and industry), agriculture, forestry, nature protection, tourism, extraction of resources and many other sectors with separated competences. Therefore, a collaboration among these sectors is crucial.

Each stakeholder plays a critical role in planning, implementing, and managing GBI networks. A successful GBI network requires coordinated efforts among policymakers, scientists, businesses, and local communities. By fostering multi-level governance, scientific research, private sector engagement, and community participation, GBI can be a powerful tool for ecological connectivity, climate resilience, and sustainable regional development.

1. Public sector and government authorities

These entities provide policy direction, regulatory frameworks, and funding for GBI projects.

Cross-border and macro-regional institutions

- Alpine Convention and EUSALP (EU Strategy for the Alpine Region) – Facilitate transnational cooperation for ecological connectivity and sustainable development.
- ESPON and EU Regional Development Programs – Support spatial data analysis and funding for GBI projects.

National and regional governments:

- Ministries of Environment, Spatial Planning, and Infrastructure – Develop and enforce national policies on land use, biodiversity, water management, and climate adaptation.
- Regional Planning Authorities – Ensure coordination between national policies and local implementation, particularly in cross-border ecological corridors.

Local municipalities and urban planners

- Municipal planning departments – Integrate GBI into urban development, zoning, and land-use plans. It is recommended to provide training and capacity building for local authorities and practitioners on the implementation and monitoring of ecological networks.
- Water and forestry management authorities – Oversee river basin management, reforestation, and sustainable land-use practices.

2. Scientific and research institutions

These stakeholders provide data, mapping, and scientific evidence to support GBI planning.

- Universities and Research Centers – Conduct studies on biodiversity, hydrology, climate adaptation, and ecosystem services.
- GIS and Remote Sensing Experts – Use spatial data to map GBI and assess connectivity.
- Ecologists and Environmental Scientists – Identify key habitats, species corridors, and ecosystem functions that need protection.

3. Private sector and business community

Private actors can invest in, implement, and benefit from GBI through NBS.

Infrastructure and Real Estate Developers

- Integrate green roofs, rain gardens, porous surfaces, and urban forests into city planning.
- Ensure new developments minimize habitat fragmentation and water pollution.

Agriculture and Forestry Sectors

- Promote sustainable farming (agroforestry, organic agriculture) to support ecosystem services.
- Encourage forest conservation and reforestation to maintain ecological connectivity.

Renewable Energy and Utility Companies

- Develop low-impact hydropower, wind farms, and solar parks in ecological corridors.
- Implement green infrastructure for stormwater management and carbon sequestration.

Financial Institutions and Investors

- Fund GBI projects through green bonds, sustainability-linked loans, and public-private partnerships.
- Support biodiversity offset programs and nature-based solutions.

4. Civil Society and Community Organizations

Community engagement ensures local ownership, social acceptance, and long-term stewardship of GBI networks.

- Environmental NGOs and Conservation Groups: Advocate for ecological connectivity and monitoring biodiversity impacts.
- Citizen and community groups: Participate in local conservation efforts, tree planting, and wetland restoration. It is recommended to encourage citizen participation in biodiversity monitoring and conservation efforts, especially in remote or difficult-to-access areas (citizen science).
- Farmers' and Landowners' Associations – Promote nature-based solutions in rural areas.
- Recreational and Tourism Associations – Ensure sustainable access to green spaces and nature trails.

5. International organizations and EU institutions

Global institutions provide policy frameworks, technical expertise, and funding mechanisms.

- European Commission (DG ENV, DG REGIO, DG CLIMA) – Develop EU policies on biodiversity, regional planning, and climate adaptation.
- European Environment Agency (EEA) – Provide environmental data and assessments.
- United Nations Environment Program (UNEP) – Support global biodiversity and ecosystem restoration initiatives.
- WWF and IUCN – Implement conservation projects that align with GBI objectives.

6. Multi - stakeholder collaboration platforms

Joint platforms foster cross-sectoral cooperation and knowledge exchange for GBI planning.

- Intergovernmental and Cross-Border Initiatives (e.g., Interreg Alpine Space Program, ESPON, Alpine Convention).
- Public-Private Partnerships (PPPs) – Promote sustainable investment in GBI.
- Living Labs and Pilot Projects – Test innovative solutions with stakeholder involvement.

2.5. Cross-border coordination for transnational ecological corridors

Species migration, water cycles, and ecosystem processes often transcend national borders. Transnational GBI planning prevents fragmentation by political boundaries:

- International cooperation: It is recommended to establish bilateral or multilateral agreements for shared ecological connectivity goals. Cross-border environmental agreements can enhance collaboration between countries for transboundary ecosystems and reduce policy barriers.
- Joint monitoring: Transnational GIS-based systems (e.g., JECAMI) for assessing habitat fragmentation across borders.
- Policy harmonization: Align national laws with the EU Green Infrastructure Strategy, Alpine Convention, SACA frameworks.
- Conflict resolution: Manage cross-border land-use conflicts and competing economic interests collaboratively.
- Cross-border cooperation of nature parks:
  From the point of view of protected area administrations, there is a need to integrate protected area planning into the management of surrounding landscapes based on an ecosystem approach. Parks may promote cooperation between different municipalities or across borders but are in some cases faced with reluctance by municipal administrations to cooperate outside their own boundaries. Cooperation may be hampered by unsupportive legal situations, and the operational possibilities of park administrations are sometimes constrained by a lack of legal authority. A secure financial base is of course a prerequisite for effective park operation but is not always guaranteed by national or provincial governments.

2.5.1. Proposal for transnational procedure to integrate ecological connectivity into Spatial Planning

The following step-by-step procedure gives recommendations for transnational integration of ecological networks into country-specific planning instruments.

Step 1: Transnational collaboration and coordination

Establish a governance structure, formalize agreements and shared information systems: Create a transnational governance body or working group under an existing framework (e.g., the Alpine Convention) to supervise ecological connectivity efforts across countries. The development of memorandums of understanding or legally binding agreements between countries to embed ecological connectivity into spatial planning at national, regional, and local levels can be important for a common understanding and agreed objectives. Based on these preconditions, a good practice is to establish a centralized, accessible database to share ecological data, best practices, and monitoring results. Such a platform should enable all stakeholders to contribute and use information for spatial planning purposes.

Step 2: Ecological connectivity mapping and prioritization

Create trans-regional connectivity maps, possibly by participatory mapping: it is recommended to collaborate across borders to create or update transnational ecological connectivity maps, using common methodologies and standards for data collection and interpretation. A good practice is to engage local communities, landowners, and stakeholders in the mapping process to ensure local knowledge and perspectives are integrated. Identify priority corridors and core areas. A gap analysis should be conducted to identify where connectivity is most threatened, where restoration is needed, and where natural or semi-natural landscapes can be enhanced to serve as corridors or steppingstones (see standardized protocol for GBI network design D1.4.1).

Step 3: Legal and policy integration

Review and align planning to national and international policies: Ensure that the network design is aligned with broader EU policies (e.g., the EU Green Infrastructure Strategy, the EU Biodiversity Strategy 2030) and international commitments (e.g., the Convention on Biological Diversity, the Ramsar Convention) to create coherent connectivity frameworks across borders.

Step 4: Stakeholder engagement, public participation and capacity building

It is recommended to create awareness and capacity-building programs for local authorities, planners, and decision-makers to integrate ecological connectivity in spatial planning. The

provision of technical training on ecological connectivity mapping, tools (e.g., GIS), and ecological restoration techniques can help to ensure that stakeholders at all levels are able to implement the guidelines effectively. Engaging the public, particularly communities near priority areas or mitigation measures is highly recommended, to promote buy-in and support for ecological connectivity measures. Mitigation or restoration projects should be managed by public administrations, which should implement them through a transversal vision, involving different sectors. Such an approach should support flexibility and multidisciplinary in public administration skills and a management structure that is recognized by all the stakeholders involved in the design, development and implementation of GBI. Every planning tool or project should be, then, developed referring to the capacity building from public administrations.

Step 5: Incorporation into spatial planning

As regional administrations have wide competences in spatial planning in most countries of the Alpine arc, it is useful to focus primarily on regional planning frameworks, which are the connecting elements between trans-national, trans- regional and local planning perspectives. Therefore, it is recommended to include priority areas for a transnational and alpine- wide ecological network in regional spatial plans. They should be considered essential components for the conservation of the regional ecological network, and they should be possibly integrated into planning instruments that deal with landscape protection. At the local planning scale, it should be ensured that local-level spatial plans integrate ecological corridors, core areas, and restoration zones. As spatial planning frameworks differ widely among transnational regions, but the hierarchical structure of planning instruments are mostly similar, it is not possible to give a unified proposal for local planning instruments, protection categories, and standards to consider. However, local planning instruments must fulfil regional requirements.

The cross-sectoral integration of ecological corridors can contribute to a sound implementation of connectivity measures. It is recommended to ensure that the most important sectors (agriculture, transport, energy, tourism) consider ecological connectivity in their planning processes. For example, transport infrastructure projects should be designed to minimize fragmentation, using wildlife crossings where necessary.

Step 6: Monitoring and Adaptive Management

It is recommended to develop a standardized transnational monitoring framework to track progress in the conservation and restoration of ecological connectivity. This should include indicators for species movement, habitat quality, and landscape permeability, but also the spatial cover, type of protection and protection status of implemented protection zones. A flexible, adaptive management allowing to adjust priority connectivity areas based on

monitoring results, could address new challenges (e.g., climate change, land use changes). The creation of a reporting system where regional and national authorities report on the status of ecological connectivity measures could improve the implementation of spatial planning guidelines continuously.

2.5.2. Best Practice: The Trilateral Transboundary Pilot Site (Austria-Italy-Slovenia) harmonized corridor planning across national boundaries via a joint connectivity framework.

The activities focused on establishing a cooperation platform between the nature conservation sector, authorities responsible for spatial planning, municipalities and regional governments.

For the Trilateral Transboundary Pilot Site (Austria-Italy-Slovenia), the institutional cooperation is different within the three countries. In nature conservation, the recently established transboundary biosphere reserve Julian Alps between Italy and Slovenia is a strong cooperation asset for the management of ecological corridors, while Austria with the Nature Park Dobratsch represents ecological and sustainable tourism topics on this site of the border. In a memorandum of understanding, the collaboration in terms of connectivity was signed by the three parks. In Austria, corridors harmonized with the neighbouring countries are established and visualized on an online platform for ecological corridors (https://lebensraumvernetzung.at/en/map).

For the Trilateral Transboundary Pilot Site (Austria-Italy-Slovenia) the PlanToConnect project contributed to create a solid basis for cooperation by bringing together conservation and spatial planning experts from Italy, Slovenia and Austria in several workshops to discuss the obstacles for coordinated management of ecological corridors and the concrete steps to overcome them. The stakeholders worked together and identified which activities need to be taken at policy level and with which legal instruments. They identified all relevant sectors at national, regional (provincial) and local level (municipalities/municipalities) that need to be involved in the process, such as spatial planning, nature conservation, forest, hunting, agriculture and water.

With a view to harmonized spatial planning and the integration of corridors into future plans, stakeholders proposed to initiate a Memorandum of Understanding between the municipalities within the geographical boundaries of this case study. The parks herby also serve as established structure and platform to work with the respective communities and to communicate ecological targets. Thus, this project has already created the basis for future cooperation and serves as a collaborative exchange of ideas and initiatives. However, a binding legal framework is still lacking. The main objective remains to strengthen the exchange of information between all relevant sectors in order to improve harmonized spatial planning for ecological connectivity. The knowledge about existence, location and

importance of the connection corridors in this geographic area is the first step for considering it in further planning activities in the border areas and to avoid the placing of infrastructures into the “last corner” of the three countries. A “corridor”- or “connectivity contract” between the three states should be signed by stakeholders at different levels: At national level, at regional level and at community level by the respective border communities.

Best Practice: The Alpine-wide connectivity strategy under PlanToConnect aligns conservation efforts across multiple countries, maintaining seamless corridors for migratory species.

3. Pressures, mitigation measures, barrier removal and defragmentation techniques

Green and Blue Infrastructure (GBI) plays a vital role in maintaining ecosystem services, biodiversity, and climate resilience. However, human activities exert pressure on these systems, necessitating targeted mitigation, barrier removal, and defragmentation strategies to restore ecological connectivity and enhance resilience. Addressing pressures on Green and Blue Infrastructure requires a multi-pronged approach involving policy interventions, nature-based solutions, barrier removal, and defragmentation strategies. By ensuring ecological connectivity, we can enhance biodiversity, climate resilience, and ecosystem service delivery across regions.

Given the region's reliance on transport and energy networks, it is essential to reconcile infrastructure development with connectivity restoration. This balance is achieved by applying the mitigation hierarchy (Avoid → Minimize → Mitigate → Offset → Defragment) and by integrating defragmentation principles into large-scale planning from the outset.

3.1. Identifying barriers and anthropogenic pressures (GIS + Field Methods)

A central challenge in designing GBI networks is identifying and managing barriers to connectivity. These obstacles may be topographic ones, (like natural or human-made steep ridges), infrastructure – based including roads, railways, and urban sprawl, and in some cases they can be also ecological barriers. The PlanToConnect Workshop highlighted that in some areas, mitigation measures (e.g., wildlife crossings) are no longer sufficient, necessitating proactive defragmentation strategies.

For barrier identification, it is recommended to analyze transport infrastructural barriers, bottlenecks and barriers caused by urbanization, and linkages passing through intensive agricultural land uses by GIS analysis. These three types of barriers are the most important anthropogenic pressures in the PlanToConnect pilot sites for species on land and their typical ecological corridors, which was revealed by an explorative expert survey and the barrier analysis of the macro-regional model using GIS.
Land-Use Change based on urbanization is caused by expansion of cities, and industrial development, and lead to habitat loss and fragmentation. Infrastructure Development of roads, railways, dams, and pipelines disrupt ecological corridors and water flows.
Agricultural intensification led to physical barriers, but also to overgrazing, and the use of pesticides affects the soil and water quality.

Additional pressures on ecosystem services and their connections can be water pollution and overuse, e.g. by industrial discharge, agricultural runoff, and excessive groundwater extraction threaten aquatic ecosystems. Climate change can alter precipitation patterns,

extreme weather events, and rising temperatures which can affect biodiversity and ecosystem functions and reinforce barrier effects. Pressures can also be caused by natural events, not only anthropogenic pressures: Erosion and landslides are natural degradation processes which can impact on soil stability and water retention. Extreme climate states, like e.g. flooding and droughts can disrupt water cycles and aquatic habitats. Non-native (invasive) species can alter ecosystem dynamics, outcompeting indigenous flora and fauna.

Procedures on barrier analysis and anthropogenic pressures are therefore useful to get an overview, especially when working on higher scales (intermunicipal to regional and trans-regional). But also on the local level, a barrier analysis with GIS can help to identify the most important pressures and barriers in the study area.

While GIS can highlight roads, railways, and urban centers, on-site inspections can reveal finer mapping details to assess corridor functionality.

Collecting field data is essential to have a finer understanding of the local functionality of a corridor. To gather information quicker and easier on the field, an application can be used such as "*ODK collect*". Made for androids, it allows to create filling out forms and to georeferenced data while on a field. Data collected can be directly linked to a GIS project. A form with a range of questions and answer types should be created beforehand.

Several information can be gathered during a fieldwork to improve mapping data analysis on corridor functionality, such as:

- Barriers: fences, walls, road surrounding infrastructures, riverbed infrastructures, unintended traps
- Natural infrastructures: hedges, tree alignments, isolated trees in open land, ditches, riparian forest, grass buffer strip, pylon feet, thickets, ponds, etc.
- Fauna signs of corridor usage: direct observation of an animal, fauna hints of corridor usage (path tracks, paw imprints, feces, hairs on barbed wire, etc.), direct observation of road killing.
- Planned infrastructures already functioning for corridors improvement: culverts, road panels, fence escapes, reflect stakes, existing Wildlife Overpasses/Underpasses, etc.

3.2. Practical solutions for avoiding, minimizing and mitigating infrastructural impacts on connectivity

This section tries to summarize the most important practical measures for reducing the barrier effects that can affect ecological corridors. Measures should follow the mitigation hierarchy: avoidance → minimization → mitigation → restoration → compensation (Johnson & Mayfield in Dodd et al., 2024).

For roads and railways issues:

- Wildlife overpasses/ underpasses: Engineered structures allowing safe crossing of highways and rail tracks. Species at stake must be defined to dimension the scale of the wildlife overpasses/ underpasses (big, medium or small species).
- Ease the access of terrestrial species to an underpass riverbed by creating a side uplifted shoulder.
- Reduce the speed of drivers in crucial wildlife crossing zones (speed limit sign to 50 km/h for cars)
- Raise awareness of drivers in crucial wildlife crossing zones (crossing fauna sign, fauna radar that lights a crossing fauna sign)
- Install reflect stake on the side of roads to alarm fauna and to prevent them from crossing when a vehicle passes (experimental measure in Upper Savoy, France, since 2015)
- Install fences to prevent fauna from crossing dangerous roads (highways, high speed trains)
- Guide fauna to safe crossings and gates with hedges and fences.
- Remove obstacles from road and railway lines such as high walls, fences, dense hedges, road infrastructures, etc... to ease the crossing of fauna.
- Manage differently natural infrastructures by late embankment cutting and communicate about it with road signs.

For open lands and agricultural fields permeability

- Fencing Alternatives: reach more permeability of fences and walls with minimum and maximal height adaptation, length consideration or strategically placed escapes.
- Removal of fencing: targeting useless fences on corridor paths to remove them
- Recreate natural infrastructures on unused land portion, fields sides, river sides by financing projects of hedges plantations, tree alignments, etc.
- Protect key natural infrastructures in local urban plans.
- Manage differently natural infrastructures by late reaping of open lands and grass buffer strips on field sides, hedges.
- Communicate and raise awareness of local policy makers, landowners, farmers and residents about natural infrastructure management.
- Increased structuring by establishment of smaller entities or by extensivation of land use (meadows instead of crop fields) and surrounding land use patches by structuring elements like hedges or tall herbaceous meadow.

For urban expansion:

- Efforts to preserve large, undissected open spaces as part of green corridors in the urban fabric (e.g. urban green belts) and safeguard inner-urban trees as connecting elements
- Appropriate location of new urban/industrial development (avoid areas of high nature conservation value including ecological corridors)

- Minimizing the road infrastructure associated with urban/industrial development, keeping vehicle speeds low.
- reducing use of fertilizers and pesticides in maintenance of public and private green
- minimizing artificial lighting
- runoff water management: minimize water runoff into streams.

Focus on urban Green Infrastructure enhancement:

- Integrate continuous green spaces into cities, such as greenways and linear parks:
- To create Biodiversity enhancing landscapes, it is recommended to integrate biodiversity enhancing design elements into the garden and park design in public spaces. This should include the choice of autochthon plants (trees and shrubs) for public spaces and the integration of "biodiversity islands" like small patches of flower rich meadows or deadwood structures and stone walls within the public areas.
- Enhance ecological friendly garden design for privately owned spaces by campaigning for such an approach (allowing structure rich and natural corners to grow).
- Multi-functional landscapes: Combine agriculture, forestry, and conservation for balanced land use.

For aquatic corridors permeability:

- Remove dams and thresholds.
- Restore riverbed to a more natural shape for more natural river flows to lower the speed of the water current, refresh water, allow meandering and natural river processes to express.
- Suppress dam height to lower its general structure and allow fishes to jump through
- Install fish pass or scale next to impassable dam and threshold to restore fish migration routes.
- Removal of embankments to allow natural hydrological processes for reconnecting wetlands and floodplains
- Riparian Buffer Zones: Maintain vegetation along rivers to reduce pollution and improve water quality. Reconnect via planting of tree rows, hedges and forest patches as connective element.

Ecological barrier reduction:

- Control of Invasive Species: Remove non-native plants and animals disrupting local ecosystems.
- Soil remediation and rewilding: Restore degraded land to support natural ecological processes.

Examples of measures for protecting GBI and ecosystem services by Nature-Based Solutions (NBS):

- Reforestation and Afforestation: Restore native vegetation to improve carbon sequestration and habitat connectivity.
- Wetland Restoration and Sustainable Drainage Systems: Maintain water retention capacity and improve flood resilience.
- Agroecological Practices: Promote crop diversification, buffer zones, and organic farming to support biodiversity.
- Green Buildings and Urban Forests: Enhance urban resilience by integrating GBI into city planning.

3.3. Land management of anthropogenic pressures & systematic defragmentation

Spatial and landscape planning instruments are important levers for steering infrastructural developments and safeguard natural landscapes. However, not each important administrative sector which can influence ecological connectivity can be covered by spatial planning, e.g. when it comes to agriculture and forestry. Land - or landscape management measures should be considered as complementary approach to spatial planning instruments for measures where spatial and landscape planning have little competence. (see PlanToConnect report on conflicting anthropogenic uses in priority connectivity areas D.1.2.1).

"Landscape management" means operating from the point of view of sustainable development, which should ensure regular maintenance of the landscape and direction, and coordination of changes brought about by social, economic and environmental processes (European Convention on Landscape in University of Ljubljana, 2021). Pressures include for example: Extraction and cultivation of biological living resources (other than agriculture and forestry), Military action, public safety measures, and other human intrusions, alien and problematic species, climate change, mixed source pollution, human - induced changes in water regimes, geological events, natural processes, and catastrophes.

Here, other management tools and instruments needs to be used to steer the developments of the landscapes, such as agreements or economic instruments. An example might be for example the encouragement of landscape transition to connectivity improvement in agricultural areas by respective incentives for farmers. These incentives for landowners to maintain ecosystem services through financial compensation are called "Payment for Ecosystem Services" (PES).

Traditional approaches for barrier removal have focused on avoiding fragmentation and mitigating barriers. However, many parts of the Alpine region have already experienced significant fragmentation. New methodologies, as outlined in guidelines like the CMS

Infrastructure Mitigation Guidelines (2022), now emphasize active defragmentation systematically reversing fragmentation rather than solely preventing it. This may involve mapping critical barrier areas, prioritizing sites where removal or retrofitting is ecologically beneficial, decommissioning redundant roads, or rerouting transport corridors to improve connectivity, as well as considering scale-Specific Defragmentation. At the Alpine-wide scale, coordinated cross-border actions, supported by the PlanToConnect structural ecological network model (JECAMI tool) and its Strategic Alpine Connectivity Areas (SACA), can address large-scale fragmentation. At the local or regional level, targeted measures such as modifying local barriers (e.g., replacing impermeable fences with wildlife-friendly designs) and converting disused infrastructure (like former railway lines) into ecological corridors are critical for restoring connectivity.

4. Monitoring and adaptive management

Monitoring of ecological connectivity is important to identify which connectivity elements are used by wildlife, which sections are functional or respectively not functional as migration structures, and where landscapes lack structures. It should help to understand which are the target areas for ecological connectivity measures (Sedy et al. 2022:10).

Monitoring and evaluation are part of a planning process that encompasses various planning steps.

Monitoring and controlling cycle:

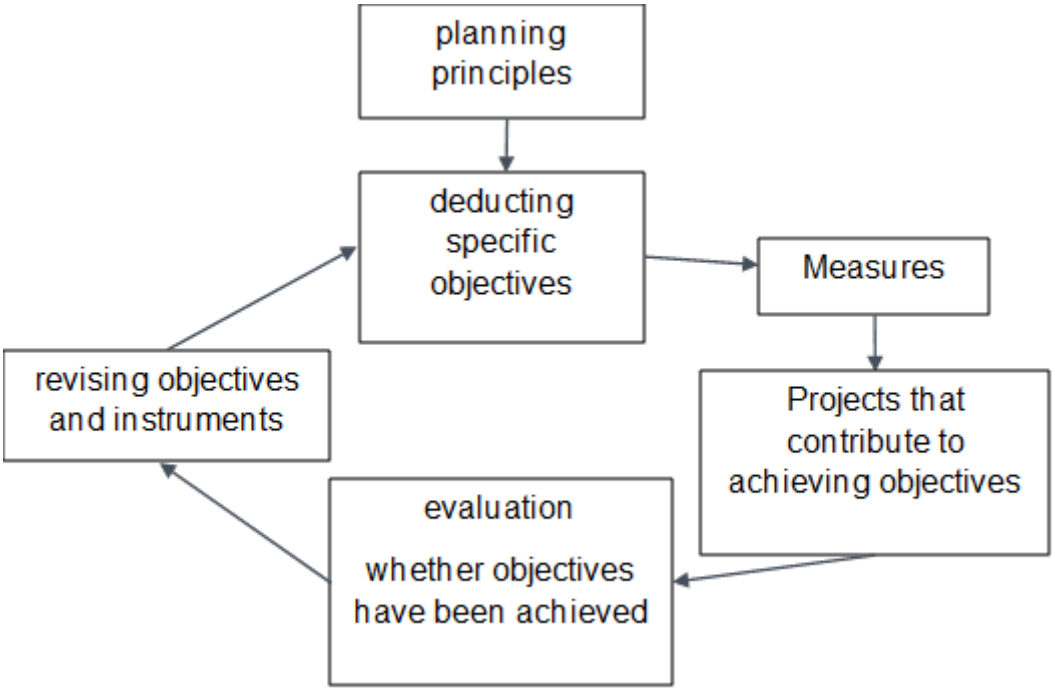

Figure 1: Monitoring and controlling cycle

(according to ARL 2005:673)

Monitoring as a tool is not limited to optimising administrative processes but can also be used as an input for discussions among political stakeholders and decision-makers. However, monitoring also has its methodological constraints: It requires clear target values and causal relations between land use changes or other influencing factors and changes observed regarding ecological connectivity. Additionally, spatial planning is often confronted with target conflicts, which consequently also affect the conclusions that need to be drawn based on monitoring results e.g. deteriorating ecological connectivity (ibid).

While in D.1.4.1 a description of monitoring techniques and indicators is provided, we focus here on ppolicy and regulatory monitoring.

Indicators for the integration into planning instruments:

The adaptive management should be monitored by indicators regarding the integration of ecological connectivity into spatial planning policies and instruments, e.g.:

- Number and percentages of administrations (e.g. municipalities/ regions/ etc.) considering ecological connectivity in (local/ regional) development plans,
- degree of binding character of ecological connectivity concepts,
- quality of ecological connectivity concepts, fulfilling planning standards/ following planning guidelines for connectivity.
- Compliance checks for environmental regulations (e.g., Natura 2000, Water Framework Directive).

Adaptive implementation based on monitoring:

To ensure effective implementation and monitoring of ecological networks and Green Infrastructure (GBI), a series of strategic monitoring measures are proposed:

- Monitoring and evaluation framework: Develop standardized indicators to monitor the effectiveness of ecological networks and GBI (e.g., species richness, habitat quality, movement patterns, see D1.4.1).
- Reporting Mechanism: Establish a reporting mechanism where countries regularly share data on connectivity measures and biodiversity status.
- Adaptive Management: Create a system of adaptive management that allows for policy or practice changes based on monitoring results and emerging ecological threats (e.g., invasive species, climate change impacts).

An assessment of the state of ecological connectivity should go hand in hand with the revision and update of spatial plans, following the same period. The updates of spatial plans are significant opportunities because they represent the right moment to integrate new connectivity measures.

- Zoning Laws and local development plans: Update of legal corridor designation and restoration measures.
- Regional and provincial development plans: Update of connectivity objectives in supra-local spatial development plans
- EIA: Ensuring major projects do not fragment habitats.
- Biodiversity Offsets: Compensation for ecological damage.

Effective monitoring and adaptive management are essential to ensure the long-term success of Green and Blue Infrastructure (GBI) and the ecosystem services they support. These strategies help assess performance, respond to environmental changes, and improve spatial planning decisions over time. Monitoring and adaptive management are critical tools for maintaining the effectiveness of Green and Blue Infrastructure and sustaining ecosystem services. By leveraging technology, stakeholder participation, and policy flexibility, spatial planners can create resilient and responsive GBI networks that support biodiversity, climate adaptation, and human well-being.

Adaptive management allows planners to adjust strategies based on new data and changing environmental conditions, involving policymakers, scientists, and local communities in decision-making (Stakeholder Engagement and Co-Design). An iterative learning process can be started, using monitoring results to refine policies and management practices. It is useful to develop multiple future scenarios (scenario planning) to prepare for uncertainties, and to guarantee a certain flexibility. To ensure a holistic approach for managing ecological networks and Green Infrastructure (GBI), it is essential to integrate efforts across various sectors by aligning GBI strategies with urban planning, climate adaptation, biodiversity conservation, agriculture, tourism etc.

5. Case studies from pilot regions and best practices

Real-world examples provide valuable insights into the practical application of Green and Blue Infrastructure (GBI) planning principles. This chapter reviews pilot projects that demonstrate successful integration of GBI measures in diverse geographical and governance contexts. The following case studies illustrate how different regions in the Alpine Space address ecological connectivity, transboundary coordination, and urban-rural integration of GBI networks.

5.1. Trilateral transboundary pilot site (Austria-Italy-Slovenia) – cross-border ecological connectivity

This pilot site spans across three countries—Austria, Italy, and Slovenia—focusing on transboundary ecological connectivity. The region maintains good connectivity due to its low population density and large protected areas, but gaps and barriers remain near settlements in the valleys.

- **Key Strategies:**

- Using the SACA approach to map connectivity gaps and barriers.
- Proposing targeted subprojects and spatial planning instruments to enhance ecological corridors.
- Developing mechanisms for cross-border governance and coordinated biodiversity conservation.

- **Outcomes:**

- A harmonized transboundary GBI network map was created to support cross-border conservation efforts.
- Strengthened institutional cooperation for managing ecological networks across national boundaries.

5.2. Salzburg (Austria) – Urban development and regional GBI networks

The Salzburg region, particularly the municipalities in Tennengau and Flachgau (e.g., St. Gilgen), focuses on balancing urban expansion with ecological connectivity through GBI integration.

- **Key Strategies:**

- Development of an Integrated Urban Development Concept (ISEK) that prioritizes GBI corridors.
- Addressing fragmentation from infrastructure projects (e.g., roads, dams) and intensive land use.
- Implementing measures for inner densification to reduce urban sprawl and preserve open spaces.

- **Outcomes:**

- A regional green corridor was maintained within urban development plans.
- Strengthened ecological networks that link urban centers with surrounding natural areas.

5.3. Illertal South of Kempten (Germany) – Strengthening ecological connectivity

This pilot site in Southern Bavaria focuses on enhancing ecological connectivity within the Illertal region, a landscape characterized by agricultural land, urban development, and attitude gradients.

- **Key Strategies:**

- Introducing ecological stepping-stones to improve species mobility (reducing distances between the functional areas)
- Introducing Protection and Enlargement of existing core areas (expansion areas) especially within the functional areas providing diverse site conditions (e.g. different gradients)
- Engaging with local stakeholders to include on site information

- **Outcomes:**

- Increased habitat connectivity for terrestrial species.
- Improved land-use management suggestions

5.4. South of Lake Annecy (France) – Strengthening ecological corridors

Located in Haute-Savoie, France, this region is characterized by a mix of urbanized areas, agricultural landscapes, and high ecological value zones near Lake Annecy.

- **Key Strategies:**

- Strengthening green corridors that connect the lake with adjacent mountain habitats.
- Implementing nature-based solutions to mitigate urban expansion pressures.
- Engaging local authorities in participatory land-use planning.

- **Outcomes:**

- Development of a GBI-oriented urban plan to ensure long-term connectivity.
- Enhanced collaboration between environmental agencies and municipalities.

5.5. South Tyrol (Italy) – Ecological connectivity concept for the Province

South Tyrol aims to develop a provincial **ecological connectivity concept**, integrating conservation goals into provincial and municipal planning processes.

- **Key Strategies:**

- Establishing ecological corridors to improve landscape permeability, focusing on the valley bottoms, where the most important pressures occur.
- Validation of ecological connectivity models through stakeholder involvement and site visits.
- Incorporating ecological connectivity objectives into regional strategic planning and concrete “nature corridors” on local zoning and land-use plans.

- **Outcomes:**

- Better information on permeable areas in the valley bottom, due to new datasets identifying existing, problematic and potential ecological linkages for red deer species
- Integration of conservation policies at the local level and proposals for provincial spatial planning instruments.
- Enhanced cooperation between administrative offices and scientists. Information of spatial planning professionals and local communities.

5.6. Planungsregion 17 "Oberland" (Germany) – Regional GBI implementation in a rural landscape

This pilot focuses on integrating regional planning instruments for structural connectivity of GBI elements into rural and peri-urban areas in the Upper Bavarian region, where agricultural expansion and suburban development impact landscape connectivity.

- **Key Strategies:**

- Strengthening green corridors along rivers and forests.
- Encouraging sustainable agricultural practices that support biodiversity.
- Enhancing ecosystem-based flood protection through natural water retention measures.

- **Outcomes:**

- A regional GBI framework was established to guide future land-use planning.
- Improved integration of agriculture and conservation in regional policies.

5.7. Caorle lagoon (Italy) – ecological connectivity in a coastal wetland landscape

The Caorle Lagoon pilot aims to strengthen ecological connectivity in a coastal wetland system shaped by centuries of human–nature interaction. The project area spans multiple municipalities and builds on a contract for the wetland area to integrate biodiversity and connectivity goals into local planning.

- **Key Strategies:**

- Mapping green and blue infrastructure and assessing ecosystem services to identify key areas for action.
- Analysing vulnerabilities and resilience across macro-landscapes to inform planning priorities.
- Engaging local stakeholders in a participatory process to support long-term implementation.
- Coordinating existing investments and aligning them with ecological goals.

- **Outcomes:**

- Improved knowledge of habitat quality and ecological corridors in the lagoon landscape.

- Identification of priority areas for GBI implementation and removal of ecological barriers.
- Integration of nature-based solutions into planning tools and better coordination between institutions.
- Strengthened ecological functionality of the lagoon and improved regional governance for biodiversity.

5.8. Lessons learned, best practices, and insights

- **Lessons Learned:**

- Data-Driven Decision Making: All pilot regions used ecological models and GIS-based mapping to identify connectivity gaps and guide interventions.
- Policy Integration: Aligning GBI measures with land-use plans and environmental regulations is essential for long-term institutional support.
- Multi-Stakeholder Engagement: Collaboration among municipalities, landowners, farmers, NGOs, and civil society proved crucial to overcoming implementation barriers.
- Cross-Border Cooperation: Ecological connectivity requires joint planning beyond administrative boundaries to ensure continuity of habitats and corridors.
- Adaptive Planning: Monitoring, evaluation, and iterative adjustment of strategies help maintain the effectiveness of GBI over time.

- **Best Practices:**

- Sustainable Land-Use Management: Integrating biodiversity goals with economic activities like agriculture, tourism, and energy fosters co-benefits.
- Participatory Processes: Local ownership, early engagement, and co-design approaches increase acceptance and effectiveness of connectivity planning.
- Integrated Spatial Planning: Embedding GBI into formal planning instruments ensures enforceability and financial viability.

- **Insights:**

- There is no one-size-fits-all solution – each region requires context-specific approaches tailored to landscape, governance, and societal factors.
- The Alpine Space serves as a pioneering model for transnational and multi-level GBI integration, with lessons applicable to other European and mountain regions.

6. Funding, Partnerships, and Capacity Building

The long-term implementation and resilience of Green and Blue Infrastructure (GBI) networks depend on more than well-designed spatial strategies and scientific evidence. Without sustainable financial frameworks, stable partnerships, and adequate capacities among key stakeholders, even the most carefully developed ecological connectivity concepts risk remaining theoretical. This chapter provides an in-depth discussion of the financial and institutional prerequisites for embedding GBI into spatial planning and land-use decisions in the Alpine context. It reflects on the range of available instruments, identifies persistent implementation challenges, and outlines integrated approaches for aligning funding, partnership structures, and administrative capacity.

6.1. Strategic Financial Planning: From Projects to Programmes

A recurring challenge in GBI implementation is the reliance on short-term, project-based funding cycles, which are often detached from strategic territorial planning frameworks. While pilot actions and innovation projects provide crucial impetus, they are rarely matched by dedicated resources for long-term maintenance, monitoring, or institutional consolidation. This structural mismatch calls for a shift toward **programmatic and integrated financing approaches**.

The Alpine region, with its strong conservation tradition and decentralised planning structures, offers a rich field of experimentation. Yet, regional disparities in administrative capacity, co-financing potential, and political commitment create unequal starting conditions. Financial planning for GBI must therefore not only identify funding sources but embed them in **cross-sectoral policy alignment** – between biodiversity conservation, spatial planning, climate adaptation, agriculture, and infrastructure development.

A meaningful shift requires the **institutional embedding of GBI priorities** into regional development programmes, environmental strategies, and climate action plans – both to enhance eligibility for funding and to justify budget allocation across planning levels.

6.2. Multi-Level Funding Architecture

The architecture of available funding sources reflects the complexity of European territorial governance. Relevant instruments are distributed across EU, national, and sub-national levels, each with different thematic priorities, eligibility rules, and administrative requirements. Figure 2Figure 2: Typology of funding sources (source financing guide 3 billion’s tree pledge illustrates the typology of available funding instruments and their relation to different levels of authority.

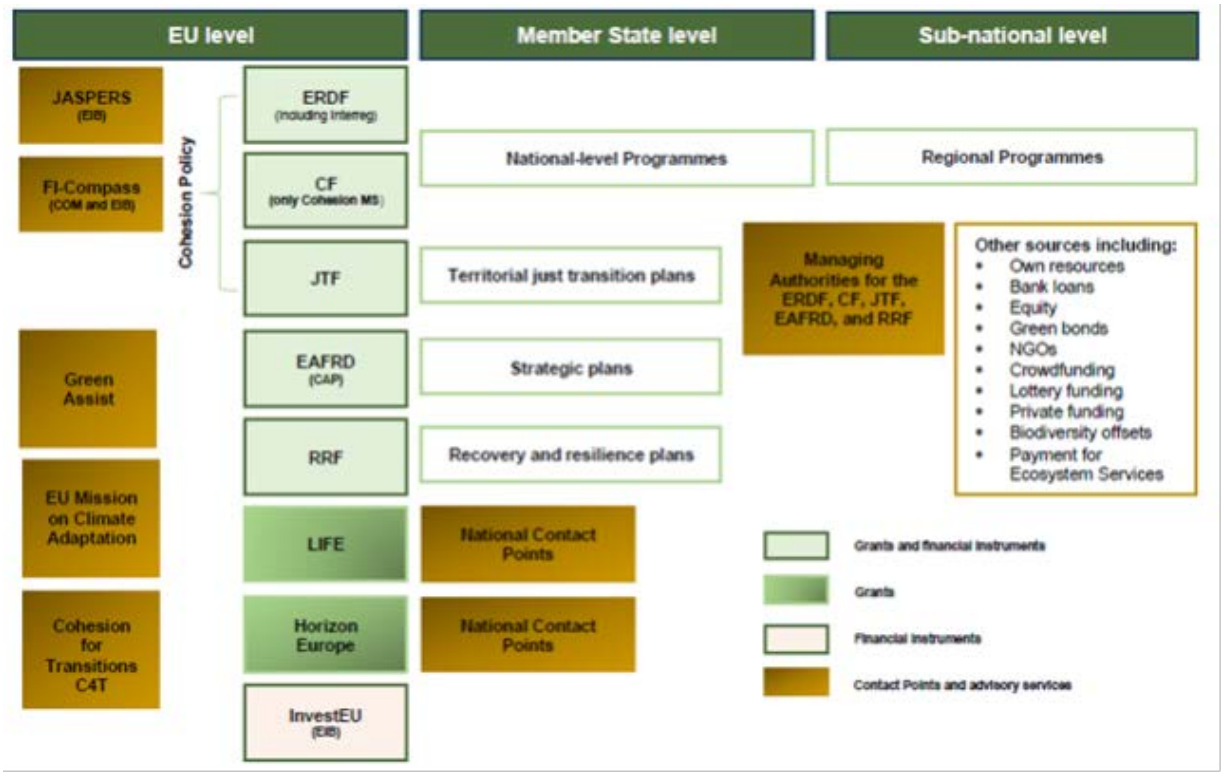

Figure 2: Typology of funding sources (source financing guide 3 billion's tree pledge

At the European level, structural funds such as the European Regional Development Fund (ERDF), the Just Transition Fund (JTF) and the Recovery and Resilience Facility (RRF) are central to supporting GBI-related projects. These funds offer opportunities to mainstream ecological connectivity into regional development and climate adaptation. Sector-specific programmes such as the LIFE Programme and Horizon Europe complement these instruments by financing biodiversity conservation and nature-based innovation. Importantly, InvestEU facilitates access to loans and blended finance for sustainable infrastructure – a still underutilised resource in the GBI context.

At the member state level, national biodiversity strategies, CAP implementation plans, and rural development programmes provide a framework for regionally adapted support. For example, agri-environmental measures under the Common Agricultural Policy (CAP) can be used to promote landscape permeability through buffer zones, hedgerows, or extensified grassland use.

Sub-national governments – such as provinces, districts or municipalities – can establish co-financing schemes, local biodiversity funds, or earmark parts of tourism revenue for the

maintenance of ecological corridors. These measures are essential for long-term sustainability but are often vulnerable to political cycles and limited budgetary autonomy.

6.3. Beyond Subsidies: New Instruments and Hybrid Models

In recent years, increasing attention has been given to alternative and hybrid financing approaches that complement public funding and enhance stakeholder engagement. These include:

- **Payments for Ecosystem Services (PES):**
  These schemes compensate landowners or managers for providing ecological services, such as maintaining connectivity elements in agricultural or peri-urban landscapes. Their success depends on transparent governance, reliable measurement of ecological value, and long-term funding security.
- **Carbon farming and biodiversity crediting schemes:**
  These are emerging as tools to link ecological performance with climate policy objectives. While promising in principle, they require harmonization of metrics and alignment with spatial planning systems to ensure ecological coherence.
- **Green bonds and crowdfunding initiatives:**
  These mobilize private or community capital for ecological restoration. Examples such as the **WoW Nature platform (ETIFOR, Italy)** show that reforestation and habitat protection can be co-financed through corporate social responsibility (CSR) or ESG commitments. However, the administrative effort required to manage these models remains high for smaller municipalities.

The Alpine region is well-positioned to test such hybrid models due to its strong tradition of landscape stewardship and multifunctional land use. Nevertheless, legal certainty, monitoring capacity, and inter-agency coordination are critical conditions for their broader applicability.

6.4. Partnerships as Institutional Infrastructure

Financing ecological connectivity is not merely a matter of securing funds – it is equally about **building governance partnerships** that can design, manage, and maintain GBI measures over time. PlanToConnect demonstrates that effective partnerships:

- span across administrative levels and sectors (e.g., nature conservation, spatial planning, transport, agriculture).
- include both public and private stakeholders.

- integrate scientific knowledge and local experiential expertise.
- formalize cooperation (e.g., via memoranda of understanding, steering committees, or joint plans).

In the **trilateral pilot region between Austria, Italy, and Slovenia**, cooperation between protected area administrations and spatial planning authorities was initiated via a structured dialogue process, supported by a common corridor model. The **Salzburg region** incorporated GBI into Integrated Urban Development Concepts (ISEK), linking planning law with ecological functionality. These examples illustrate that partnerships function not only as a means of coordination, but as **institutional infrastructure** for financial and procedural continuity.

6.5. Capacity Building as an Enabler

Administrative capacity remains a bottleneck in many Alpine regions, particularly at the local level. Funding instruments often assume a level of planning, reporting, and technical know-how that smaller municipalities cannot easily meet. Therefore, **capacity building must be considered part of the investment logic**.

Effective capacity development involves:

- training planning staff in ecological connectivity, spatial data use, and legal implementation tools.
- providing standardized guidance and templates for project development.
- fostering peer-learning networks across municipalities and countries.
- integrating GBI into higher education and vocational training curricula.

Pilot regions such as **Caorle Lagoon** have shown how participatory processes can raise awareness, enable co-design, and build trust – all prerequisites for the uptake of GBI beyond project boundaries.

6.6. Conclusion: Toward Financial and Institutional Resilience

Ensuring ecological connectivity in the Alpine region is not simply a matter of ecological design, but of institutional endurance. This requires planning cultures that can manage complexity across scales, funding systems that bridge short-term implementation with long-term stewardship, and governance models that engage stakeholders beyond formal obligations.

By strategically combining public funding, hybrid financial instruments, and knowledge-based capacity development, Alpine regions can move from isolated projects to resilient GBI systems – contributing to biodiversity conservation, climate adaptation, and integrated territorial development.

7. Implementation checklist

Implementing Green and Blue Infrastructure (GBI) networks requires a structured planning approach that builds on the strategic foundations outlined in the PlanToConnect Deliverable D1.4.1 and complements them with operational tools for practical application to strengthen ecological connectivity, biodiversity protection, and climate-resilient land use. This section outlines a six-step methodology guiding practitioners from initial assessments to long-term monitoring and policy integration. Each step provides methodological guidance, stakeholder strategies, and practical tools to support effective implementation across different planning systems and governance levels.

Ecosystem services (ES) mapping plays a crucial role (see Sedy et al., 2021; IUCN, 2020) in identifying socio-ecological values and developing territorial strategies. By analysing the spatial distribution of natural and semi-natural capital, planners can assess vulnerabilities, resilience potentials, and opportunities for multifunctional benefits. This process integrates environmental and landscape assessments with participatory approaches that incorporate stakeholder knowledge, policy contexts, and local needs. Through these insights, GBI becomes a key lever for sustainable land-use strategies and long-term environmental resilience (European Environment Agency, 2021).

Environmental economics further complements this approach by enabling cost-benefit analysis of proposed GBI measures and monetising ecosystem services (Benedict & McMahon, 2006), while policy-oriented frameworks such as the ARL (2022) and CEMAT guidelines underline the spatial relevance of integrating ecological infrastructure in regional development strategies by enabling cost-benefit analysis of proposed GBI measures and monetising ecosystem services (Benedict & McMahon, 2006). The combined use of ecological modelling, participatory diagnostics, and economic valuation ensures that GBI networks are not only ecologically sound, but also financially viable and politically anchored.

Step 1: Situation analysis & baseline assessment

Objective: Understand the existing landscape, identify gaps in connectivity, and build stakeholder engagement.

Key Actions:

Mapping existing Green and Blue Infrastructure: Use GIS and remote sensing tools to analyse natural and semi-natural areas (e.g., forests, wetlands, urban green spaces) (EEA, 2021).

Assessing ecosystem service (ES) supply: Identify the functional capacity and deficiencies of ecosystems in delivering key services (IUCN, 2020).

Identifying fragmentation and barriers: Map land-use changes and ecological disruptions; detect critical connectivity gaps (Sedy et al., 2021).

Stakeholder mapping and consultation: Engage municipalities, landowners, and environmental agencies early in the process (PlanToConnect D2.1.2).

Step 2: Defining objectives & priorities

Objective: Establish clear, measurable goals that align with ecological and socio-economic priorities.

Key Actions:

Setting biodiversity and climate objectives: Define targets for species conservation, habitat connectivity, and climate adaptation (European Commission, 2021).

Ecosystem service integration: Include benefits such as flood mitigation, air quality improvement, and carbon sequestration .

Policy alignment: Ensure consistency with local zoning laws, sectoral policies (e.g., transport, agriculture), and regional development plans (CEMAT, 2018).

Step 3: Data collection & connectivity analysis

Objective: Use spatial analysis tools to assess ecological networks and define priority areas for intervention.

Key Actions:

GIS-based connectivity modelling: Apply tools such as Circuitscape, Linkage Mapper, and JECAMI to assess landscape permeability (McRae et al., 2008; Rudolf et al., 2019).

Corridor and stepping-stone identification: Map and prioritise ecological linkages essential for species movement (IUCN, 2020).

Scenario analysis: Model the effects of alternative land-use configurations on ecological connectivity (PlanToConnect D1.4.1).

Step 4: Scenario development & stakeholder consultation

Objective: Test planning options and involve stakeholders in co-designing solutions.

Key Actions:

Multi-scenario modelling: Develop land-use scenarios that reflect urban, agricultural, and conservation priorities (ARL, 2022).

Participatory decision-making: Organise workshops and consultations to integrate stakeholder perspectives (PlanToConnect, 2025).

Conflict resolution and compensation schemes: Address competing land uses and define fair compensation for GBI-compatible measures (CEMAT, 2018).

- Ensure that GBI networks align with socio-economic needs while maintaining ecological functionality.

Resolving land-use conflicts through participatory planning:

- Address competing land-use demands (e.g., infrastructure projects vs. biodiversity corridors).
- Develop compensation measures for landowners affected by GBI zoning restrictions.

Step 5: Implementation & policy integration

Objective: Anchor GBI in legal and institutional frameworks to ensure sustainability.

Key Actions:

Legal mechanisms: Incorporate GBI into zoning regulations, conservation designations, and EIA procedures (European Commission, 2021).

Financing instruments: Leverage EU funding (e.g., LIFE, Interreg), green bonds, and public-private partnerships (PPP) (European Commission, 2023).

Institutional responsibilities: Clarify roles across local, regional, and national levels; create interdepartmental coordination bodies (ARL, 2022).

Funding Typology:

To support long-term financial planning, a diversity of instruments is required. The following Figure 2 (based on the 3 Billion Trees Pledge Guidance) categorizes funding sources:

- EU Grants (e.g., LIFE, Horizon Europe, Interreg)
- National and regional public funding
- Private sector investment (e.g., PPPs)
- Innovative mechanisms (e.g., green bonds, carbon farming, crowdfunding)
- Local revenues (e.g., environmental taxes or fees)

Monitoring & adaptive management

Objective: Ensure long-term effectiveness and flexibility through structured monitoring and evaluation.

Key Actions:

Establishing KPIs: Define indicators for biodiversity trends, ecosystem services, and network performance (IUCN, 2020).

Ongoing data collection: Use remote sensing, monitoring stations, and citizen science initiatives (EEA, 2021).

Adaptive policy updates: Revise planning instruments based on performance data and emerging challenges (e.g., climate impacts) (PlanToConnect D1.4.2).

By following this structured planning framework, planners can draw on concrete outcomes of the PlanToConnect project, including lessons learned from pilot regions, tested participatory mapping methods, and successful examples of funding integration. The modular approach enables replication and transfer to other Alpine and European regions. Furthermore, this framework supports cross-border alignment and provides a practical complement to the strategic principles outlined in Deliverable D1.4.1, practitioners can ensure that GBI networks are functionally robust, socially supported, and financially sustainable. These steps contribute to a resilient, biodiverse, and climate-adaptive Alpine region and provide a transferable model for other European territories.

8. Conclusion

By applying data-driven tools, involving stakeholders at every step, and adopting adaptive management cycles, GBI projects can thrive. This document complements D1.4.1 by translating strategic insights into actionable methods, ensuring Alpine ecosystems, and the communities that depend on them, benefit from well-designed ecological networks. Linking back to the PlanToConnect Standardized protocol for GBI network design, this technical guide supports the broader PlanToConnect vision outlined in D1.4.1. While you will find strategic design principles in D1.4.1, this document focuses on practical execution and the policy context. We encourage spatial planners to consult both to gain a comprehensive perspective on GBI network establishment.

Key Takeaways for integrating GBI into spatial planning are

- To focus on data quality by considering robust, and accurate datasets, that guide evidence-based decisions.
- To engage stakeholders early and often. If involved from the start, they are more likely to support GBI.
- To balance ecology and economics by using cost layers (e.g., in Marxan) to find feasible solutions with long-term buy-in.
- To plan for change by integrating adaptive management to pivot as climate conditions, policy environments, or land use evolve.
- Leverage multiple funding streams, by combining EU grants with local or private partnerships, which could keep GBI projects sustainable over decades.

By implementing these guidelines, you can ensure that GBI networks are functionally robust, financially viable, and socially supported—ultimately contributing to a resilient, biodiverse, and thriving Alpine region.

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Mainstreaming ecological connectivity in spatial planning systems of the Alpine Space

Project partners:

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Veneto Region (IT)
ALPARC – the Network of Alpine Protected Areas (FR)
Asters, organisation for the conservation of natural areas in Upper Savoy (FR)
Eurac Research (IT)
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Salzburg Institute for Regional Planning and Housing (AT)
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Guide on procedural steps for integrating GBI networks into planning
Guidelines for implementing Green and Blue Infrastructure (GBI) networks for spatial planners

Reference in AF: D1.4.2: Guide on procedural steps regarding GBI network planning

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