

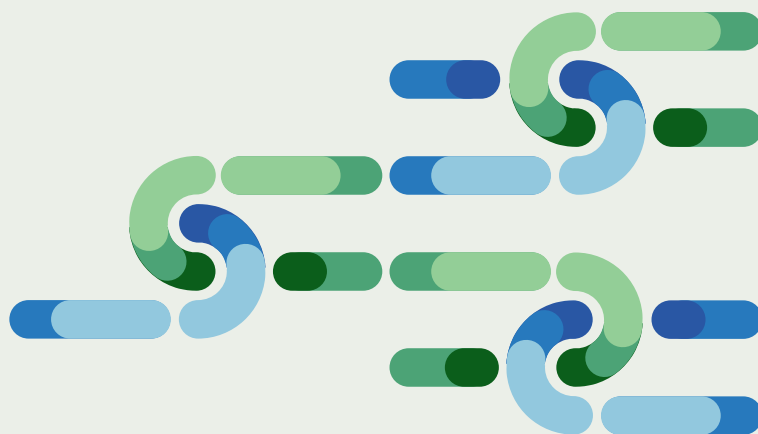
Technical proposal(s) for implementing GBI connectivity networks in spatial plans and sector instruments

Province of Sondrio

Reference in AF: D2.5.1 including outcomes of D2.2.1, D2.2.2, D2.3.1, D2.4.1

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Case Studies 4th step: Draft a technical proposal integrating the project for a GBI connectivity network into planning tools/sector plans in pilot areas. A2.2, A2.3 and A2.4 deliverables are parts of it.

Technical proposal(s) for implementing GBI connectivity networks in spatial plans and sector instruments

Multifunctional GBI for the Province of Sondrio

Regional and local corridors driving the transnational ecological (re)connection

Authors:

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Politecnico di Milano, DASTU/LabPPTE

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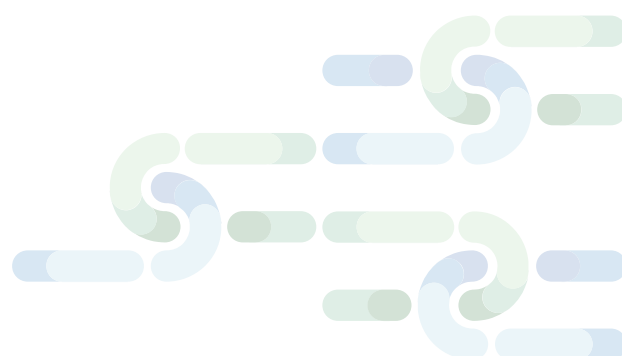
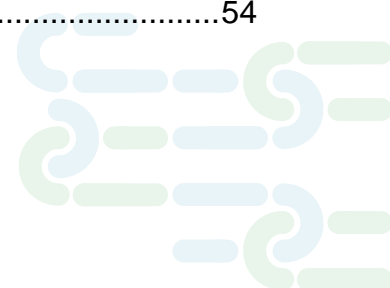


Table of Contents

Glossary.....	5
Executive summary	6
REPORT.....	7
1 Pilot region.....	8
2 GBI network project	9
2.1 Multifunctional approach guiding the GBI design	9
2.2 ESs assessment and Strategic frameworks definition	10
2.3 Regional and local corridors driving the transnational ecological (re)connection....	11
2.4 The Multifunctional GBI for the Province of Sondrio	13
2. Pressures and Threats to connectivity conservation and restoration areas	26
2.1 Main pressures and threats	26
2.2 Mapping unsuitable areas for multifunctional connectivity enhancement	28
3 Connectivity measures and governance settings.....	30
3.1 Connectivity measures / action plan	30
3.2 Key Stakeholders.....	34
3.3 Governance settings	39
3.4 Funding instruments	42
4 Proposal(s) for the implementation of the GBI network plan into spatial and sector planning tools.....	46
4.1 State of art of connectivity planning and implementation in the pilot area.....	46
4.2 Integrating the Green and Blue Network project into spatial and local planning instruments	47
5 References	51
Annexes.....	54



List of Tables

Table 1 - Regenerative framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group.....	14
Table 2 - Multifunctional framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group	16
Table 3 - Conservative framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group.....	18
Table 4 - Funding instruments for the GBI implementation. Source: developed by FPM – DASTU/Lab PPTE working group	43
Table 5 - Overview of spatial planning instruments addressed. Source: developed by FPM – DASTU/Lab PPTE working group	48

List of Figures

Figure 1 - GBI Strategical Frameworks. Source: developed by FPM – DASTU/Lab PPTE working group	11
Figure 2 - Regional Potential Linkages' characterisation. Source: developed by FPM – DASTU/Lab PPTE working group	12
Figure 3 - GBI scheme. Source: developed by FPM – DASTU/Lab PPTE working group ..	21
Figure 4 - GBI legend. Source: developed by FPM – DASTU/Lab PPTE working group	22
Figure 5 - GBI extract . Source: developed by FPM – DASTU/Lab PPTE working group ...	23
Figure 6 - GBI extract 2. Source: developed by FPM – DASTU/Lab PPTE working group .	24
Figure 7 - GBI extract 3. Source: developed by FPM – DASTU/Lab PPTE working group .	25
Figure 8 - Threats and barrier analyses. Source: developed by FPM – DASTU/Lab PPTE working group	27
Figure 9 - Unsuitable and critical areas for anthropic development. Source: developed by FPM – DASTU/Lab PPTE working group.....	29
Figure 10 - Pilot corridor context. Source: developed by FPM – DASTU/Lab PPTE working group.....	30
Figure 11 - Corridor 5 GBI Design. Source: developed by FPM – DASTU/Lab PPTE working group.....	32

Figure 12 - Preliminary Mapping of Stakeholders for the Pilot Area. Source: Developed by the FPM – DASTU/Lab PPTE Working Group	37
Figure 13 - Stakeholder Map of the RCWG: core actors at the center and potentially involved actors positioned around the circle based on the thematic focus of activities. Source: Developed by the FPM – DASTU/Lab PPTE Working Group	39
Figure 14 - Timeline and Diagram of the Flexible and Incremental Process of RCWG Activities and Emerging Priority Themes (Flexible and Incremental Process). Source: Developed by the FPM – DASTU/Lab PPTE Working Group	39

List of Annexes

Annex 1a Multifunctional GBI project_ENG	54
Annex 1b Pilot corridor GBI design_ENG	54

Annex_2 Technical proposal in local language_ITA

Annex_2a RVB multifunzionale_ITA

Annex_2b Corridoio pilota_ITA



Glossary

“Connectivity” (structural and functional)

“Connectivity comprises two components, structural and functional connectivity. It expresses how landscapes are configured, allowing species to move. Structural connectivity, equal to habitat continuity, is measured by analysing landscape structure, independent of any attributes of organisms. [...]. Functional connectivity is the response of the organism to the landscape elements other than its habitats (i.e. the non-habitat matrix). This definition is often used in the context of landscape ecology. A high degree of connectivity is generally linked to low fragmentation.” (EUROPEAN COMMISSION - Technical information on Green Infrastructure (GI), 6.5.2013, Glossary)
(Definition of connectivity see also Deliverable 1.1.1, chapter 8)

“GBI – Green and blue infrastructure”

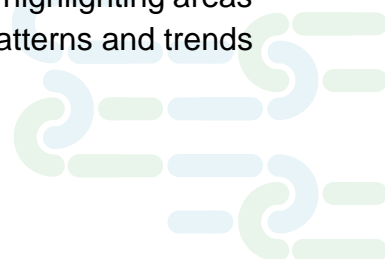
“Green infrastructure (GI) is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.” (EUROPEAN COMMISSION - Green Infrastructure (GI) — Enhancing Europe’s Natural Capital, 6.5.2013)
(Definition of connectivity see also Deliverable 1.1.1, chapter 6)

“Composite multisystemic mapping”

Composite multisystemic mapping refers to the integrated value derived from the overlap of multiple ecological layers within a specific area. This approach synthesizes various ecosystem characteristics, each represented by distinct layers, to produce a comprehensive mapping of the overall capabilities of the area under multiple ecological perspectives. The resultant composite value reflects the cumulative contributions of individual layers, providing insights into the multifunctionality of the landscape.

“Hot spot analyses”

The analyses is a statistical technique used in spatial data analysis to identify areas with a significantly high or low concentration of values or events, often referred to as “hot spots” and “cold spots.” The results of the analysis are then visualized on a map, highlighting areas of high and low concentration. This visualization helps to easily identify patterns and trends within the data.



Executive summary

Green and Blue Infrastructure (GBI) represents an innovative and integrated approach to urban, spatial, and landscape planning, aimed at promoting the incorporation of natural systems within anthropogenic landscapes. A central concept underpinning this strategic infrastructure model is multifunctionality: the recognised ability of specific territorial areas within the network to simultaneously perform multiple roles. These include climate change mitigation, biodiversity conservation, sustainable food production, the provision of accessible recreational green spaces, and the generation of employment opportunities.

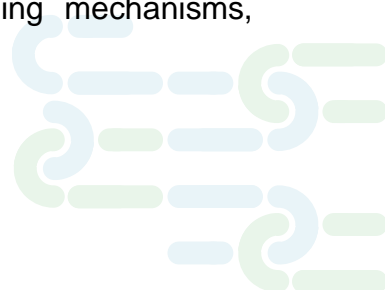
Within the proposed GBI framework developed for the Province of Sondrio, the principle of multifunctionality is articulated through the capacity of the identified areas to provide multiple ecosystem services (ES). This is intrinsically linked to the concept of physical and ecological connectivity, which is fundamental to ensuring the efficient delivery of ecosystem services through the facilitation of ecological flows. Enhanced connectivity not only reinforces the functional performance of the GBI network, but also significantly contributes to ecological resilience in response to pressures stemming from urban expansion and climate change.

The GBI methodology adopted integrates both quantitative and qualitative dimensions, emphasising the multiple ecosystemic, cultural, and social functions of diverse landscape typologies, as well as the synergies and interdependencies among them.

This document outlines a Multifunctional GBI infrastructure for the Province of Sondrio, structured around a set of strategic guidelines and operational actions aimed at the protection, enhancement, and regeneration of the territory's natural assets and its adaptive capacity to climate challenges, alongside its cultural and recreational values.

A second layer of analysis is conducted at the local corridor scale, with a specific focus on a corridor identified within the SACA framework, among the Regional Potential Linkages, as a potential axis for ecological reconnection between the two mountainous slopes. Strategic indications are provided to support the re-establishment of landscape and ecological continuity within this corridor.

To support implementation at the local level and facilitate uptake by territorial authorities, the document further includes governance models and potential funding mechanisms, designed to operationalise and sustain the proposed GBI interventions.



REPORT



1 Pilot region

The Province of Sondrio represents an area of interest as a pilot case for the PlanToConnect project due to its high landscape-environmental values, which coexist with elements of fragility and pressure caused by a variety of factors. Moreover, the initiation of the process to update the Provincial Territorial Coordination Plan (PTCP), in force since 2010, provides a key opportunity to test the potential impacts of the project within territorial planning tools, particularly concerning the construction of a multifunctional green and blue infrastructure aimed at strengthening ecological connectivity and preserving the rich environmental and landscape heritage of the area.

Several natural elements contribute to defining the rich and diverse biodiversity of the province, such as the watershed of the first stretch of the Adda River, the lateral valleys, and the mountainous slopes forming part of the Alpine arc. Sondrio is the only province in Lombardy with an entirely mountainous territory, covering over 3,000 km², with nearly half of it located above 2,000 meters in elevation, reaching the top elevation on the Bernina Mount 4050 mts. The Valtellina is further characterized by a widespread historical and cultural heritage and unique landscapes, which enhances the area's tourism appeal, primarily linked to outdoor recreational and sports activities. In this context, the project aims to develop a multifunctional green and blue network design based on an assessment of the territory's ecosystem performance, identifying areas of high value and critical issues. The project's outcome could serve as a potential contribution to provincial and local planning, identifying priority areas for intervention within a broader framework of transalpine ecological connectivity. Specifically, the multifunctional green and blue infrastructure design developed through the project will aim to enhance the environmental and ecosystem quality of the territory, sustainably leveraging its recreational potential in line with the area's needs. The results of this project will be integrated, on one hand, into the strategic framework defined by the identification of transalpine-scale ecological connectivity corridors and, on the other, into the objectives and strategies set for the provincial territory by existing planning tools at various levels, such as the Regional Territorial Plan (PTR), the Regional Landscape Plan (PPR), the Regional Plan for Protected Areas (PRAP), the current Provincial Territorial Coordination Plan (PTCP), and the Regional Area Territorial Plan (PTRA) for "Middle and Upper Valtellina". The goal is to define a strategic design for provincial-scale green and blue infrastructure capable of translating European and national strategies to a local level, ensuring the protection and conservation of biodiversity and ecosystems, while simultaneously enhancing the natural heritage and cultural landscape. The integration of ecological connectivity and multifunctionality objectives can represent a significant contribution to the territorial planning practices of the provincial area.



2 GBI network project

2.1 Multifunctional approach guiding the GBI design

Green infrastructure (GI) represents a transformative approach to land use and urban planning, emphasizing the integration of natural systems into human-dominated landscapes. One of its key strengths is landscape multifunctionality, which enables spatial areas to serve multiple purposes, including climate change mitigation, biodiversity conservation, food production, the creation of recreational greenspaces, and the provision of employment opportunities. Multifunctionality in this context refers to the capacity of green infrastructure to deliver multiple ecosystem services (ES), making it a fundamental principle of the GI approach. This concept is closely tied to physical connectivity, which is essential for facilitating the effective delivery of ecosystem services through ecological flows. Enhanced connectivity not only supports the functionality of GI but also increases ecological resilience to the stressors associated with urbanization and climate change, while bolstering regional economic stability. As an interconnected landscape framework, GI emphasizes the significance of both the quality and quantity of diverse landscapes, highlighting their multiple functions and the crucial interconnections among them. When thoughtfully planned, developed, and maintained, GI has the potential to significantly contribute to ecosystem services and sustainability, identifying and leveraging positive synergies among the ecosystem services present in various landscapes (LeBrasseur, 2022).

In this case the definition of GI is influenced primarily by two factors: multi-scale levels and a multi-functional perspective. The multi-scale approach is necessary when addressing ecological and landscape issues through planning disciplines that correspond to administrative levels. However, natural and landscape processes often do not align neatly with administrative boundaries, necessitating an integrated multi-scale approach. This entails starting from a macro scale, which encompasses the broader ecosystem functions, and moving down to a micro scale that focuses on site-specific ecosystem services.

Furthermore, this multi-scale approach requires a flexible legislative framework for planning instruments. For example, the promotion of a GI framework at the regional level should translate into actionable measures at the local level. In addition, the multi-functional perspective emphasizes the incorporation of ecological, recreational, cultural, and aesthetic functions within GI structures. This perspective recognizes the ability of areas to serve multiple purposes simultaneously, such as providing opportunities for healthy recreation while delivering essential natural services. Achieving this necessitates advancements in both planning analysis and management strategies to optimize these diverse functions effectively (Arcidiacono et al., 2016).

The Green Blue Infrastructure (GBI) project for the Province of Sondrio is grounded in the principle of multifunctionality, guiding the preservation and respectful utilization of the area's rich natural, ecological, and ecosystemic heritage. The definition of the infrastructure involves several steps that inform its characterization and delineation which will be briefly outlined in the following paragraphs.

2.2 ESs assessment and Strategic frameworks definition

The main structure of the green and blue infrastructure for the province of Sondrio is based on the analysis and assessment of a series of ecosystem services selected according to the area's specific characteristics: Habitat Quality, Stormwater Management, Crop Pollination, Nutrient Retention, Agricultural value, Sediment Retention and Cultural value. These models, widely addressed in the document D.2.3.1, represent the knowledge base for the GBI together with the contextual territorial elements such as land cover, the natural protected areas'system, the multifunctional entities concerning the local identity, tradition, tourism.

A composite analysis was able to synthesize and provide an overview of the individual mappings, thereby identifying areas of high ecosystem and multifunctional value as well as those that currently exhibit lower richness in these respects. The overlaying of these datasets reveals new relationships and dynamics among the various elements, which are instrumental in defining a categorization of the network. The subsequent extraction of the most significant data of the overlay, in a GIS environment, was able to identify three main strategic frameworks (Figure 1): conservative, multifunctional and regenerative (then divided in 5 classes outcome on the intersection of these).

The first class consists exclusively of SACA areas and nodes; the second represents the overlap between class 1 and areas with high multisystemic capacity; the third is comprised solely of areas with high multisystemic capacity; the fourth represents the overlap between areas of high multisystemic capacity and valley floor regenerative elements; and the fifth is made up exclusively of the valley floor regenerative elements.

This type of interpretation enhances the understanding of the key characteristics that define the multifunctional green and blue infrastructure project. The classes that represent the exclusivity of a single category outline the three primary attributes: conservation, multifunctionality, and connectivity. The first has a predominantly conservation-oriented role, as the areas of high ecological value located in the high mountains must be protected and preserved from potential anthropogenic uses. The second frame, derived from the overlap of multisystemic layers, is the primary bearer of the network's multifunctional character. The composite value is multisystemic, integrating natural, agricultural, and cultural components to create a fabric that reflects ecological, natural, recreational, and productive values. The third one is defined by a regenerative character in the valley floor, shaped by the strategic roles of the river and adjacent agricultural areas, as well as existing and potential ecological corridors. The connection between the two valley floors is the responsibility of this last class, both in terms of ecological continuity and accessibility.



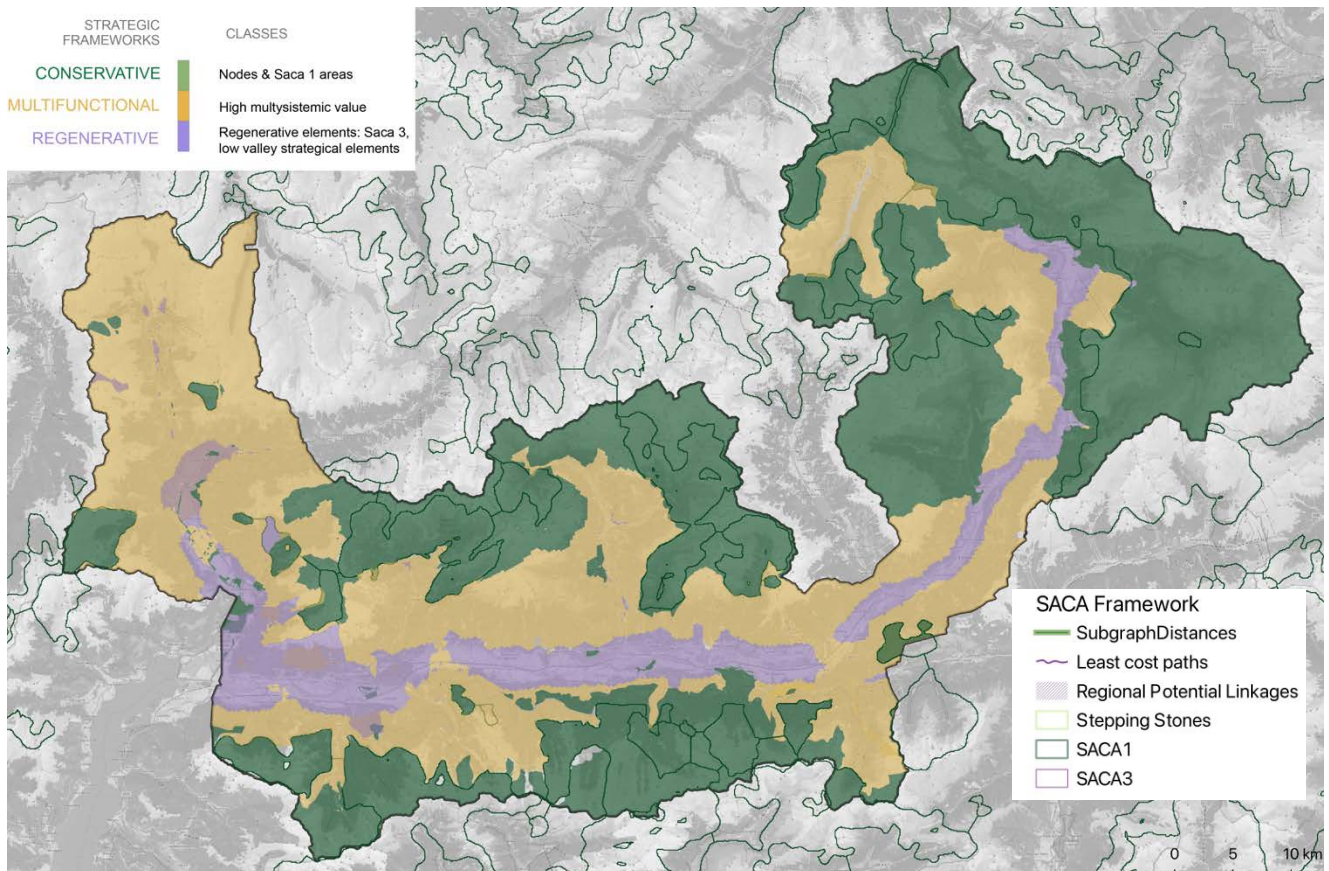


Figure 1 - GBI Strategic Frameworks. Source: developed by FPM – DASTU/Lab PPTE working group

2.3 Regional and local corridors driving the transnational ecological (re)connection

Following the definition of the strategic frameworks that constitute the structural foundation of the GBI project for the Province of Sondrio, the analysis proceeded with the identification of priority areas for intervention. This phase is intended to support the overarching objective of the ecological network: the defragmentation of the valley floor corridor within urbanized areas, with the ultimate goal of restoring ecological connectivity both within urban contexts and between the two valley slopes. These areas represent critical zones where anthropogenic pressures and threats—previously identified and analyzed—are most heavily concentrated. Such pressures constitute both tangible and intangible barriers to ecological continuity, as well as to the environmental and ecosystem value of the landscape. This phase was characterized by the systematic examination, interpretation, and contextualization of the regional potential linkages delineated within the SACA framework (AlpBioNet2030).

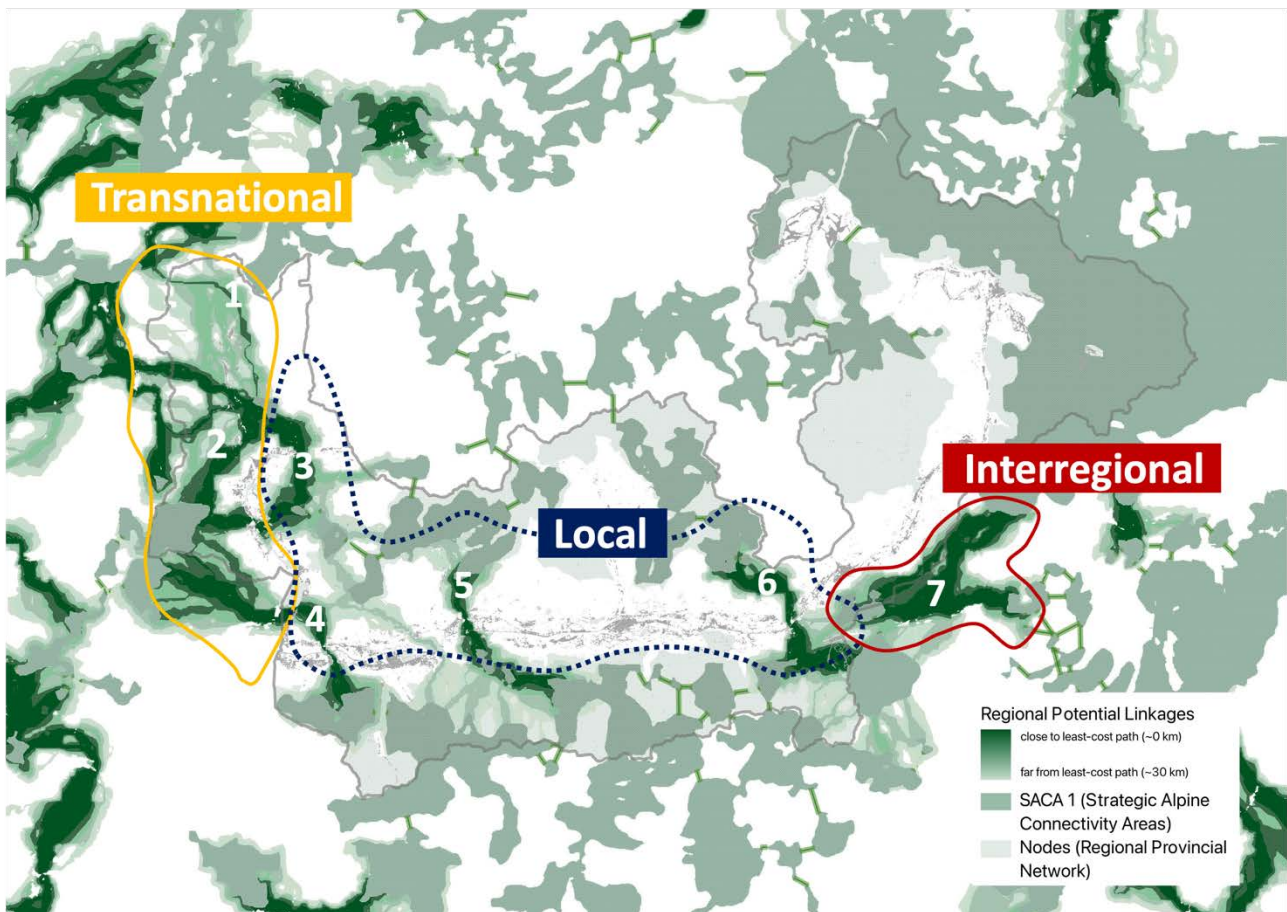


Figure 2 - Regional Potential Linkages' characterisation. Source: developed by FPM – DAsTu/Lab PPTE working group

A total of seven principal connective structures have been identified within the provincial territory. Each exhibits distinct characteristics and has been classified into three overarching categories: *transnational*, *interregional*, and *local*.

The *transnational* corridors traverse national borders, extending toward Switzerland. This category is of critical importance, as it supports the transboundary and international ambitions inherent to the objective of restoring ecological continuity at a macro-regional scale. Corridor 1 currently exhibits limited functional capacity but is identified as a strategic axis for future reinforcement. Its enhancement aims to facilitate connectivity between extensive ecological zones located to the south and the areas situated immediately beyond the northern border. Corridor 2 comprises a system of multiple, partially overlapping ecological trajectories within a common spatial framework. Together, these represent a significant opportunity for the ecological linkages in this area, due to the extensive coverage and multiplicity of ecological flows. These micro-corridors frequently correspond to and overlay with the potential ecological corridors delineated by the provincial ecological network. In these area are recognizable one significant aerial corridor and few terrestrial ones.

The *local* category assumes a central role in the current phase of the project, as it provides the foundation for the implementation of the ecological network's pilot initiative. These corridors are primarily oriented toward re-establishing ecological connectivity between the two mountain slopes

that border the valley floor. This area represents the most complex operational context, given the concentration of structural barriers, ecological threats, and evident urbanization trends. Four local corridors have been identified where morphological and territorial conditions have enabled interruptions in urban development, thereby preserving strategic openings for ecological reconnection. These sectors also encompass several elements of notable ecological value, including the Adda River's active channel, adjacent riparian habitats, and traditional terraced agricultural landscapes.

The *interregional* category is represented by a single connective structure that bifurcates toward the provinces of Brescia and Trentino-Alto Adige. This corridor plays a pivotal role in expanding the ecological influence of the provincial network eastward, thereby enhancing its functional integration within the broader alpine ecological framework.

2.4 The Multifunctional GBI for the Province of Sondrio

The design of the multifunctional green and blue infrastructure network is founded on the previously defined strategic frameworks, which provide a structural basis for the development of area-specific strategic guidelines.

These frameworks interact with the multiscale logic of the corridors identified by the SACA which define an overlaying component of the network, hereafter referred to as “restoration” framework.

By applying the least-cost path methodology, the SACA approach identifies the most efficient routes for connecting areas of high ecological and natural value. Among these, the local corridors—primarily located between Morbegno and Tirano—have proven to be the most significant for the project. These offer a valuable opportunity to address a key territorial challenge: mitigating the fragmentation of the urbanized valley floor and restoring ecological connectivity between the northern and southern slopes.

This paragraph contributes to outlining strategic directions for the entire provincial area, organized according to the identified frameworks, aiming to detail and further clarify the methodological and theoretical concepts outlined previously. A more detailed action plan focused on a specific corridor will be presented in Chapter 3 as a pilot restoration area.

Each strategic framework is characterized by a guiding objective that informs strategic directions for the key elements within each area, namely those related to the valley floor and regeneration zones, the multifunctional and recreational landscape, and the high mountain areas to be preserved. In the following pages, for each framework a general objective, strategic indications and actions are outlined.

All three frameworks identify elements of the cultural and human systems that participate in the multifunctional RVB project by varying extents. The elements of the cultural system, in particular, can play a key role in activating more sustainable forms of territorial and landscape use that are alternatives to winter tourism, which is mainly linked to skiing. This sector has significant environmental impacts, including those attributable to overtourism. The objective is, on the one

hand, to identify lower-impact recreational potentialities that combine the tourist attractiveness of the territory with progressive deseasonalization of the sector. On the other hand, the objective is to promote actions and management methods for the most ecologically sensitive areas to ensure their respectful and sustainable use. The category of cultural and landscape elements encompasses a complex system of values spread throughout the territory. This system can work in synergy with the network of parks and areas of environmental interest, based on the principles of the European Charter for Sustainable Tourism in Protected Areas (Europarc Federation, 2021).

This can be achieved by enhancing the network of paths and fruitive itineraries on the valley floor and slopes. This would contribute to the deseasonalization of tourist activities by promoting an alternative model of tourist and recreational attractiveness.

In the anthropic system, fall includes elements or phenomena that are critical for ecological connectivity, the preservation of natural capital, and the ecosystem performance of the territory.

Regenerative framework

The primary objective of this framework is to restore ecological connectivity between the two slopes through the enhancement of several potential ecological corridors identified by the network. Alongside efforts to defragment the central urban corridor, the framework also includes interventions aimed at enhancing the environmental compatibility of obsolete anthropogenic uses, thereby supporting the ecological revitalization of urban open spaces.

Table 1 - Regenerative framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group

Regenerative framework	Strategic indication	Actions
NATURAL entities		
Adda river	R1_Enhancing the river's role as a primary ecological corridor in the provincial Ecological Network	<ul style="list-style-type: none"> _Interventions for the valorisation, requalification and recovery of systems of environmental value; _Interventions to restore the natural course of the Adda and river functionality; _Creation of controlled flooding areas to mitigate the hydraulic risk in urban and peri-urban areas.
Natural riverine areas	R2_Safeguard the quality and continuity of the natural environments that characterise the riparian belt of the main hydrographic reticulum	<ul style="list-style-type: none"> _Rehabilitation of riparian areas of river corridors by cleaning or replacing damaged species; _Restoration and enhancement of peri fluvial vegetation by means of tree or shrub buffer strips; _Protection of residual wetlands along the river course.
Setback of agricultural land in favour of forest and invasive species	R3_Counteracting the abandonment and loss of biodiversity of agricultural terraces (ES Pollination)	<ul style="list-style-type: none"> _ Control of invasive species through clearing and deforestation; _ Monitoring of the state of conservation of terracing; _Incentives to support typical local production (vineyards, apple orchards and orchards); _Adoption of techniques that reduce the use of pesticides and insecticides.
Potential ecological corridors (Sondrio)	R4_Promote the maintenance, strenghtening or restoration of ecological connectivity and avoid or	<ul style="list-style-type: none"> _Enhancement or restoration of shrub vegetation; _Creation of wildlife passages at infrastructure crossings;

Regenerative framework	Strategic indication	Actions
Provincial Ecological Network – REP)	contain conurbation processes in the valley floor	<ul style="list-style-type: none"> _Maintenance and enhancement of stable meadows on the valley floor (sustainable mowing practices); _Limitation of land take process within urban planning tools in order to maintain ecological gaps and passages.
AGRICULTURAL entities		
Agricultural land	R5_Maintain the integrity and increase the biodiversity of agricultural areas in order to promote the safeguard, strenghtening or restoration of ecological connectivity	<ul style="list-style-type: none"> _Enhancement of the ecosystem values of agricultural areas through the enhancement of edge vegetation and conservation farming techniques; _Maintenance and recovery of mowing plans; _Increase of hedges and rows in agricultural areas near to or enclosed by built-up areas.
CULTURAL entities		
Adda cyclable path	R6_Strenghtening the Valtellina cycle path as the backbone of slow mobility in the province by improving links with the local recreational route system	<ul style="list-style-type: none"> - Designing connection points with the local cycle network system and main routes for the use of systems of environmental and cultural-historical value; _Promoting intermodality (bike interchange, local public transport and rail transport)
Landscape routes	R7_-Strenghtening the network of slow mobility routes and landscape connections	<ul style="list-style-type: none"> _Maintenance and securing of paths by clearing brush or installing diverters; _Protection of sensitive views, belvederes and perspective cones along paths; _Connection with the Adda Greenway and with public transport stations and stops
Historical centres, Areas of aesthetic and visual significance, Traditional values	R8_Promote the sustainable use of the environmental and cultural heritage across the territory	<ul style="list-style-type: none"> _Enhancement of the relation between historical centres and open spaces' network; _Protection of sensitive views, belvederes and perspective cones along paths; _Enhancement of fruitive itineraries that network the historic villages and the system of assets and areas of cultural and landscape interest on the slopes
Agricultural terraces	R9_Promoting the maintenance, conservation and enhancement of terraced systems to safeguard the identity feature of the historic landscape and to maintain the slope stability	<ul style="list-style-type: none"> _Monitoring of abandoned terraces _Providing economic incentives for the maintenance and protection of dry-stone walls and the maintenance of agricultural practices along terraced slopes
ANTHROPIC entities		
Plants, decay areas, quarries and landfills	R10_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity	<p><i>Common indications:</i></p> <ul style="list-style-type: none"> _Mitigation of visual impact through vegetation elements; _Improvement of the environmental quality of the appurtenances through the creation of green areas <p><i>Areas affected by mining activities whose impacts are to be contained and mitigated:</i></p> <ul style="list-style-type: none"> _Reforestation of exhausted quarries with native species; _Agricultural reuse of exhausted quarries with crops suited to the quarry morphology; _Mitigation of the visual impact of active quarries through vegetated strips <p><i>Hydropower plants and technological networks to contain and mitigate impacts:</i></p>

Regenerative framework	Strategic indication	Actions
		<ul style="list-style-type: none"> _Where possible, burying of power lines located in areas of high landscape value; _Positioning of pylons in non-invasive positions with respect to preferential visual axes; _Installation of bird deterrents on power lines
Planned transformation	R11_Areas to counter current conurbation trends	<ul style="list-style-type: none"> _Implementation of an effective compensatory scheme to restore the natural value loss for the transformation (see paragraph 2.2 and D.2.4.1) _Incentives to locate new functions in disused buildings or areas rather than new construction; _Buffer strips and green areas at urban edges; _Provision of appropriate environmental standards (permeability indices, hydraulic invariance...)
Continuous and Discontinuous urbanized areas	R12_Promoting environmental regeneration and restoration of nature in urban areas	<ul style="list-style-type: none"> _Creation of buffer strips and green areas at urban fringes; _Greening of waste areas with indigenous and various plant species; _Actions of depaving, urban forestation, biodiversity increase

Multifunctional framework

This framework embodies the network's most distinctly multifunctional character, defined by the simultaneous presence of high ecological value areas, cultural elements linked to recreational use, and strategic accessibility due to its position between the high mountain regions and the urbanized lowland valley. The strategies proposed here aim to enhance the territory's cultural, recreational, and environmental assets, fostering an adaptive transition to climate change through the promotion of sustainable outdoor activities.

Table 2 - Multifunctional framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group

Multifunctional framework	Strategic indications	Actions
NATURAL entities		
Permanent meadows and bushes	M1_Promoting the maintenance of pasture land and counteracting the biodiversity loss of the rural landscape	<ul style="list-style-type: none"> _Arrangement of pasture management plans to preserve pastures _Sustainable mowing in permanent meadows on valley floors
Wooden areas	M2_Safeguarding the wooden ecosystems and countering the trivialisation of forest vegetation	<ul style="list-style-type: none"> _Monitor and counter the spread of non-native species; _Adopt systemic silviculture techniques; _Safeguard the presence of chestnut groves; _Promote widespread maintenance interventions to reduce plant biomass and counter the risk of fire; _Initiating timely interventions to rehabilitate forest ecosystems damaged by fires; _Promoting the adoption of forest management plans also aimed at wildlife management and favouring

Multifunctional framework	Strategic indications	Actions
		genetic variability, wild and native species, mixed stands with variable structure
Areas affected by bark beetle invasive species	M3_Support for the rehabilitation of degraded forest ecosystems (bark beetle)	<ul style="list-style-type: none"> _Monitoring of infestation by means of traps and satellite images; _Phytosanitary cutting of infested plants, with priority given to protective forests; _Stabilisation of slopes affected by infestation by means of light natural engineering measures; _Active management by setting up groups of bait plants to distract insects from the protected trees; _Arranging monitoring and early warning systems for infested areas.
Setback of agricultural land in favour of forest and invasive species	M4_ Counteracting the abandonment and loss of biodiversity dynamics	<ul style="list-style-type: none"> _Setting up Pasture Plans for the maintenance and preservation of existing grazing areas; _Restoration of former grazing areas through controlled clearing and deforestation
Forest impacted by the 2018 Vaia storm	M5_Restoration of forest ecosystems with species native to the areas damaged by the Vaia storm	<ul style="list-style-type: none"> _Definition of priority criteria for vegetation restoration: protective function prioritised over landscape and production functions; _Restoration of forest ecosystems with local species _Creation of temporary structures to protect against rockfalls and hydrogeological instability, using wood from crashed forests; _Vegetational diversification of new plantings to reduce their vulnerability to future events; _Restoration of forest infrastructure and grazing areas affected by damage
Areas exposed to erosion dynamics	M6_Promoting actions to prevent erosive risk conditions along the water network	<ul style="list-style-type: none"> _Vegetation enhancement along the riparian strip to slow down outflows (e.g. creation of wooded or shrub buffer strips); _Restoration of perfluvial vegetation (ex. Wood maintenance, selective vegetational trimming..) _Increasing morphological diversity in the riverbed (introduction of timber, laying of boulders)
CULTURAL entities		
Landscape routes	M7_Enhancing the recovery and valorisation of existing historical routes linking the valley floor to the hillsides	<ul style="list-style-type: none"> _Reconversion towards integrated use (cycling and biking routes, snowshoe tourism) _Realisation and enhancement of trail continuity between different itineraries and with the Adda cycle route
Historical centres Areas of aesthetic and visual significance Traditional values	M8_Promoting the sustainable use of the environmental and cultural heritage across the territory	<ul style="list-style-type: none"> _Enhance the relationship between the historical centres and the system of open spaces; _Protection of sensitive views, belvederes and perspective cones along the paths; _Enhancement of fruitive itineraries that connect historic villages with areas and assets of cultural and landscape interest on the slopes.
Mountain refuge	M9_Promote the network of hiking trails and paths of scenic interest at high altitudes and along slopes	<ul style="list-style-type: none"> _Sustainable recreational development measures (upgrading of footpaths, enhancement of mountain pastures, agritourisms, refuges); _Enhancement of cycling and walking routes across mountain pastures
Alpine pasture	M10_Stimulate the multifunctional valorisation of alpine pasture	<ul style="list-style-type: none"> _Extension of cycling and walking routes that cross the mountain pastures; _Inclusion in tourist circuits linked to dairy production; _Supporting actions to ensure water availability.

Multifunctional framework	Strategic indications	Actions
		_Multifunctional valorisation of inactive or underused malghe (e.g. reutilisation of the structure or part of it for use as a bivouac for hiking)
ANTHROPIC entities		
Plants, decay areas, quarries and landfills	M11_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity	<p><i>Common indications:</i></p> <p>_Mitigation of visual impact through vegetation elements;</p> <p>_Relocate obsolete activity when possible in order to maintain the ecological and natural value (see chapter 2 and D.2.4.1)</p> <p>_Improvement of the environmental quality of the appurtenances through the creation of green areas</p> <p><i>Areas affected by mining activities whose impacts are to be contained and mitigated:</i></p> <p>_Reforestation of exhausted quarries with native species;</p> <p>_Agricultural reuse of exhausted quarries with crops suited to the quarry morphology;</p> <p>_Mitigation of the visual impact of active quarries through vegetated strips</p> <p><i>Hydropower plants and technological networks to contain and mitigate impacts:</i></p> <p>_Where possible, burying of power lines located in areas of high landscape value;</p> <p>_Installation of bird deterrents on power lines</p>
Ski infrastructures	M12_Encourage integrated restoration strategies and diversification of supply towards more sustainable forms of tourism	<p>_Promotion of environmentally and landscape-sustainable activities to complete the winter recreational offer;</p> <p>_Environmental upgrading of Alpine ski slopes by technical grassing operations to carry out after the snowpack melts;</p> <p>_De-impermeabilization of parking areas;</p> <p>_Promote collective transport system development to ease ski domains access</p> <p>_Promote renewable energy production system along ski infrastructures</p>

Conservative framework

This framework focuses on high mountain areas of outstanding environmental, landscape, and cultural value. It embraces a strongly conservation-oriented strategy aimed at preserving the area's natural richness by limiting existing anthropogenic activities and discouraging further human-induced pressures. The ecological importance of these areas requires active protection to ensure long-term resilience and integrity.

Table 3 - Conservative framework: GBI strategic indications and actions. Source: developed by FPM – DASTU/Lab PPTE working group

Conservative framework	Strategic indication	Actions
NATURAL entities		

Conservative framework	Strategic indication	Actions
Protected areas and parks	C1_ Strengthening the ecological and functional connections between the protected areas' system and other significant natural areas	<ul style="list-style-type: none"> _Reforestation and enhancement of ecosystem values within buffer zones _ Promote sustainable recreational use of parks and adjacent natural areas, as outlined in the European Charter for Sustainable Tourism in Protected Areas _Refer to the respective management plans for information on actions to maintain, monitor and increase biodiversity within the protected area
Permanent meadows and bushes	C2_Promoting the maintenance of pasture land and counteracting the biodiversity loss of the rural landscape	<ul style="list-style-type: none"> _Arrangement of pasture management plans to preserve pastures _Sustainable mowing in permanent meadows
Wooden areas	C3_ Safeguarding the wooden ecosystems and countering the trivialisation of forest vegetation	<ul style="list-style-type: none"> _Monitor and counter the spread of non-native species; _Adopt systemic silviculture techniques; _Safeguard the presence of chestnut groves; _Promote widespread maintenance interventions to reduce plant biomass and counter the risk of fire; _Initiating timely interventions to rehabilitate forest ecosystems damaged by fires; _Promoting the adoption of forest management plans also aimed at wildlife management and favouring genetic variability, wild and native species, mixed stands with variable structure
Areas exposed to hydraulic vulnerability	C4_Promoting actions to mitigate hydraulic risk	<ul style="list-style-type: none"> - Promote sustainable forest management aimed, especially on steep slopes, at containing surface runoff and preventing landslides, by adopting controlled naturalisation methods or naturalistic engineering interventions; - Promote slope consolidation and remodelling as well as the installation of drainage systems to reduce water infiltration; - Promote the soil desealing interventions in urban areas; - Promoting the construction of detention basins, also in combination with fruitive functions.
Areas exposed to erosion dynamics	C5_Promoting actions to prevent erosive risk conditions along the water network	<ul style="list-style-type: none"> _Vegetation enhancement along the riparian strip to slow down outflows (e.g. creation of wooded or shrub buffer strips); _Vegetation enhancement of riparian areas (e.g. forest maintenance, selective cutting of vegetation in the riverbed); _Morphological diversity enhancement in the riverbed (introduction of timber, laying of boulders)
CULTURAL entities		
Landscape routes Areas of aesthetic and visual significance	C6_Encourage the recovery and valorisation of existing historical routes linking the valley floor to the hillsides and the protection of the most sensitive views	<ul style="list-style-type: none"> _Enhancement of recreational routes and viewpoints (e.g. identification of routes and equipped areas, creation of dedicated signposts); _Maintenance and enhancement of hiking routes and along Adda cycle path; _ Limitation and mitigation of planned or planned slope alterations.
Alpine pasture	C7_ Stimulate the multifunctional valorisation of alpine pasture	<ul style="list-style-type: none"> _Extension of cycling and walking routes that cross the mountain pastures; _Inclusion in tourist circuits linked to dairy production;

Conservative framework	Strategic indication	Actions
		<ul style="list-style-type: none"> _Creation or upgrading of routes serving the facility to ease the transport of goods and equipment. _Supporting actions to ensure water availability. _Multifunctional valorisation of inactive or underused malghe (e.g. reutilisation of the structure or part of it for use as a bivouac for hiking)
“Silent Landscape” (Paesaggi del silenzio – PTRa)	C8_Valorisation of landscapes of silence and enhance their sustainable access	<ul style="list-style-type: none"> _Maintenance and enhancement of hiking routes; _Inclusion of alpine pastures, agritourism, refuges in visitor circuits; _Manage visitor flows, activities, and behaviors in sensitive areas and sites
ANTHROPIC entities		
Plants, decay areas, quarries and landfills	C9_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity	<p><i>Common indications:</i></p> <ul style="list-style-type: none"> _Mitigation of visual impact through plant elements; _Improvement of the environmental quality of appurtenances through the creation of green areas; _Creation of green bridges and ecological corridors to reconnect fragmented areas _Relocate obsolete activity when possible in order to maintain the ecological and natural value (see chapter 2 and D.2.4.1)
Ski infrastructures	C10_Implementing integrated restoration strategies and diversification of supply towards more sustainable forms of tourism	<ul style="list-style-type: none"> _Promotion of environmentally and landscape-sustainable activities to complete the winter recreational offer; _Environmental upgrading of Alpine ski slopes by technical grassing operations to carry out after the snowpack melts; _Environmental upgrading of the ski slopes for their use also during the summer season _De-impermeabilization of parking areas; _Promote collective transport system development to ease ski domains access _Promote renewable energy production system along ski infrastructures

The general map at the provincial level is focused on the representation and spatialisation of the strategical indications for each significant entity in the framework. While in the next chapter the focus will be the analyses at the scale of a local corridor, taken as pilot project area, where priority action areas are outlined.



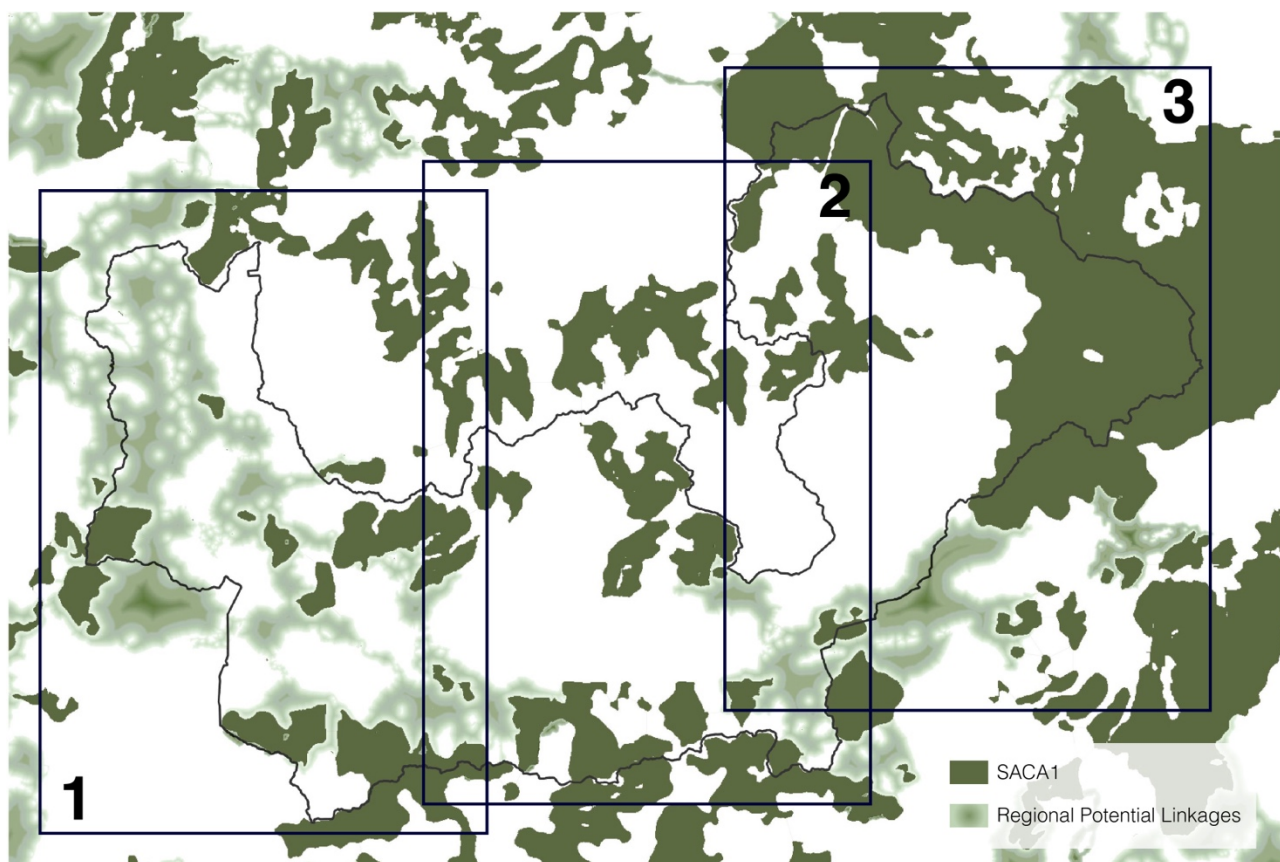


Figure 3 - GBI scheme. Source: developed by FPM – DASTU/Lab PPTE working group







Multifunctional GBI for the Province of Sondrio

Regenerative framework


The primary objective of this framework is to restore ecological connectivity between the two slopes through the enhancement of several potential ecological corridors identified by the network. Alongside efforts to defragment the central urban corridor, the framework also includes interventions aimed at enhancing the environmental compatibility of obsolete anthropogenic uses, thereby supporting the ecological revitalization of urban open spaces.

Entities







NATURAL

-  Adda river
R1_Enhancing the river's role as a primary ecological corridor in the Sondrio Regional Ecological Network
-  Natural riverine areas
R2_Safeguard the quality and continuity of the natural environments that characterise the riparian belt of the main hydrographic reticulum
-  Setback of agricultural land in favour of forest and invasive species
R3_Counteracting the abandonment and loss of biodiversity of agricultural terraces (ES Pollination)
-  Potential ecological corridors (Sondrio Provincial Ecological Network - REP)
R4_Promote the maintenance, strengthening or restoration of ecological connectivity and avoid or contain conurbation processes in the valley floor





AGRICULTURAL

-  Agricultural land
R5_Maintain the integrity and increase the biodiversity of agricultural areas in order to promote the safeguard, strengthening or restoration of ecological connectivity

CULTURAL

-  Adda cycleable path
R6_Strengthening the Valtellina cycle path as the backbone of slow mobility in the province by improving links with the local recreational route system.
-  Landscape routes
R7_Strengthening the network of slow mobility routes and landscape connections
-  Historical centres
R8_Promote the sustainable use of the environmental and cultural heritage across the territory
-  Areas of aesthetic and visual significance
-  Traditional values
-  Agricultural terraces
R9_Promoting the maintenance, conservation and enhancement of terraced systems to safeguard the identity features of the historic landscape and to maintain slope stability

ANTHROPIC







-  Plants, decay areas, quarries and landfills (Density of elements)
R10_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity
-  Planned transformation (Density of elements)
R11_Areas to counter current conurbation trends
-  Continuous urbanized areas
-  Discontinuous urbanized areas
R12_Promoting environmental regeneration and restoration of nature in urban areas

Multifunctional framework







This framework embodies the network's most distinctly multifunctional character, defined by the simultaneous presence of high ecological value areas, cultural elements linked to recreational use, and strategic accessibility due to its position between the high mountain regions and the urbanized lowland valley. The strategies proposed here aim to enhance the territory's cultural, recreational, and environmental assets, fostering an adaptive transition to climate change through the promotion of sustainable outdoor activities.

Entities



NATURAL

-  Permanent meadows and bushes
M1_Promoting the maintenance of pasture land and counteracting the biodiversity loss of the rural landscape
-  Wooden areas
M2_Safeguarding the wooden ecosystems and counteracting the trivialisation of forest vegetation
-  Areas affected by bark beetle invasive species
M3_Support for the rehabilitation of degraded forest ecosystems (bark beetle)
-  Setback of agricultural land in favour of forest and invasive species
M4_Counteracting the abandonment and loss of biodiversity dynamics
-  Forest impacted by the 2018 Vaia storm
M5_Restoration of forest ecosystems with species native to the areas damaged by the Vaia storm
-  Areas exposed to erosion dynamics
M6_Promoting actions to prevent erosive risk conditions along the water network

CULTURAL

-  Landscape routes
M7_Enhancing the recovery and valorisation of existing historical routes linking the valley floor to the hillsides
-  Historical centres
-  Areas of aesthetic and visual significance
-  Traditional values
M8_Promoting the sustainable use of the environmental and cultural heritage across the territory
-  Mountain refuge
M9_Promote the network of hiking trails and paths of scenic interest at high altitudes and along slopes
-  Alpine pasture
M10_Stimulate the multifunctional valorisation of alpine pastures

ANTHROPIC






-  Plants, decay areas, quarries and landfills (Density of elements)
M11_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity
-  Ski infrastructures
M12_Encourage integrated restoration strategies and diversification of supply towards more sustainable forms of tourism

Conservative framework




This framework focuses on high mountain areas of outstanding environmental, landscape, and cultural value. It embraces a strongly conservation-oriented strategy aimed at preserving the area's natural richness by limiting existing anthropogenic activities and discouraging further human-induced pressures. The ecological importance of these areas requires active protection to ensure long-term resilience and integrity.

Entities



NATURAL

-  Protected areas and parks
C1_Strengthening the ecological and functional connections between the protected areas' system and other significant natural areas
-  Permanent meadows and bushes
C2_Promoting the maintenance of pasture land and counteracting the biodiversity loss of the rural landscape
-  Wooden areas
C3_Safeguarding the wooden ecosystem and counteracting the trivialisation of wooden vegetation
-  Areas exposed to hydraulic vulnerability
C4_Promoting actions to mitigate hydraulic risk
-  Areas exposed to erosion dynamics
C5_Promoting actions to prevent erosive risk conditions along the water network

CULTURAL

-  Landscape routes
C6_Encourage the recovery and valorisation of existing historical routes linking the valley floor to the hillsides and the protection of the most sensitive views
-  Alpine pasture
C7_Stimulate the multifunctional valorisation of alpine pasture
-  "Silent Landscape" (Paesaggi del silenzio - PTSA)
C8_Vvalorisation of landscapes of silence and enhance their sustainable access

ANTHROPIC

-  Plants, decay areas, quarries and landfills (Density of elements)
C9_Limit, contain and mitigate the impacts of human activities on the environmental quality and ecological connectivity
-  Ski infrastructures
C10_Implementing integrated restoration strategies and diversification of supply towards more sustainable forms of tourism

Strategical Alpine Connectivity Areas (AlpBionet 2030)

-  SACA1
-  Regional Potential Linkages

CONTEXT ELEMENTS



-  Pilot area - Province of Sondrio
-  Land use - DUSAF 2021
-  Hydrographic network
-  Agricultural areas (intensive and extensive)
-  Debris builtup, gravel, dunes
-  Permanent meadows and bushes
-  Wooden areas
-  Sparse vegetation
-  Glaciers and permanent snow
-  Artificial catchment areas
-  Dense and continue urban fabric
-  Sparse urban fabric
-  Artisanal, commercial and industrial settlements
-  Roads and railways



Figure 4 - GBI legend. Source: developed by FPM – DASTU/Lab PPTE working group

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

Fondazione Politecnico di Milano in collaborazione with LabPPTE/DASTU - Politecnico di Milano, April 2025

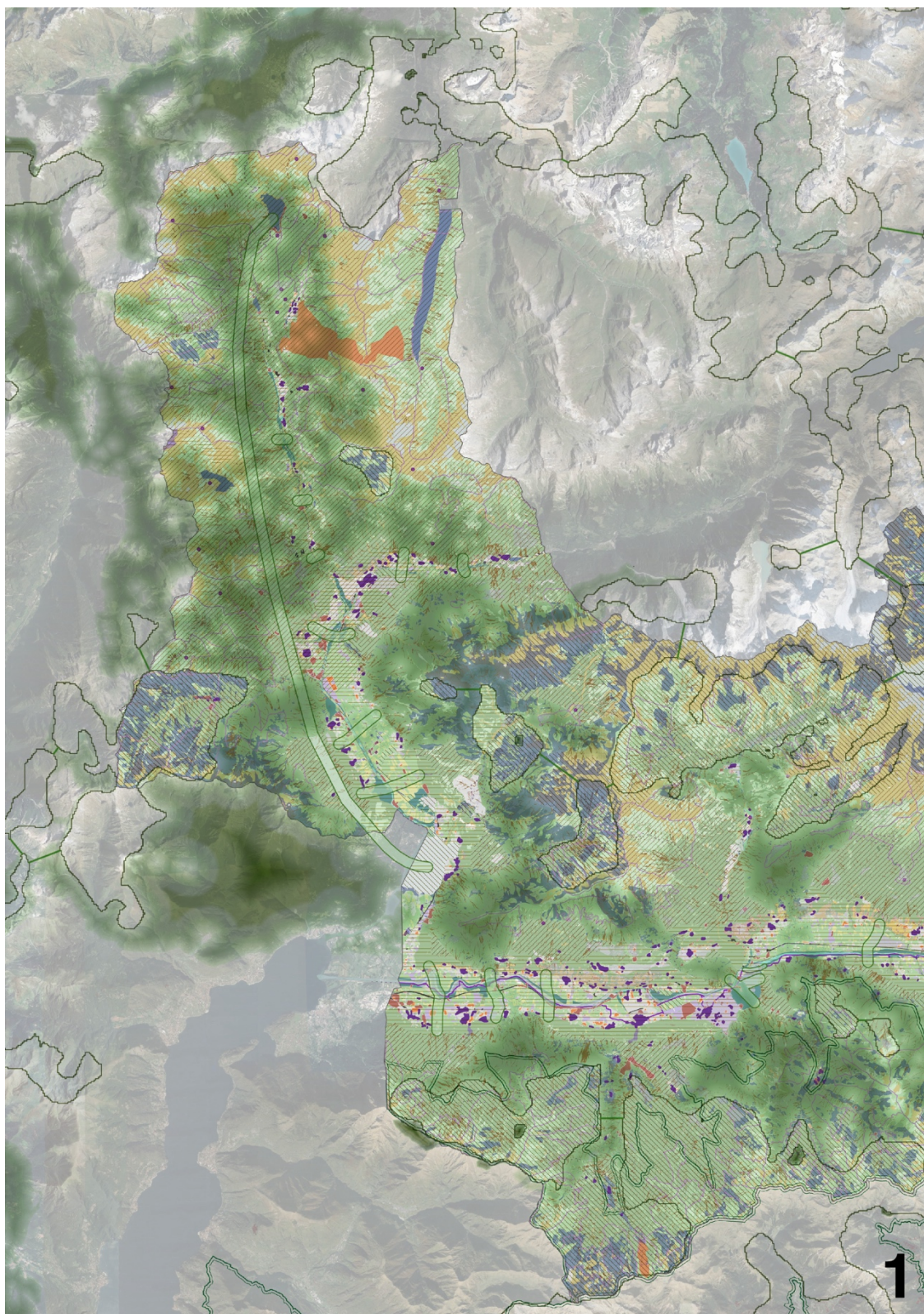


Figure 5 - GBI extract . Source: developed by FPM – DASTU/Lab PPTE working group

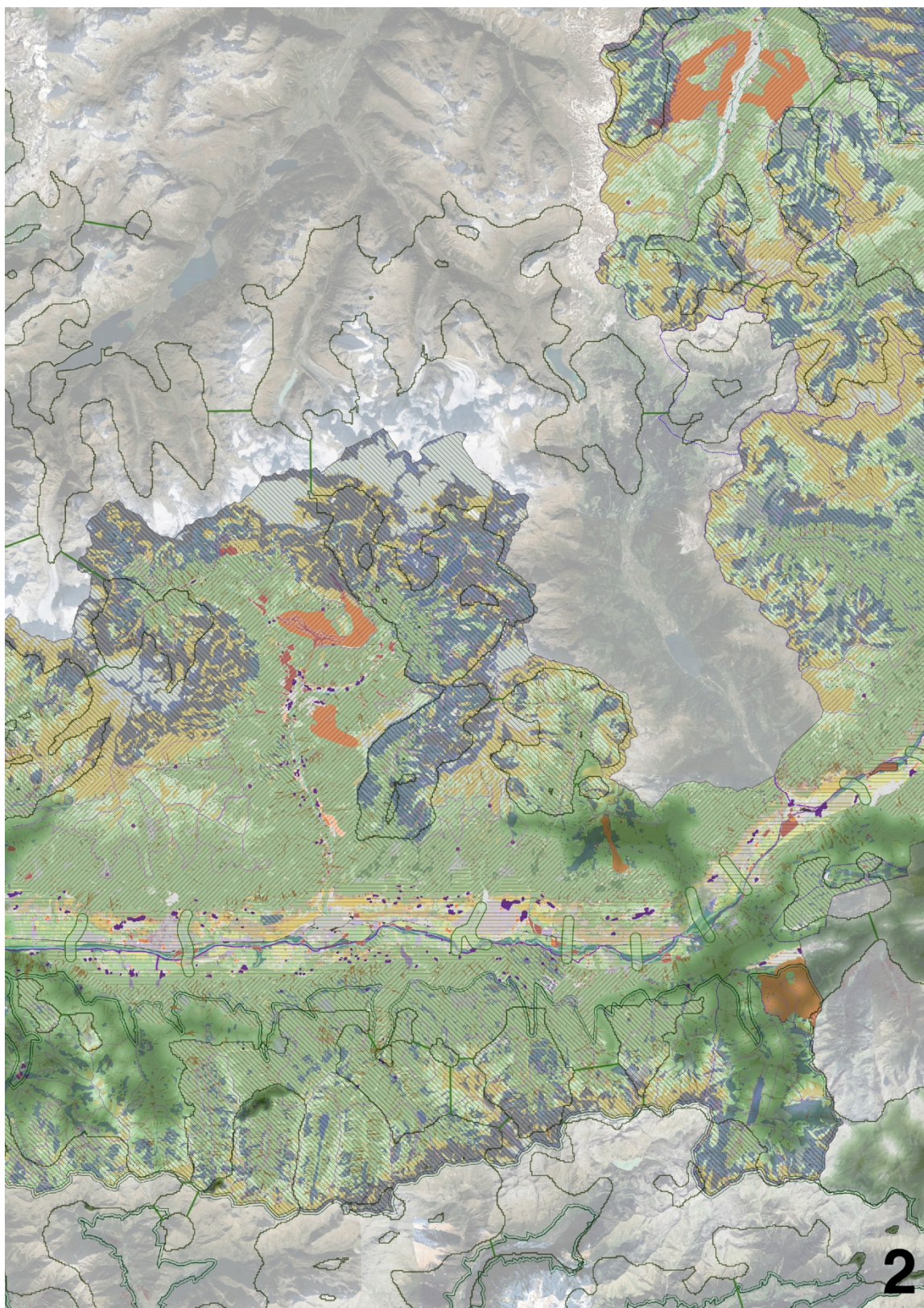


Figure 6 - GBI extract 2. Source: developed by FPM – DASTU/Lab PPTE working group

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

Fondazione Politecnico di Milano in collaboration with LabPPTE/DASTU - Politecnico di Milano, April 2025

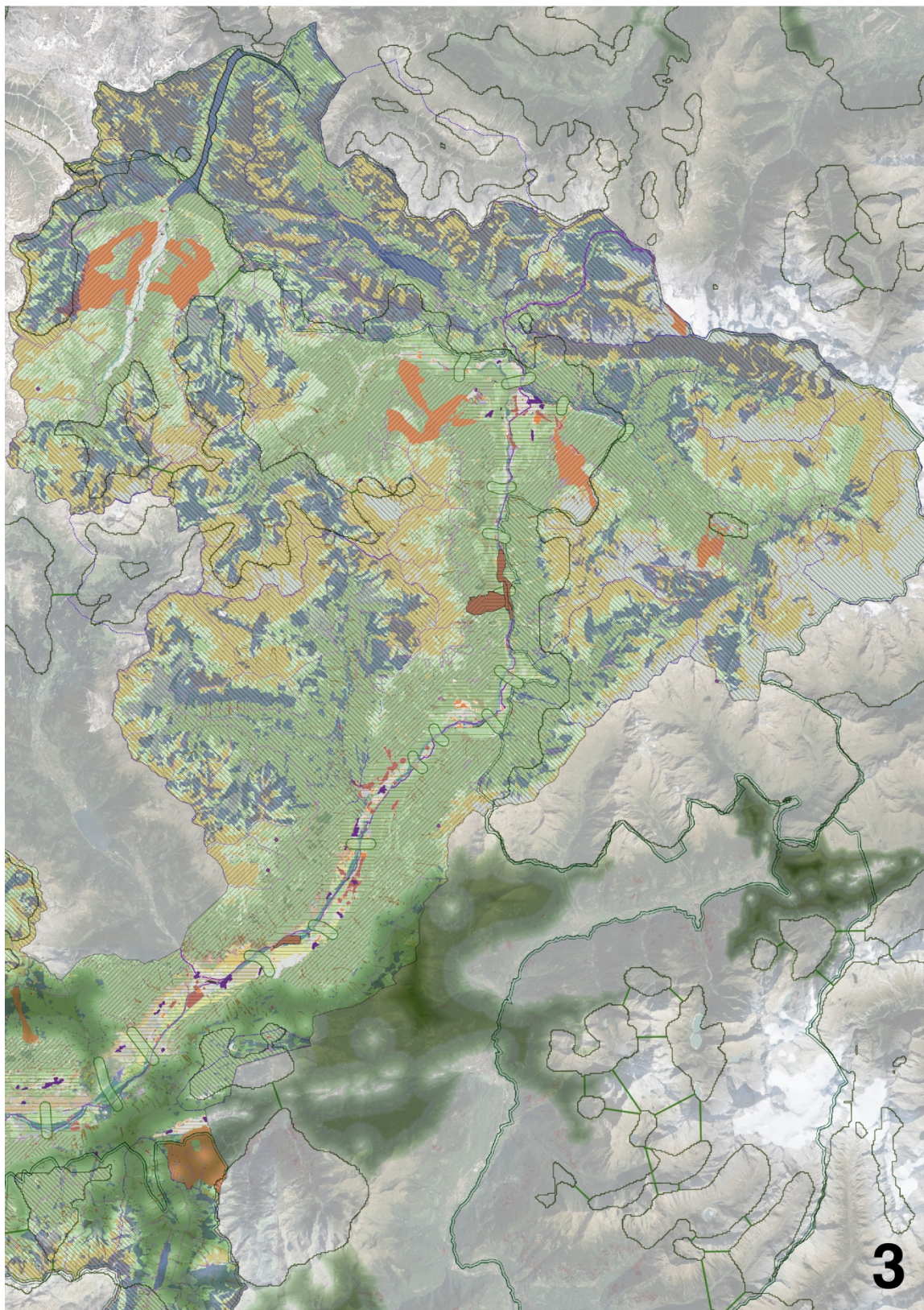


Figure 7 - GBI extract 3. Source: developed by FPM – DASTU/Lab PPTE working group

2. Pressures and Threats to connectivity conservation and restoration areas

2.1 Main pressures and threats

The pilot area is highly fragmented by human settlements and infrastructure, which are primarily concentrated in the lower part of the valley. This development effectively divide the valley into two slopes, acting as a physical barrier and fragmenting the ecological connectivity.

The main threatening elements identified in the documents (A.1.2.1 and D.2.4.1) include high-flow transport infrastructure, dispersed settlements and infrastructure, ski domains, degraded and abandoned areas, forecasted transformation related to residential, tourism, productive and tertiary functions and renewable energy plants.

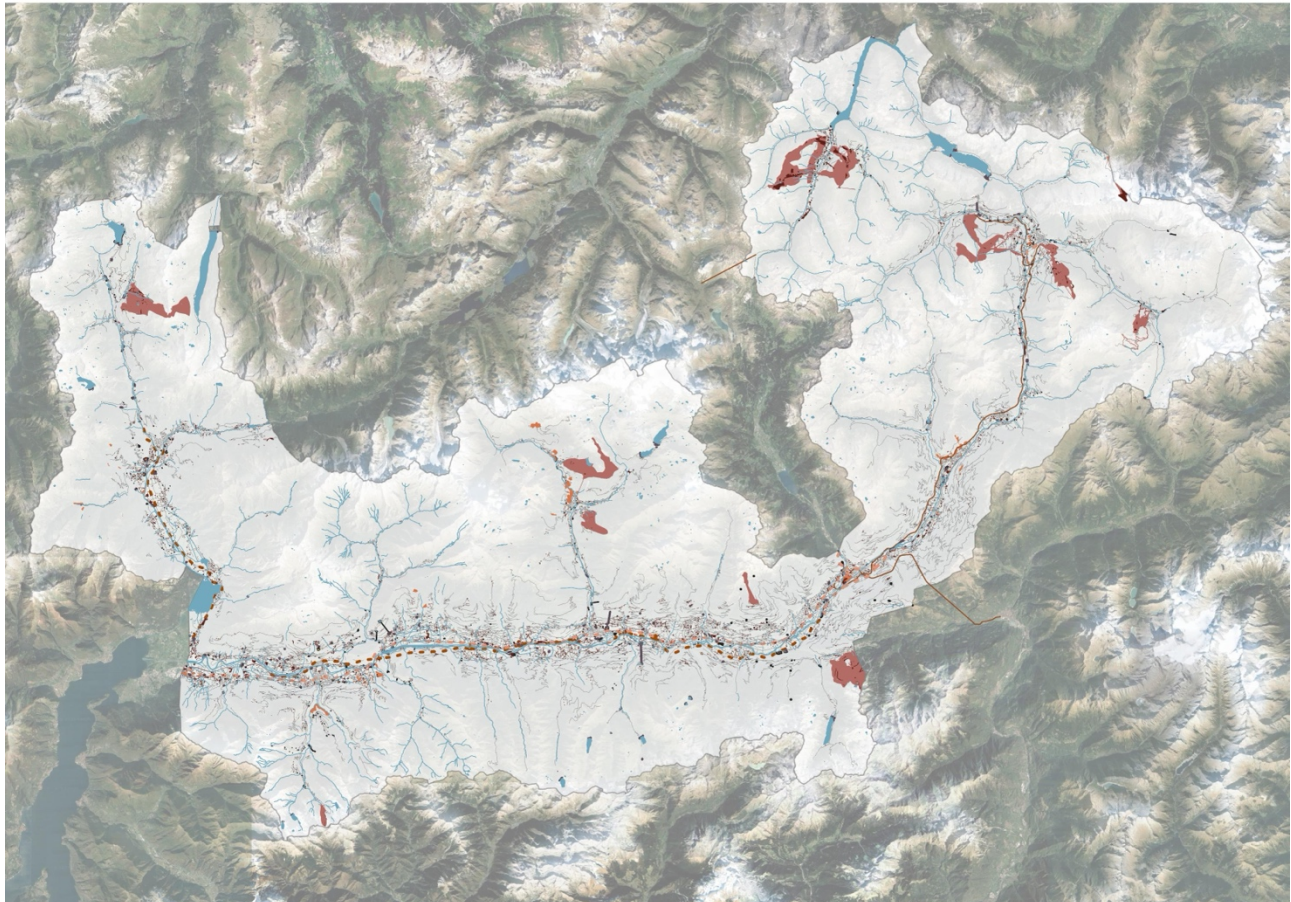
The initial focus of the D.2.4.1 was concerning renewable energy plants as one of the main threat to ecological connectivity, considering the significant investments and the widespread deployment of these installations across Europe. This analysis proved more complex than the previous one, as the regulation linking renewable energy development to environmental value threats is relatively recent. The analysis of renewable energy installations has been carried out considering the current provisions of the National Decree on Suitable Areas, published in July 2024, which mandates that the Regions adopt or restate national guidelines at the regional level. In December, the Lombardy Region published the Decree "Approval of New Regional Guidelines for the Authorization of Installations for Electrical Energy Production from Renewable Sources (RES)," following updates to national legislation in this field. In addition to this decree, other technical and legal documents were reviewed.

A major challenge encountered was the geo-referenced mapping and forecasting of renewable energy installations at the provincial level (and thus at the scale of our pilot case). In fact, the most recent documents addressing these issues are the 'Energy Plan' and the 'Water Plan' from 2010 and these are just available in the PDF version.

The available data, presented in the map below (Figure 8), pertains to plants that were either operational or planned as of 2023 taken from the regional data collection of the transformation foreseen by municipal urban plans. The primary facilities identified in the dataset include combined heat and power plants, water purification facilities, waste treatment plants, and hydroelectric stations. However, we lack confirmation on whether these facilities are still operational, whether the planned projects have been realized, or if other facilities have been introduced in local plans since then.



The analyses has been divided into existing threats, which include urbanized soil (for the period 1999-2021), mobility infrastructure, existing facilities, ski infrastructure and degraded areas, and planned threats, which consist of transformation areas and planned facilities. Planned areas have been deliberately shown in a lighter colour as, in theory it would be



Threats to ecological and multifunctional connectivity

Soil consumption period 1999-2021

- Traffic mobility infrastructures
- Urban settlements
- Plants (hydroelectric, water purification, landfill, thermal power, waste treatment and recovery, other)

- Ski infrastructure
- Areas of decay

Interventions in project

Mobility infrastructures

- Road
- Olympics games' related road intervention
- Railway

Urban settlements

■ Transformation area

Plants

■ Hydroelectric, water purification, waste treatment and recovery

■ Hydrographic network

■ Mobility network

■ Urban settlements

Figure 8 - Threats and barrier analyses. Source: developed by FPM – DASTU/Lab PTE working group



possible to positively influence planning decisions through the Multifunctional Green and Blue Infrastructure Project. The aim is to relocate proposed developments in ecologically unsuitable areas that threaten ecological connectivity or, where relocation is not possible, to implement appropriate environmental mitigation measures.

A similar approach can also be applied to degraded areas which, if properly rehabilitated and reintegrated, could represent potential assets within the multifunctional green and blue infrastructure project.

Analysis of the map shows that the most extensive threats in terms of surface area are related to facilities and transformation areas outside the consolidated urban fabric in the valley floor, while in the mountain areas the primary threats are related to ski infrastructure.

However, there are many critical issues at a smaller scale which, as mentioned above, are less visible at this scale but still have a significant impact on the fragmentation of ecological corridors and the associated loss of habitat. In particular, mobility infrastructure, existing facilities and degraded areas contribute to these ecological disturbances.

2.2 Mapping unsuitable areas for multifunctional connectivity enhancement

These analyses led to the identification of four levels of unsuitability in terms of new developments and existing obsolete elements, related to the threats identified in the previous paragraph. The whole area is characterized as unsuitable or critical, as any new land consumption poses a threat to the overall multisystemic value and to the ecological connectivity.

The four distinct levels are defined as follows: two levels of unsuitability and two levels of criticality. The first level concerns the *areas for natural and ecosystem conservation* unsuitable for transformation located within the Conservative framework. These areas, as previously outlined, constitute the natural heritage of the Alpine region, defined by the system of protected areas and SACA1 zones. No transformations should be permitted in these areas, in accordance with the conservative character of the multifunctional infrastructure of the project.

The second level, subject to the same restrictions in the design project, includes the areas designated as *restoration areas*, which will serve as defragmentation devices for the urbanized valley corridor, essential for the ecological restoration of the project area. In these areas, the prohibition of transformation is not intended for conservation per se but rather for restoration, preventing further land consumption or the introduction of functions that are inconsistent with the renaturalization of the area.

Conversely, multifunctional areas (in legend *Areas for multifunctional connectivity enhancement*, *any transformation must enhance the ecosystem value of the area*), which exhibit high multi-systemic capacities and play a key role in shaping the multifunctional GBI project, follow a different regime. Given the necessity of minimizing land consumption—particularly in mountainous regions—and avoiding functions incompatible with the surrounding natural environment, any transformation deemed essential will require appropriate compensatory measures. These measures should be commensurate with the function and scale of the intervention as outlined in the next chapter. As with the multifunctional framework, the regenerative framework (in legend *Areas for urban regeneration*, *any transformation must contribute to the requalification of natural urban spaces*) will also include a

provision for restrictions. If the planned interventions are deemed necessary and cannot be located in already urbanized, abandoned, and/or degraded areas, they must be adequately mitigated and compensated. This approach is intended to ensure alignment with the objectives of the GBI project for these areas, namely urban regeneration and the defragmentation of the dense and compact urban corridor.

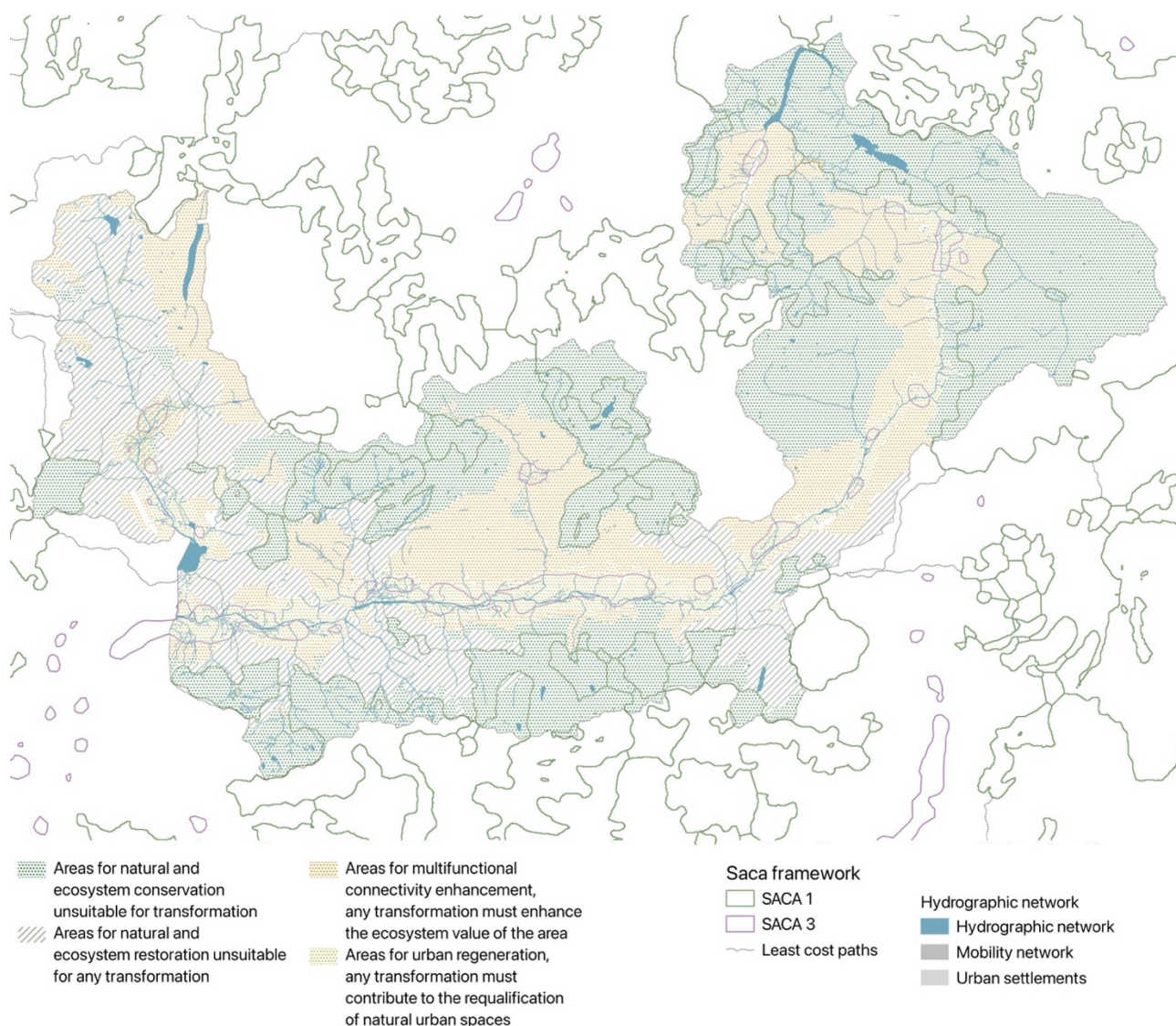


Figure 9 - Unsuitable and critical areas for anthropic development. Source: developed by FPM – DASTU/Lab PPTE working group



3 Connectivity measures and governance settings

3.1 Connectivity measures / action plan

The pilot project for our provincial Green Infrastructure Network (GBI) follows the boundaries of the previously identified local Corridor 5 (Figure 2). The selection of this specific area was primarily driven by its exemplary representation of the main objective of the GBI: to guide the defragmentation of the urbanized central corridor. The chosen corridor effectively connects two SACA1 areas located on opposite slopes, successfully identifying a potential link across the discontinuity caused by the dense urbanization of the settlements of (...).

Secondly, the choice was influenced by its geographical location. Although the project has so far maintained a provincial scale, its ultimate goal is to explore opportunities for restoring ecological connectivity within the densely urbanized area between Morbegno and Tirano.

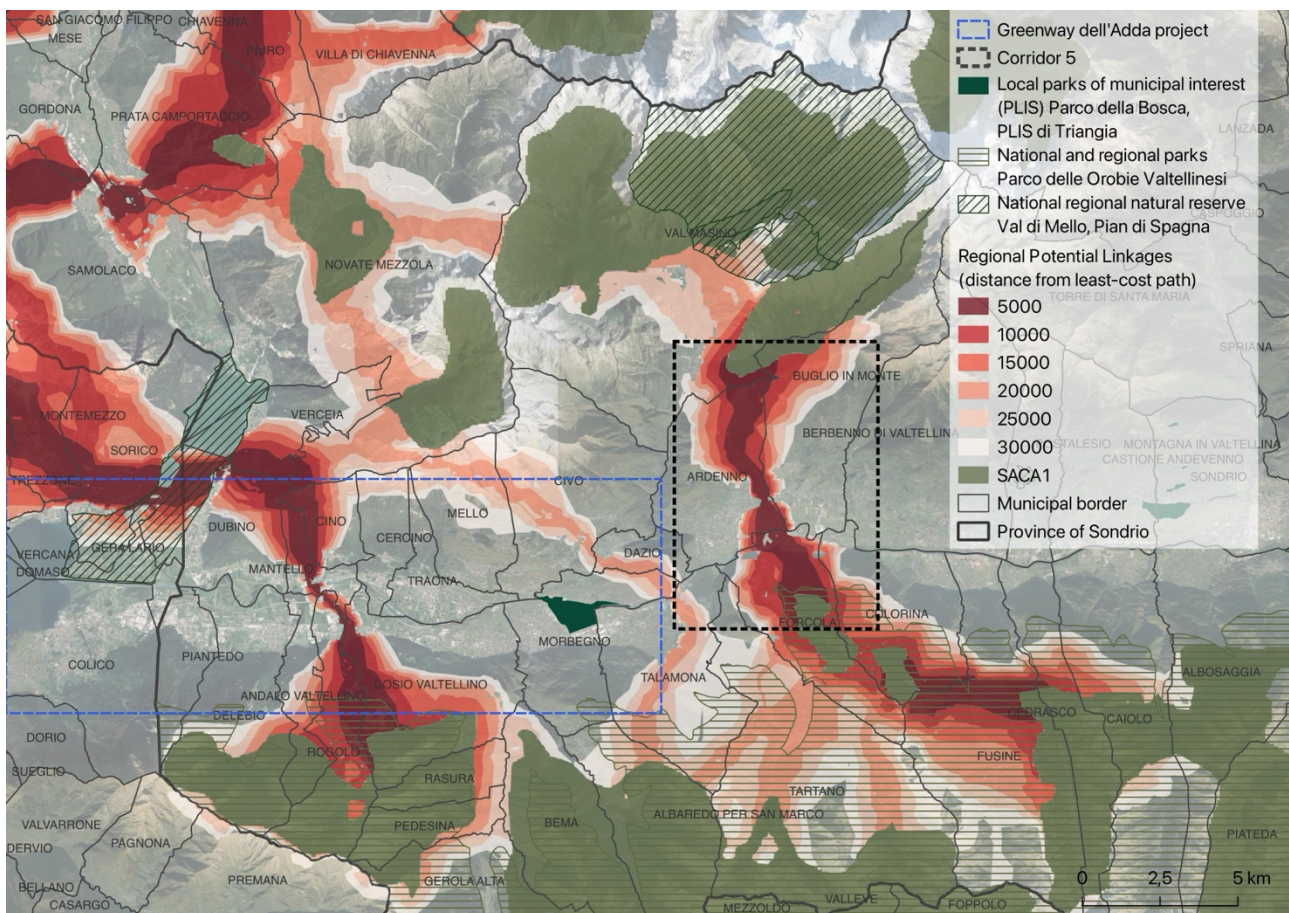


Figure 10 - Pilot corridor context. Source: developed by FPM – DASTU/Lab PPTE working group

As shown in Figure 10, the corridor is adjacent to an area of interest identified by the Life Greenway Adda project, which focused on a section of the Lower Valtellina as an opportunity for ecological restoration and improved public accessibility to the Adda River. As detailed in the following sections,

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

this initiative is in line with the multifunctional character of the GBI project. It not only proposes to increase the protection of specific areas, through the creation of ecological gateways and the proposal of new PLIS (Local Parks of Supra-local Interest) but also aims to establish a network with existing natural areas while promoting their sustainable use.

The corridor is located immediately to the east of the area covered by the Greenway Adda project and seeks to create continuity with this pre-existing initiative. It contributes to the promotion of further alternatives for the rehabilitation of the valley floor and the valorization of the existing natural heritage. In contrast to the Greenway Adda project, which addresses an east-west axis, the Regional Potential Connection identifies a north-south axis.

This supports the integration of elements, critical issues and vulnerabilities that characterize the territory from one valley to another, traversing different local specificities. These efforts reflect the strategic framework of the GBI: regenerative, multifunctional and strategic.

The further zoom into the corridor will not reiterate the three overarching frameworks but rather identify macro-areas for priority interventions in line with the strategic recommendations established at the provincial level. The corridor project proposes a more detailed identification of individual criticalities, previously represented as element densities, and aims to define priority areas for intervention. These are identified through the co-presence of multiple network elements, with each area accompanied by strategic guidelines as outlined in Tables 1, 2 and 3.



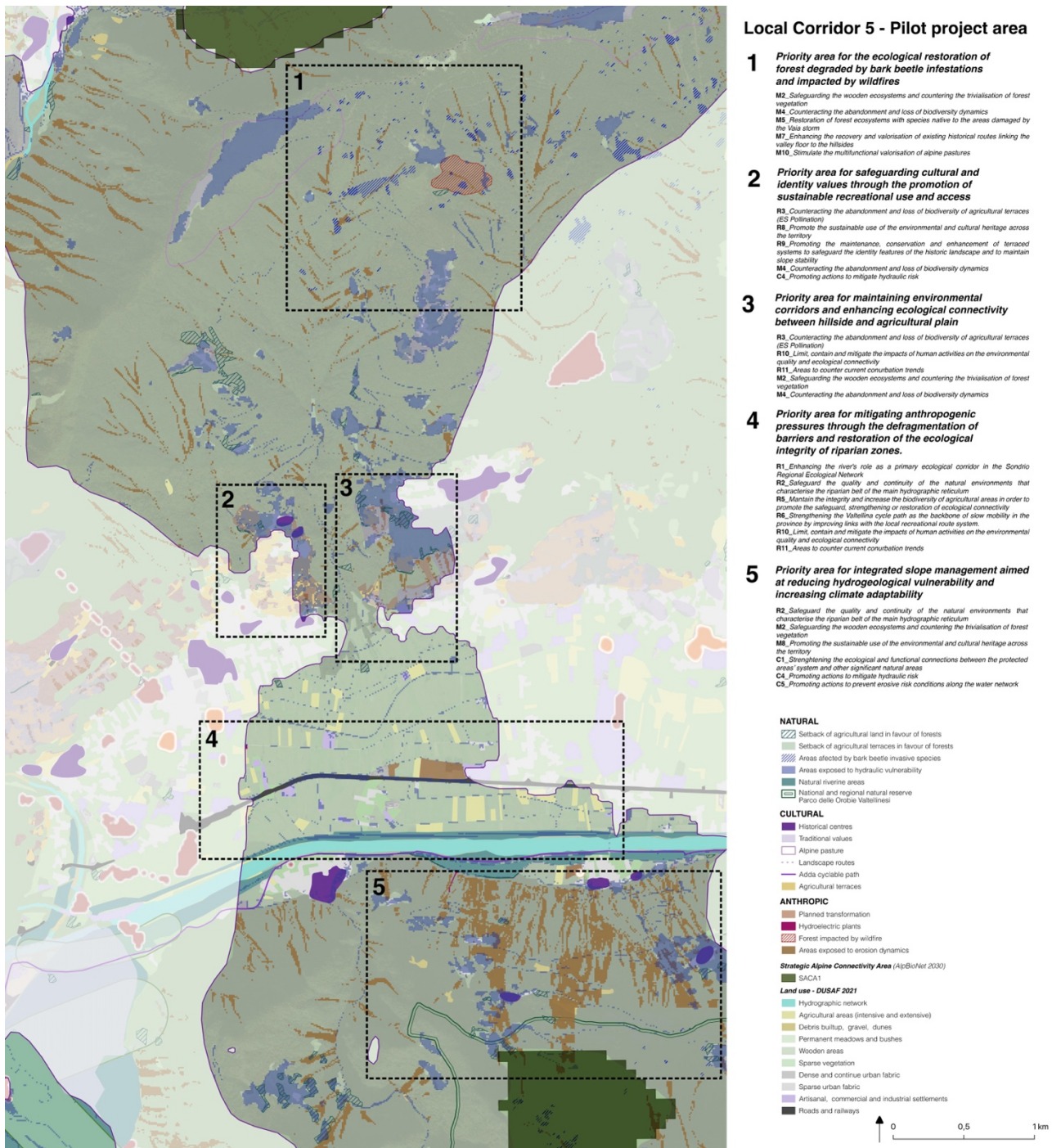


Figure 11 - Corridor 5 GBI Design. Source: developed by FPM – DASTU/Lab PPTE working group

Within the pilot corridor, five macro-areas for priority interventions have been identified. These areas are characterised by a concentration of key landscape and ecological features, which highlight priority zones for action within the multifunctional GBI framework. Each macro-area encompasses a set of territorial entities considered critical for the functionality and coherence of the GBI network, shaping specific objectives across thematic domains (climate-adaptation, cultural and recreational accessibility, slow mobility, anthropic activity).

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

For each macro-area, strategic guidelines have been defined to both reinforce and enhance the existing virtuous entities and dynamics, and to prevent or mitigate vulnerabilities and criticalities identified in the previous chapters. These strategic orientations are directly linked to the actions outlined in Tables 1, 2, and 3, which are to be contextually adapted to local specificities and implementation conditions.

1. Priority Area for the Ecological Restoration of Forests Degraded by Bark Beetle Infestations and Impacted by Wildfires

This area is characterised by significant environmental vulnerabilities, typical of mountain landscapes. On one hand, it includes extensive forested zones heavily affected by bark beetle outbreaks, where measures are required to counter the spread. These include systematic monitoring, sanitary felling of infested trees and/or engineering interventions to stabilise affected slopes and prevent further degradation.

Additionally, the area comprises forest stands degraded by wildfires, which require restoration and re-naturalisation through the planting of native tree and shrub species to re-establish ecological structure and resilience.

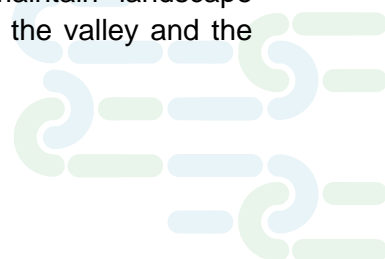
Strategic recommendations also aim to promote the multifunctionality of these landscapes by enhancing their ecological, recreational, and cultural value. This includes the restoration and valorisation of scenic trails, and the improvement of connectivity between mountain slopes, alpine pastures, and valley floors, contributing to both ecological continuity and sustainable local development.

2. Priority Area for safeguarding cultural and identity values through the promotion of sustainable recreational use and access

This area, situated in close proximity to the valley floor, is characterised by the interplay between natural vulnerabilities and human-induced pressures, both cultural and agricultural. A major concern is the progressive abandonment of traditional agricultural practices, particularly within terraced landscapes. This trend has led to forest advancement, resulting in a measurable decline of both pollination services and the cultural values historically embedded in these agro-ecological systems. Reversing this dynamic is essential to preserve both biodiversity and the cultural identity of the landscape.

3. Priority areas for maintaining environmental corridors and enhancing ecological connectivity between hillside and agricultural plain

This area, similarly to the previous macro-zone, is characterised by the dual presence of natural and anthropogenic elements. Given the proximity to the urbanised zones, there is a tangible risk of urban sprawl and the gradual conurbation of settlements. These processes threaten the ecological continuity between the valley floor and the surrounding mountainous areas. It is therefore crucial to implement planning measures that prevent further urban development, maintain landscape permeability, and enhance the ecological connectivity and continuity between the valley and the mountain area.



4. Priority area for mitigating anthropogenic pressures through the defragmentation of barriers and restoration of the ecological integrity of riparian zones

This area corresponds to the location of key physical barriers that contribute significantly to the ecological fragmentation within the project territory. In particular, the alignment of major transport infrastructures, as the main road and the railway line, creates substantial obstacles to ecological connectivity between the two valley slopes.

Running parallel to these infrastructures is the river corridor, which represents a primary ecological corridor of the area, together with the riparian zone that hold high ecological and naturalistic value. In this context, the Green and Blue Infrastructure (GBI) strategy faces the critical challenge of strengthening and enhancing the role of the river system as a core element of the ecological network. This objective is further supported by the presence of the Valtellina cycling route, which runs adjacent to the Adda River and provides an opportunity to integrate ecological restoration with sustainable mobility and recreational functions.

5. Priority area for integrated slope management aimed at reducing hydrogeological vulnerability and increase climate adaptability

The southern slope is characterised by a high degree of environmental vulnerability, primarily related to erosion and hydrogeological instability. Targeted strategies must be developed to identify and monitor high-risk zones, with the application of soft engineering techniques aimed at improving slope stability and preventing potential landslide events, particularly in areas close to human settlements. An integrated approach is required, able to combine risk mitigation with a redefinition of the recreational accessibility to the area. This includes the restoration and reconnection of landscape corridors linking the slope with the riparian zones of the Adda River and the adjacent cycling route. Such an approach supports the transition toward a more resilient and antifragile territorial system, enhancing both ecological connectivity and adaptive capacity in the face of environmental change.

3.2 Key Stakeholders

The analysis of stakeholders potentially involved in the implementation of the multifunctional green-blue network project for the pilot area of the Province of Sondrio began with the development of a preliminary mapping. This mapping was organized according to stakeholder categories commonly adopted by all project partners, namely:

Public Authorities and Institutions, which include both local entities at different levels (technical representatives from key sectors of the Province of Sondrio, institutional representatives from municipal administrations, municipal unions, or Mountain Communities), as well as representatives of national governmental institutions, particularly the Ministry of the Environment and Energy Security (MASE). The project is also closely aligned with the coordination activities of the Alpine Convention for the 2025–2026 period. This collaboration has been further reinforced by the seminar hosted at the Politecnico di Milano on 16 April 2025, which provided a platform for strategic dialogue and knowledge exchange among key stakeholders.

Users, namely representatives of trade associations and consortia such as CIA – Italian Farmers Confederation, Coldiretti, Confagricoltura, Confartigianato, the Valchiavenna Tourism Consortium, the Valtellina Cultural District, and environmental, volunteer, or territory-based associations, such as Volontari per la Cultura, Associazione Dappertutto ODV, hiking associations, local WWF chapters, etc.

Experts, including representatives from organizations and professional associations operating in various sectors in the region, such as members of technical professional orders (architects, engineers, etc.); representatives of the Rural Network or EBAS – the Agricultural Bilateral Entity of the Province of Sondrio; representatives of cultural associations such as the Valtellinese Economic Society or the Valtellinese Historical Society; representatives of organizations or consortia dedicated to the protection and promotion of specific agro-food supply chains, who may act as both experts and users — such as the Quality Agro-Food District or the various consortia for the protection and promotion of typical local products (pizzoccheri, wines, apples, cheeses, bresaola, etc.).

Funders, including foundations or banking institutions operating in the provincial territory (e.g., Banca Popolare di Sondrio or Fondazione Credito Valtellinese) as well as cooperatives or foundations focused on enhancing the local area, such as Fondazione ProVinea or Fondazione ProValtellina.

To these four categories common to all project partners, a fifth was added: **"Users/Authorities"**, which includes institutional entities that are custodians of specific ecological-environmental knowledge and can be involved in the project both as implementers and as beneficiaries of actions contributing to the implementation of the strategic design of the multifunctional green-blue network. This category includes, for example, representatives of the two large parks present in the provincial territory (Stelvio National Park and the Orobie Valtellinesi Park), local parks (PLIS), and nature reserves.

The stakeholder mapping served as a foundation for activating the **Regional Connectivity Working Group (RCWG)** — the technical panel initiated by the FPM/DASStU Polimi working group as part of the *PlanToConnect* project activities, aimed at actively involving key stakeholders in developing green-blue network strategies for the pilot area.

In the preliminary mapping (Fig. 17), each stakeholder was also assigned a **high/low potential level of influence**, understood as the ability to concretely intervene in the implementation of the green-blue network project, and a **high/low level of interest**, based on the potential impacts of the project's implementation.

This preliminary categorization aimed to identify the stakeholders to be involved as a priority.

The analysis highlights the particularly significant roles of the **Province of Sondrio**, as well as of **park authorities and Mountain Communities**. The Province is especially relevant due to the ongoing revision of the **Provincial Territorial Coordination Plan (PTCP)** — an important opportunity to integrate the outcomes of the green-blue network project for the pilot area into the main territorial and landscape planning tool at the provincial scale.

Park authorities and Mountain Communities are key players operating closely on the ground for the protection, preservation, and enhancement of natural capital. They can therefore act in synergy with the Province to implement widespread territorial maintenance actions, promote increased naturalization, and involve additional stakeholders and resources — including through participation in further research projects or by accessing new funding opportunities.

The Province also plays a crucial role in **guiding municipal administrations**, both in territorial planning and in potentially coordinating inter-municipal actions to implement the green network strategy.

The involvement of municipalities is essential, especially for **redefining development forecasts** that may impact the territory and for identifying **mitigation and compensation measures** related to future transformations.



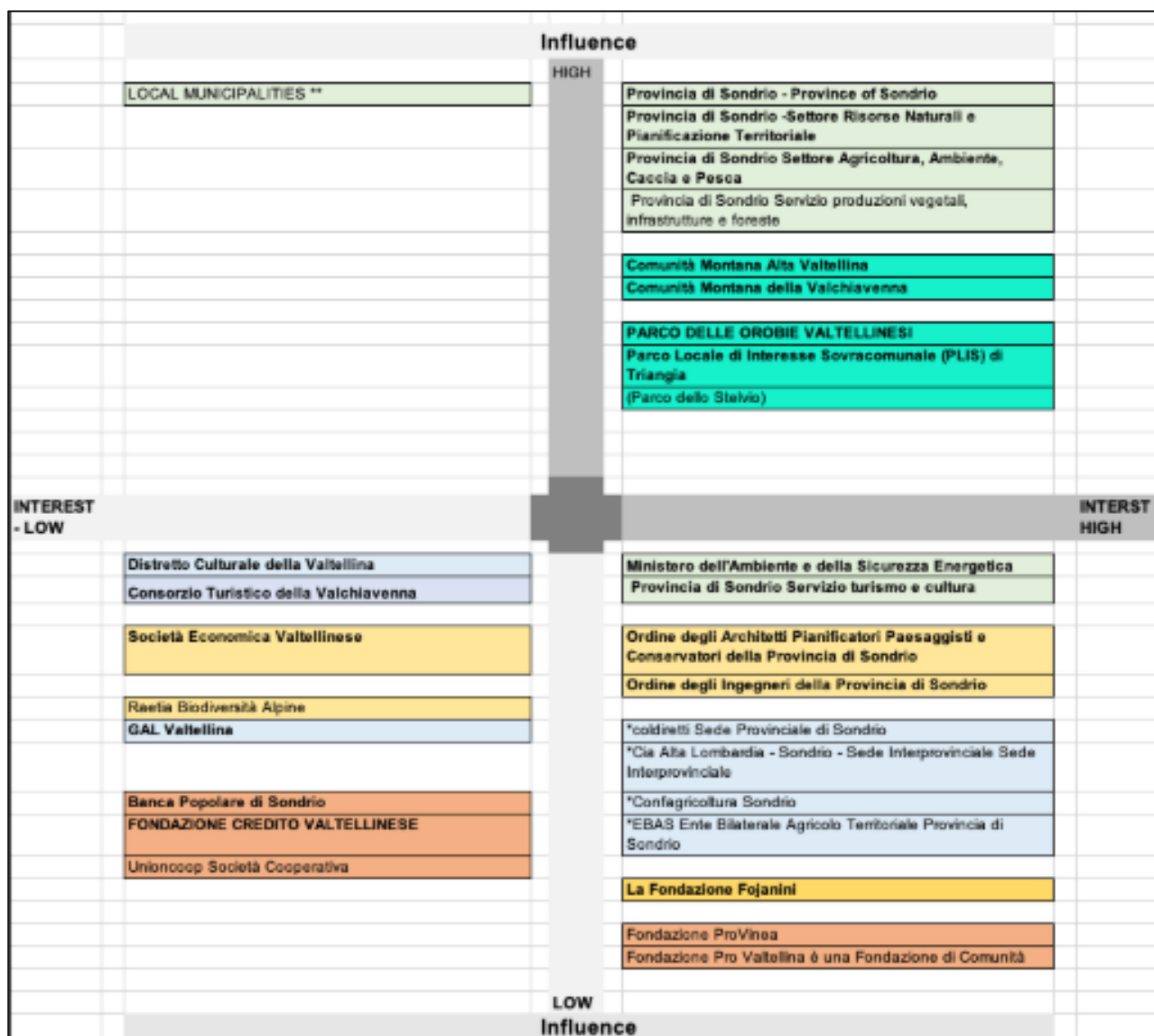


Figure 12 - Preliminary Mapping of Stakeholders for the Pilot Area. Source: Developed by the FPM – DASTU/Lab PPTE Working Group

Regional Connectivity Working Group of Sondrio Province

The RCWG (Regional Connectivity Working Group) is tasked with supporting and enriching the technical-scientific process of developing the multifunctional green-blue network in the province of Sondrio. This will be achieved through a process of dialogue and collaboration, including workshops and collaborative work sessions, training and mutual learning activities, and dissemination events.

The goal of the Pilot in the Province of Sondrio is to enhance the collaborative dimension by integrating the three types of activities foreseen by the European Project. This will be done by building an integrated and synergistic path together with the stakeholders of the RCWG.

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

For this reason, the RCWG's workshop activities (A3.1), mutual learning sessions (3.2), and dissemination through the Pilot's final event (A2.6) will be approached in an incremental and flexible manner. This process will involve a small core group of stakeholders (the core RCWG) on an ongoing basis. Together with Fondazione Politecnico di Milano and the Department of Architecture and Planning, this group will define and subsequently follow the activity/meeting programme. The RCWG will then expand to include a flexible number of stakeholders depending on the topic or focus of individual workshops or mutual learning sessions.

The composition of the RCWG should be understood as incremental and flexible: the working group will grow throughout the process, involving new stakeholders in relation to the themes and challenges that emerge during the development of the multifunctional green-blue network project.

The stakeholders involved in all activities are:

- Representative from the Territorial Planning Service, Province of Sondrio
- Representative from the Agriculture-Forestry Service, Province of Sondrio
- Representative of the Valchiavenna Tourism Consortium
- Representative of the Valchiavenna Mountain Community
- Representative of the Alta Valtellina Mountain Community
- Representative/Manager of the CIA (Italian Farmers Confederation) Alta Lombardia
- Director and Scientific Manager of the Stelvio National Park
- Representative of the Ministry of the Environment and Energy Security (MASE), Alpine Convention and National Biodiversity Strategies
- Biodiversity expert/consultant for the province and University of Pavia / REsilienceLAB
- Expert planner/consultant for the Territorial Plan of Sondrio
- Manager of the Pian di Spagna and Lake Mezzola Nature Reserve
- Ministry of the Environment and Energy Security (MASE)





Figure 13 - Stakeholder Map of the RCWG: core actors at the center and potentially involved actors positioned around the circle based on the thematic focus of activities. Source: Developed by the FPM – DASTU/Lab PPTE Working Group

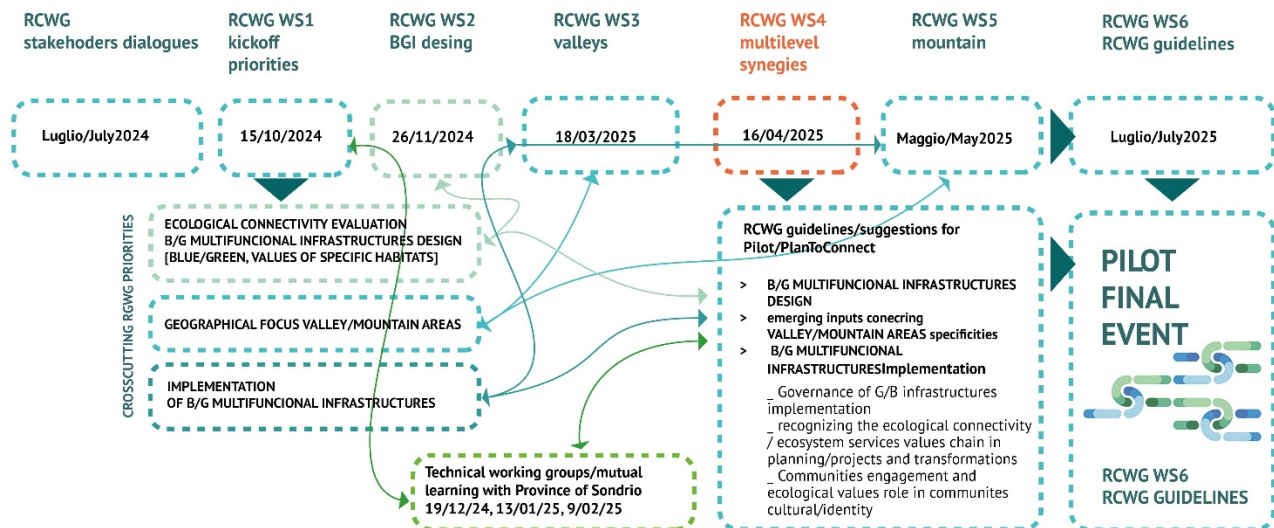


Figure 14 - Timeline and Diagram of the Flexible and Incremental Process of RCWG Activities and Emerging Priority Themes (Flexible and Incremental Process). Source: Developed by the FPM – DASTU/Lab PPTE Working Group

3.3 Governance settings

In the governance processes aimed at safeguarding and enhancing ecological connectivity within the provincial territory, a key role can be played by the Province, the Mountain Communities, and

Multifunctional Green & Blue Infrastructure for the Province of Sondrio

especially by the entities responsible for the management of parks and protected areas. As previously mentioned, these areas collectively cover over 40% of the province's surface. Through management plans or territorial plans of the parks, specific objectives and actions are defined to maintain ecological corridors and to protect animal species and ecosystems within the designated protected areas. Moreover, managing authorities carry out essential monitoring activities to assess the effectiveness of implemented actions and to identify necessary adjustments.

A core objective of the **PlanToConnect** project is the establishment of widespread ecological connectivity, aimed at integrating areas that already hold high ecological and environmental value while simultaneously enhancing the overall ecosystem services performance across the territory. Achieving this goal requires the activation of shared governance frameworks involving a variety of stakeholders operating at different levels in the territory, including actors from the agro-silvo-pastoral, energy, and tourism sectors. In this regard, park authorities are well positioned to assume a coordinating role in the development of joint initiatives and in facilitating the formulation of agreements or conventions.

Among the tools available to these entities, particular attention should be paid to **Payments for Ecosystem Services (PES)** schemes, which can be instrumental in managing relationships with individual land users and operators to achieve specific objectives related to the conservation, management, and enhancement of natural capital. As illustrative examples, two recent PES-based initiatives implemented in the Lombardy region—relevant to the context of the Province of Sondrio—are briefly presented below. These initiatives aim to foster virtuous collaboration between park authorities and stakeholders in the agro-silvo-pastoral sector for the restoration and safeguarding of ecosystems and can serve as valuable governance references for the RVB project developed under PlanToConnect.

The first case is the “**Natura Vagante**” project, co-funded by Fondazione Cariplo under the “Natural Capital 2018” call and coordinated by the Adda Nord Regional Park. The project was developed within a partnership involving local authorities, Local Parks of Supra-municipal Interest (PLIS), universities, and environmental and cultural associations. It introduced a PES scheme to support environmental services associated with transhumant sheep grazing, with the aim of fostering sustainable and consistent land stewardship practices and controlling invasive alien species. The PES operates as an agreement between landowners and shepherds, supported by the park authority or local governments. It acknowledges the role of grazing in conserving semi-natural habitats of high ecological value (e.g., dry meadows along riverbanks), contributing to the maintenance of undergrowth, clearing of abandoned lands and riverbanks, and conservation of ponds and wetlands. A second example is the “**ECOPAY-Connect Oglio Sud**” project, promoted by the Oglio Sud Regional Park to enhance biodiversity through ecological and river restoration activities. The project developed participatory PES schemes to establish public-private partnerships involving the park authority, the wood industry, and poplar growers under the common framework of **FSC® (Forest Stewardship Council) certification**. Given the market's growing demand for FSC-certified poplar wood and the associated requirement to set aside 10% of plantation land for ecosystem restoration, participating agricultural enterprises signed a five-year agreement with the park authority. This agreement commits them to carry out equivalent conservation actions on natural parkland, thereby avoiding the need to forgo productive land within their own properties. The ECOPAY-Connect model

was later adopted as a best practice by the **LIFE IP GESTIRE 2020** project, which aims to implement integrated management of the **Natura 2000 Network in Lombardy**, optimizing the use of resources and investments to fulfill the **2014–2020 Prioritized Action Framework (PAF)**.

Among the actions promoted by the Lombardy Region within the LIFE IP GESTIRE 2020 project, a noteworthy example is the **pilot governance model for the Adda Greenway in Lower Valtellina** (Action C21), previously mentioned as covering a significant portion of the provincial territory. The participatory process initiated by the project engaged local authorities in developing a shared cartographic representation and a strategic framework document outlining investment opportunities for the Greenway's development, with a particular focus on enhancing the supra-municipal ecological network. The goals were to establish a local partnership, promote inter-institutional cooperation, and improve the financial sustainability of actions to maintain and strengthen ecological connectivity. A key strategic element defined during the planning phase was the **Valtellina Trail**, envisioned as the unifying axis of the valley floor, around which actions for the valorization and restoration of natural resources, sustainable land use, and ecological rehabilitation of degraded landscapes could be structured. The process may serve as a useful reference for the activation of similar initiatives across other parts of the province, especially where connected to the broader recreational and hiking trail network of the valley and its slopes.

As well as the Adda Greenway project in Lower Valtellina was developed in continuity with the **“Contratto di Fiume dell’Alto Bacino del Fiume Adda” (Upper Adda River Basin River Contract)**. The strategic intervention framework produced by the Greenway project has been formally incorporated into the River Contract's Action Program. While the governance tools described above may serve as models for initiating shared projects and targeted actions, the River Contract offers a valuable existing framework to structure governance efforts at the provincial scale. This is a **negotiated planning instrument**, locally initiated by the **Comunità Montana Valtellina di Sondrio** in 2015, not as a regional imposition, with the goal of protecting and enhancing the landscape and riverine environment of the Upper Adda River Basin. It is a voluntary agreement that aims at shared planning and active participation by all stakeholders in the area. Signing the contract entails a commitment to implement actions based on public utility, economic efficiency, social value, and environmental sustainability. The negotiated planning framework and its corresponding action program were approved in May 2019, with more than 50 entities and associations involved.

Based on the River Contract model, another notable experiment in participatory governance is the **Ecological Network Contract**, specifically designed to support the implementation of ecological networks beyond traditional watershed boundaries. This initiative was led by the Province of Varese, LIPU, and other partners through a sequence of interconnected projects: i) “Natura 2000 VA” (2008–2009), funded by Fondazione Cariplo; ii) “Ecological Connectivity for Biodiversity – Feasibility Study” (2009–2011); iii) “Biodiversity Project – Completion of the Network Contract Process” (2011); iv) “LIFE10 NAT IT 241 – TIB: Trans Insubria Bionet”, co-funded by the LIFE+2010 Programme, aiming to connect and improve habitats along the Insubric ecological corridor from the Alps to the Ticino Valley.

The initiative involved over 50 municipalities situated between the Campo dei Fiori Regional Park and the Lombardy Regional Park of the Ticino Valley. Following the initial feasibility study identifying two priority corridors, a participatory process was launched to engage stakeholders in drafting a preparatory protocol for the Ecological Network Contract. This protocol was signed in February 2011 by the Province, the two park authorities, and 32 municipal administrations. In 2013, two key documents were approved: i) the Ecological Network Contract itself, a voluntary agreement adopted by the Provincial Government, the two Parks, and local councils, committing them to the conservation of the Campo dei Fiori–Ticino ecological corridor through integration into spatial planning documents and identification of priority conservation actions; ii) the Campo dei Fiori–Ticino Ecological Network Scheme, formally approved by the Natura 2000 site managers, the Province, and the two Parks. This scheme introduced simplified Appropriate Assessments (screenings) for plans and projects affecting the corridor, even when located outside Natura 2000 sites. This case too represents a best practice that can serve as a replicable model for the governance of GBI-related projects in the pilot area of the Province of Sondrio.

3.4 Funding instruments

The successful implementation of the Green and Blue Infrastructure (GBI) strategy for the Province of Sondrio requires the identification and mobilisation of appropriate funding mechanisms, tailored to the different types of actions foreseen. Based on a preliminary review of the main financial instruments currently available, three broad categories of funding sources can be outlined: i) European-level instruments, including, among others the Cohesion Fund, the European Regional Development Fund (ERDF), the Horizon Europe and LIFE programmes, the European Agricultural Fund for Rural Development (EAFRD), including the National Rural Development Programme (NRDP); ii) National and regional instruments, covering a wide range of public funding opportunities and economic incentives provided by the central government or regional authorities, often linked to specific thematic areas (e.g., regional support for the restoration of traditional terraced landscapes); iii) Innovative and hybrid mechanisms, such as public-private partnerships (PPPs), and market-based tools including Payments for Ecosystem Services (PES), which can support targeted biodiversity conservation, landscape maintenance, and ecosystem service enhancement.

To facilitate the identification of suitable funding sources, the actions included in the GBI strategy have been grouped into six thematic macro-categories. For each category, a non-exhaustive selection of potential financing mechanisms is proposed. The detailed list of actions, referenced through their specific alphanumeric codes, is provided in the final column and corresponds to those presented in the strategic framework tables (Tables 1, 2 and 3).

It is important to note that many of the financing instruments listed are tied to specific calls for proposals or time-limited programming periods. Nonetheless, they have been included here as indicative references, given their alignment with EU, national, and regional strategic objectives. It is reasonable to assume that these instruments—or their successors—will continue to be made available in future programming cycles. This assumption is particularly relevant in light of the fact

that the implementation timeline for the proposed GBI actions remains flexible and subject to further development.

Table 4 - Funding instruments for the GBI implementation. Source: developed by FPM – DASTU/Lab PPTE working group

Connectivity measure	Funding Instrument	EU, National, Innovative	Description	GBI actions
Protection and enhancement of biodiversity and ecological connectivity of the environmental system (protected areas)	LIFE Programme	EU	EU financial instrument for the environment and climate action. Through LIFE calls, projects to protect, maintain and restore natural capital are funded, contributing to the achievement of the objectives of the EU Biodiversity Strategy 2030, the Birds and Habitats Directives and the Invasive Alien Species Regulation.	M3; M5; C1; C3
	Natura 2000 Funding / Prioritised Action Frameworks PAF - ERDF Funds	EU	These are strategic documents for the long-term planning of the implementation of the Habitats and Birds Directives, as well as the management of the Natura 2000 Network. They identify the priority measures necessary for maintaining or restoring the favourable conservation status of habitats and species of community interest, and provide an estimate of the related financial requirements linked to the most appropriate EU funding programmes.	
	Nature Restoration Law	EU/National	Within two years of its introduction, each Member State must have a Restoration Plan mapping the conservation needs of its territory and identifying measures to achieve the 2030, 2040 and 2050 goals. These targets include increasing the population of pollinating insects, protecting forest and urban ecosystems, and removing barriers to river connectivity.	
Protecting and enhancing the biodiversity and ecological connectivity of the rural system	National Development Programme PAC 2023-2027 – FEASR Funding	EU/National	Financing measures for the implementation of the priority objectives of the PAC, in particular: (i) combating climate change by reducing greenhouse gas emissions and improving carbon sequestration in the agricultural sector; (ii) protecting the environment through efficient management of natural resources (water, soil, air); (iii) preserving the landscape and halting biodiversity loss	R4; R5; M1; M4; C2
	Funds for Small Reservoirs and Water Collection and Storage Systems 2023	National/Lombardy region	Call for contributions for the optimisation of water resource management in mountain territories through the construction, restoration and extraordinary maintenance of small reservoirs and water collection and storage systems, as well as the related adduction and distribution systems. Aimed at mountain municipalities,	

Connectivity measure	Funding Instrument	EU, National, Innovative	Description	GBI actions
			mountain communities, agricultural enterprises, owners or managers of mountain pastures, mountain huts, mountain pasture forestry consortia. (expired December 2023)	
	PES	Innovative tools	Public-private agreement for the management and enhancement of the natural capital	
Restoring the naturalness of watercourses and riparian strips (Adda river and water reticulum)	LIFE programme	EU	* See category Protection and enhancement of biodiversity and ecological connectivity of the environmental system (protected areas)	R1; R2; C2
	Nature Restoration Law	EU/National		
Extensive land maintenance and prevention of hydrogeological risks	Call for agricultural terraces 2023 – Lombardy region	National/Lombardy region	Grants for the extraordinary maintenance and recovery of terraces and structural elements of the rural landscape in the mountain context. The call for applications is currently closed but similar calls for applications may be envisaged in the future pursuant to LR 31/2008, art. 23.	R3; R9; M2; M6; C3; C4; C5
	Hydrogeological Instability call 2024 – Lombardy region	National/Lombardy region	Non-repayable financing is available from the FOSMIT fund (Fund for the Development of the Italian Mountains) to support soil protection measures in mountain areas. This funding can be used for soil protection interventions and works, settlement of hydrogeological instability (including on slopes), and the extraordinary maintenance and hydraulic regulation of the minor water reticulum of municipal jurisdiction. (Expired in 2025)	
	ERSAF Convention - Lombardy region 2025-2027	National/Lombardy region	Convention for the financing of hydraulic defence works on the main water reticulum of regional competence.	
	PES	Innovative tools	Public-private agreement for wooden areas management	
Mitigation of the existing/planned anthropic activities	Green area fund	National/Lombardy region	This fund collects proceeds from increased construction contributions for new urbanisation projects on agricultural land. Municipalities that have contributed to the fund may apply for funding, which may include an additional regional bonus, to finance projects that create green spaces.	R10; R11; R12; M11; M12
	Cariplo Foundation Fund – Climate strategy	National	Supporting territorial alliances in initiating pathways to climate neutrality and community resilience by 2040. The aim is to establish partnerships between entities to drive climate transition processes in various action areas. (Deadline: April 2024/June 2025.)	

Connectivity measure	Funding Instrument	EU, National, Innovative	Description	GBI actions
Promotion of sustainable touristic and recreational	Sustainable Tourism Fund 2024	National	A ministerial fund with three-year validity (2023–2025) is available to accommodation facilities and tourism enterprises. The fund is intended to support initiatives aimed at mitigating tourist overcrowding, creating innovative tourist itineraries, promoting intermodal tourism, and desaisonising tourism.	R6; R7; R8; M7; M8; M9; M10; M12; C6; C7; C8
	FOSMIT – Development of Italian Mountains' Fund	National	Fund for the development of the Italian mountains (FOSMIT) for local authorities, public mountain entities and private entities involved in trail development.	
	Cariplo Foundation Call – Mountains in transition	National	Call for supporting the new challenges for the highlands against the backdrop of the climate crisis: fostering the spread of mountain economies alternative to snow tourism; facilitating the dissemination of good practices for adapting to climate change; deseasonalising the tourism offer. (deadline May 2025)	



4 Proposal(s) for the implementation of the GBI network plan into spatial and sector planning tools

4.1 State of art of connectivity planning and implementation in the pilot area

The GBI project was developed in alignment with the framework of objectives and strategies established for the provincial territory by the existing planning instruments at different governance levels. These include: the Regional Territorial Plan (PTR), the Regional Landscape Plan (PPR), the Regional Plan for Protected Areas (PRAP), the current Provincial Territorial Coordination Plan (PTCP), and the Regional Area Territorial Plan (PTRA) for “Medium and Upper Valtellina”.

Specifically, in Lombardy, the "System of Lombard Protected Areas", established under Regional Law 86/1983, is governed by the PRAP, which includes national and regional parks, supra-municipal parks, national and regional nature reserves, natural monuments, Natura 2000 sites, SPAs (Special Protection Areas), and the Regional Ecological Network (RER).

This network forms part of a cascading planning system, within which regulatory and legislative references are defined for the establishment and management of nature reserves, parks, and natural monuments, as well as areas of significant naturalistic and environmental value at subordinate spatial levels. The plan is integrated into the National Biodiversity Strategy and implemented at the regional level through the “Regional Biodiversity Strategy”, within the Regional Development Plan (PRS), and in coherence with both the Regional Territorial Plan (PTR) and the Regional Landscape Plan (PPR).

The 2022 update of the current PTR identifies the Regional Green Network (RVR) and the Regional Ecological Network (RER) as strategic projects, with the latter considered the main green infrastructure (GI) to be implemented at the provincial level through the PTCP and at the municipal level through the Municipal Territorial Governance Plans (PGT). Moreover, the PTR, pursuant to Regional Law 12/2005, mandated the drafting of the PTRA for the Medium and Upper Valtellina, which defines additional objectives in terms of environmental, landscape, and territorial rebalancing, and promotes cross-border connections to create new development opportunities and synergies across Alpine regions.

At the provincial level, the primary planning reference for the definition of multifunctional connectivity objectives is the current PTCP (2010), which already anticipates several topics of interest for the project. These will be further detailed and updated in the ongoing revision of the PTCP. This update will directly engage with the guidelines of the 2022 “Regional Biodiversity Strategy” of the Lombardy Region, which aligns with both the European and National Biodiversity Strategies. Given the area's high natural value and rich landscape character, the current PTCP defines a set of priority guidelines for the territory aimed at restoring terrestrial ecosystems, conserving and

enhancing ecological-ecosystem values, and implementing an RVB capable of ensuring ecological-functional connectivity at both local and supra-local scales. These guidelines form the basis of the PlanToConnect RVB project.

The overarching objective of conserving, protecting, and enhancing the overall environmental quality of the territory is fundamental to achieving a balanced socioeconomic development of the province.

This general goal is further articulated into eight macro-actions, among which the following are particularly relevant to the project: i) the valorisation of widespread landscape and environmental features; ii) the rational use of natural resources such as soil and water; iii) territorial regeneration aimed at addressing key existing landscape challenges.

Specifically, the current PTCP directs municipal planning to reduce practices contributing to ecological fragmentation, concerning urban and peri-urban fringes and the conurbation process.

In line with the guidelines set by higher-level planning instruments, in 2021 the Province of Sondrio developed a set of strategic guidelines to support the revision process of the PTCP, which is currently underway. These guidelines identify strategic objectives for the ecological and green networks at the provincial scale. In particular, with respect to the ecological network, the PTR's Objective OS17—ensuring the quality of natural and environmental resources specific to mountain areas—is reinterpreted at the provincial level with some enhancements to strengthen its connectivity dimension. Two large-scale projects defined by the PTR are integrated into this framework:

- Development of the **Adda River greenway as a slow mobility backbone** (MAV 1_1.B) through the rehabilitation of degraded riparian and ecological areas and the promotion of sustainable mobility;
- Promotion of the **ecological network** (MAV 1_1.E) by enhancing the role of the provincial ecological network, consolidating its ecological corridors, and counteracting fragmentation in critical ecological passages.

These objectives aim to strengthen the ecological connectivity necessary for biodiversity conservation and to mitigate the isolation of Natura 2000 sites.

4.2 Integrating the Green and Blue Network project into spatial and local planning instruments

The following table provides a summary of the potential impacts of the GBI project on existing planning instruments. The table is structured according to a common format adopted by all project partners, facilitating comparative analysis across the different project proposals developed for the PlanToConnect pilot cases.

The table identifies the main planning instruments that could fully or partially incorporate the contents of the GBI project, specifying whether such instruments are mandated by the current planning framework or developed on a voluntary basis or in response to specific needs or priorities. It then outlines the role these instruments play in relation to ecological connectivity and suggests how they could be integrated with the strategic content of the GBI.

Focusing on the Sondrio province pilot, the core theme of the GBI project is **multifunctionality**. For this reason, the analysis highlights whether and how this concept is already addressed within the planning instruments under consideration. This allows for the identification of possible further

synergies between the strategic and regulatory frameworks of these instruments and the objectives of the GBI project.

Regarding the target audiences of the proposal, the Province of Sondrio has been directly involved in the various stages of project development through the activities of the Regional and Cross-border Working Group (RCWG). Regione Lombardia (responsible for the PTR) may be engaged at a later stage, particularly in relation to the ongoing PTR revision process. Municipal administrations, on the other hand, may participate in dissemination and outreach activities related to the project results, as outlined in section 3.2.

Table 5 - Overview of spatial planning instruments addressed. Source: developed by FPM – DASTU/Lab PPTE working group

Instrument	Mandatory Voluntary	Relevance for connectivity in pilot area. Gaps or inconsistency	Recipient and content of the integration proposal
Provincial Coordination Territorial Plan (PTCP)	M	<p><i>Ecological connectivity:</i></p> <p>Provincial ecological network project: integration of currently planned corridors, integration of widespread actions on the territory according to the characterisation of RVB frameworks and priorities, redevelopment of periglacial areas.</p> <p><i>Multifunctionality:</i></p> <p>Possible PTCP contents integrations concerning</p> <ul style="list-style-type: none"> Assessment of the abandonment state of terraces; Assessment of fruitive routes, elements of decay and landscape values of the territory; Assessment of hydrogeological instabilities 	<p>Province of Sondrio, Territorial Planning Sector</p> <ul style="list-style-type: none"> Methodological proposal for the assessment of the ecosystem performance for the provincial territory; Methodological proposal for the assessment of pressure and threat elements for ecological connectivity; Proposal of new corridors able to connect the two valleys and characterisation of corridors; Proposal of priority actions for ecological connectivity and extensive actions to safeguard and increase the ecosystem performance of the provincial territory; Focus Corridor 5 / Action Plan.
Territorial Plan for the Upper and Central Valtellina	V	<p><i>Ecological connectivity:</i></p> <p>MAV ecological network project, Landscape of silence (Valli del silenzio) ecological core and possible updates and additions concerning the strategic objective of promoting environmentally compatible energy actions</p> <p><i>Multifunctionality:</i></p> <p>Possible integrations with respect to the following PTR objectives</p> <ul style="list-style-type: none"> Restore skiing domains; Developing the Adda Greenway as a slow mobility backbone; 	<p>Lombardy Region, General directory Territory and Green System</p> <ul style="list-style-type: none"> Methodological proposal for the assessment of pressure and threat elements for ecological connectivity; Proposal of new valley interconnection and characterization corridors; Proposal of actions for the promotion of sustainable tourism and deseasonalisation.

Instrument	Mandatory Voluntary	Relevance for connectivity in pilot area. Gaps or inconsistency	Recipient and content of the integration proposal
		<ul style="list-style-type: none"> Supporting the multifunctional value of rural landscape activities; Enhance the historical paths; Enhance the identity of the historical landscape. 	
Municipal Urban Plan (PGT)	M	<p><i>Ecological connectivity:</i></p> <p>Municipal ecological network project (REC): possibility of identification of new PLIS and integration at the local scale of the strategic orientations of the GBI project;</p> <p>Plan Document and NTA: definition of settlement forecasts and related compensation and mitigation measures.</p> <p><i>Multifunctionality:</i></p> <ul style="list-style-type: none"> Identification of strategic agricultural areas at the local scale; Identification of the network of recreational routes and slow mobility in connection with the Adda Greenway; Identification of actions for sustainable water management (SUDs). 	<p>Municipalities involved in RCWG dissemination activities:</p> <ul style="list-style-type: none"> Identification of areas unsuitable for the location of new settlements or human activities; Indications for the identification, maintenance and defragmentation of crossings at the local scale; Indications for the agrobiodiversity enhancement of the peri-urban landscape; Indications for the activation of integrated projects oriented towards multifunctionality; Guidelines for the activation of innovative tools (PES) for the implementation of the GBI project.

As previously mentioned, the main planning instrument into which both the methodological approach adopted for structuring the GBI project in the Province of Sondrio and its related strategic-design guidelines could be integrated is the Provincial Territorial Coordination Plan (PTCP), currently undergoing revision.

Specifically, the contents of the proposed project could be incorporated into the structure and objectives of the provincial ecological network, which is already conceived in the current PTCP as a multifunctional tool. This network integrates aspects focused on the conservation and enhancement of natural capital with broader strategies aimed at territorial regeneration and the valorisation of the province's landscape features.

In parallel, the GBI project could contribute to the periodic revision of the Territorial Area Plan (PTRA) for the Middle and Upper Valtellina, which defines its own ecological network framework for the area under its jurisdiction. This network is then incorporated into the PTCP. Of relevance is the extension of the PTRA scope to adjacent territories, particularly to the Valle Camonica, which forms part of one of the key SACA1 areas (Areas of Strategic Alpine Connectivity) of high relevance for the ecological connectivity system of the Alpine Space.

In both planning instruments, the GBI proposal could reinforce the structure of the ecological network by incorporating transnational-scale connectivity axes, as defined by the PlanToConnect project and detailed within the pilot project area. This would allow for a broader, integrated vision of the corridor

system defined by the PTCP and PTRAs, including the identification of additional corridors beyond those currently recognized.

Furthermore, the strategic frameworks developed within the GBI project could support the identification of intervention priorities or widespread defragmentation actions, measures aimed at enhancing ecosystem service performance, and territorial maintenance efforts, all of which could be incorporated into ecological network projects.

At the local level, certain priority actions defined within the GBI project could contribute to the identification of new Local Parks of Supra-municipal Interest (PLIS), particularly in valley floor areas, or support the revision of settlement forecasts within the ongoing or future updates to Municipal Land Use Plans (PGT).

Also at the local scale, the GBI design, consistent with PTCP and PTRAs directives, could inform the configuration of Municipal Ecological Networks (REC) as strategic components of the PGT, and guide the definition of mitigation and compensation measures for developments or activities that are inconsistent with, or potentially detrimental to, the maintenance or enhancement of ecological connectivity and ecosystem functions within open space systems.



5 References

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Multifunctional Green & Blue Infrastructure for the Province of Sondrio

Fondazione Politecnico di Milano in collaboration with LabPPTE/DAStU - Politecnico di Milano, April 2025 **51**



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PlanToConnect

Mainstreaming ecological connectivity in spatial planning systems of the Alpine Space

Project partners:

Urban Planning Institute of the Republic of Slovenia (SI)
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)
ifuplan - Institute for Environmental Planning and Spatial Development (DE)
University of Würzburg (DE)
Salzburg Institute for Regional Planning and Housing (AT)
E.C.O. Institute of Ecology Ltd. (AT)
Fondazione Politecnico di Milano (IT)

Multifunctional GBI for the Province of Sondrio

Methodology, strategical actions and operative indications for the GBI implementation

Technical proposal for implementing GBI connectivity networks into spatial plans of pilot sites.

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Annexes

Annex 1a Multifunctional GBI project_ENG

Annex 1b Pilot corridor GBI design_ENG

