Green Infrastructure for the Alpine Space: from theory to practice

Deliverable D.T1.1.1- State of the art overview on existing ESS studies as connected to specific GIs in the Alpine space and pilot regions.

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Contents

What is LUIGI?

"Linking Urban and Inner-Alpine Green Infrastructure: Multifunctional Ecosystem Services for more liveable territories" (LUIGI) is a 33-months project funded by the European Union (EU) through the Interreg Alpine Space (AS) programme. The project involves 14 partner institutions and 26 observers from Austria, France, Germany, Italy, Slovenia, and Switzerland.

By recognizing the anthropogenic pressures on Alpine Space ecosystems and the benefits that those deliver to a wider area beyond mountain regions, **LUIGI aims to strengthen the link between mountain ecosystems and urban centers at the foot of the Alps, based on sound economic and social exchanges**. The LUIGI project seeks to i) recognize the benefits deriving from a green infrastructure (GI) network developed between mountain/rural and urban areas, ii) valorize their potential for a sustainable economic development, and iii) contribute to assuring higher quality of life harnessing the benefits deriving from the natural capital. The project targets actors involved along the urban/rural value chain, civil society, planners, and policy makers in order to foster investments, planning, and the maintenance of GI throughout the Alpine Space territory. LUIGI will provide guidance to support, among other things, i) the development of GI networks , ii) the assessment/evaluation of the environmental, social and economic benefits deriving from GI iii) effective and innovative governance and management of GI, and iv) the development of business models around the societal benefits of GI, and the mobilization of financial resources to support them.

LUIGI meets the priority of the Alpine Space programme of achieving a liveable Alpine Space, and especially its objective to enhance the protection, the conservation, and the ecological connectivity of Alpine Space ecosystems. The project is furthermore aligned with the objectives of the EU strategy for the Alpine Region (EUSALP), which aims to ensure sustainability in the Alps, and, more specifically, to develop ecological connectivity in the whole EUSALP territory.

The first Work Package

The first work package of the project "LUIGI" will spotlight the multiple benefits (ecological, economic, social, and cultural) of GI as a "common natural capital" and an ecosystem services provider. Its main output will be to illustrate the state of the art and delineate guidelines for the conservation and the enhancement of the provision of multiple ecosystem services deriving from GI. More specifically, it aims to provide a summary of existing knowledge and best practices on ecosystem services, GI design, and their interaction within the Alpine Space and the pilot regions. The results will feed into the other work packages and support all project activities.

Part B-The Green Infrastructure concept in practice

Introduction

This is the first deliverable of the first work package of the Interreg Alpine Space project LUIGI- Linking Urban and Inner-Alpine Green Infrastructure: Multifunctional Ecosystem Services for more liveable territories". It aims to provide essential information about Green Infrastructure in the Alpine region to LUIGI stakeholders and project partners, or to whoever wishes to understand and apply this concept. It seeks to help public authorities, decision-makers, practitioners, and researchers to plan and manage Green Infrastructure (GI) networks in the Alpine Space. This deliverable is presented as a handbook, divided in two parts, focusing on key notions underlying the GI concept in the European Union and in the Alpine region, and on the benefits deriving from the establishment of a GI network.

Part A explains what ecosystem services and Green Infrastructure are, illustrates the role of Green Infrastructure in European policy, in the EUSALP macroregional Strategy, and in the Alpine Space programme, and presents past EU-funded project on GI.
Part B focuses on how to translate the GI framework into practice, i) highlighting important ecological and socio-economic principles that can guide a GI network development, and ii) describing the most common and important GI components found in the alpine region and spotlighting their associated ecosystem services.

Refer to **part A** of this deliverable if you are not confident answering the following questions:

What are ecosystem services and why are they important?
What is green infrastructure? Which criteria should it meet?
What does a GI network look like?
What is the European Union vision for GI?
How would a GI network help harness synergies between different EU policies?
What is the European Union doing to support GI in the Alpine Space?
Which European funded projects have dealt with GI before?

Read **part B** of this deliverable to know:

How can the structure of a GI network maximise the benefits I get?
Why is connectivity important for biodiversity?
Who should get involved in planning and managing GI?
Which are the economic benefits I could get out of a GI network?
Which are common and/or important GI components in the Alpine Space?
Which ecosystem services do those GI components provide to the community?

1. Applying the GI concept

This chapter aims to spotlight some important concepts relating to GI that should be kept in mind when designing, planning, or managing GI networks. These concepts are only briefly introduced here, with the aim to make the reader aware of the wider ecological, social, and economic relevance that a GI network can have in the landscape and in a community.

The first part of this chapter addresses key features of GI that are especially relevant to understand how the structure of a GI network can maximise ecological benefits and the provision of ecosystem services. The second part of this chapter spotlights i) good governance practices that should be followed in the stages of GI design and planning, and ii) the socio-economic impact that GI can have in a community.

Which are the benefits of the GI approach?

GI uses land efficiently and enhances nature's ability to deliver multiple, valuable ecosystem goods and services. GI networks foster a better quality of life and **human well-being**, improve **biodiversity**, protect us against **climate change** and other environmental disasters, and encourage a **smarter, more integrated approach to development**. Moreover, the GI approach contributes to multiple EU and national Policies, such as those on agriculture, climate change, biodiversity, and water use.

Designing the network

As described in part A of the report, the underlying requirement of GI is that the GI components of the network are in a good ecological condition and are therefore able to support multiple socio-ecological functions. It is however also important to understand i) how GI components are interconnected, and ii) over which scale, because this will determine the socio-ecological benefits that the GI network can provide, and set the aim and scope of the GI planning process.

Scale

The Green Infrastructure approach can potentially be implemented at all spatial scales, from a neighbourhood to a city, region, state, or even at a transnational level. It is important to have a clear idea of the scale at which one is designing a GI network, however, because the GI components and the ecosystem services considered, along with the degree of connectivity created, will depend on it.

According to the scale foreseen when planning a GI network, some GI elements might be more important than others. Whether the elements of a GI network are sufficiently interconnected will also depend on the scale considered and on the aims of the planners. For example, a town planner aiming to connect urban parks might focus on urban GI components such as roadside vegetation or green belts. A consortium of natural parks in the Alps aiming at increasing the connectivity across the mountain range, however, will not consider as much a tree-lined street, and might focus instead on river riparian zones or wildlife overpasses.

Connectivity

Each natural feature of GI components has an intrinsic multifunctional value, but if it becomes part of a wider GI network, the functions and benefits it delivers will be enhanced. The value of a GI network is higher than the mere sum of its components, as the fact that they are interconnected enhances their average ecological quality, bringing an added value to the network. Most ecological functions are indeed scale-dependant. An isolated park might have some value as it is, but once it becomes part of a GI network, for example, it might host species previously confined to other parks and might provide more interesting recreational opportunities. **Ecological connectivity is furthermore a critical element for the preservation of animal populations over time and for the maintenance of a high ecological condition of the GI network**. As a rule of thumb, the bigger and the more diverse an interconnected GI network is, the higher the quality and the number of ecosystem services it delivers usually is.

According to the European Environmental Agency,

"**connectivity expresses the configuration of landscapes**, **and the degree to which this allows the movement of species**."

In order to conserve and enhance biodiversity through the development of a GI network, it is important to consider two interrelated components of connectivity important for animal movement: structural and functional connectivity. The European commission describes **structural connectivity** as the extent to which landscape units (at multiple spatial scales) are contiguous or physically linked to one another. It is measured by analysing landscape structure, independent of any attributes of organisms. **Functional connectivity**, often used in the context of landscape ecology, is instead the response of the organism to the landscape elements other than its habitats (i.e. the non-habitat matrix) (EC, 2013). An important aspect is that functional connectivity depends on the species or process considered i.e. functional connectivity will be different for the dynamics of a bird or a small mammal population.

In this graph developed by the Habitat Network of the Cornell University, **corridors** are an example of structural connectivity, while **stepping-stones** are an example of functional connectivity (i.e. certain animal species might be able to use the stepping-stones to move between patches of favourable habitat).

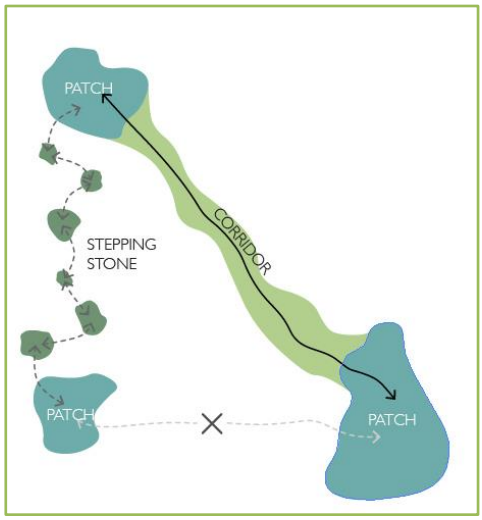

Figure 1. Patches, corridors, and steppingstones. Copyright © 2020 Cornell University

A high degree of connectivity is generally linked to low habitat fragmentation. This means that organisms can move to find mates, food, and shelter, and that the population will have higher chances of survival in that area. Moderate or high levels of connectivity therefore allow to sustain viable metapopulations and populations (Hilty et al, 2006).

The AlpBIONET2030 project conducted an analysis on the fragmentation caused by transport infrastructure in the Alpine Space territory and found that all the largest valleys in the Alps are considerably fragmented. The objective of the EUSALP Action Group 7 is indeed reducing habitat

fragmentation in the Alpine Arc with the aim of enhancing and restoring biodiversity as well as the provision of ecosystem services. **Conservation efforts must therefore aim at ensuring that landscapes across the entire Alpine region have functional ecological networks and are therefore permeable to animal species.** Since connectivity depends on structural natural features, such ecological networks need to be implemented on the ground, preventing land conversion, and restoring habitats in strategic areas important for network-level connectivity (Jongman, 2008).

Being familiar with the concept of connectivity can help understand which natural features can be considered part of a GI network or not. **Individual natural or semi natural features will indeed need to be multifunctional and functionally connected to the rest of the network in order to be considered part of a green infrastructure**. A backbone of areas of high ecological importance, such as the Natura 2000 sites, reserves, or parks, can be connected through different natural or man-made environmental features to form a wider GI network across the landscape. Connectivity is a very important aspect in the LUIGI project because its objective is to foster the deployment of GI networks that connect mountain rural and (peri) urban areas across the Alpine Space region.

> "No protected area is large enough to fulfil essential conservation goals. In order to achieve these goals, protection will necessarily extend into the complex, patchy multi-use matrix that stretches between protected area islands".
>
> (AlpBIONET2030)

Further read:

- A seminal book behind the concept of GI, addressing the issue of scale:
  Benedict & McMahon (2006) Green infrastructure: Linking landscapes and communities. Washington, DC: Island Press.
- Results from the ALPBIONET AS project, which looked at ecological connectivity in rural areas: https://www.alpine-space.eu/projects/alpbionet2030/en/project-results/wpt4
- An introduction to habitat connectivity developed by Cornell University and The Nature Conservancy: https://content.yardmap.org/learn/habitat-connection/

GI in the social and planning context

The broad social perspective

Cooperation across sectors and across borders

As discussed in the previous section, multifunctionality is a defining feature of GI. **Given that GI enables multiple functions and services to coexist in the same place, different sectors and stakeholders should be involved in the stages of GI design, planning and implementation, ensuring a holistic approach** (Artmann et al., 2017; Hansen & Pauleit, 2014). This means, for example, that the transport, health, nature conservation and water management sectors of a public authority should work together in the development of a GI network. Results from the "MaGICLandscape" Interreg Europe and the "LOS_DAMA!" Interreg Alpine Space projects indeed point out the importance of inter-sectoral communication, coordination and the cooperation of stakeholders, local authorities, and interest groups for maximising the multifunctionality of a GI network.

Since neither ecosystems, nor the services they deliver follow administrative or sectoral borders, **inter-municipal as well as cross-border cooperation is required for the development of a wider and strategic GI network** that is supported by coordinated decision-making at higher levels**.** In response to this need, the "LOS_DAMA!" AS Project in partnership with EUSALP launched the **Alpine City Network** with the aim of improving the development and the conservation of landscapes and peri-urban green spaces throughout the Alpine Space.

Participatory processes and land use conflict resolution

Given that there are multiple ecosystem services deriving from natural areas, distinct sets of people might value each service differently. Moreover, some ecosystem disservices (i.e. those ecosystem functions that negatively influence human health and well-being, e.g. pollen allergies) could have a greater impact on specific categories of people and should be well considered. Bottom-up initiatives and a participatory approach should therefore be encouraged to ensure that the whole spectrum of society is included in the development of GI and in determining the ecosystem services to be delivered. Elderly people might for example prefer a natural area to be managed to enhance the quiet contemplation of the aesthetic value of nature sitting on a bench, while a younger group might favour, for example, the establishment of a mountain bike track. The involvement of landowners and land managers is also crucial, as they can either support or impede the implementation of a GI project (Hansen & Pauleit, 2014). **An inclusive and participatory approach therefore aims to make sure that a GI network is supported by the community and that its provision of ecosystem services is in accordance with the requirements of different sectors of society**.

Depending on the context, several synergies and trade-offs might develop between multiple combinations of ecosystem services. **Finding a compromise over which ecosystem services and functions should be privileged can sometimes become a difficult and delicate task**. One should indeed carefully navigate and mitigate the conflicts arising from the contrasting interests, opinions, needs and desires of different stakeholders (e.g. conflict between intensive recreation and the protection of sensitive species from disturbance). Moreover, a lack of resources could make it hard to establish a broad participatory

discussion (LOS_DAMA! AS Compendium). Given that different scenarios can be derived from the perspectives and preferences of each individual, dealing with land use conflicts is a major challenge of landscape planning.

The economic value of GI

Having access to capital and funding opportunities is necessary for the development of a GI network, therefore spotlighting the economic value of GI can help make the case for investing in GI. Building a GI network is indeed often promising also from an economic point of view, but one should not focus entirely on the economic value of GI. The "GREEN SURGE" Interreg Europe project highlights how this might lead to the risk of overlooking ecological and social benefits that are not easily quantifiable in economic terms. Keeping this caveat in mind, **GI generates value through the provision of ecosystem services and contribute to a more sustainable and resource efficient economic development process**. The reason behind this is the capacity of green natural capital to attract investments for new business models and value chains in the direction of a greener economy, which activate cash flows and increase employment through new high- and low-skilled job opportunities. Moreover, GI represent an efficient environmental cost saving tool: the capacity of green spaces such as floodplains and parks to reduce storm water runoff and to buffer floods, for example, reduces the costs of water related damages to buildings and urban historical heritage. **The ecosystem service value generated by green spaces is therefore transferable between the urban and the rural settings**.

According to the results from the "GREEN SURGE" Interreg Europe project, households surrounded by green spaces and natural amenities are for example likely to be characterized by a higher price. The monetary value of cultural ecosystem services is indeed often demonstrated by indirect valuation measures such as hedonic pricing (Hirons et al., 2016). While raising property prices is generally positive for the local economy, practitioners should carefully consider the development of potential negative social consequences such as gentrification: original residents being forced to move to another location because they cannot afford to stay there any longer. **It is therefore important to avoid environmental injustice episodes and to ensure equal access to the multiple benefits of green spaces to all citizens**.

"Social inclusion and transdisciplinary are two crucial governance aspects that should be ensured in the determination and assessment of the demand of ecosystem services in a community"

(Artmann et al., 2017).

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- John, H, Marrs, C., Neubert, M. 2019. *Green Infrastructure Handbook - Conceptual and Theoretical Background, Terms and Definitions.* Interreg Central Europe Project MaGICLandscapes. Output O.T1.1, Dresden. Published online: https://www.interregcentral.eu/Content.Node/MaGICLandscapes.html#Outputs

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- Hilty, J., Lidicker Jr, W.Z. & Merenlender, A.M. 2006. *Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation*. Island Press.

- Hirons, M., Comberti, C., & Dunford, R. 2016. Valuing cultural ecosystem services. *Annual Review of Environment and Resources*, *41*, 545-574.

- Jongman R. 2008. *Ecological Networks, from Concept to Implementation*. In: Hong SK., Nakagoshi N., Fu B., Morimoto Y. (eds) Landscape Ecological Applications in Man-Influenced Areas. Springer, Dordrecht

- LOS_DAMA! Interreg Alpine Space Project 2019. *LOS_DAMA! Compendium*. https://www.alpine-space.eu/_directuploads/bricks/brick-downloadlist/190926_ld_compendium_en_web_1.pdf

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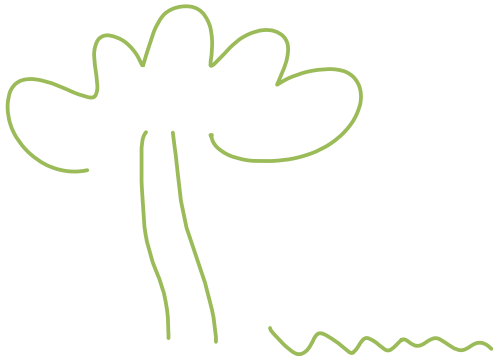
2. GI and Ecosystem Services in the Alpine space

Making the link between Ecosystem Services and GI

This chapter draws the links between potential components of Green Infrastructure in the Alpine region and the ecosystem services (ESS) they support. The information is presented in an approachable way as a series of stand-alone factsheets, which can be easily used by stakeholders. We recommend, however, reading i) part A of the report, to ensure that the notion of green infrastructure and its application within the European Union is well understood and, ii) the previous section, to learn about important concepts that allow to design, plan and manage GI networks in a way that maximizes environmental, social and economic benefits.

The factsheets have been developed for 13 GI components that are common and/or important for GI networks in the urban, peri-urban, and rural areas of the Alpine region: Tree avenues, Grass lawns, Green Roofs, Urban parks, HNV farmland, Hedgerows, HNV Vineyards, Orchard meadows, Riparian areas, Forests, Alpine Meadows, Mountains, and Wetlands. Building from the list of CORINE land cover (CLC) classes used by the MaGICLandscape project to map GI (Neubert & John, 2019), we excluded water bodies and land cover classes not relevant for the Alpine region (i.e. olive groves, dunes, salines, etc.), we defined the land use conditions for agricultural and semi-natural land cover classes, and added smaller landscape features (i.e. green roofs, parks, lawns, tree avenues, hedgerows) as GI components. The GI components considered are therefore defined for the scope of this assessment as either i) CORINE land cover classes, ii) the extensive, sustainable land use of semi-natural CORINE land cover classes, or iii) smaller landscape elements not represented by CLC classes. Please note that we reference the CORINE classification only for a paradigmatic description of land covers, and not for mapping purposes.

For each GI element considered, we qualitatively indicate i) whether it is typically a urban, peri-urban, or rural element, ii) which level of connectivity it supports, and iii) whether the component considered is part of the scope or scale of the LUIGI project. These assessments are to some extent subjective, as they were dependent on expert judgment based on the literature reviewed. Furthermore, **we describe how each GI component considered delivers ecosystem services,** and we list the groups of the ecosystem services supported, as found in v5.1 of the Common International Classification for Ecosystem Services (CICES). Finally, we reference the main piece of scientific literature consulted that supports the link between the GI element considered and ESS, and we indicate other sources for further reading.



GI Factsheets

Tree Avenues

Definition: Trees planted along roads and paths either solitary or in rows. Hedges along roads or paths (GreenSurge project). Fruits are not typically used by humans. There is limited or absent natural/grass ground coverage. Also called tree alley, urban trees

Urban-Rural gradient positioning: Urban

Connectivity potential: Low/Medium **LUIGI scale/scope**? No

Main ESS supported: Mediation of wastes or toxic substances of anthropogenic origin by living processes; Mediation of nuisances of anthropogenic origin; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Water conditions; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment

Key reference: Roeland, S., Moretti, M., Humberto Amorim, J., Branquinho, C., Fares, S., Morelli, F., Niinemets, lo, Paoletti, E., Pinho, P., Sgrigna, G., Stojanovski, V., Tiwary, A., Sicard, P., & Lei, Y. 2019. Towards an integrative approach to evaluate the environmental ecosystem services provided by urban forest. *Journal of Forestry Research*, *30*(6), 1981–1996. https://doi.org/10.1007/s11676-019-00916-x

Description: Trees in an urban setting are especially important for regulating air quality, improving human health by filtering atmospheric particulates such as nitrogen dioxide (NO_2), particulate matter (PM) and sulphur dioxide (SO_2). Trees store carbon and, regulating the micro-climate, decrease the urban heat island effect. Tree canopy, and in some cases tree pits, intercept precipitation and reduce stormwater runoff. Trees provide habitat notably to birds and insects species, and, if the ground coverage is vegetated, tree avenues can act as corridors for small sized animals. As the capacity of tree avenues to act as corridors largely depends on the ground coverage and the overall structure, we scored connectivity as ranging from low to medium. Trees act as visual screening, ameliorate the neighbourhoods, and increase well-being. Pollen and nuisance species could however translate to ecosystem disservices in some cases.

Further read:

- 4th MAES Report, 2016. Mapping and Assessment of Ecosystems and their Services. Urban ecosystems.
- For this and following urban GI components:
  "A typology of urban green spaces, ecosystem services provisioning services and demands" developed by the GREESURGE project (D3.1):
  http://assets.centralparknyc.org/pdfs/institute/p2p-upelp/1.004_Greensurge_A+Typology+of+Urban+Green+Spaces.pdf

Grass Lawns

Definition: Herbaceous vegetation. Grassy vegetation, natural banks, rough grasses, ornamental plants, flat lawns, and ground covering vegetation (Derkzen et al., 2015). For example, sport fields, front yards, courtyards, school yards etc.

Urban-Rural gradient positioning: Urban

Connectivity potential: Low **LUIGI scale/scope**? No

Main ESS supported: Mediation of wastes or toxic substances of anthropogenic origin by living processes; Mediation of nuisances of anthropogenic origin; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Regulation of soil quality; Water conditions; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment.

Key Reference: Ignatieva, M.; Haase, D.; Dushkova, D.; Haase, A. 2020. Lawns in Cities: From a Globalised Urban Green Space Phenomenon to Sustainable Nature-Based Solutions. *Land*, 9,73. https://doi.org/10.3390/land9030073

Description: Grass lawns and herbaceous ground vegetation in general are particularly important for the regulation and maintenance services they provide. They retain and filtrate water, contributing greatly to storm water management by decreasing runoff and improving water quality in polluted cities where most of the ground is sealed and impermeable. They reduce noise and smell, trap air pollution, store carbon and support soil formation and nutrient cycling. Moreover, they contribute to cooling local climate by absorbing solar radiation and decreasing the urban heat island effect. They support pollination and provide habitat especially to insects, nematodes, earthworms, and spiders. They support many sport and recreation activities and improve the aesthetics of yards and gardens. The overuse of herbicides or fertilizers might however have negative consequences on the overall ecological conditions.

Further read:

- Derkzen, M. L., van Teeffelen, A. J. A., Verburg, P. H. 2015. REVIEW: Quantifying urban ecosystem services based on high-resolution data of urban green space: an assessment for Rotterdam, the Netherlands. *Journal of Applied Ecology*, *52*(4), 1020–1032. https://doi.org/10.1111/1365-2664.12469

Green Roofs

Definition: A vegetative roof system that hosts plants in a growing medium installed over a waterproof membrane, often including an irrigation system and a drainage layer (Langemeyer et al. 2020).

Urban-Rural gradient positioning: Urban

Connectivity potential: Low **LUIGI scale/scope**? No

Main ESS supported: Cultivated terrestrial plants for nutrition, materials or energy; Mediation of wastes or toxic substances of anthropogenic origin by living organisms; mediation of nuisances of anthropogenic origin; Regulation of baseline flow and extreme events; Lifecycle maintenance, habitat and gene pool protection; Atmospheric composition and conditions; physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment.

Key reference: Langemeyer et al. 2020. Creating urban green infrastructure where it is needed – A spatial ecosystem service-based approach decision analysis of green roofs in Barcelona. *Science of the Total Environment.* 707, 135487. https://doi.org/10.1016/j.scitotenv.2019.135487.

Description: The wide range of benefits offered by green roofs in densely built up metropoles include reduction in peak flow rates and stormwater runoff control. Green roofs indeed absorb rainwater, reducing flood risk and drainage infrastructure costs. Green roofs regulate urban temperature by reducing the urban heat island effect thanks to the increase in solar reflectance and vegetative evapotranspiration. They improve air quality by reducing noise pollution and absorbing airborne particles and heavy metals deriving from the urban atmospheric environment. Green roofs also improve the energy efficiency of buildings. Depending on the design alternatives, green roofs also promote urban biodiversity by replicating various habitats for local fauna, particularly for insects and birds. Moreover, they hold significant potential for urban agriculture and the production of fruits and vegetables.

Further read:

- PERFECT Interreg Europe project, tcpa (Town and Country Planning Association). December 2019. Factsheet 5 green roofs available at: https://www.interregeurope.eu/perfect/library/#folder=1133

Urban park

Definition: Urban parks are green public open spaces located within the border of urban settlements. They are characterized by trees and grassy coverage and can also include few or small bushes. Fruits are not typically used by humans. They are meant to offer recreation and green spaces to urban residents.

Urban-Rural gradient positioning: Urban, Peri-urban

Connectivity potential: Medium **LUIGI scale/scope**? Yes

ESS supported: Wild plants (terrestrial and aquatic) for nutrition, material or energy; groundwater used for nutrition, material or energy; mediation of wastes or toxic substances of anthropogenic origin by living processes; mediation of nuisances of anthropogenic origin; regulation of baseline flows and extreme events; lifecycle maintenance, habitat and gene pool protection; regulation of atmospheric composition; physical and experiential interactions with natural environment; spiritual, symbolic, and other interactions with natural environment; intellectual and representative interactions with natural environment.

Key Reference: Maes et al. 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020, *Ecosystem services, 17, 14-23.* https://doi.org/10.1016/j.ecoser.2015.10.023;

Description: Among green urban areas, urban parks are some of the most frequent and important nature-based solutions to multiple environmental problems in cities. They provide important regulatory and cultural services. Tree canopies absorb human induced pollution, reduce noise and contribute to air purification. Urban parks are important for the absorption and filtration of water runoff to mitigate flood hazards and improve water quality. Urban parks sequester carbon from the atmosphere and regulate the urban microclimate reducing the heat-island effect. They provide habitat to resident or transient animal species, and offer hotspots for pollination and honey production. Moreover, urban parks are important public open spaces that, supporting social interaction opportunities, sport and recreation, enhance the social and psychological well-being of urban residents.

Further read:

- Mexia et al. 2018. Ecosystem services: Urban parks under a magnifying glass. *Environmental Research.* Volume 160, pages 469-478. http://dx.doi.org/10.1016/j.envres.2017.10.023
- European Commission. 2014. Mapping and Assessment of Ecosystem and their Services, 4th Report 2016

HNV Farmland

Definition: High Nature Value farmlands are landscapes where low intensity agriculture is dominant (low levels of agrochemical inputs and low livestock stocking levels, minimal mechanization, and rotational use of the land). HNV farmlands are characterized either by a high cover of semi-natural vegetation/habitats (HNVf type 1), a high density of small scale landscape elements such as shrubs, hedges or field margins (HNVf type 2), or those landscapes, often more intensively managed, that support species with high conservation interest (HNVf type 3) (Lomba 2020; Andersen et al. 2003). Please note that vineyards and orchard meadows are discussed separately.

Urban-Rural gradient positioning: Rural

Connectivity potential: Medium-High **LUIGI scale/scope**? Yes

Main ESS supported: Cultivated terrestrial plants for nutrition, materials or energy; Reared animals for nutrition, materials or energy; Surface and Ground water used for nutrition, materials or energy; Mediation of wastes or toxic substances of anthropogenic origin by living organisms; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Pest and disease control; Regulation of soil quality; Regulation of water condition; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; spiritual, symbolic and other interactions with natural environment; Intellectual and representative interactions with natural environment.

Key reference: Lomba, A., Moreira, F., Klimek, S., Jongman, R. H. G., Sullivan, C., Moran, J., McCracken, D. I. (2020). Back to the future: Rethinking socioecological systems underlying high nature value farmlands. *Frontiers in Ecology and the Environment*, 18(1), 36– 42. https://doi.org/10.1002/fee.2116

Description: By definition, HNV farmlands support biodiversity conservation, but they are also responsible for the sustained supply of a broad range of ecosystem services. "Provisioning services include food production, fodder for livestock, and water supply, while cultural services include recreation, agro- and ecotourism, sense of place, and maintenance of cultural heritage and scenic landscapes. HNV farmlands also sustain important regulating services, including climate regulation, prevention of soil erosion, pollination, and biological control. Finally, the soils of HNV farmlands contain higher levels of organic carbon than the soils of non-HNV farmlands, underscoring their potential contribution to climate regulation, maintenance of soil fertility, and prevention of soil erosion and desertification." Often the result of traditional farming practices, HNV farmland are vulnerable to farm abandonment or intensification (Lomba et al., 2020).

Further read:

- Paracchini, M. L.; Petersen, J.-E.; Hoogeveen, Y.; Bamps, C.; Burfield, I. and van Swaay, C., 2008. High Nature Value Farmland in Europe. An estimate of the distribution patterns on the basis of land cover and biodiversity data. JRC Scientific and Technical Reports. European Communities, Luxembourg. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC47063/hnv_final_report.pdf
- Strohbach MW, Kohler ML, Dauber J, et al . 2015. High nature value farming: from indication to conservation. *Ecological Indicators* 57: 557– 63. https://doi.org/10.1016/j.ecolind.2015.05.021

Hedgerows and field margins

Definition: "Hedgerows" encompass lines of trees as well as classic shrubby hedges. It also includes associated basal and marginal vegetation where clearly influenced by the existence of the shrubs and trees, and any associated earth banks and ditches. As such, hedges can be up to 9 metres wide or more. This definition encompasses those linear boundary features known as windbreaks, together with thin shelterbelts. It also encompasses many buffer strips where these have shrubs or trees in addition to permanent herbaceous (usually grassy) growth. Even where buffer strips do not support any woody growth, they have some similar functionality to hedges. (Wolton et al. 2014)

Urban-Rural gradient positioning: Rural, Peri-urban

Connectivity potential: High **LUIGI scale/scope**? Yes

Main ESS supported: Cultivated terrestrial plants for nutrition, materials or energy; Mediation of wastes or toxic substances of anthropogenic origin by living processes; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Pest and disease control; Regulation of soil quality; Water conditions; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment.

Key reference: Dover, J. 2019. *The Ecology of Hedgerows and Field Margins*. Routledge

Description: Hedgerows and field margins are particularly important for regulation and maintenance ESS in farmland, and for acting as corridors that facilitate animal movements through the landscape. Hedgerows prevent run-off containing soil, nutrients, and agrochemical pollutants from reaching water bodies, improving water quality, and reducing soil loss. Reducing the volume and the speed of storm water, hedgerows increase infiltration, store water, and reduce the risk of flooding. When managed as windbreaks, hedgerows also provide shelter to crop and livestock, and reduce evapotranspiration. Hedgerows provide shelter and habitat to resident and transient populations, enhancing the population of natural enemies of crop pests, supporting (crop) pollination and animal movement. Hedgerows store carbon above and below ground and reduce air pollution. Hedgerows are part of cultural landscapes, provide recreation, create a sense of place, and improve human health and wellbeing.

Further read:

- Wolton, R.J., Pollard, K.A., Goodwin, A. & Norton, L. 2014. Regulatory services delivered by hedges: the evidence base. LM0106 Report for Defra and Natural England
- Van Vooren L., Reubens B., Broekxx S., De Frenne P., Nelissen V., Pardon P., Verheyen K. 2017. Ecosystem service delivery of agri-environment measures: a synthesis for hedgerows and grass strips on arable land. *Agriculture, Ecosystems & Environment*., 244, pp. 32-51., https://doi.org/10.1016/j.agee.2017.04.015

HNV Vineyards

Definition: Organic and/or sustainably managed vineyards, defined as "*Areas planted with vines, vineyard parcels covering >50% and determining the land use of the area"* (CLC class 221). Extensive inter-row vegetation management (vegetation cover, organic or other types of extensive vegetation management). No inter-row use of pesticides or soil tillage.

Urban-Rural gradient positioning: Rural

Connectivity potential: Medium-High **LUIGI scale/scope**? Yes

Main ESS supported: Cultivated terrestrial plants for nutrition, materials or energy; Genetic material from plants, algae or fungi; Mediation of wastes or toxic substances of anthropogenic origin by living processes; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Pest and disease control; Regulation of soil quality; Water conditions; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment.

Key reference: S. Winter, T. Bauer, P. Strauss, S. Kratschmer, D. Paredes, D. Popescu, B. Landa, G. Guzmán, J.A. Gómez, M. Guernion, J.G. Zaller, P. Batáry. 2018. Effects of vegetation management intensity on biodiversity and ecosystem services in vineyards: a meta-analysis. J. Appl. Ecol., 55 (2018), pp. 2484-2495. https://doi.org/10.1111/1365-2664.13124

Description: All vineyards are managed to provide grapes, but the delivery of regulation and maintenance ESS largely depends on inter-row vegetation management. If extensively managed, cover crops in vineyard decrease run-off and soil erosion, reducing surface water pollution. At the same time, they increase water infiltrations, the presence of soil organic matter, and nutrient use efficiency, sequestering carbon and improving soil fertility. Moreover, cover crops in vineyards support biodiversity and pollination, regulating pests and natural enemies. Some vineyards might grow ancient or local grape varieties which might prove to have a high potential for adapting to climate change. Vineyards are an example of cultural, man-shaped landscapes, that support wine-related tourism and are important to many alpine cultures.

Further read:

- Garcia L.; Celette F.; Gary C.; Ripoche A.; Valdés-Gómez H.; Metay A.; Management of service crops for the provision of ecosystem services in vineyards: A review, Agriculture, Ecosystems & Environment, Volume 251,2018, Pages 158-170, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.09.030.

Orchard meadows

Definition: Extensive and sustainable land use of fruit trees plantation, defined as "*Cultivated parcels planted with fruit trees and shrubs, intended for fruit production, including nuts. The planting pattern can be by single or mixed fruit species, both in association with permanently grassy surfaces"* (CLC class 222). No use of pesticides or soil tillage. They often support ancient or rare fruit varieties, and species-rich grasslands.

Urban-Rural gradient positioning: Rural, Peri-urban

Connectivity potential: Medium-High **LUIGI scale/scope**? Yes

Main ESS supported: Cultivated terrestrial plants for nutrition, material or energy; Genetical material from plants, algae and fungi; groundwater used for nutrition, material or energy; Mediation of wastes or toxic substances of anthropogenic origin by living processes; Mediation of nuisances of anthropogenic origin; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Pest and disease control; Regulation of soil quality; Regulation of water condition; Regulation of atmospheric composition and condition; physical and experiential interaction with the natural environment; Intellectual and representative interactions with natural environment; Spiritual, symbolic and other interactions with natural environment.

Key reference: Demestihas, C., Plénet, D., Génard, M. et al. 2017. Ecosystem services in orchards. A review. *Agronomy for Sustainable Development*. 37, 12. https://doi.org/10.1007/s13593-017-0422-1

Description: Orchard meadows typically provide high quality edible fruits that are not treated with pesticides. Moreover, given that they are managed extensively, they have the potential to deliver many additional services compared to intensively managed orchards. Their perennial character and multi-layer habitat structure supports high levels of biodiversity. They provide habitat to resident and transient animal populations and have a high pollination potential. This contributes to biodiversity conservation, pest and disease control, crop pollination, and the production of honey and other beekeeping goods. Their woody biomass stores carbon from the atmosphere, and, through root and microbial activity, they contribute to nitrogen fixation, organic matter accumulation, and soil formation. Moreover, ground vegetation and the soil help regulate water flow and quality. In peri-urban area, tree canopies contribute to absorb air pollution and noise derived from human activities.

Further read

- Traditional orchard meadows in Hessen/Baden-Wurttemberg http://pegasus.ieep.eu/case-studies/list-of-case-studies
- Plieninger, T., C. Bieling, B. Ohnesorge, H. Schaich, C. Schleyer, and F. Wolff. 2013. Exploring futures of ecosystem services in cultural landscapes through participatory scenario development in the Swabian Alb, Germany. *Ecology and Society* 18(3): 39. http://dx.doi.org/10.5751/ES-05802-180339

Riparian areas

Definition: This GI element is defined by its location and by the fact that under this context some of its functions become particularly important and beneficial to humans (e.g. Flood prevention). Here we assume it is composed of trees, shrubs, grasses, and hedges. Riparian areas are defined as the interface between land and freshwater ecosystems and are characterized by distinctive soil, hydrology, and biotic conditions.

Urban-Rural gradient positioning: Urban, Rural, Peri-urban

Connectivity potential: High **LUIGI scale/scope**? Yes

Main ESS supported: Wild plants (terrestrial and aquatic) for nutrition, material or energy; Wild animals (terrestrial and aquatic) for nutrition, materials or energy; Groundwater used for nutrition, materials or energy; Mediation of wastes or toxic substances of anthropogenic origin by living processes; Mediation of nuisances of anthropogenic origin; Regulation of baseline flow and extreme events; Lifecyle maintenance, habitat and gene pool protection; Regulation of soil quality; Regulation of water conditions; Regulation of atmospheric composition and conditions; Physical and experiential interaction with the natural environment; Spiritual, symbolic and other interactions with natural environment.

Key reference: Cole L. J., Stockan J., Helliwell R. 2020. Managing riparian buffer strips to optimise ecosystem services: A review. *Agriculture, Ecosystems & Environment*, Volume 296, 106891, ISSN 0167-8809. https://doi.org/10.1016/j.agee.2020.106891

Description: Riparian areas offer high quality habitat for both aquatic and terrestrial riparian species. Riparian vegetation dissipates flood energy, decreasing downstream flood intensity. This helps to stabilize riverbanks and allows the deposition of sediments in the riverbed and in the floodplain. Moreover, riparian vegetation traps pollutants such as heavy metals and nutrients before they reach streams or rivers, thus filtering and purifying water. Plants provide organic matter and tree canopies shade streams, reducing air and water temperature, favouring fish communities. The linear feature of riparian areas is very important for animal populations, as it allows individuals to move, protected by vegetation, along great distances and through otherwise impermeable land covers or urban areas. Additionally, riparian areas typically offer pleasant spots for recreation and spiritual interaction with the natural environment.

Further read:

- Government of western Australia, Water and Rivers Commission. 2000. Water notes- Advisory notes for land managers on river and wetland restoration. Available at https://www.water.wa.gov.au/__data/assets/pdf_file/0008/3113/11441.pdf

Natural Forests

Definition: Multi-purpose or natural forests, described as *"Areas occupied by natural forests and woodlands with a vegetation pattern composed of native or exotic coniferous and/or broad-leaved trees and which can be used for the production of timber or other forest products. The forest trees are under normal climatic conditions higher than 5 m with a canopy closure of 30 % at least"* (CLC classes 311, 312,313). Commercial forests managed for the only purpose of logging cannot always be considered part of GI.

Urban-Rural gradient positioning: Rural, Peri-urban

Connectivity potential: High **LUIGI scale/scope**? Yes

Main ESS supported: Wild plants (terrestrial and aquatic) for nutrition, materials or energy; Wild animals (terrestrial and aquatic) for nutrition, materials or energy; Surface water used for nutrition, materials or energy; groundwater used for nutrition, materials or energy; mediation of wastes or toxic substances of anthropogenic origin by living processes; mediation of nuisances of anthropogenic origin; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Pest and disease control; Regulation of soil quality; Regulation of water conditions; Regulation of atmospheric compositions and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment; Spiritual, symbolic and other interactions with natural environment.

Key reference: Tasser et al., 2020. Towards an integrative assessment of land-use type values from the perspective of ecosystem services. *Ecosystem Services.* Vol 42, 101082, ISSN 2212-0416, https://doi.org/10.1016/j.ecoser.2020.101082

Description: Forest ecosystems are some of the most multifunctional ecosystems. For example, forests supply timber, which can be used for carpentry and for energy production, small edible fruits such as berries and mushrooms, and game. Thanks to weathering, decomposition and nitrogen fixation processes, forests are crucial for the production of organic matter and soil formation. Tree canopies and the forest floor intercept rainwater, reducing stormwater runoff and controlling groundwater storage. Moreover, the root system of trees filtrate pollutants and excessive nutrients from water that eventually flows into streams or aqueducts for human use. Forests sequester carbon dioxide from the atmosphere, thus contributing to mitigate climate change, and absorb pollutants and noise, ameliorating air quality and human health. Forest ecosystems offer habitat to many species of plants, animals, fungi, etc., and are hotspots for biodiversity conservation. Forests are very important for the mitigation of natural hazards such as landslides and rockfalls. In addition, forests offer opportunities for leisure and outdoor activities, and typically represent aesthetically appealing spots for intellectual, spiritual, and cultural experiences.

Further read:

- Web portal on Forest Ecosystem Services: https://foresteurope.org/themes/?sfm=/themes/forest-europe-expert-groups/

Alpine Meadows

Definition: Alpine meadows, as defined in the Corine Land Cover classification: *"Grass formations which occur in high mountains above the timberline as natural climax-state herbaceous plant communities, where growing conditions do not allow development and survival of woody vegetation."* This is applicable for "*Alpine grassland which are either completely unused or only in very extensive use under grazing with low livestock units/ha"* (particularity of CLC class 321).

Urban-Rural gradient positioning: Rural

Connectivity potential: High **LUIGI scale/scope**? Yes

ESS supported: reared animals for nutrition, materials or energy; wild plants for nutrition, material or energy; wild animals (terrestrial and aquatic) for nutrition, material or energy; groundwater used for nutrition, materials or energy; regulation of baseline flows and extreme events; lifecycle maintenance, habitat and gene pool protection; regulation of soil quality; regulation of water condition; regulation of atmospheric composition and conditions; physical and experiential interactions with natural environment; spiritual, symbolic and other interactions with natural environment; intellectual and representative interactions with natural environment.

Key Reference: Maes et al. 2016. An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020, *Ecosystem services, 17, 14-23.* https://doi.org/10.1016/j.ecoser.2015.10.023;

Description: Alpine meadows located above the tree line are very important for alpine plant and animal species biodiversity because of low human presence and pressure. They host species and communities endangered by climate change. They store water and regulate water flow, mitigating extreme events and reducing natural hazards. They store carbon, and filtrate water. Alpine meadows are sometimes exploited during the summer season for extensive livestock grazing. They provide recreation opportunities, contribute to local identity, and hold a spiritual and symbolic value.

Further read:

- European Commission. 2014. Mapping and Assessment of Ecosystem and their Services, 2nd Report 2014. https://doi.org/10.2779/75203
- Schirpke U., Leitinger G., Tasser E, Schermer M., Steinbacher M., Tappeiner U. 2013. Multiple ecosystem services of a changing Alpine landscape: past, present and future, *International Journal of Biodiversity Science, Ecosystem Services & Management*, 9:2, 123-135. https://doi.org/10.1080/21513732.2012.751936

"High" Mountain

Definition: We consider here "high mountains" to be composed of the following land cover types, found above the tree line. Please note that alpine meadows and forests are discussed separately. The descriptions of the CLC classes included here are: CLC 322- *Vegetation with low and closed cover, dominated by bushes, shrubs, dwarf shrubs and herbaceous plants, forming a climax stage of development. In the Alpine region, dwarf mountain pine scrub (Pinus mugo) coverage above the tree limit is an example.* CLC 333- *Areas with sparse vegetation, covering 10-50% of surface. Includes steppes, tundra, lichen heath, badlands, karstic areas and scattered high-altitude vegetation***.** CLC 332- *Scree, cliffs, rock outcrops, including areas of active erosion, rocks and reef flats situated above the high-water mark, inland salt planes. For example, the Dolomites.* CLC 335- *Glaciers and perpetual snow.*

Urban-Rural gradient positioning: Rural

Connectivity potential: High **LUIGI scale/scope**? Yes

Main ESS supported: Wild plants (terrestrial and aquatic) for nutrition, materials or energy; Wild animals (terrestrial and aquatic) for nutrition, materials or energy; Genetic material from animal, plants, algae or fungi; Surface water used for nutrition, materials or energy; Ground water for used for nutrition, materials or energy; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment; Spiritual, symbolic and other interactions with natural environment.

Key reference: Grêt-Regamey, A., Brunner, S. H. & Kienast, F. 2012. Mountain ecosystem services: who cares? *Mountain Research and Development* 32, S23–S34. https://doi.org/10.1659/MRD-JOURNAL-D-10-00115.S1

Description: Mountains, and most notably the mountain range of the Alps, are hotspots of biodiversity, act as the water towers of Europe, and represent key attraction for recreation and tourism. Mountain ecosystems provide wild plants and game, and most importantly, provide ground and surface freshwater to many areas beyond alpine areas all year round. Retaining and storing water in snow and glaciers, mountains are key players in regulating the hydrological cycle. Mountains are critical core habitats that sustain many species important for the ecology of the area and for society. Mountains regulate the global climate, sequestering carbon in soil and contributing to the earth albedo effect. Mountains provide many opportunities for recreation and aesthetic experiences, and host many symbolic species, as national emblems, important for the cultural heritage.

Further read:

- Schirpke, U., Meisch, C. & Tappeiner, U. 2018. Symbolic species as a cultural ecosystem service in the European Alps: insights and open issues. *Landscape Ecology* 33, 711–730. https://doi.org/10.1007/s10980-018-0628-x

Wetlands

Definition: Inland Wetlands, as defined by the Corine Land cover classification: "*Areas flooded or liable to flooding during the great part of the year by fresh, brackish or standing water with specific vegetation coverage made of low shrub, semi-ligneous or herbaceous species. Includes water-fringe vegetation of lakes, rivers, and brooks and of fens and eutrophic marshes, vegetation of transition mires and quaking bogs and springs, highly oligotrophic and strongly acidic communities composed mainly of sphagnum growing on peat and deriving moistures of raised bogs and blanket bogs*" (CLC classes 411 and 412).

Urban-Rural gradient positioning: Rural, Peri-urban

Connectivity potential: Medium **LUIGI scale/scope**? Yes

Main ESS supported: Wild plants (terrestrial and aquatic) for nutrition, materials or energy; Wild animals; Surface and Ground water used for nutrition, materials or energy; Mediation of wastes or toxic substances of anthropogenic origin by living processes ; Regulation of baseline flows and extreme events; Lifecycle maintenance, habitat and gene pool protection ; Regulation of soil quality; Water conditions; Atmospheric composition and conditions; Physical and experiential interactions with natural environment; Intellectual and representative interactions with natural environment; Spiritual, symbolic and other interactions with natural environment.

Key Reference: De Groot, R.S., Stuip, M.A.M., Finlayson, C.M. & Davidson, N. 2006. *Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services*. Ramsar Technical Report No. 3/CBD Technical Series No. 27. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN 2-940073-31-7. Available at: https://www.ramsar.org/sites/default/files/documents/pdf/lib/lib_rtr03.pdf

Description: Inland marshes and peatbogs store water and regulate water flow, thereby reducing the risk of floods and provisioning water to agriculture and industry. Removing excess nutrients and pollutants, they filtrate water and provide drinking water. They retain sediments and organic matter, contributing to soil formation, nutrient cycling, and carbon storage. Peatbogs are indeed very important carbon sinks, which however become carbon sources when drained or burned. Peat and vegetation provide fuel, fodder, and materials, create suitable habitat for resident and transient species, and support pollination. Wetlands provide recreation opportunities, contribute to local identity, and hold a spiritual and symbolic value.

Further read:

- Ramsar convention on Wetlands https://www.ramsar.org/

Other

Wildlife crossings and the "Natura 2000" network are discussed here because they are frequently mentioned as GI components and play a key role in GI networks. They are not presented as factsheets, however, because they are not linked to specific biophysical structures providing particular sets of ESS but are respectively characterized by their function and their ecological importance.

Wildlife crossings

Wildlife crossings refer to a wide variety of semi-natural structures which are characterised by the fact that they allow animals to cross man-made barriers. Some examples of wildlife crossing are wildlife tunnels, viaducts, overpasses, green bridges, and fish ladders.

They are important for the GI network because they ensure structural and functional connectivity in areas where roads, rail or dams are present and limit animal movement and dispersal.

Natura 2000 network

Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. The Natura network is a Europe-wide ecological network of nature conservation areas and the largest coordinated network of protected areas in the world.

Natura 2000 sites refer to a wide variety of ecosystem types that have been designated specifically to protect core areas for a sub-set of species or habitat types listed in the Habitats and Birds Directives. They are deemed to be of European importance because they are endangered, vulnerable, rare, endemic, or present outstanding examples of typical characteristics of one or more of Europe's nine biogeographical regions. (DG ENV website, 2020)

They are important for the GI network because they can act as core areas for animal population dynamics and can form the backbone of the network.