Green Infrastructure: from benefits to planning

Simonetta Alberico,[1] Paola Vayr[2]

[1]Città metropolitana di Torino, Direzione Sistemi Naturali - simonetta.alberico@cittametropolitana.torino.it
[2]Città metropolitana di Torino, Direzione Sistemi Naturali - paola.vayr@cittametropolitana.torino.it

Abstract: The increase of urban land use and in general human activities lead to disruptive effects on ecological functionality, environmental services, land naturalness and landscape quality, especially evident in peri-urban areas. Territorial planning and management have to aim at a better coordination among settlement and transport development policies, biodiversity and landscape protection, hydrogeological structure, land use for agricultural and forestry purposes. In this new planning scenario Green Infrastructure (GI) can play a strategic role. The MaGICLandscapes project, to which the Metropolitan City of Turin (CMTo) is taking part, focuses on how to identify, protect and enhance GI for the benefit of the environment and society at transnational, regional and local level. Collaborating with stakeholders, the project aims at providing land-managers, policy makers and communities with tools that help to assess and increase GI functionality. CMTo is testing the methodologies provided by the project in its case study area - Po Hills around Chieri - in order to assess GI functionality, to develop a Public Benefit Assessment Tool that takes over local specific needs and to provide the decision makers with an Action Plan in order to support them to maximize benefits provided from GI within their spatial planning and management process.

Keywords:: green infrastructure; ecological functionality, ecosystem services, landscape planning.

Introduction

Green Infrastructure (GI) is a concept, not a set of rules and there are many interpretations of this concept across Europe and the rest of the world.

As we all know, the benefits of well-planned and well-managed GI are manifold: they go beyond those often associated with natural green spaces such as providing space for wildlife. GI also provides the benefits and services that we as human beings require to thrive as well as to maintain a quality of life. GI should be considered as *multi-functional*, with different types providing different services/benefits dependent on local needs and circumstances. Those needs include making space for and protecting wildlife, providing access to nature, recreation and social interaction, reducing flood risk, improving despoiled landscapes (including those within our settlements) and reducing the negative effects of climate change among many others. A lot of research have already proven GI to be a sound investment with returns far higher than the initial investment (i.e a proven reduction in costs to health services where **GI** is accessible and promoted).

Finally GI is a key strategy in the European Landscape Connectivity Agenda aimed at reconnecting vital natural areas to urban hubs and restoring and improving their functional roles. It is an essential planning concept towards protecting natural capital and simultaneously enhancing quality of life.

While this approach is not yet implemented in Central Europe's landscape planning policies, which seldom consider the ability of land to deliver multiple benefits, ten partners from five Central European countries (Austria, Czech Republic, Germany, Italy, Poland) are working together within the project *Managing Green Infrastructure in Central European Landscapes* (MaGICLandscapes)[1] to introduce public to the GI concept, to improve its management and enhance the benefits and the services it provides.

The goal of MaGICLandscapes is to provide tools and information to help policy-makers, land managers and communities to manage GI in a way that meets local needs and maximizes the benefits it provides at the local, regional, national and transnational level.

The concept of GI

The first output developed by the MaGICLandscapes project was the *GI Handbook - Conceptual & Theoretical Background , Terms and Definitions.* It covers issues such as definitions of important terms or GI and its relationships to territorial laws/policies of the five partner countries and EU regulations and programmes. As a conclusion of this work the GI definition on which all partners agree is the one provided by the European Commission:

"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 such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity. The Natura 2000 network constitutes the backbone of the EU green infrastructure (EU Commission 2016)"

As this Handbook covers the territorial/international needs for a green infrastructure approach, its contribution to sustainable development, and how a GI approach can address specific territorial and common challenges, we expect it to be used as a reference for stakeholders and target groups wanting to know more about GI.

To increase and maximizing the public benefit that can be achieved through GI approaches to issues such as health and well-being/recreation, mitigating climate change, flooding or loss of pollinators, supporting productivity of the land, protecting and enhancing our natural capital, as a second step, a guidance was developed to assess the structure and types of GI at the transnational level: the *Manual of GI Mapping - Decision support tool.* Also if there are manifold datasets available, only few are suitable for a transnational GI mapping. Due to its full coverage and a low amount of misclassification the CORINE land cover (CLC) dataset was proved to be the more appropriate dataset. The suitability of data provided by the European Copernicus Programme was chosen for assessing GI in Central Europe, together with the provision of a method for ground-truthing at a more regional level. At first a GI map on transnational scale for whole Central Europe was produced based on the transnational legend using CLC data from 2012. The CORINE classes were then classified in a simplified

1 MaGICLandscapes is a project cofinanced by the European Commission within the Interreg Central Europe 2014-2020 Program. https://www.interreg-central.eu/Content.Node/MaGICLandscapes.html

transnational legend with just three classes (GI, GI under specific circumstances or partly GI, no GI), based on a coordinated legend among the project partners., as seen in Figure 1.

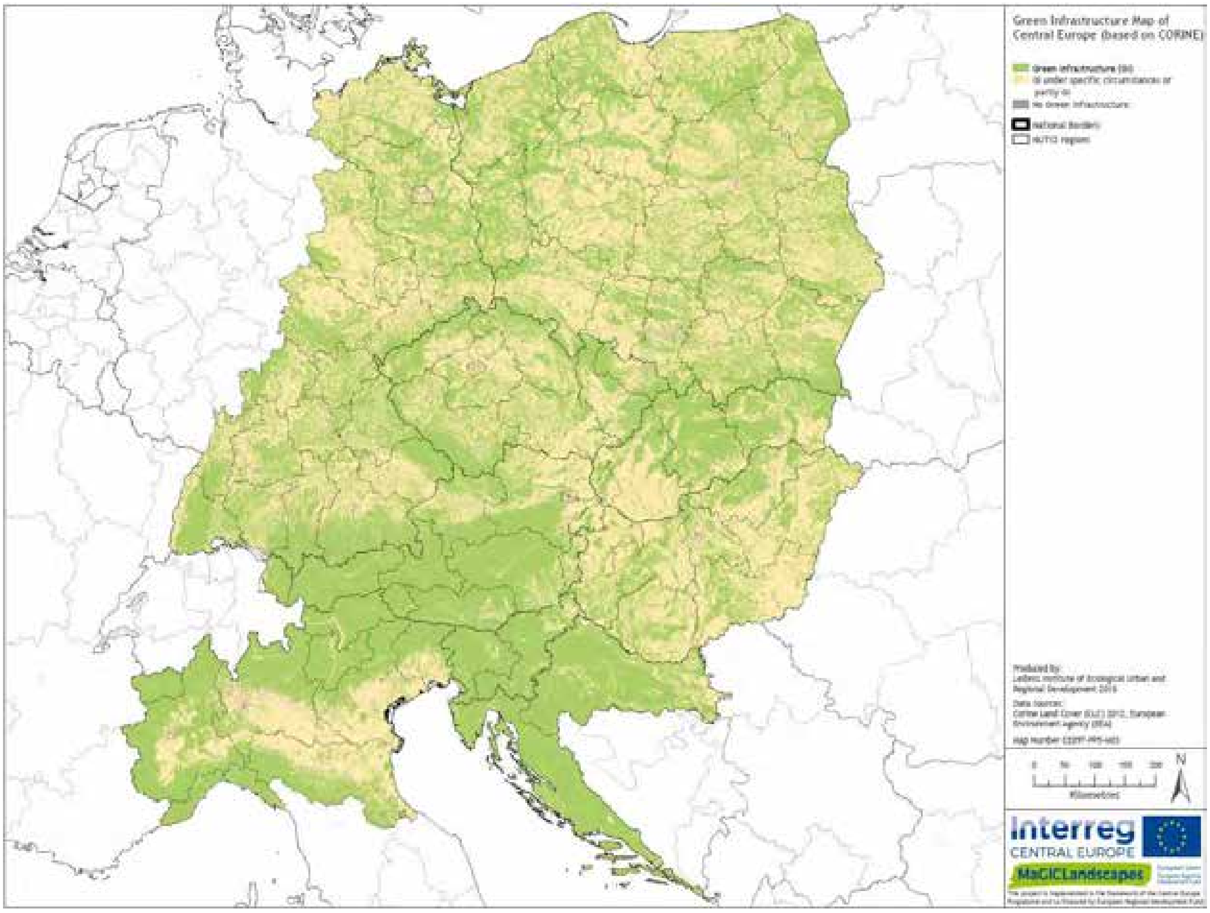

Figure 1: Map of green infrastructure for the Central Europe Programme Area – simplified legend (CORINE land cover data 2012)

Due to some shortcomings regarding transnational data, such as their spatial resolution, accuracy or the type and scope of the classified elements, the mapping was refined at the national/regional level and nine regional maps, one for each case study area, were produced. Among them CMTo produced the map showing the GI/ GI under specific circumstances or partly GI/ not GI elements within its case study area "Po Hills around Chieri" as seen in Figure 2

Also if these maps provide a useful tool to raise awareness into the public of GI and its benefit to humans, a close cooperation with local stakeholders is needed in order to elaborate strategies and action plans for enhancing the existing green infrastructure resource in Central Europe.

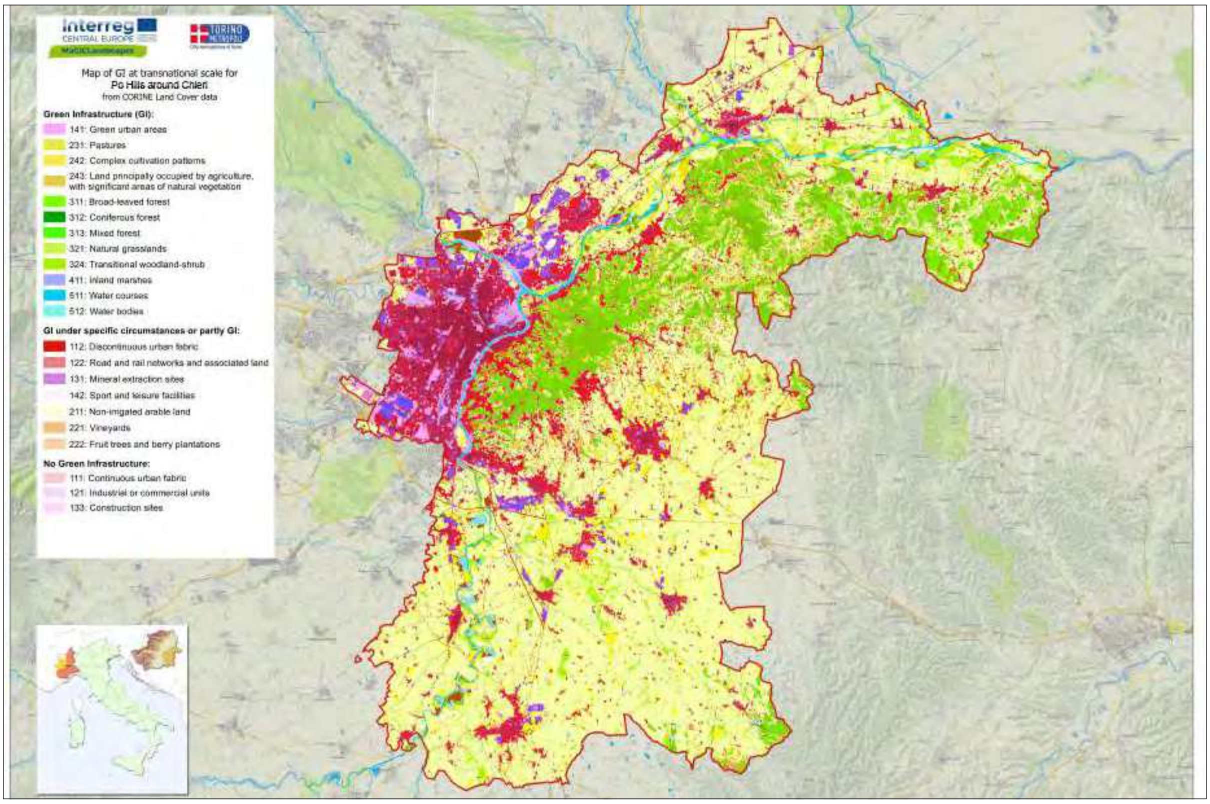

Figure 2: Map of GI for the Italian CSA Po Hills around Chieri based on the transnational legend using CLCdata from 2012 refined with Land Cover Piedmont data.

GI functionality assessment

The field survey is a key component for the testing of the assessment method for elements of GI. To gain in-depth knowledge of crucial zones within our case study areas (core zones, nodes, corridors, etc...) and to close gaps of coverage of geodata each partner tested a shared methodology for the assessment of the naturalness level of the main elements of GI. CMTo selected two sample quadrants of 1 square kilometre located in areas of special interest: the Natural Protection Zone of Arignano Lake and the "Isolone Bertolla" inside the Natural Reserve and Special Conservation Area of Meisino and Bertolla Island. Through a field work activity we attributed a range of local hemeroby[2] (human influence) according to a 7 degree scale for gradients of human influence: from the highest level (ahemerobic) = natural/non-disturbed to the lowest level (metahemerobic) = totally disturbed or "artificial", as seen in Table 1

In combination with the regional biotope catalogue based on the list of EUNIS habitats (level 3), produced by each project partner referencing the extract of EUNIS to their national/regional classification system, habitat types and landscape features were digitalized in a geographic information system (GIS) integrated with the information on the level of naturalness detected trough the field surveys.

2 We adopted the Reference scale for hemeroby values of Joint Research Centre, European Commission - Institute for Environment and Sustainability

Hemeroby value	Hemeroby level	Degree of naturalness	Example	Processes/Human impact
1	Ahemerobe	Natural	Bogs, tundra	No disturbance
2	Oligohemerobe	Close to natural	Forest with species typical for the site, semi-natural grasslands	Limited removal of wood, pastoralism, minor changes in matter circles, emissions through air and water
3	Mesohemerobe	Semi-natural	Forest with species atypical for the site, extensive grasslands	Clearing and occasional ploughing, extensive grazing, rare and small doses of fertiliser
4a	β-euhemerobe	Relatively far from natural	Annual crops associated with permanent crops (extensive), agro-forestry	Use of fertilisers and biocides melioration, ditch drainage
4b			Intensive grassland, extensive arable land,	
5a	α-euhemerobe	Far from natural	Intensive arable land (short rotations), intensive vineyards	Deep plowing, planting, major changes in matter circle, drainage, heavy use of fertilizers and biocides
5b			Cereal monocultures, rice fields and irrigated crops (intensive)	
6	Polyhemerobe	Strange to natural	City green, golf courses, pits	Strong changes in biocenosis, covering of the biotope with external material
7	Metahemerobe	Artificial	Streets, buildings	Sealed surface, biocenosis destroyed

Table 1: Reference scale for hemeroby values (Joint Research Centre, European Commission)

Connectivity analysis

As in digital image analysis concepts of mathematical morphology are widely used (Soille, 2013) we opted to use the Graphical User Interface for the Description of image Objects and their Shapes (GUIDOS)[3] to perform the Morphological Spatial Pattern Analysis (MSPA). The MSPA is a generic and universal pattern analysis framework provided by a custom sequence of morphological operators (Soille & Vogt, 2009) that performs a segmentation on a binary image to identify and localise mutually exclusive morphometric feature classes describing the shape, connectivity and spatial arrangement of image objects by mapping and classifying them into seven categories: Core, Islet, Perforation, Edge, Loop, Bridge, and Branch (Vogt et al., 2017) as seen in Figure 3.

3 GuidosToolbox is a free software collection by Peter Vogt (Joint Research Centre, European Commission) and offers a variety of modules targeted to investigate several spatial aspects of raster image objects, for example pattern, connectivity, cost, fragmentation, etc.

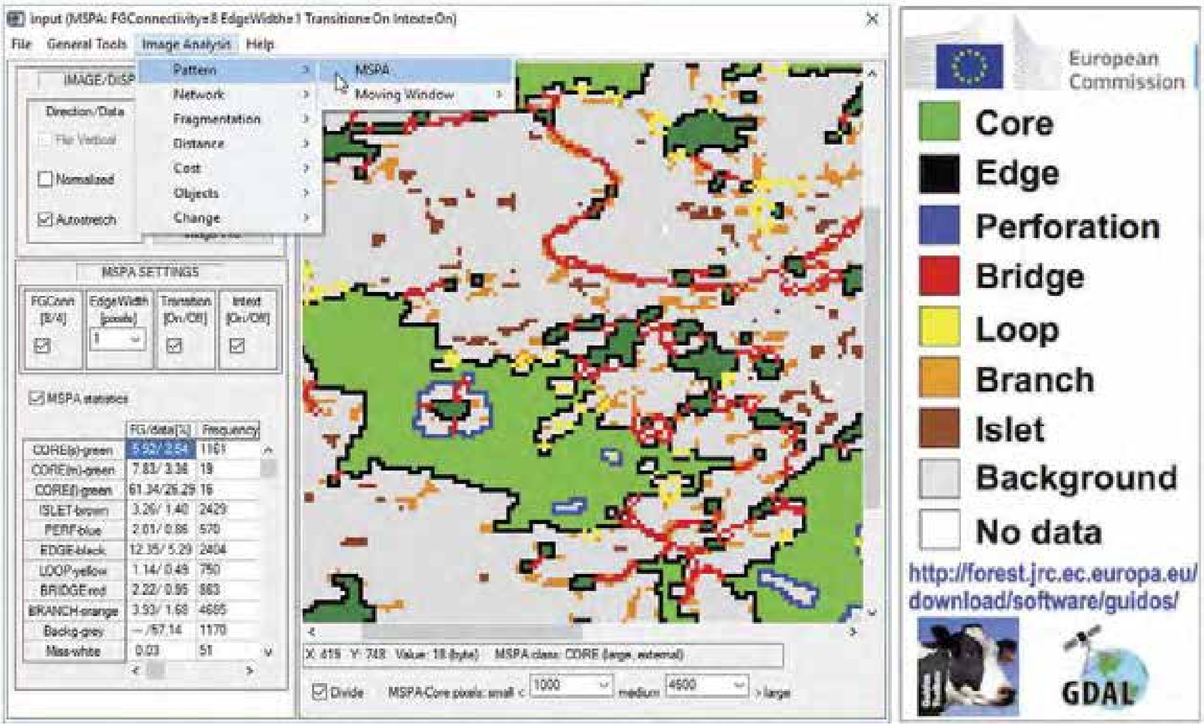

Figure 3: The GuidosToolbox software interface showing the MSPA pattern analysis illustrating various morphological feature classes: Small Core areas (dark green); large Core areas (green); Core area boundaries (Edge/external–black, Perforation/internal–blue); connecting pathways between different Core areas (Bridge–red) and returning back to the same Core area (Loop–yellow); isolated forest patches and too small to contain Core area (Islet–brown); and Branches (orange), reprinted from (Vogt et al., 2017)

In terms of assessment of GI connectivity MSPA uses a series of image processing routines to identify hubs, links (corridors), and other features after reclassifying the raster land-cover map into foreground (Green Infrastructure) and background (all other classes) (Vogt et al., 2007). To align the terminology of GI, the category of *core* was considered equivalent to hub, and *bridge* as synonymous to link (corridor). As the input map must contain only two data classes: foreground and background, we integrated the geodata-base with the attribution of each CLC class as GI or not GI element. The attribution of the patches belonging to the "partly GI" classes was performed considering as not GI all the artificial and anthropic surfaces, with the exception of the Green urban Areas and some specific typology of agricultural uses as shown in Table 2. Moreover, in the application of MSPA in MaGICLandscapes we used eight-neighbour connectivity and edge width values of five (5) respectively ten (10) (depending on the pixel size of 20 respectively 10 metres) corresponding an effective pixel size of 100 metres for this analysis.

CORINE Land Cover (CLC)			
Level 1	Level 2	Level 3	Revised
1. Artificial surfaces	1.1. Urban fabric	111 Continuous urban fabric	
		112 Discontinuous urban fabric	
	1.2. Industrial, commercial and transport units	121 Industrial or commercial units	
		122 Road and rail networks and associated land	
		123 Port areas	
		124 Airports	
	1.3. Mine, dump and construction sites	131 Mineral extraction sites	
		132 Dump sites	
		133 Construction sites	
	1.4. Artificial non-agricultural vegetated areas	141 Green urban areas	
		142 Sport and leisure facilities	
2. Agricultural areas	2.1. Arable land	211 Non-irrigated arable land	
		212 Permanently irrigated land	
		213 Rice fields	
	2.2. Permanent crops	221 Vineyards	
		222 Fruit trees and berry plantations	
		223 Olive groves	
	2.3. Pastures	231 Pastures	
	2.4. Heterogeneous agricultural areas	241 Annual crops associated with permanent crops	
		242 Complex cultivation patterns	
		243 Land principally occupied by agriculture, with significant areas of natural vegetation	
		244 Agro-forestry areas	
3. Forests and semi-natural areas	3.1. Forests	311 Broad-leaved forest	
		312 Coniferous forest	
		313 Mixed forest	
	3.2. Shrub and/or herbaceous vegetation associati	321 Natural grasslands	
		322 Moors and heathland	
		323 Sclerophyllous vegetation	
		324 Transitional woodland-shrub	
	3.3. Open spaces with little or no vegetation	331 Beaches, dunes, sands	
		332 Bare rocks	
		333 Sparsely vegetated areas	
		334 Burnt areas	
		335 Glaciers and perpetual snow	
4. Wetlands	4.1. Inland wetlands	411 Inland marshes	
		412 Peat bogs	
	4.2. Coastal wetlands	421 Salt marshes	
		422 Salines	
		423 Intertidal flats	
5. Water bodies	5.1. Inland waters	511 Water courses	
		512 Water bodies	
	5.2. Marine waters	521 Coastal lagoons	
		522 Estuaries	
		523 Sea and ocean	
Legend:			
no GI			
GI according to specific circumstances			
GI			

Table 2: Correspondences between CLC classes and GI/not GI classes

In the CMTo case study area "Po Hills around Chieri", as shown in figure 4, the MSPA produces a Core area of GI with notable extension in the upper half part of the area and some smaller ones along the rivers within the southern part of it. Both, the Po river and the Stura river are identified as bridge (red). The landscape structure in terms of provision of GI decreases from the north-east to the south-west due to the change in the morphology of the territory that passes from the hill to the flood plain. In the hilly upper area the cores of GI seem to be provided almost exclusively by broad-leaved and mixed forests with a more or less high level of hemeroby, while. going down in altitude mixed formations of complex cultivation patterns consisting of vineyards, wood-lots, pastures and land principally occupied by agriculture with few spots of areas of natural vegetation predominate. In correspondence of the city of Turin, instead, the flat territory at the foot of the hills on the left bank of the Po river is almost entirely covered by urban areas.

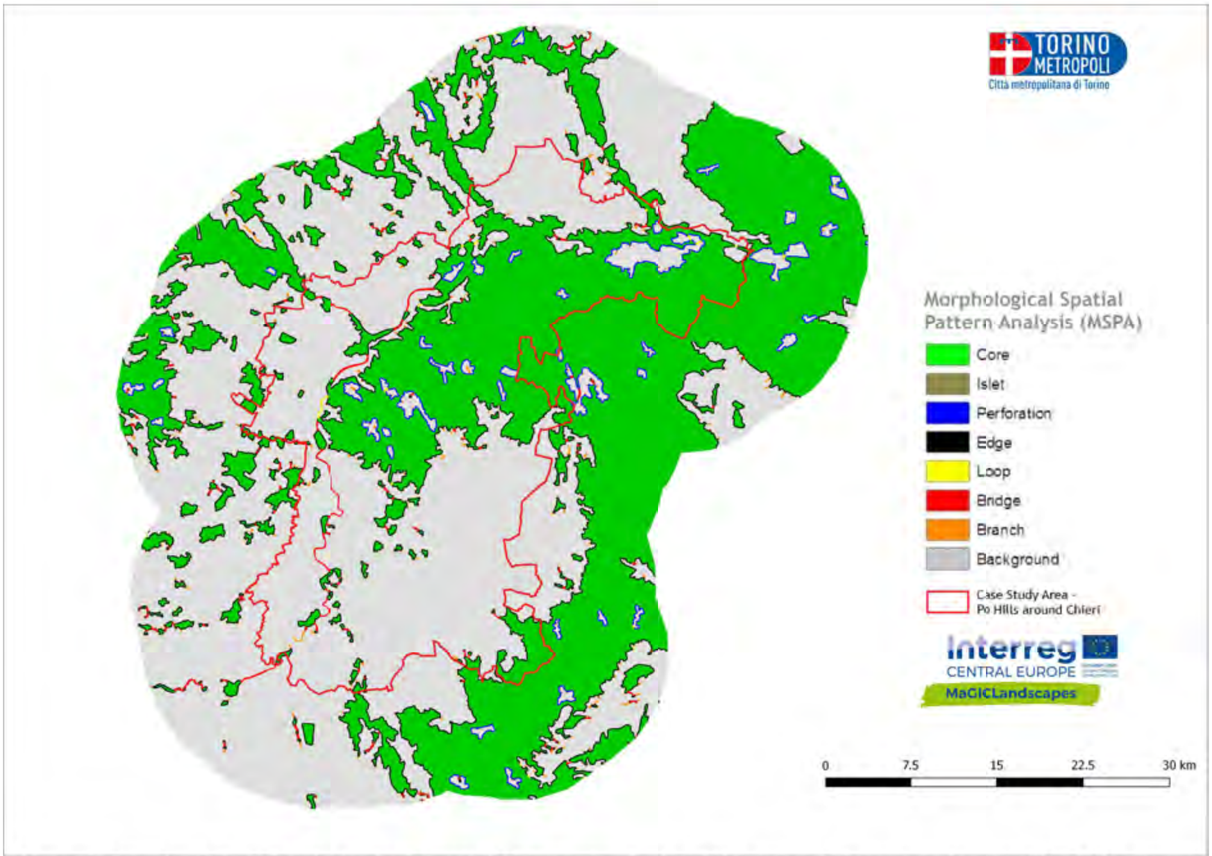

Figure 4: Result of the Morphological Spatial Pattern Analysis of the extended case study area "Po Hills around Chieri" in Piedmont Region – yellow circles indicate the primary links which should be reconnected.

In these zones, as in the southern part, , due to the fact that the land is mostly occupied by intensively farmed agricultural landscapes, complex cultivation patterns and, along the Po river banks, mining activities and sand and gravel extraction sites, there is a generalized lack of GI as shown in Figures 5 and 6.

Figure 5: Corridor cut by a urban settlement

Figure 6: Canalised water with poor occurrence of vegetation

Network analysis

Another informative feature of the Guidos Toolbox is the automatic detection of connecting pathways between core areas of image objects based on the results of the initial application of MSPA and their ranking with respect to the relative importance of each component, node and link, in a given network consisting of Nodes (MSPA class: Core) and Links (MSPA class: Bridge respectively connectors between various Cores); the remaining MSPA classes are neglected (Vogt et al., 2017).

This analysis shows the connectivity importance for each node and each link of the network, displaying their relative importance in decreasing intensity of black (nodes) and red to green (links) colour.(Saura et al. , 2010).

Within the CMTo case study area, as shown in Figure 7, the network analysis highlighted two nodes, respectively of high and medium importance and value: the confluence between the Stura and the Po Rivers (actually a Protected and Special Conservation Area) and the upstream connected area, always along the Stura River: both these areas represent the main corridor through the flat plain that connects the Po hills with the mountain valleys. Its conservation and implementation in terms of connectivity preservation is therefore essential.

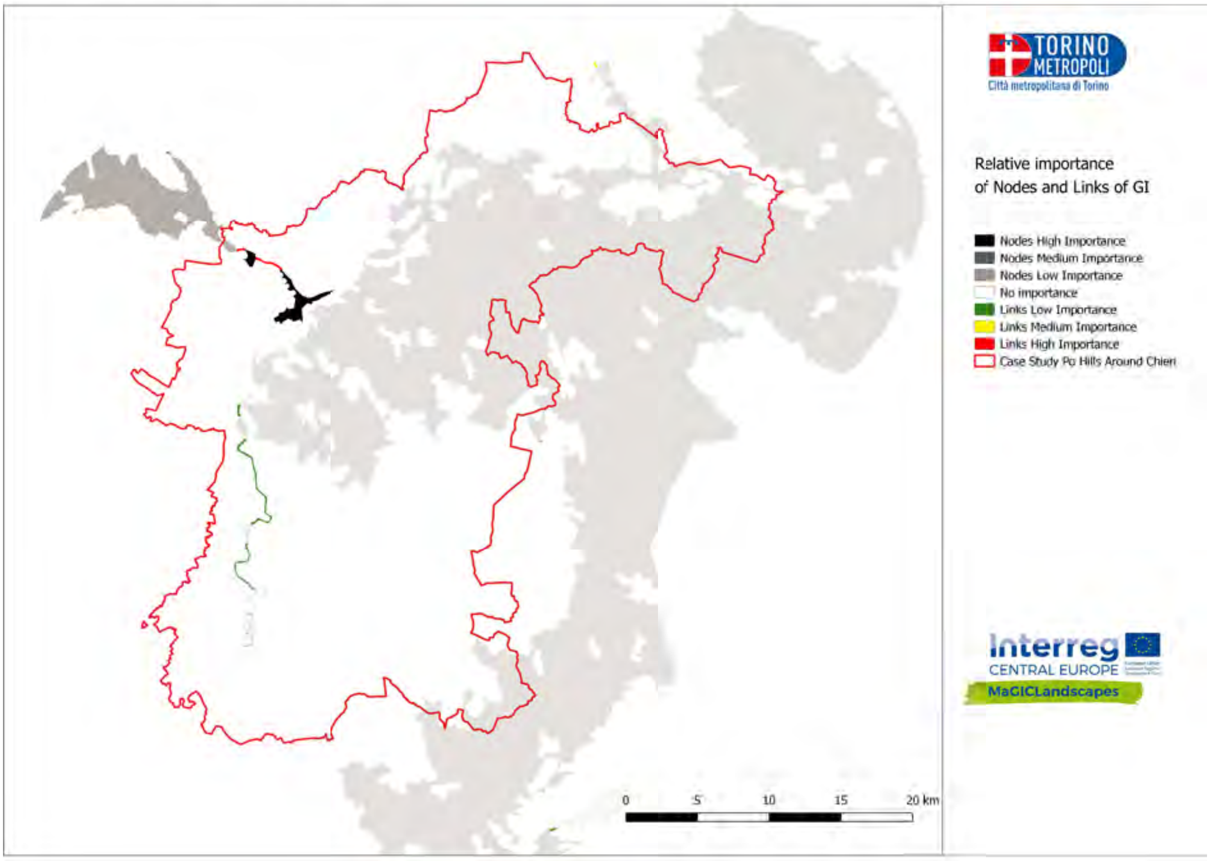

Figure 7: Result of the network analysis based on MSPA of the CMTo case study area "Po Hills around Chieri". In black the most significant areas in terms of connection.

Measuring Euclidean Distance

To measure the degree of intactness, shape and spatial arrangement of patches on a given binary map, the analysis methodology of Euclidean Distance and Hypsometric Curve (HMC) offers a practical and effective method of implementation. This module is available in GuidosToolbox, too and uses the same input data as the MSPA described above. This application creates maps of objects of interest showing the Euclidean distance map inside and outside those objects. This type of analysis may be further pursued to illustrate the influence zones of each object and to derive the pairwise proximity between neighbouring objects. Proximity, then, may be used for the establishment of cost-efficient reconnecting pathways in restoration planning (Vogt et al., 2017).

In terms of the connectivity of GI the generated distance maps provide spatially explicit information allowing for highlighting hotspots of highly fragmented areas or those dominated by well-established networks of GI. The spatial information of these distance maps of GI may be of high importance for monitoring, planning and risk assessment.

Additionally the simple, yet intuitive analysis scheme is easy to communicate and can be related to a variety of spatial planning measures by illustrating the degree of fragmentation or intactness.

Through the analysis of Euclidean Distance of elements of GI , as shown in Figure 8, existing connections and extensions in turquoise to blue colours illustrate both efficient links and reconnecting pathways useful to enhance the connectivity of the network of GI based on the Cores represented by the woodland and mixed formations of complex cultivation patterns displayed in green and red colours.

Deepening the investigation we can observe that the actual and potential connecting elements are represented almost entirely by the hydrographic network, both the natural as the canalised. The natural rivers Dora Baltea, Orco, Malone, Stura and Sangone, in addition, obviously to the Po river,form the main ecological network between the Turin hills and the alpine foothill area, despite the widespread presence of urban fabrics and roads.

But the results underpin the importance as an element of GI of the channeled streams, too. Also if they are often characterised by a lack of natural buffer zones like riparian strips, woodlands or wet meadows. they can be a useful support for the recreation of the ecological connectivity.

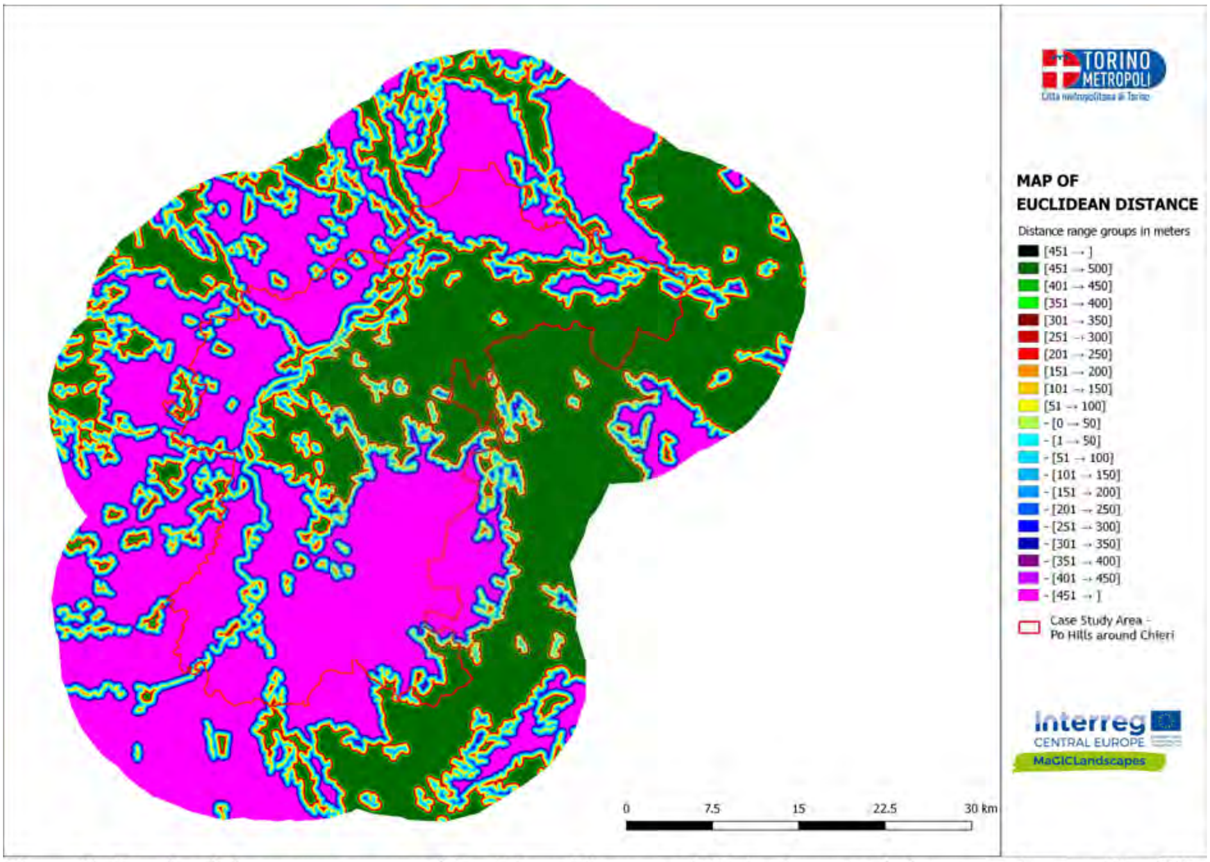

Figure 8: Result of the measurement of Euclidean Distance of GI in the extended case study area "Po Hills around Chieri" in Piedmont Region with highlighting of high value links that should be joined.

Conclusion

The considerations made above are the result of a large scale analysis. Deepening at a more local scale we noted thatalso within the hilly wooded areas, a less uniform and homogeneous situation come out.

As the main objective of the MaGICLandscapes project is to provide local land managers, policy makers and communities with the tools and knowledge to ensure the persistence of GI functionality and the consequent benefits to society, of course they couldn't base managing choices on so raw data. For this reason, with the upècoming project activities, we are going to apply the MSPA analysis using the Land Cover Piemonte (2010) a more detailed geodata produced on the regional basis, to better survey the different typologies of land use cover.

Moreover a "Public Benefit Assessment Tool - PBA - is envisaged by the project to enable organisations to develop GI strategies and action plans based on evidence from GI assessment and local needs, opportunities, and threats.

The PBA will be aimed at producing an analysis of the Public Benefit situation on a local scale in order to allow the definition of strategies and action plans to preserve and increase GI in each partner case study area. Thanks to this integrated approach, strategies and action plans will be based on the evidence of the situation in the targeted areas and will respond to specific local and regional needs, will mitigate the threats and will seize the opportunities for the local stakeholders tomaximizemultiple benefits from investment in GI.

The PBA procedure is going to be based on two contemporary processes:

- the assessment of the level of "available" public benefits provided by the territory of each case study and their location within the analysed territory
- the gathering of the information to identify existing needs and perspectives regarding the implementation of the Green Infrastructure network in as well as the collection from the territory and from the institutional stakeholders of additional data on the benefits provided by the existing Green Infrastructure (as an integration to what was obtained with the previews process).

On the basis of the land use, a series of maps will be produced presenting the distribution of the benefits supplied by each territory. Subsequently, on the basis of the single needs or the single opportunities linked to one or more benefits, each partner will identify the better policies and strategies that could support the drafting of the local action plans.

Acknowledgements

The authors thank all the MaGICLandscapes project partnership and, in particular, Marc Neubert and Henriette John from Leibniz Institute of Ecological Urban and Regional Development (IOER) for the coordination of the Work Package 1, Thomas Wrbka and Florian Danzinger from Division of Conservation Biology, Vegetation Ecology and Landscape Ecology (CVL) of University of Vienna for the coordination of the Work Package 2, Gianluigi Rossi, Maria Rita Minciardi and Simone Ciadamidaro from Italian Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) for the coordination of the Work Package 3 and, of course, Elmar Csaplovics and Christopher Marrs from the TU Dresden's, lead-partner of the project.

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