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Green infrastructure - the smart interpreting of natural capital

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Abstract: *Humanity continues to degrade natural capital, threatening its long-term sustainability. This more and more categorically imposes the need to create a specific green infrastructure - a response to the natural solutions to the accumulating problems (environmental pollution, floods, natural disasters and cataclysms). The failure of decisions to pay sufficient attention to ecological consequences and to apply systematic measures of high quality are among the main reasons for the current situation in most ecosystems. The fast-paced and highly mechanized way of life of modern man creates the illusion of remoteness from the natural world. Yet all human activity depends entirely on ecosystems and their functions and at the same time has (threatening) impacts on them. Therefore, the achievement of greater efficiency in the use of natural resources and the creation of suitable ecological living conditions are critically important goals both for Europe and for the whole world. Green Infrastructure (GI) is a successfully tested tool for providing environmental, economic and social benefits through environmentally sound solutions. Such a tool helps to understand the values provided by nature to human society and mobilizes investments for their maintenance and growth.*

Keywords: green infrastructure, natural capital, ecosystem services, environmentally friendly solutions, tourism

Introduction

Human society depends on the benefits provided by nature (food, raw materials, clean water, clean air, fertile climate, etc.). However, many of these benefits (often referred to as "ecosystem services") are used as if they are in near-limitless supply and are treated as free goods whose true value is not fully

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appreciated. Moreover, humanity continues to degrade the natural capital, threatening its long-term sustainability. This more and more categorically imposes the need to create a specific infrastructure to solve the accumulating problems (environmental pollution, floods, natural disasters and cataclysms).

About 80% of Europeans live in urban areas, where the effects of a number of environmental problems are felt most strongly. Noise, poor air quality, heavy traffic, poor environmental management and lack of strategic planning lead to health problems and a lower quality of life. In many areas, people prefer to live on the outskirts of cities because they realize that their well-being is affected by urban pollution. On the other hand, urban sprawl generates even higher levels of traffic and pollution, and problems continue to accumulate as the focus shifts from the center to the periphery.

Failed decisions to pay enough attention to ecological consequences and to apply systematic measures of high quality are among the main reasons for the contemporary situation in urban ecosystems. The fast-paced and highly mechanized way of life creates the illusion of remoteness from the natural world. Yet all human activity depends entirely on ecosystems and their functions and at the same time has (threatening) impacts on them. Therefore, the achievement of greater efficiency in the use of natural resources and the creation of suitable ecological living conditions are critically important goals, both for Europe and for the whole world.

Definition of terms

Natural Capital is defined by the European Commission as biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests to productive land and seas, from good quality fresh water and clean air to pollination and climate regulation and protection against natural disasters. Natural capital accounting is an alternative indicator that allows the benefits of green infrastructure to be expressed in economic terms.

Ecosystem services are the benefits that humans derive directly or indirectly from nature. They are summarized in 4 main groups:

- *Supporting services* – create the conditions necessary for the provision of all other ecosystem services (for example, nutrient cycling or soil formation). They differ from the rest in that their action on humans is indirect or very slow;
- *Material services* – refer to the production obtained from ecosystems and directly used in production or for personal consumption by people (all the goods that nature provides us - food, minerals, fuels, herbs and medicinal plants, genetic material, drinking water, etc.);
- *Regulatory services* – are related to the ability of ecosystems to regulate important natural processes (regulation of climate, water quality and quantity, etc.);
- *Cultural services* – intangible benefits that people derive from ecosystems. Although not essential for survival, they are important for human well-being and development. Examples include the use

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of ecosystems for scientific development, education and creativity, recreation, entertainment and recreation.

Natural ecosystems can provide a wide range of these services simultaneously. This multi-functionality is one of the key and valuable characteristics of green infrastructure, because modern societies and economies are increasingly dependent on healthy and sustainable nature. A few examples:

• Diverse mixed forests absorb large amounts of water and protect the soil, preventing and reducing the impact of floods and landslides; absorb carbon dioxide and enrich the air with oxygen; provide important habitats for animals as well as attractive places for recreation and tourism;

• Well-designed urban green spaces (parks, gardens, green roofs, plots of land, etc.) contribute to biodiversity conservation while helping to tackle climate change, keep cities cool, reduce flood risks and improve people's health and well-being the townspeople;

• Restoring wetlands is a suitable (and often cheaper) alternative to building new treatment plants. Other human benefits provided by the normal functioning of these areas are: agriculture, logging, energy sources, transport, high concentration of animal and plant species, opportunities for recreation and tourism.

In this paper, **green infrastructure** is interpreted as "an appropriate combination of diverse material elements of predominantly natural origin, which are necessary to create and maintain suitable recreational and/or environmentally friendly conditions for human life" [1]. These are numerous interconnected natural and semi-natural areas, zones (marine, terrestrial, freshwater, coastal, etc.) and areas in rural and urban territories, as well as parks, forest reserves, ecoducts and bicycle paths, etc.

Green Infrastructure (GI) is a successfully tested tool for providing environmental, economic and social benefits through environmentally friendly solutions. Such a tool helps to understand the values provided by nature to human society and mobilizes investments for their maintenance and growth. The conscious integration in spatial planning and territorial development of the protection and support of nature processes with the resulting benefits for people is a basic principle of GI. In other words, green infrastructure is a set of natural and semi-natural areas and green spaces, providing ecosystem services that contribute to human well-being and quality of life.

The benefits generated through GI extend across multiple sectors and have a positive impact on society, the environment and the economy. They usually accumulate over a long period of time and sometimes take years to manifest. Examples include:

• *Economic benefits* – production of food and natural resources, indirect and direct increase in employment, saved costs from increased energy or water efficiency, reduced costs from environmental damage, increased property values and reduced costs for public health, tourism development and etc.;

• *Ecological benefits* – preservation of biological diversity, provision of habitats for biodiversity, regulation of air and water quality, climate mitigation;

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• *Social benefits* – increased opportunities for recreation, benefits for physical and mental health, improved social cohesion, adaptation to the climate, etc.

Compared to traditional (so-called "grey") infrastructure, which generally fulfills a single purpose, such as drainage or transport, green infrastructure is more attractive because it has the potential to solve several problems at the same time. Traditional infrastructure continues to be necessary, but can often be enhanced with environmentally friendly solutions.

For example, thanks to the natural ability to retain and absorb moisture inherent in vegetation and soils, green infrastructure can be used to reduce the amount of stormwater runoff entering sewer systems and ultimately lakes, rivers, and streams. The benefits of green infrastructure can also include improving air and water quality, mitigating the urban heat island effect, providing additional habitats for wildlife, providing pleasant places for people to relax, etc. Green spaces also contribute to the cultural and historical landscape, giving identity to the places concerned, as well as to the landscape of the urban and suburban areas where people live and work. Research shows that green infrastructure solutions cost less than 'grey' infrastructure and offer a wide range of co-benefits to local economies, social fabric and the wider environment.

In the European institutions' documents on the subject, green infrastructure is interpreted as an interconnected network of natural areas, including agricultural land, greenways, wetlands, parks, forest reserves, communities of native plant species and marine areas that naturally regulate storm runoff, temperature, flood hazards, as well as water, air and ecosystem quality [2]. It is a territorial intervention - "a strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to provide a wide range of ecosystem services while enhancing biodiversity" [3]. Such services include, for example, water purification, air quality improvement, provision of recreational space, and assistance in climate mitigation and adaptation. This network of green (land) and blue (water) spaces improves the environmental quality, condition and connectivity of natural areas, as well as improving the health and quality of life of citizens. GI development can also support the green economy and create job opportunities.

Elements of green infrastructure

Green infrastructure components include a variety of natural and restored ecosystems and landscape features that function as an ecological whole. They are required to be of high quality and to be part of an interconnected network. They vary in size, function and ownership. To be successful, they need active protection through long-term planning and management, as well as responsible commitment.

Determining the components of green infrastructure is important for its identification, promotion and assimilation, and zoning is a widely applied approach in spatial planning (Table 1).

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Table 1. Components of green infrastructure [4]

Hubs	Core areas of high biodiversity value, such as protected areas (like Natura 2000 sites) and non-protected core areas with large, healthy and functioning ecosystems
Corridors and stepping stones	Natural features like small watercourses, ponds, hedgerows and woodland stripes
Restored habitats to reconnect or enhance existing natural areas	Artificial features such as eco-bridges, fish ladders or green roofs to enhance ecosystem services or assist wildlife movement
Buffer zones	Improve the general ecological quality and permeability of the landscape to biodiversity (e.g. wildlife-friendly farming)
Multifunctional zones	With compatible land uses that support multiple land uses in the same spatial area (e.g. food production, tourism and recreation)

Zoning is the most frequently applied method in the implementation of territorial planning of tourism. It represents the division of the territory into zones with different structure, purpose and use. The zone is a territorial unit with a different area and location, intended for a certain type of tourist activities. Zoning in different types of territories is specific.

When zoning the territories for short-term recreation (parks), the following zones are distinguished [5]:

• According to the concentration of visitors - areas with an active gathering of visitors and areas with less traffic;

• According to the provision of tourist infrastructure and superstructure - areas saturated with facilities and areas poorly provided with facilities;

• According to the degree of noise load - areas with noise load and areas of silence;

• According to changes in the appearance of the environment - areas with greater and areas with less changes in the appearance of the natural environment.

Usually, areas with a high concentration of visitors concentrate the corresponding material base within themselves, which leads to significant changes in the appearance of the natural environment, and also to noise pollution. A typical example is the beaches and the territories located in close proximity to them.

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On the other hand, areas with a small concentration of visitors are less equipped with special facilities for tourism, have a lower impact on the environment and are, accordingly, areas of silence. A typical example is the territories developing rural tourism or ecotourism.

As already emphasized, GI should support and promote ecosystem services by enhancing and synergizing the benefits provided by nature. Located in an urbanized environment, green infrastructure plays a critical and increasingly important role. In Table. 2 some of the most common elements of GI within specific urban and non-urban environments are outlined, as well as brief notes on their benefits. Due to their specific characteristics, these elements manifest at different levels and interact to different degrees. Studying them will allow their potential to be used to the maximum and provide additional benefits for the functioning and development of the environment.

Table 2. Types of green infrastructure in urban and non-urban environments and main characteristics [6]

Category	Urban green infrastructure element	Brief notes
Building greens	Balcony green, ground based green wall, facade-bound green wall, extensive green roof, intensive green roof, atrium, green pavements and green parking pavements, green fences and noise barriers	Green roofs and facades provide habitats and food to insects and small animals (including pollinators), improve building energy efficiency and indoor/outdoor climates, and are particularly useful in dense urban areas with limited open space.
Urban green areas connected to grey infrastructure	Tree alley and street tree/hedge, street green and green verge, house garden, railroad bank, green playground/school ground, green parking lots, riverbank greens	Beyond serving as habitats and ecological stepping stones, street trees provide shade and green space for relaxation for urban residents, as well as improve air quality and climate, thereby also reducing energy needs for heating and cooling.
Parks and (semi)natural urban green areas, including	Large urban park, historical park/garden, pocket park/parklet, botanical garden/arboreta, zoological	Pocket parks are a new trend in urban areas across the globe. They consist of very small greened spaces,

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urban forests	garden, neighbourhood green space, institutional green space, cemetery and churchyard, green sport facility, forest, shrubland, abandoned and derelict area with patches of wilderness	often in reclaimed parking or street spaces, and frequently also include resting or play areas. They utilize small spaces efficiently to bring biodiversity into urban areas and provide high-quality recreation space for residents, improving quality of life.
Allotments and community gardens	Allotment, community garden, horticulture	Community gardens create spaces not only for biodiversity, but also for urban food provision. They encourage residents to get involved in garden management, contributing to social inclusion and cohesion.
Agricultural land	Arable land, grassland, tree meadow/orchard, biofuel production/ agroforestry, horticulture	Agricultural land in urban and peri-urban areas are important for providing habitat to agricultural species in and near cities, and also for provision of urban residents with fresh and healthy food when adequate food market structures are in place
Green areas for water management	Rain gardens or sustainable urban drainage systems (SUDS), rain gardens, swales / filter strips	Systemic approaches to protect urban areas from flood damage and help adapt to changing rainfall patterns by eg combining green, blue and grey components; can include e.g. green roofs, permeable surfaces, infiltration trenches, swales, detention basins.
Blue areas	Lake/pond, river/stream, dry riverbed, canal, estuary, delta, sea coast, wetland/bog/fen/marsh	Sea coasts provide many benefits beyond being habitats for coastal and marine species. For example, they are sources of food and other resources, support tourism, can be

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		part of storm surge and flood management, and provide recreation and exercise space.

Green infrastructure and tourism

When developing and implementing the recreation system of the territories, it is necessary to observe the principle of integrated development, according to which tourism should contribute to the improvement of the socio-economic development and the way of life of the local population, and not hinder it [7]. This principle is also based on the so-called *recreational nature use in tourism*, which postulates moderate exploitation of natural complexes of natural origin [8].

Tourism is one of the sectors most closely related to green infrastructure. In this sector, it can create spaces for sustainable development, for healthy recreation. Green infrastructure is particularly important for short-term daily or weekend recreation. Green spaces are a mandatory element in the territorial planning of recreational areas. In the territorial planning of any territory, especially if it will perform tourist functions, it is extremely important to provide sufficient number and size and optimally located green areas. Between 50% and 70% of the area should be provided for green areas in the resorts, and of the territories for general use no less than 20% should be designated for such purposes. Green areas include all parks, gardens, street landscaping, suburban and forest parks, botanical gardens, arboretums, protected plantations and nurseries, as well as cemetery parks [9].

The benefits of green infrastructure in the field of tourism are:

- Creation of various opportunities for relaxation and sports, improving people's physical and mental health, their social well-being and their quality of life;
- Increasing the income and employment of the local population;
- Reducing the impact of carbon, water and waste from the tourism sector;
- Building a sustainable green infrastructure architecture for tourism;
- Formation of green/wild areas or managed landscapes with bicycle and pedestrian paths;
- Improving the aesthetic appeal of landscapes;
- Raising awareness about the protection and restoration of ecosystems and biodiversity;
- Preserving not only the natural but also the cultural heritage;
- Attracting investments and creating opportunities for the development of ecological and sustainable business, etc.

Tourism-related green infrastructure can help reduce the carbon and ecological footprint of transport and mitigate the effects of habitat fragmentation caused by transport infrastructure by building:

• Green bridges and eco-tunnels over/under roads and railways for increased habitat connectivity;

• Permeable and landscaped pavements in parking lots and parking spaces;

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• Green noise barriers;

• Sustainable (urban) drainage, flood protection and regulation of the water cycle, etc.

Green and blue elements in urbanized territories have a significant impact on the long-term socio-economic and ecological functionality of the territory. Resource-efficient cities and suburbs are compact and climate-resilient, with green facades and roofs; bicycle and pedestrian infrastructure; urban gardens; Sustainable Urban Drainage Systems - SUDS; parks, rivers, lakes, wild areas, etc. The resulting benefits with a direct impact on tourism are:

• Improvements in mobility and transport sustainability;

• Social cohesion and sustainable urban development;

• Provision of habitats for biodiversity protection and people's recreation;

• Reduced energy consumption due to improved temperature regulation in buildings;

• Reduced carbon footprint in cities and the environment;

• Improved drainage and reduced flooding.

European Green Infrastructure Concepts and Policies

Green infrastructure is a relatively new and complex concept, so there is no generally accepted definition for it. Quantitative analyzes and indicators are also lacking. For this reason, it is difficult to integrate into the general political picture. However, this does not apply to all GI features. For example, wildlife crossing facilities (ecoducts), water management systems, green roofs, etc. They usually have clear functions and measures exist to assess their effectiveness.

Financially, green infrastructure also seems complicated, but in addition to providing multiple benefits, it is often cheaper, more robust and more sustainable. Therefore, rather than reverting to already implemented 'grey' solutions such as levees and flood pipes, planning authorities should first consider the benefits of restoring floodplains or wetlands.

Green infrastructure is enshrined in a number of EU program and legislative documents (EU Biodiversity Strategy, EU Green Infrastructure Strategy, Eighth Environmental Action Program 2030, Agenda 2030 for Sustainable Development, etc.). GI can significantly contribute to the achievement of the EU's political objectives oriented towards regional and rural development; to climate change, disaster risk management, agriculture and forestry, and environmental protection. The goal is the full integration of this infrastructure into EU policies and its transformation into a standard element of territorial development.

The EU's concept of GI overlaps strongly with the concepts of nature-based solutions and measures for natural water retention and disaster risk reduction and ecosystem-based approaches to climate adaptation and mitigation (Fig. 1.).

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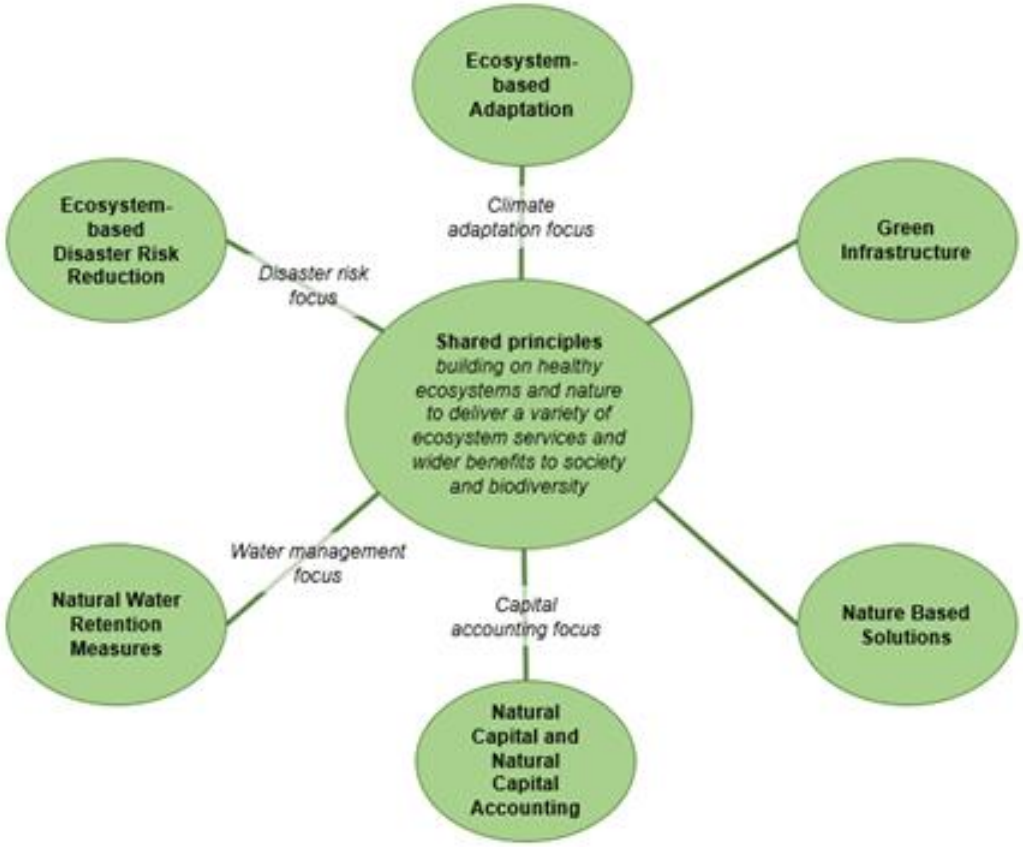


Figure 1. Concepts related to green infrastructure [10]

Nature-based solutions (NbS) are solutions to societal challenges that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience. They focused on delivering societal and biodiversity benefits through ecosystem services. NBS bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. The link between NBS and GI is that both use generally the same principles, concepts, and practical approaches – therefore, NBS can be considered part of green and blue infrastructure networks.

Ecosystem-based adaptation (EbA) is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" [11]. Green infrastructure measures that contribute to climate adaptation can be considered EbA measures. They include a variety of interventions to address adaptation challenges such as high temperatures, changing rainfall and extreme weather patterns, higher risk for certain natural disasters, erosion, and others. Examples of interventions that constitute both EbA and GI measures include green roofs and facades, floodplain restoration, and restoration of natural sedimentation processes to adapt coasts to sea-level rise.

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Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes. The main goal of NWRM is to enhance the retention capacity of aquifers, soil, and aquatic and water dependent ecosystems with a view to improve their status. NWRM interventions form a part of green and blue infrastructure networks. They improve the quantitative and qualitative status of water bodies, and reduce vulnerability to floods and droughts. The restored ecosystems also contribute both to climate change adaptation and mitigation.

Ecosystem-based Disaster Risk Reduction (ecoDRR). The European Commission promotes ecosystem-based approaches that contribute to the conservation, enhancement and restoration of biodiversity, ecosystems and ecosystems services in urban, rural, coastal and natural areas for the purpose of disaster risk reduction. These initiatives constitute a positive and cost-efficient way of supporting disaster risk reduction and adaptation to climate change, while often providing significant co-benefits in terms of climate change mitigation or human health, safety and well-being. Green infrastructure that benefits disaster risk reduction can be characterised as ecoDRR.

Although each concept arose from different sectoral and political needs and therefore differs in its specificities, they all share the goal of using nature as a tool to address societal challenges in a cost-effective and sustainable way. The design of a GI determines the range of benefits it can provide.

Conclusion

Green infrastructure is not simply an alternative description of conventional open space. Its key characteristics – (1) a network of integrated ecological spaces and elements and (2) multifunctionality – predetermine its mission to:

- Maintain people's mental and physical health;
- Provide cool urban areas during heat waves;
- Attract investments;
- Encourage active travel;
- Reduce water runoff during flash floods;
- Maintain a neutral level of carbon emissions;
- Ensure sustainable development in urban areas.

The extent to which green infrastructure provides these benefits depends on how it is designed and maintained, as well as the maturity and health of the elements that make it up.

Green infrastructure is a link between urbanized urban and resort areas and natural capital. Through its specifics and characteristics, green infrastructure is an important means of ensuring sustainable development of these territories.

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