# Green Infrastructure

## Guide (not only) for the local governments

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mestskej-casti/perfectplanning-for-environmental-resourceefficiency-in-european-cities-and-towns/.

Logos

## Introduction

Despite the fact that the term "green infrastructure" is used in a number of political documents and strategies of the European Commission dealing with the protection of biodiversity, adaptation to climate change, protection of water resources and flood prevention, this is still a fairly new concept on the local/national level. The reason may not only be the newness of the terminology and its ambiguity, but also a lacking methodology that would accurately define the concept of green infrastructure. The guide you're holding right now should not only help governments but also public stakeholders to get more familiar with this issue and thus facilitate the introduction of the concept of green infrastructure into everyday practice. The opinion of the European Economic and Social Committee regarding Green Infrastructure states that the crucial responsibility for green infrastructure projects lies with the individual Member States of the EU and in particular the bodies responsible for regional and local planning.

**What is "green infrastructure?"**

**1.2 Definition of "green infrastructure."**

The term "green infrastructure" reflects a holistic approach of natural, semi/natural and „man made" greenery and natural areas interlinked together in different levels, starting from the local level in frame of the built environment of cities and municipalities to the countryside. In general, it is a shift from the perception of areas or elements of urban or rural greenery as being separate, towards the integration of these elements into a coherent system. Several definitions of green infrastructure have gradually been created. Regarding the green infrastructure "official" definition there is a principal european strategy promoting the use of green infrastructure called "Green Infrastructure – Enhancing Europe's Natural Capital," where the European Commission 1 defines green infrastructure as a ".

a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings[2]

The following definition was proposed within the PERFECT project3:

"Green infrastructure is a network of natural and semi-natural elements, green areas and aquatic ecosystems that provide ecosystem services, support biodiversity, offer nature near solutions for problems especially in the built-up areas and ensure the linking of the built-up area with the natural surrounding countryside"

All the above definitions show that "green infrastructure is a network/interconnected system of:

- "man made" green areas in settlements (e.g. areas with public greenery or parks, green plazas and squares, alleys, the greenery in resindentional areas, cemeteries, private greenery, such as private gardens, semi-public greenspaces nearby administrative buildings, etc.)
- semi-natural and natural areas and a variety of natural ecosystems valuable from the nature protection point of view (e.g. forest and wetland areas, protected areas, including NATURA 2000, etc.)
- special (often in different levels) greenery elements like green roofs (intensive and extensive), roof gardens (visual, ornamental, production gardens), green walls (vines on vertical structures or special vertical structures with plants) or Eco ducts (bridges or flyover structures that enable wildlife to overcome road barriers)
- linear elements of greenery, such as bio corridors, alleys, green avenues, greenways and green belts, etc.

[1] COM/2013/0249 final

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249

[3]https://www.karlovaves.sk/wp-content/uploads/Vyhodnotenie-dotaznikoveho-prieskumu-pre-zainteresovanu_verejnost.pdf

- natural and semi-natural water and wetland elements in urban settlements, such as watercourses, surface water, rain gardens, shallow terrains and other features designed for the capture and gradual absorption of rainwater, etc.

The types and kinds of green infrastructure are covered in more detail in Chapter 4.

**The application of the concept of green infrastructure**

**2.1 Conventions, strategies and other EU documents as a basis for the application of the concept of green infrastructure**

Green infrastructure is among important policies of the European Union, promoted in a number of areas, ranging from protection of biodiversity to the climate change, the protection of water resources, flood prevention and, in particular, the planning of the urban environment.

The first document on the European level that also deals with the protection and the creation of landscape, including green infrastructure in urban environments, is the Landscape Convention. It highlights the following areas: 1. The importance of the urban landscape and open public urban spaces 2. The involvement of the public in their creation and 3. The importance of the exchange of experience and information.

Unfortunately, its implementation in Slovakia has not been at a satisfactory level. The basic concept of "landscape"is defined in the Convention as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors." The definition also applies to the urban and suburban landscape. The Convention applies across the entire territory, as it covers not only the types of landscapes that can be considered as exceptional but also the ordinary (commonplace) and degraded landscape types. The European Landscape Convention, therefore, defines landscape through mankind, highlighting its significant social and societal dimension.

"EU biodiversity strategy to 2020" was approved in 2011 under the name "Our life insurance, our natural capital: an EU biodiversity strategy to 2020." The strategy defines six principal objectives that complement each other and focus on the root causes of biodiversity loss, as well as on the mitigation of the main pressures on the environment and ecosystem services in the EU. Each objective will be implemented through a set of specific time-bound measures and other related steps4.

Measure no. 6, which specifically focuses on promoting the use of green infrastructure, is proposed for objective no. 2 to "ensure the conservation and enhancement of ecosystems and their services through the establishment of green infrastructure and restoration of at least 15% of the degraded ecosystems by 2020." Specific priorities and tasks are also set here.

In addition to the fact that the European Commission undertook to draw up the Strategy for Green Infrastructure (which was also met in 2013, see additional text), it also proposes the creation of motivational factors to encourage initial investment in green infrastructure projects and conservation

[4]http://ec.europa.eu/environment/pubs/pdf/factsheets/biodiversity_2020/2020%20Biodiversity%20Factsheet_SK.pdf

of ecosystem services, for example, by using more targeted use of EU funds and public-private partnerships.

In particular, the strategy of the European Commission regarding green infrastructure5 highlights the importance of green infrastructure in urban environments, with more than 60% of the EU population living in these environments6. Green infrastructure is also understood as an effective measure to mitigate the effects of climate change. It is highlighted that the "elements of green infrastructure in major cities, such as green roofs, parks, and alleys, provide benefits to the health of the population, such as clean air and improved water quality, contribute to the protection of human health, energy conservation, and facilitate the management of rainwater."

It is also stated that the "introduction of green infrastructure elements in urban areas creates a greater sense of community, strengthens cooperation within voluntary activities of the civil society and contributes to the fight against social exclusion and isolation. Green infrastructure elements have a physical, emotional, psychological, and socio-economic benefit for the individual and the society. Green infrastructure helps with the possibility of linking urban and rural areas and creates pleasant places for life and work."

The green infrastructure strategy of the European Commission also deals with newer trends, such as urban agriculture. It literally states that "through urban food production and through community gardens, which are a powerful tool for education and, in particular, for arousing the interest of young people, the issue of separating food production from its consumption is being addressed in the context of green infrastructure and contributes to the increase of its perceived value. Investments in green infrastructure have a great potential to enhance regional and urban development, including the preservation and creation of jobs.

The section on integrating green infrastructure into key policy areas states that it is necessary to ensure that green infrastructure becomes a standard part of the spatial and urban planning and is also fully integrated into all policies of national states.

Another European Commission document entitled "Guidelines on best practices to limit, mitigate or compensate soil sealing" provides examples of how soil can be protected from the ever increasing construction with the help of spatial planning tools and methods, or at least how to compensate for its consequences. In urban environments, it is also possible to ensure measures to promote sustainable management of rainwater with the use of permeable surfaces, greenery, and various procedures.

The EU Strategy on Adaptation to Climate Change7 also highlights the role of green infrastructure and the provided ecosystem services and natural solutions. Support within the LIFE funding mechanism was created to promote such projects.

[5]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0249:FIN:SK:PDF

[6] Communication from the Commission to the Council and the European Parliament on the Thematic strategy on the urban environment, COM(2005) 718 in its final version.

[7] http://ec.europa.eu/clima/policies/adaptation/what/documentation_en.htm

The European Environment Action Programme to 20208 included the area of green infrastructure among measures to increase resistance to climate change and strengthen the resilience of the environment, which, moreover, can also have significant socio-economic benefits, including public health benefits.

**Main functions of green infrastructure**

**3.1 Multifunctionality of green infrastructure**

Green infrastructure is one of the basic components of the urban and rural structure and is particularly known for the positive effect of greenery on the condition and quality of the environment. Multifunctionality of green infrastructure is unquestionable since it positively affects a number of areas, including the protection and promotion of biodiversity, adaptation to climate change, health, recreation, promoting of community building, economic aspects, and so on – see Table 1.

Table 1: Multifunctionality of green infrastructure (drafted according to Magic Matrix Guidelines, the Perfect project9)

| Area | Contribution |
|---|---|
| Biodiversity | Improving the status of wildlife habitats |
| | Green Eco ducts and bio-corridors |
| | Reducing the fragmentation and separation of habitats and improving the pass ability of the territory for animals |
| Climate change and natural hazards | |
| | Flood risk mitigation: |
| | flood risk mitigation (fluvial) |
| | mitigating the risk of floods (pluvial) in urban settlements, sustainable management of rainwater, including (infiltration, detention and possible subsequent use) |
| | Strengthening the resilience of ecosystems |
| | CO2 capture and storage (sequestration) |
| | Mitigating the impact of urban heat islands |
| | mitigation and management of natural disasters, prevention of associated risks (such as storms, forest fires, landslides) |
| Environment/regulatory ecosystem services | |
| | Noise reduction |
| | Prevention and/or reduction of soil pollution |
| | Removal of contaminants from water and water quality assurance |
| | Removal of pollutants from the air |
| | Support of insect pollination |
| | Protection against soil erosion |
| | Increased pest control |

[8] http://eur-lex.europa.eu/legal-content/SK/TXT/PDF/?uri=CELEX:32013D1386&from=EN
[9] https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1526373149.pdf

| | |
|---|---|
| | Improvement of landscape quality |
| | Mitigation of pressure on the soil surface and soil sealing |
| Socio-economic area | |
| | Improved health and well-being of population: |
| | mental health |
| | physical health: |
| | dealing with obesity |
| | encouraging physical activity |
| | Creation of jobs |
| | Diversification of the local economy |
| | More attractive and greener cities |
| | Increased real estate value |
| | Creation of “genius loci,” the character and the look of the landscape |
| | More integrated energy solutions |
| | More integrated transport solutions |
| | Advanced options for tourism |
| | Advanced options for recreation |
| | Transport: reduced traffic congestion |
| | Transport - reducing the number of road fatalities and serious accidents caused by changes in the mode of transport/better protection for cyclists |
| | Reduced number of criminal offences |

### 3.2. The basic breakdown of the green infrastructure’s functions

Environmental and ecological functions of green infrastructure, e.g.:

- Improved air quality and microclimate in urban environments
- Mitigation and adaptation to climate change
- Affecting the hydrological cycle and the outflow ratios
- Promotion of biodiversity, life cycles and processes
- Regulation of soil erosion and other slope processes
- Other regulatory ecosystem services (e.g. supporting the soil-forming processes, decomposition of harmful substances, etc.)

Social, societal, health and economic functions of green infrastructure are, for example:

- Space for contact; learning tolerance and democracy
- Positive impact on the health of the population
- Promotion of recreation and tourism – recreation services
- Crime prevention
- Promotion of safe and sustainable transport
- Economic benefits (an increase in property values, increase in the attractiveness of the environment for investment)
- Promotion of local food production

Environmental and ecological functions of green infrastructure are, for example:

- Breakdown, division and merger into an urban structure
- Creation of the spirit of the place, the identity bearer, meanings, and values
- Visual enrichment of the space
- Creation of the landscape character and image – landscaping function.

Detailed information about all the functions of green infrastructure, together with a summary of existing knowledge and the results of the studies is referred to in Appendix 1.

**Types and features of green infrastructure**

As has already been explained (described) in earlier chapters, "green infrastructure" requires a holistic approach to linking the various areas and elements of greenery10 . Since this is a fairly broad topic, its breakdown and understanding is not completely clear and is subject to the evaluation and the interest of the various stakeholders and parties.

Green infrastructure can be divided according to different criteria. The basic categorization presents a breakdown into urban and rural green infrastructure, which consists of planar, point, and line features.

Just like a set of areas (biotopes), lines (bio-corridors) and interaction elements forming a coherent system that creates the basis of ecological stability in a landscape, a similar network should also be created in settlements within the concept of "green infrastructure," with these two networks forming a natural unit, since green infrastructure does not know the boundary of developed areas and is a rather coherent system that interconnects developed areas of municipalities and their surrounding open country

Greenery and natural elements in a developed urban territory should form an interconnected network of areas, points, and lines, while also being connected to the system of rural greenery. The term urban green infrastructure refers to those parts of developed and undeveloped structures, including roofs, terraces, balconies and even the facades of buildings, which are largely covered by vegetation, or they are natural and aquatic ecosystems.

While rural green infrastructure is created either naturally (without human intervention) or it is deliberately implemented or regulated, urban green infrastructure is mainly created by human activity.

Green infrastructure is inherently a dynamic system because the strengthening of natural processes in economic areas or the introduction of a natural method of greenery maintenance in urban areas can help expand and enhance green infrastructure areas. Natural processes can have a structural character (in the sense of protection of existing or supplementation of missing natural ecosystems in

[10] Forest Research 2010

rural and urban areas) or functional (method for utilizing rural ecosystems, maintenance of greenery in urban settlements).

**4.1 Elements of green infrastructure in rural areas**

Examples of green infrastructure elements in rural areas – planar

(drafted according to the "Green infrastructure" leaflet, EC, 2010):

• protected areas, e.g. Natura 2000; a national network of protected areas

• valuable ecosystems and areas of high natural value outside the protected areas, e.g., natural forests and meadows, etc.; this is how biotopes are mostly understood in the TSES

• restored biotopes that were created with a view to the protection of particular species in order

to, for example, expand the protected area, increase the area for grazing, breeding or shelter for different species and/or to enable their migration, also referred to as stepping stones for wildlife; this is how interaction elements are mostly understood in the issue of the Territorial System of Ecological Stability

• areas that contribute to the adaptation and mitigation of climate change, for example, wetland communities, alluvial forests and peatlands, which retain water and help prevent flood risks and at the same time absorb and store CO2.

Examples of green infrastructure elements in rural areas – linear and point:

- natural landscape features, such as small watercourses, small islands and forest boundaries, which can serve as a link between other areas of green infrastructure. This is how bio corridors are mostly understood in the TSES. As an example we can further mention the alleys and avenues in rural areas, windbreaks and hedgerows, river systems with shoreline vegetation; solitary trees, for example, at intersections of roads, by small sacral buildings, such as roadside crosses, wayside shrines, or smaller chapels;
- human activity created by Eco ducts or wildlife crossings, which are designed to help species travel across insurmountable technical obstacles.

**4.2 Elements of green infrastructure in urban areas**

Examples of green infrastructure elements in urban areas – planar:

Urban green infrastructure can be created by human activity, or be semi-natural or natural. In the Standard minimum requirements for municipality amenities11, the typology of greenery was categorized as follows:

Parks and other types of public park greenery

1.1 - central

[11] http://www.telecom.gov.sk/index/index.php?ids=75272

1.2 - division borough

1.3 - district

smaller modified landscape surfaces

Greenery in residential areas

- settlement greenery between blocks of low residential buildings
- settlement greenery in high-rise residential area
- private gardens, allotment gardens, community gardens

Historical greenery

- former private gardens and parks associated with historic buildings
- public historic parks and gardens

Greenery near civic amenities (according to type)

- Pre-school and school facilities and campuses (from kindergarten to university campuses)
- Hospitals and social welfare facilities
- Public and accommodation buildings
- Health and medical buildings
- Recreation centers
- Cultural and educational centers
- Business and shopping centers
- Administrative buildings
- Other greenery
- The greenery of plazas and pedestrian zones
- Botanical and zoological gardens
- Cemeteries
- Campsites, tent settlements
- Greenery on manufacturing and industrial grounds
- The greenery of a production area
- Green insulation zone (according to type)
- Landscape greenery in an urban settlement
- Forests and park forests
- Cultivated and fallow agricultural land
- Other unused greenery

In addition to the above mentioned "green" (terrestrial) elements, green infrastructure also consists of “blue” (aquatic) elements, such as water areas, watercourses, wetlands, marshes, waterlogged meadows, rain gardens, and so on, i.e., natural and constructed aquatic and wetland elements).

Examples of green infrastructure elements in urban areas – linear and point:

- Point greenery (solitary trees, etc.)

- Alleys, avenues
- Bushes, groups of bushes and hedges
- Line greenery by transport routes and streets (roadside greenery), rail side greenery, green railways

The accompanying foliage of watercourses and water areas (shoreline vegetation)

- Greenery on buildings - green roofs (roof gardens), greenery on terraces and balconies, green wall and green facades, atrium greenery12
- elements of green infrastructure for rainwater infiltration, man-made wetlands and retention ponds, plant root wastewater treatment plants, green infiltration strips, paved permeable green infiltration strips.

**4.3 Characteristics of certain selected elements of green infrastructure in urban areas**

Below we will present special elements of green infrastructure whose function is (among other things) to assist in the adaptation to the adverse effects of climate change in urban areas.

Green roofs

Green roofs can be divided into 2 main groups: extensive and intensive. Extensive green roofs only require minimal or no maintenance after their establishment. They have durable, mostly xerophytic plants which tolerate extreme environmental conditions well – dryness and intense direct sunlight. Intensive green roofs are designed to facilitate the passage or stay for the users, thus forming a specific type of open green space. Intensive green roofs are more demanding when it comes to the building's statics, their implementation, and the subsequent maintenance. Bushes and lower tree cultivars are often planted on intensive green roofs. In these cases, the projects also consider an irrigation system, since these types of plants cannot manage only with atmospheric precipitation. A green roof is an effective means of sustainable rainwater management,and it also has a cooling effect and promotes biodiversity. The main effects of green roofs are water evaporation, shade for the vegetation, the ability to reflect solar radiation, power consumption for the process of photosynthesis, etc. Green roofs influence rainfall retention in several ways. A comparison of the "classic" roof with a green roof highlights not only a significant overall decrease in the water runoff but also the differences in its distribution, with intense rain runoff from the green roof being delayed to the end of the rainfall. Green roofs can also effectively promote biodiversity, for example, to integrate innovative elements and places that will become a haven for the appropriate species, etc.

Green facades and green walls

Green facades can be divided into 3 main groups. These are facades with either vertical greenery going down the prefabricated structure or climbing directly on the facade. The third group are "green walls," which are formed not only by the greenery but also have a special substrate and irrigation built into the green walls. The effectiveness but also the acquisition and operating costs differ based

- [12] Green Surge, 2017

on this basic breakdown. In addition, the cooling effect varies on the facade itself, particularly if the lower part of the building is naturally shaded (Feng et al. 2010).

Elements of green infrastructure for rainwater infiltration

Infiltration strips, rain gardens, planar infiltration, shallow infiltration terrains, gutters, infiltration tanks, etc.

Rain gardens and infiltration and retention areas are particularly used in space-limited locations (e.g. for water absorption by roads or in heavily urbanized environments). Planar infiltration equipment and shallow infiltration terrains are surface devices with grass or planted humus layer. An infiltration channel is a hollowed linear system filled with permeable gravel material, with retention and absorption into more permeable soil and rock layers. An infiltration tank is an object with a strong retention function together with the absorption through a grassy/humus layer.

Constructed wetlands

A constructed wetland is often built as a root wastewater treatment plant, in which water flows horizontally or vertically through the porous substrate below the surface of this substrate. The main purpose of water retention is the gradual infiltration and purification, thus promoting the retention of water in the landscape and overall improvement of the microclimate.

Collection ponds and other retention areas

Ponds and other small bodies of water in urban areas help create a pleasant micro-climate and an attractive environment for people in direct contact with water. Water elements that use captured rainwater or bodies of water that also serve to capture rainwater or serve for the temporary capture of extreme rainfall can be considered as particularly advantageous.

## 5. The procedure to draft the Strategy/Action plan for green infrastructure in municipalities

In the previous chapters, we presented various functions and types of green infrastructure, as well as the requirement that greenery and natural elements in a developed territory should form an interconnected network of areas, points, and lines, while also being connected to the system of rural greenery. In order to achieve such a status in the future, the important thing is the drafting of quality documentation for green infrastructure, in particular in urban municipalities and larger towns.

The creation of the Strategy and Action plan for the green infrastructure should consist of several main steps – analyses, reviews, the design of the target state and the action plan. In the following text, we will briefly present the content of the individual parts.

### 5.1 Analytical section

Gathering information on the quantitative and qualitative indicators of green infrastructure

The source of the data should be a processed Territorial System of Ecological Stability (Regional TSES and Local TSES), other processed documentation for nature and landscape protection (e.g. Document on the care for trees), land-use planning and other sectoral documentation (Greenery gerenel, Inventory management, Forest care programs, etc.). If this information is not available, it is necessary to carry out an inventory of existing areas and elements of green infrastructure. This should include layers of point and planar elements of green infrastructure. The knowledge of the current state is a prerequisite for further planning and creation – for example, the determination of areas for replacement planting, a program for the care of green infrastructure elements and areas, etc. The collected information and documents will also serve the local government as an excellent information system for the management of urban or municipal greenery.

The mapping of green infrastructure created by human activity

The territorial projection of the occurrence and the state of point elements (such as trees) should be processed in the GIS (Geographic Information System) in a digital layer. A prerequisite for the processing of this information in GIS is the exact topography of the plants and other green elements so that the creation and management of green areas is as accurate as possible and as efficient as possible. The topography of trees determined by a topographical surveyor is an accurate and reliable basis for the inventory of trees and the subsequent planning, creation and design of the green infrastructure. In particular, their health condition, landscaping value, a method of damage, and other characteristics should be evaluated from the ecological, landscaping, and aesthetic point of view, as well as the point of view of the ecosystem services. It is important to establish the social value of trees according to the current legislation in the field of nature and landscape protection. This value is decisive, for example, in establishing the obligation of replacement planting or financial compensation for the social values of the felled trees.

Photo: A demonstration of tree mapping – point elements of green infrastructure in Bratislava, borough of Karlova ves

Planar and linear elements of green infrastructure can be mapped in accordance with the typology referred to in Chapter 4, and also set out in the Minimum standards for municipality amenities13. At the same time, it is advisable to focus on:

- areas in which the local government carries out maintenance, for example, grassy areas where mowing is being done
- buildings under the municipality's administration (for the purpose of evaluating the options of green infrastructure created on buildings)
- unused areas and land owned by the municipality, which have the potential to create new elements of green infrastructure
- semi-natural areas and elements of green infrastructure (watercourses and areas, hedgerows, lanes, wetlands, unused grasslands).

[13]http://www.telecom.gov.sk/index/index.php?ids=75272

Photo: An illustration of green infrastructure areas on which the local government carries out maintenance (Bratislava, borough of Karlova ves)

Mapping of natural green infrastructure

Mapping of natural ecosystems (forest and meadow grasslands), including elements of TSES, protected areas and sites

Mapping of non-forest vegetation in the form of roadside and watercourse vegetation, hedgerows, etc.

Mapping of aquatic ecosystems, including wetlands, marshes, and waterlogged meadows.

**5.2 Evaluation section**

Quantitative and qualitative evaluation

Quantitative evaluation should include a summary extent of the different types and elements of green infrastructure and their spatial projection. Quantitative evaluation allows to identify the options to extend the elements and areas of green infrastructure, as well as the possible link and elimination of territorial fragmentation, and to define the areas available for the expansion of the green infrastructure network

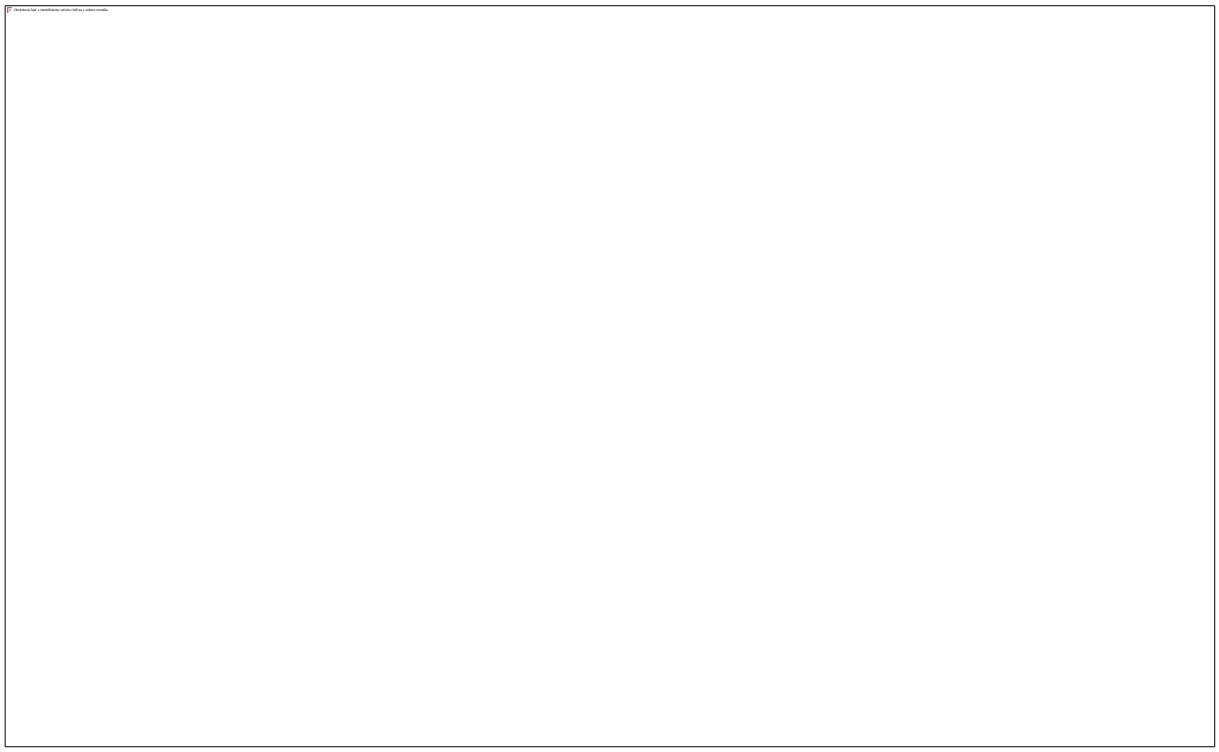
Qualitative assessment should focus on the evaluation of multi-functionality and ecosystem services of green infrastructure. Individual areas of green infrastructure (also according to their placement in a settlement) can have their primary function assigned (e.g. recreational and tourist greenery, creating the spirit of a place – representative greenery, etc.) while maintaining the requirements of multifunctionality (concurrent fulfillment of multiple functions).

An example is the evaluation of green infrastructure from the British town of Bicester14, where green infrastructure was evaluated in terms of the provision of ecosystem services with the

[14] "Tools for Planning and Evaluating Urban Green Infrastructure: Bicester and Beyond, Oxford"

assistance of point evaluation of functionality in the GIS logical framework matrix with the specified weight score on a scale of 1-5 with respect to what type of green infrastructure (in this case, expressed in terms of the basic habitat types) has the ability to provide services and individual functions15 (see an example of a database table and individual map layers – recreational function, flood control, regulating ecosystem services).

The evaluation can be processed in different ways. An example from Slovakia is the town of Trnava, which has drafted an extensive LTSES document linking the evaluation of urban and rural vegetation (Dobrucká et al. 200816) and has also drafted a detailed evaluation of the functions and ecosystem services of vegetation and undeveloped areas (Mederly et al. 201717). An example from the rural environment is the Tvrdošovce municipality, for which the concept of green infrastructure was prepared as part of a dissertation titled Green Infrastructure of the Rural Settlement and its Surrounding Landscape (Tóth, 201518).



[15]Burkhard et al. 2012, available at https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1526373803.pdf
[16]http://www.trnava.sk/sk/clanok/miestny-uzemny-system-ekologickej-stability
[17] http://147.213.211.222/node/6087
[18] Tóth, Attila. 2015. *Green infrastructure of a rural settlement and adjacent landscape:* doctoral dissertation. Nitra : Slovak University of Agriculture. 120 A3 pp.

### 5.3 Target status proposal

The following principles are important to the design of the target status of green infrastructure in the settlement and its area: quantitative aspects (planar scale and a number of elements) of green infrastructure, its quality, availability/placement of areas and elements of green infrastructure, their amenities and interconnectedness.

**Quantitative standpoint** (planar scale and number of elements)

Focuses on the assessment of the existing green infrastructure's sufficiency, any proposal for new areas and the creation of an interconnected system. An ecologically balanced settlement is considered to be one with more than 40-60% planar share of greenery (when planning "eco" neighborhoods in the UK, the general rule is that 40% of the land, private and public, should be made up by "greenery"). Based on various currently known and available sources, it can be concluded that the average need for greenery in a developed territory of a municipality is around 75m², according to the mentioned authors19. It should be noted that green infrastructure is not only made up by areas of greenery and water. At this stage, it is equally necessary to assess the technical options of creating green infrastructure elements aimed at adaptation to climate change and its mitigation, such as green walls and green roofs, elements of sustainable management or rain and waste water. Potential areas that can be integrated into the system of green infrastructure in the future are, in particular, undeveloped territories, but partly also brownfields – unused areas and fields, which there are plenty of, especially in the cities at the moment.

**Qualitative standpoint**

Focuses on the draft of measures to ensure the proper functioning of the various green infrastructure elements, but also of the entire system. Enhancement of natural processes even without regard to the quantitative increase of the planar range of green infrastructure is of great importance. As already mentioned in the previous text, functional changes, i.e. by strengthening the natural processes in economic areas or introducing a natural method of greenery maintenance in urban areas can help expand and enhance green infrastructure areas. Renaturation and protection of watercourses with functional or shoreline vegetation, maintenance and expansion of forests close to nature and natural forests, diversification of the land cover structure, planting of non-forest and forest trees, solitary trees or groups of trees and alleys, increasing the area of permanent grasslands, greening of agricultural land boundaries (edges of the plots, the boundary between arable land and road), etc., can have a structural character of green infrastructure.

In the management and maintenance of greenery in urban settlements, the maintenance will be close to nature with the exclusion of chemical products for weeding, sensible, differentiated mowing, support of pollinators by planting species, nectar giving plants, domestic tree species, etc.

**Availability/location of green infrastructure areas and elements**

[19] *Minimum standards of municipality amenities (Methodological Guide for purchasers and processors of land use planning documentation, MoE SR, 2002)*

Availability of green infrastructure in terms of population not only has environmental importance but also promotes social justice. The availability of greenery is being measured and monitored within the principle of sustainable urban development, which is defined as living within a radius of 300 meters from areas with functional greenery. A similar approach is also used in the UK, where the availability of greenery is expressed in either distance or walking time to reach the greenery or an area appropriate for short-time recreation.

An example of other standards in this area is “The Natural England Accessible Natural Greenspace Standards”:

- a person should not live at a distance greater than 300 m from the nearest natural green space with an area of at least 2 ha
- at least 1 ha of local nature reserve per every 1000 residents
- at least one 20 ha area of greenery within 2 km away from home
- one 100 ha area of greenery within 5 km
- one 500 ha area of greenery within 10 km

**The interconnectedness of green infrastructure elements**

The aim of this criterion is to achieve a planned interconnected green infrastructure network enabling a continuous movement of residents and the proper functioning of the system. Fragmentation of habitats, such as the routing of traffic through natural areas, is one of the main causes of habitat degradation and loss of biodiversity, which can reduce the fulfillment of their functions and the provision of ecosystem services. Valuable ecosystem services may disappear if the natural ecosystems become too small or isolated, because the isolated "islands" of nature, including species, do not allow for genetic exchange between populations of the same species. The TSES documents talk about the interconnection being secured by means of bio corridors. elements of green infrastructure are proposed in order to ensure the viability of technical elements, such as Eco ducts, etc.

In the urban environment, it is necessary to use other linear elements of green infrastructure – alleys and hedges, which allow several smaller species of wildlife to migrate. Mosaic or altered mowing regimen also helps to protect biodiversity (see photo below)

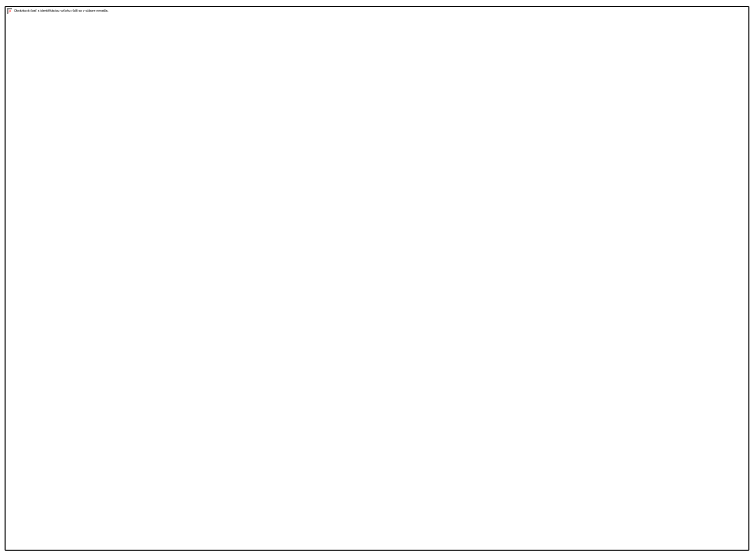


Photo:  Strips with altered (reduced) mowing regimen provide a haven, corridor, and food for a variety of animals, including pollinators (photo source: internet20), and the added value of such a solution is the increased visual attractiveness of the area for its users.

When designing the elements of green infrastructure, it is appropriate to take into account the interconnection and the needs of the various species. An example would be the creation of "highways for pollinators." In Oslo, Norway21, they managed this through the targeted planting of nectar-giving species and green roofs to create the conditions for their overpass – flight over the whole city. Another example is the project to facilitate the migration of hedgehogs in London, called the Hedgehog Highway22

The promotion of pollinators and maintenance of greenery in a manner close to nature, including the formation of flowering meadows and areas with an altered mowing regimen, is the focus of the Živica organization within its "Urban bees" program.  Examples can be seen in Bratislava, borough of Karlova ves, cities of Zvolen, Prievidza, and other.

Photo: In addition to supporting biodiversity, the altered mowing regimen also brings a new aesthetic sensation (author: Peter Svitek)

Smaller areas used for interconnection are, for example, green roofs, walls, greenery on terraces and balconies. In addition to improving the microclimate and adapting to climate change, green roofs and walls can also be created to significantly contribute to the promotion of biodiversity. On the roofs, it is possible to integrate elements such as beehives, a wide range of flowering nectar-giving plants,

[20]*https://www.burgenland.at/fileadmin/user_upload/Downloads/Umwelt_und_Agrar/Umwelt/Umweltanwaltschaft/Handbuch_Pflege_Begleitgruen_2014.pdf)*

[21]https://www.theguardian.com/environment/2015/jun/25/oslo-creates-worlds-first-highway-to-protect-endangered-bees

[22]https://www.hedgehogstreet.org/help-hedgehogs/link-your-garden/

create other innovative features to support biodiversity (places that will be a haven for the appropriate species, water feeders for bees and birds, etc.).

### 5.4 The action plan for green infrastructure

The Green Infrastructure Action Plan should build on the target proposals for the state of green infrastructure in municipalities. Its role is mainly to describe specific steps, activities, projects, responsibilities, timeframes and financial resources for the implementation of the various activities and projects23. These may be activities to create the elements of green infrastructure (green areas, green walls and green roofs, elements of sustainable rainwater management, planting of alleys and hedges, etc.), but also to create a qualitative change or improvement – i.e. functional changes within the existing areas of green infrastructure, eliminating fragmentation and creating links, increasing the diversity of plant species, resulting in an increase in the diversity of animal species, etc.

The activities included in the Action Plan are to be implemented through the land use planning process, generally binding regulations, guidelines, internal directives through which the municipality governs the performance of regional activities (e.g. the project assessment procedure, the implementation mechanism of development documents, budget creation, etc.). Within territorial plans and binding regulations, it is possible to include the requirements for the creation of "green infrastructure" elements (see the example from Trnava, Slovakia), such as requiring sustainable management of rainwaters (see the example from Prešov, Slovakia).

**Examples of applying the concept of green infrastructure in practice**

Consistent application of selected STN and sectoral standards

Examples of quality measures include the consistent application of the selected STN, such as “83 7010 Nature protection. Tree care and tree protection,” according to which trees in busy places (e.g. alley planting in developed municipality areas or public greenery) need to be assessed annually; STN 736110/Z1, which specifies 1 tree per every 4 parking spaces, and sectoral standards Cutting standard and Standards on the protection of trees during construction (in preparation).

**Trnava – generally binding regulation on the Territorial Plan of the city of Trnava, amendments 03/2015**

In 2016, the Trnava City Council
approved the proposal for a Generally binding regulation on the Territorial Plan of the City of Trnava, regulations and limits of land use, and the principles for the further development of Trnava (03/2015). Modification of the binding part of regulations is based on experience and knowledge gained from construction permissions, need for application of elimination regulations in relation to climate changes, the need for a more precise definition of certain concepts, as well as real needs in the management of urban territorial development.

The changes addressed the following in particular: expanding the parcels in the zones of family homes, expanding the areas of greenery, including public greenery, specifications in the field of greenery, rooftop greenery for amenity and industrial buildings, the obligation to build multi-storey

[23]https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1517933086.pdf

parking buildings with more than 70 parking spaces, the location of bicycle stands in next to amenity and industrial buildings, the addition of water management, guidelines in the field of energy, adding the need to process urban plans in developing areas and supplement the graphic part with the drawing of stabilized and developing territories.

It is also concerned with putting the following conditions in the area of "green infrastructure" among the binding regulations:
- apply rooftop and vertical greenery in the architecture
- implement roof greenery on terraces and roofs of new buildings with a slope of up to 20°, at least to the extent of 50% of the total area of all the new buildings in the addressed territory with these roofs, including the amenities for a relaxing stay of residents, visitors, and staff om a reasonable extent,
- direct the implementation of greenery on flat roofs of buildings for commercial amenities and services to areas in contact with the residential area as a priority
- implement vertical greenery on retaining structures, facades, fences and so on,

The mentioned example from the city of Trnava can be highly in a very positive light. Through these regulations, the construction office will be able to require their incorporation into the project documentation of buildings without which it will not issue a building permit, and full implementation of greenery according to the certified design documentation will be required for the final approval of the building (the application of these regulations will be required).

**Prešov - Territorial plan as amended in 2012**

Another example is from Prešov, Slovakia, where a binding regulation governs the sustainable management of rainwater (regulation 6.5.19), which reads as follows:

"set up smaller multipurpose reservoirs and weirs in appropriate locations and promote the restoration of destroyed aquatic areas with a suitable way to capture and use the surface runoff from paved surfaces of new buildings directly on the spot, or alternatively, an appropriate rainwater infiltration method so that the runoff from the territory into the recipient does not increase compared to the status before the implementation,and so that water quality in the recipient does not deteriorate.

**GBR on greenery – an example from Bratislava, Slovakia**

In 2018, a new general binding regulation (hereinafter GBR) of the capital city of Slovakia, Bratislava, on the care of public greenery and protection of trees that are part of the public greenery of Bratislava was conceived.

The paradox is that a paragraph preventing the reduction of public green areas (e.g. during construction, etc.) was kept in this new GBR only thanks to the initiative of the parliament members and some city boroughs, which is extremely valuable from the perspective of the creation and protection of green infrastructure. This is Section 4, paragraph 5, which reads as follows: “In the event of permanent occupation of a public green space, each natural or legal person occupying the public green space is required to establish new greenery in an area designated by the owner of the land where the occupied greenery is located, at least in the scope corresponding to the occupied

area of greenery. If the land or public greenery in the designated location is entrusted to an administrator, the owner of the land will request the administrator's opinion regarding this intent."

Funding options for green infrastructure elements

**6.1 Local sources of funding - examples**

Development fee

Municipalities in Slovakia can charge for construction on its territory since May 2017. This is enabled by the development fee, which was enacted by Act No. 447/2015 on local development fee, and a municipality can introduce it through its own generally binding regulation. This fee is the municipality's income and serves as one of the sources to build up the social and technical infrastructure necessary for the construction development, and at the same time, it should limit the willingness of the parties to "agree" on various fulfillments of different natures.

Local governments can use income from fees as capital expenditure for the construction of schools and nurseries, sports facilities, cultural and medical facilities, but also for the construction of transportation infrastructure, and the expansion and maintenance of public greenery.

Data in the building permit issued to the builder have an effect on the fee amount. It is paid in one lump sum, the rate is set by the municipality on 1 January of the calendar year,and it may vary for different parts of its territory. The law provides for a minimum (EUR 10) and maximum (EUR 35) fee amount for each, even partly used square meter (m2) of floor space of an over ground part of a building.

The fee does not apply to the construction of social and technical infrastructure, minor construction or construction works to eliminate faults and emergencies. The range of structures that are not subject to a fee has expanded and includes, for example, buildings used for the protection of children and social guardianship, as well as state defense buildings.

Act No. 447/2015 - Act on local development fee and on amendments to certain laws

Use of proceeds

The proceeds of the development fee are the municipality's income,

in Bratislava and Košice, the redistribution of income from the development fee between the city and its boroughs is determined by the city bylaws.

The proceeds of the development fee will be used to cover capital expenditure related to the construction, including settlement of land for this purpose:

a) childcare facilities

b) provision of social, sporting and cultural services

c) social housing,

d) school facilities and practical education facilities

e) medical facilities

f) publicly accessible park, modification of public greenery

g) local roads, parking areas, public lighting and technical infrastructure

Financial compensation for tree felling

Amendment to Act No. 543/2002 on the protection of nature and the countryside, which entered into force on 1 November 2017, allows the use of financial compensation for the felling of trees to plant trees and implement the elements of TSES, as well as to build elements of green infrastructure (for green roofs, green parks and Eco ducts). The municipality, as an approval body, determines reasonable replacement planting in its decision, or a fee up the trees' social value. For replacement planting, it is necessary to have a clear concept based on a thorough knowledge of the current state of the local green infrastructure.

Act No.543/2002 on nature and landscape protection

Section 48

Replacement planting

(1) The nature protection authority imposes an obligation on the applicant to carry out an adequate substitute plantingoftrees at a predefined location at the expense of the applicant as part of the tree felling permit; for this, it favors the geographically original and traditional species. If the applicant is not the owner of the land on which the replacement tree has been planted, the nature conservation authority may impose the care for this land on the applicant up to the period of three years. If the substitute planting cannot be implemented, the nature protection authority may impose a financial compensation in the amount equaling the social value of the tree (Sec. 95). The nature conservation authority will impose the obligation to pay compensation up to the social value of the tree to a person who cuts down trees without the permit. The financial compensation is the income of the municipality on the territory of which the felling takes place; the municipality is obliged to use these revenues to cover only the costs associated with

a) the preparation of tree care documentation

b) the preparation of a document on local ecological stability system

c) in particular, the planting of geographically original and traditional tree species and the care of trees growing on its territory,

d) the implementation of measures relating to the creation of elements of the local territorial system of ecological stability [Sec. 2, par. 2, letter a, the second sentence] according to the approved document on a local territorial system of ecological stability

e) the building of green infrastructure elements, such as green parks, green roofs, or Eco ducts.

Example

During the construction of a new railway station in Tvrdošovce, the adequate replacement planting for a single chestnut tree with a trunk circumference of 250 cm was determined at 11 new trees with a root ball – 5 linden trees, 3 maples and 3 oaks with the trunk circumference of 20-25 cm and the height of 2.40 m. The municipality received more earmarked funds as well as compensation for the felling on the outskirt in connection with the construction of new electric wiring. These funds were subsequently defined in the municipality's budget for the planting of new trees and care for the greenery. It is imperative that municipalities employ or enter into contracts with professionally competent people who know how to make decisions on requests for the felling of trees, determine an adequate replacement planting or financial compensation for the felling and then supervise the technical realization of the replacement planting of trees and shrubs.

Many communities currently do not have a prepared tree care document or other documentation with a focus on the green infrastructure. The funds obtained as compensation for the felling of trees are one of the possible sources to remedy this deficiency. Careful design and documentation allows meaningful and sustainable planning and the creation of greenery in the territory of the municipality. Another shortfall is the fact that replacement plantings are often inadequate, poorly made and aftercare is often absent. When implementing replacement planting, the concept and planning, as well as the subsequent care for the trees (cutting, watering, etc., for at least three years) are as important as the performance of the replacement planting.

### 6.2 Trans-national funding sources

Operational programmes

Environmental Fund

The Environmental Fund is primarily set up for the purpose of conducting the promotion of state support of care for the environment and the creation of the environment on the principles of sustainable development. The main mission of the Fund is to provide funding to applicants in the form of subsidies or loans to support projects in the framework of activities aimed at achieving the objectives of the state environmental policy at a national, regional or local level24.

The support of Envirofond in the form of grants can be obtained in connection with the green infrastructure in the following areas/for the following measures:

D. Area: Nature and landscape protection

Activity D1: The formation of TSES and green infrastructure elements on the basis of the agreed TSES documentation

POD. Area: The village restoration program – improving the quality of the environment in rural areas

[24] http://www.envirofond.sk

Activity POD1: The quality of the environment in rural areas – activities aimed at promoting the conservation of aquatic conditions and water resources at the local level – cleaning, restoration and protection of watercourses, pass ability of cross profiles, bridges and culverts, restoration (pass ability) of dead streams, management of floodplain forests

Activity POD2: Green infrastructure and adaptation measures to mitigate the impacts of climate change – activities

- processing of documentation aimed at addressing green infrastructure, a design study of adaptation to climate change (flood control measures, measures aimed at reducing energy consumption and the use of renewable sources of energy, etc.), and local strategy of adaptation to the impacts of climate change;
- activities focused on building green infrastructure elements outside the developed territory (planar, group, linear, solitary): planting, rehabilitation, and care of non-forest tree vegetation (e.g. old and regional varieties and original species, shoreline vegetation, windbreaks, alleys, hedgerows, avenues and scrub, for example, along managed and field roads, at borders of agricultural plots, natural terrain boundaries, isolating vegetation, vegetation strips planted along the contour lines, etc.)
- activities focused on building elements of green infrastructure in urban areas (planar, group, linear, solitary): building and revitalization of public spaces and parks, flowerbeds or herb beds, tree alleys, avenues, mobile greenery, community gardens (including the construction of small architecture elements reflecting the character of the rural landscape in the maximum range of 50% of the requested subsidy budget)
- the protection of the characteristic appearance of the landscape, care of the historical landscape structures and their reconstruction (mining relics, agrarian structures, the rehabilitation of terraces, lines of vegetation, etc.), the care of significant landscape features and attractions (e.g. peatlands, prairie communities, hedgerows, permanent grasslands, deposits of minerals and fossils, artificial and natural rock formations, wayside shrines, chapels and crosses which form part of the landscape)
- monitoring and disposal of invasive plant species (including disposal of invasive species along the waterways, in agreement with the watercourse administrator)
- activities to mitigate the impacts of climate change, adaptation measures at the local level in accordance with the strategy of adaptation to the adverse impacts of climate change in the Slovak Republic (implementation activities: the establishment of vegetation on the roofs of public buildings, establishment of stable aquatic elements, the collection of rainwater from impervious surfaces (roofs) and its use, for example, as irrigation water for public green areas, the use of shading elements – sun guards in combination with the cooling effects of vegetation, rain gardens, draining of water by building gutters with impermeable surfaces by the roads, sidewalks, parking lots, public areas, etc., flood control carried out on the watercourses in collaboration with the watercourse administrator and promotion of bicycle transport on the basis of a professionally processed project documentation)
- the exchange and the development of public water-permeable areas in the max. the range of 50% of the requested grant, and in combination with the planting of public greenery (e.g. in the form of tiled paving stones, interlocking pavement using a permeable/semi-permeable substrate (bed) and maintaining 2-3 mm spaces filled with silica sand)

### 6.3 Trans-national funding sources

LIFE 2014 – 2020 Programme

The LIFE Programme is a specialized funding program for the environment and climate protection under the authority of the European Commission25. Projects that improve the functional interconnectedness of green infrastructure and facilitate the movement of species between protected areas, such as Natura 2000, can be co-financed under this financial instrument. The LIFE Programme also offers funding opportunities for the construction of green infrastructure elements in urban areas and their outskirts,
as well as funding projects that promote an ecosystem approach to fragmentation, multipurpose soil use and other.

The EEA Financial Mechanism and the Norwegian Financial Mechanism for 2014 – 2021

The EEA and Norway grants are resources from the countries of Iceland, Liechtenstein and Norway to reduce economic and social disparities and strengthen cooperation with the 15 EU countries in central and southern Europe and the Baltics. This financial mechanism offers a total of EUR 2.8 billion for the 2014-2021 period in 5 priority areas and a total of 23 programs. The priorities also include theme no. 3 – Environment, Energy, Climate Change and Low-carbon Economy, also covering an area no. 13 – Mitigation and Adaptation in the Context of Climate Change. Green infrastructure is one of the green adaptation measures

The national allocation for Slovakia for the 2014 – 2021 period from is EUR 113.1 million (of which EUR 54.9 million for the EEA Financial Mechanism and EUR 58.2 mil. for the Norwegian Financial Mechanism).

Cross-border and transnational cooperation programmes for 2014-2020

**Conclusion**

Green infrastructure is one of the main preconditions for the sustainable development of a durable urbanized environment. The obligation, but also a great opportunity for local governments of municipalities is to develop and enhance their local green infrastructure.

Great potential also lies in micro regional cooperation at the level of Local Action Groups (LAGs) which have a prerequisite for the making of common micro regional green infrastructure.

Towns and cities should have a clear concept for the creation and management of their green infrastructure as a whole, as well as its individual elements, such as green areas, new and replacement planting of trees, etc. This should be facilitated by the conceptual documents (e.g. local TSES, General greenery plan, Tree care document), but mainly a comprehensive green infrastructure Strategy, including an Action Plan.

[25] http://ec.europa.eu/environment/life/index.htm

Green infrastructure can be the solution to two major challenges that mankind will face in the coming years – the loss of biodiversity and climate change. The significance and immediate urgency to seriously deal with the green infrastructure grows that much more. We hope that this brochure will also contribute to it.

Appendix 126

Environmental and ecological functions of green infrastructure

Improvement of microclimate in urban environments

Mitigation of summer heat through green infrastructure

The cooling effect of vegetation has been confirmed by a number of studies, but the extent of this effect depends not only on the size of public space, the service and quality of the vegetation but also on the location of the green space within the city, the nature of the surrounding buildings, terrain and other. On the basis of multiple sources, it can be said in general that the difference in temperatures between, for example, parks and built-up areas, averages from 0.94°C to 2.26°C. Increasing the proportion of greenery by 10% can reduce the temperature in the urban area by 3%. Research undertaken in Manchester shows that the increase in the proportion of vegetation by 10% in those parts of the city where the proportion is very low, will maintains the temperature at the level from 1961-1990 even in 2080.

The cooling effect of vegetation on the surroundings is reflected only in the parks with a sufficiently large area. This effect is noticeable at a distance of 500 m, depending on the nature of the surrounding buildings; near parks, with an area of more than 150 hectares, it can be up to a distance of 1 km. Put simply, it can be said that large areas of greenery cool down their environment and this effect is noticeable from the edge of the park to a distance corresponding to approximately its size.

When discussing the efficiency of green areas, it is necessary to also focus on the qualitative side, and specifically on the representation of trees, which have a significant impact not only on the temperature of that area but also on the possibility of cooling down the surroundings. Potscher et al. (2006) confirmed that in the case of parks with only a small proportion of trees or just low decorative plants, the temperature is the same or even be slightly higher than in their surroundings.

In terms of the effectiveness of greenery on heat reduction, we can refer to studies that have been carried out on grassy areas. Separately, it also depends on whether the parking lot is shaded or not and on the condition of the soil moisture in the substrate. If the areas is shaded and has enough moisture, the effect is significantly higher. Ca et al. (1998) measured a 2 degree Celsius difference between asphalted parking and a grassy area.

As mentioned above, active cooling is mainly based on the principle of water evaporation. Vegetation cools down the environment thanks to its low albedo (degree of reflectivity), energy consumption in the process of photosynthesis, and also thanks to the shade in the case of taller trees.

The cooling effect of the vegetation can be explained relatively easily with the help of physics: approximately 2.5MJ is needed to transform one liter of water into vapor, which is 0.69kWh. Trees transpire water through their stomata, which they then convert to vapor by taking heat energy from

[26] The appendix is prepared in accordance with the chapter entitled "Greenery" in the Catalogue of adaptation measures for the Bratislava Self-Governing Region (Steiner et al, 2016) and the document entitled "Creating the conditions for the establishment of territorial planning principles and rules" (AZ Project, 2013)
on-line http://www.azprojekt.sk/data/v-zasady-pravidla/ZP%203%20N%C3%A1vrh%202013.pdf

the environment.  Their "cooling power" reaches values as high as a few hundred watts per m2. It can thus be clearly confirmed that a grown tree, well supplied with water, cools its surroundings with power comparable with some air conditioning units. However, this also depends on the air flow; a breeze mixes the ambient overheated air with the air cooled with the aid of vegetation.

According to research, the proportion of water that gets into the air with the help of transpiration is really admirable. The number for adult deciduous trees is around 300 liters per day. For example, adult apple tree creates 65-140 gallons of vapor during a summer day, an adult birch can evaporate up to 7000 liters of water per season. In accordance with the described effect of cooling, this does not only include air humidification, but also rich and active cooling.

However, the above described phenomenon occurs only provided that the trees have enough moisture; otherwise, gas exchange stops and the cooling effect happens only thanks to the shading, especially for species that handle drought well. Closure of the stomata on the leaves causes an increase in leaf temperature (Leizinger et al. 2005). In this respect, trees planted in paved surfaces or those that have compacted soil in the root area exhibit differences in the effectiveness in this context, compared to trees in the terrain or in the lawn.  This difference is given by the fact that the increased ambient temperature above the paved surfaces leads to increased transpiration.

The research of growth of chanticleer ornamental pear (Pyrus calleryana) that took place for a period of 6 years in the British city of Manchester (Rahman et al., 2011) is worth mentioning in this context. Not only did the trees in the unpaved ground or planted in a special tree "substrate" ("Amsterdam soil") grew 2 times faster than trees in paved surfaces with a compacted substrate, but their cooling effect was also about five times higher (evapotranspiration potential was up to 7kW).

However, not only a tree itself can be thought of as a separate "air conditioner unit." The transformation of the country, i.e. the change of an undeveloped territory to a developed one has a similar effect. Development on one hectare of high-quality land with a high retention clip capacity of approx. 4 800 m3 leads to a significant decrease in evapotranspiration. The energy needed for the evaporation of such a quantity of water is equivalent to the energy consumed by approximately 9,000 freezers per year, which is about 2.5 million kWh.

From the point of view of effectiveness regarding the summer heat mitigation, it is still necessary to add that trees with all their leaves absorb 70-90% of solar radiation in the summer and 20-90% in the winter (the difference is mostly in deciduous trees).  Properly planted trees by buildings represent about 2% savings on heating. Green areas increase air humidity (average given value is 5 to 7%).

Leizinger et al. measured the temperature among a group of trees at 24 – 29°C, while the temperature on the street was 37°C and 45°C on the roofs of buildings.

In Bratislava and in Piešťany was made by drone tree mapping, where temperature measurements at the height of 2 m above ground were done with the help of a thermovision camera (see Figure 3). Measurements showed an already proven fact that the difference in temperature in Bratislava is really striking, from 29.87°C in a floodplain forest to 42.06°C in the commercial area by the Aupark shopping center[27].

[27]Hudeková, 2011

Several papers from abroad and Slovakia have found big differences in temperature on various vegetation's areas, depending on the amount of woody plants, especially trees. For example, measurements from 2006 28detected the maximum temperature difference between the air above a lawn and under a solitary tree (measurements at ground level) to be 14.6°C. Cooling effect was manifested in this measurement in all areas with trees and shrubs. Surprisingly high air temperature values were detected on the grass, which in some cases were comparable to air temperatures measured on asphalt areas (roads and parking lot).

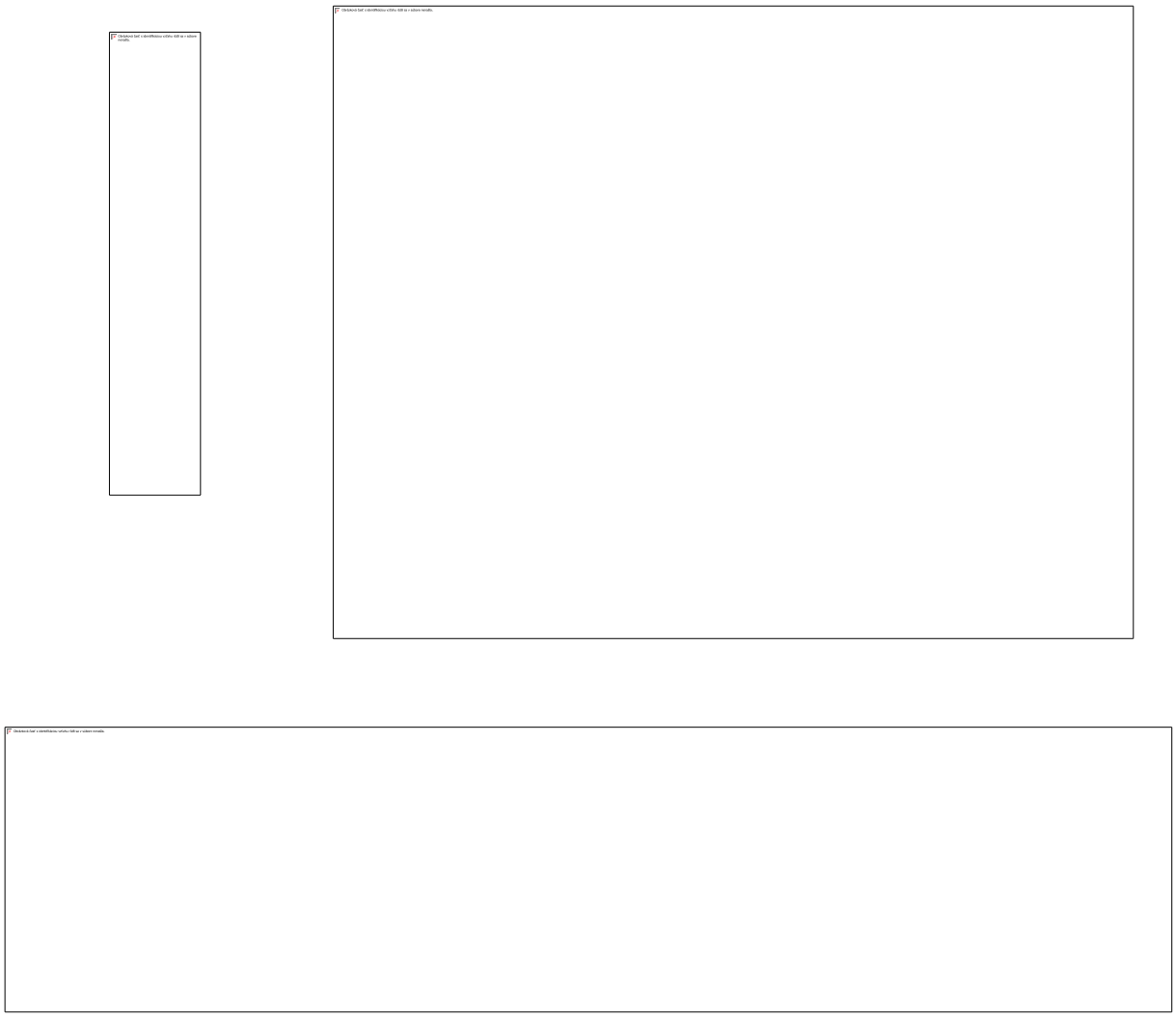


Fig. ?: Areas mapped by drones with the help of a thermovision camera – an illustration of the temperature differences depending on the type of urban landscape structure, surface, and the amount of greenery (source: REC Slovensko, 2007, personal communication)

Evapotranspiration requirements for water are increasing with an increase in the average annual air temperature. Periods of drought in the summer months are becoming longer, so trees often suffer from a lack of water in the urban environment. The stress brought by drought is becoming the primary abiotic stressor, limiting not only the growth and development of the trees but also their

[28] *Reháčková, Pauditšová, 2006*

ability to cool the area through evapotranspiration. For this reason, it is very important to ensure enough moisture at the time of the summer heat. Obviously, the best solution would be the infiltration of rainwater at the point of contact or its capture and subsequent use for the watering of vegetation.

This measure is part of the increase of the population's adaptive capacity, that is, the ability to find a temporary "refuge" from extreme heat, especially at the peak time. Although these parks are mainly available for residents living or working in their vicinity (within 500 m, or 10 min walk), they can often be used by residents from greater distances, e.g. pensioners and mothers on maternity leave.

Mitigation of summer heat through an aquatic element

Water in an urban area is not only very attractive but also has great importance in several respects. The use of an aquatic element in the cooling of the environment is already known from the past (e.g. Moorish architecture in Granada or Alhambre). Aquatic areas that also serve to capture rainwater are particularly advantageous.

Water efficiently cools down the environment and creates a pleasant microclimate. On the basis of some studies, the temperature on the leeside is greatly reduced,and the cooling effect reaches up to 35 m from the aquatic element29.

Pond, small bodies of water

Ponds and other small bodies of water in the urban environment help create a pleasant microclimate. Water elements that use captured rainwater or bodies of water that also serve to capture rainwater or serve for the temporary capture of extreme rainfall can be considered particularly advantageous. In the context of the described water evaporation phenomenon, it is very useful to replace the evaporated water with rainwater in areas of water bodies.

In the case of a water element without water circulation, the cooling effect is based on a combination of water vapor, for which energy is taken from the surrounding environment and the water in the form of heat. The cooling effect of evaporation is proportional not only to the quantity of evaporated water but is also based on the principle of equalizing the different temperatures of the cooling water and the ambient air.

Wetlands, wet habitats

Wetlands are defined as areas with marshes, moors, peat bog and natural or artificial, permanent or temporary, standing and flowing water. Often in the past, these territories were assessed as "useless" areas, which need to be dried out, covered, or otherwise adapted to other purposes. This is probably the reason why more than 60% of the wetlands in the world have disappeared since the beginning of the 20th century. However, the importance of wetlands is immense, not only from the point of view of adaptation to climate change but also from the perspective of mitigation

Studies, as well as practical experience, show that vapor from wetland and other hydrophilous vegetation with sufficient water supply has a beneficial effect on climatic conditions. In addition, as has already been described in previous clauses, this is cooling with the assistance of vapor from the

[29]Nishimura et al.,1998

water surface, because water consumes 2500 kJ/m2 to evaporate 1 mm of water. Currently, there is not much known research that would address the combined cooling effect of water evaporation and evapotranspiration from wetland and other vegetation. In his research, Hammel et al. (2012) pointed to the favorable state of moisture in the surrounding soil, which also has a positive impact on the cooling of the environment.

Green roofs

Green roofs decrease the temperature of buildings by several °C under the roofs. The green roof can reduce heat transfer through the roof from the external to the internal environment by more than 90%. Measurements from the summer days of recent years in Germany have shown that if the outside temperature is 25-30°C, reduction of the temperature inside a room under the green roof is 3-4°C. Measurements have shown that 20-40 cm vegetation which grows on a 20 cm substrate has characteristics comparable with a 15 cm mineral wool insulation. A number of studies have shown that buildings with green roofs overheat less, which leads to significant savings in the use of air conditioning. Any reduction of internal temperature by 0.5°C leads to savings in electricity for air conditioning by 8%. The assumption is that green roofs absorb 150W/m2 of thermal energy. Based on several studies, green roofs (depending on the thickness and quality of the substrate, plants, the season, etc.) hold about 60-80% of rainfall. Based on research and situation modeling in Brussels, the creation of green roofs on 10% of currently existing roofs would result in drainage reduction by 2.7%, while the largest proportion in the reduction would be directly in the most densely built-up parts of the city.

In particular, it is necessary to emphasize the positive effect of green roofs on water quality.

Green facades

The walls of the house are exposed to sunlight throughout the year and have relatively large fluctuations in temperature. A facade with no shade can heat up to 40°C on a hot summer day, while the temperature of the wall under the green cover is lower by as much as 15°C (Perez et al. 2011), which has a positive effect on the temperature in the interior. Coverage of the walls with vines moderates the extremes between the exterior and interior. Solar radiation is captured by the leaves on the green facade, which release water vapor into the environment, thus efficiently cooling the space thanks to "transpiration."

In addition to the influence on the temperature in the interior, green facades also have an effect on the temperature of its surroundings separately in the narrow street areas. According to research in southern Europe, this difference in temperatures can be up to 9°C (Alexandrie et al. 2008).

The amount of research papers on green walls is still relatively low, but their cooling effect has been confirmed up to 60 cm from the green wall (Wong et al. 2010). Professional literature sometimes talks about a 10-30% energy cost savings for the season. Just a fraction of solar energy reaches the outside wall thanks to the vine facade. Therefore, if an uncovered wall heats up to, for example, 42°C in the sun, the same wall under a green facade reaches only about 22°C.

Vines significantly reduce the temperature of the wall, not only depending on the climatic zone but mainly on the areas that they cover. Reduction in temperature ranges from 10°C to 30°C.

It has been calculated that the reduction of the walls temperature by about 5.5 °C will save about 50% of power expended on air conditioning. When we take into account that 1/3 energy for heating in winter is spent on the wind-cooled walls, vines (particularly evergreens such as ivy) bring energy profits.

Improving the quality of urban air through green infrastructure

Air quality in urban areas varies, depending on the activities, used fuels, and industrial technologies. Dust and solid particles, gaseous chemical compounds such as carbon oxides, sulfur oxides, nitrogen oxides, fluorides, chlorides, ammonium substances, hydrocarbons, etc., get into the air from a variety of technological processes, transport, and housing. According to the comparison of the urban atmosphere with open countryside, the urban ambient air has 10 times more dust particles, the SO2 concentration is 5 times higher, the CO2 concentration is10 times higher, and the CO concentration in the urban ambient air is 25 times higher than in the open countryside. According to the World Health Organization, the value of pollutants was exceeded at least once in 70-80% of the monitored sites30. For example, the SO2 developments were different in Western and Eastern Europe. Positive trends are associated with strict emission standards and industrial restructuring.

It is proven that greenery can improve the quality of urban air. 31Filtration effects of greenery are widely known. Trees and bushes have a beneficial effect on the purity of air, serve as a filter for dust particles (indicated value of 20 g of dust particles per m2 of leaf area. Researchers from Columbia University found that the ratio of asthma in children was 4 to 5 times lower in children living in an urban environment with tree avenues. For example, a 50-year-old maple (Acer platanoides) absorbs 0.0295 kg of sulfur, 0.0860 kg if chlorine and 0.0039 kg of fluorine per vegetation period. Trees on the streets are able to remove sulfur dioxide and reduce particulate matter by up to 75%32. The biggest effect of dust capture and absorption of the contaminant was found in a double-row of trees with a relatively high planting density33. But even solitary trees capture 15-20 % of dangerous particulate matter PM 1034. The capture of PM in an urban area seems to be very significant, as these greatly threaten the health of the inhabitants of the cities. In accordance with the report of the World Health Organization, hazardous dust particles reduce the average life of the inhabitants of European cities by roughly one year35.

A number of works deal with the effectiveness of capturing volatile organic compounds and dust according to the type of trees.Several authors evaluated the trees in this regard on the basis of the urban tree air quality score “UTAQS”36

[30] World Health Organisation ,WHO
[31] Nowak et al 2006
[32] TCPA, 2008
[33] Jim, Chen, 2008
[34] Bealey et al., 2007; Mitchell and Maher, 2009
[35] Lagner, 2011
[36] More information, together with a more detailed evaluation of individual tree species, can also be found in the Urban air quality Report, 2012

Noise reduction and an increase of humidity through green infrastructure

The function of greenery in terms of noise level reduction in the urban environment and wind speed reduction is non-negligible. Noise reduction may be up to 30 dB per 100 feet. Green areas increase air humidity (the average value is 5 to 7 per cent); mature birch (Betula pendula) can evaporate up to 7000 liters of water per season 37

Promotion of biodiversity and ecosystem services

The United Nations Environment Programme has drawn up a report, stating that biodiversity at the global level is currently falling faster than at any time in the past38. The importance of biodiversity in urban areas continues to grow due to the fact that 2007 was the first year when more people resided in urban areas than in rural areas. We often encounter the view of cities as the opposite of the countryside, where the environment modified by people does not play an important role from the perspective of biodiversity. But the opposite is true – the level of biodiversity, a number of species in the urbanized environment, whether of animals or plants, often exceeds even the surrounding rural areas. Natural elements, parks, forests, gardens, cemeteries, open spaces and even buildings and their roofs provide a great diversity and create a unique environment for the various species. Contact with nature and the natural environment is also very important for the city residents and is one of the indicators of the quality of their lives.39

It is, therefore, necessary to create suitable conditions for the promotion of biodiversity, not only on the citywide level but also in the design and creation of various public spaces at the local level40. The quantity and spatial relationships between different areas of greenery have a direct impact on the status of biodiversity in the urban environment. The fragmentation of natural elementstherefore raised the request for the inclusion of public spaces in the local system of interconnected areas on the citywide level. Development of a green network is important not only in terms of the movement of species but also from the point of view of feasibility by the residents.

There is a lot of options for the protection of biodiversity at the local level. These include, for example:

• increasing the proportion of vegetation, especially in developed city centers

• including biodiversity conservation into land-use planning

• establishing landscaping close to nature

• caring of public greenery in a manner close to nature

• protecting habitats and species and creating corridors linking the various habitats

The area of ecosystem services is closely linked to the issues of greenery functions in the public areas. Ecosystem services have various benefits, such as the provision of regulatory services, climate,

[37]Hudeková, 2007a

[38] MEA, 2005
[39] Hudeková, 2012b
[40] Werner et al. 2009

disease control, water purification, a recreational and educational function for residents, and other41. Ecosystem services have a direct link not only to the protection of biodiversity but also to the modification of the microclimate and other regulatory functions of the vegetation in the country.

Influence on the hydrological cycle, damping of the flood waves

Appropriately designed public spaces with plenty of greenery can have a significant positive impact on the hydrological cycle in an urbanized environment because they can provide an important space for the temporary capture of surface water during storms until it is removed by the drainage system. Public spaces with permeable surfaces can, in addition to capturing rainfall, enable direct infiltration of precipitation into the soil, thereby lowering the requirements for traditional drainage systems and at the same time, the greenery captures additional significant quantities of precipitation on its surface. This precipitation can then evaporate into the atmosphere, thus increasing atmospheric humidity, or slowly seep into the soil.

Overall, vegetation in public urban areas is involved in the management of rainwater at several levels in many ways:

Trees capture rainfall very efficiently, depending on the size and type. Studies indicate that while massive trees capture 80% of rainfall, saplings capture only 15%. Coniferous trees are more efficient at capturing rainfall because deciduous trees capture only 10% to 30% in their leaf-free state42 . The capture of water while “above the surface” reduces the amount of water which is then absorbed into the soil.

Thanks to its root system, vegetation aids the infiltration of rainwater to the lower layers of soil 43and into groundwater.

With the help of transpiration (the evaporation of water by the plant’s surface), plants draw water out of the ground by the roots. And finally, when rainwater gets accumulated in temporary polders, it can be very effectively drained by trees that tolerate waterlogging well.

Maintenance of the ground’s permeability in an urbanized environment is of particular importance in addition to the greenery. The study shows that a 10% increase in the proportion of greenery in the cities would help reduce the rainwater runoff by 5%.44

Minimization of impervious surfaces in public places can very effectively help prevent and avoid torrential flooding during the rainy season when the sewer network capacity is not able to divert the amount of rainfall in the short interval. Permeable surfaces in public areas enable the infiltration of rainwater and help maintain the effectiveness of the water cycle in the urban environment, but also help reduce the increased volume of drained water and contribute to reducing the potential for a flood wave.

[41] Eamus, 2005
[42] Q. Xiao and E. McPherson,2009, Calder, J. et al. 2008
[4343] H. Bramley In J. Bartens and The Mersey Forest Team 2009
[44] Handley, 2010

Terrain modeling of natural or artificially created shallow depressions, which drain excess water from the surrounding terrain, roofs, parking lots, or the landscape through dry polders in public areas, can be used to capture rainfall.

In the hinterland of municipalities, forests and park forests on slopes are of utmost importance in this respect.

Social, societal, health and economic functions of green infrastructure

Several authors point to the social aspects of greenery and public spaces as a basis for social contacts and community forming. Public spaces with greenery work as a social platform45. Green and public urban spaces are a key part of the public domain and provide an important platform on which people from a variety of social, cultural and demographic groups come together46.

The optimal social interaction requires a range of different, hierarchically arranged green areas of various character, from the public to private. Semi-private areas that are only available to a clearly defined group of people, for example, residents of a particular residential block, are particularly important in this context.

The contact areas between the areas of greenery with various availability also offer important means of social control.

Influencing the physical and mental health of people and their well-being

More and more evidence points to the fact that there are measurable health benefits, which have their roots in the availability of green areas close to where people live and work.

Public spaces and green areas are important for healthbecause they:

- allow the contact with nature, promote regeneration from stressful situations, are beneficial to mental health and help improve behavior and attention of children
- promote the physical activity of people 47

Several studies have shown a direct influence between public health, level of physical activity and the availability of public spaces - e.g. studies of eight European cities show that people who live in areas with abundant greenery are three times more likely to be physically active, with a 40% lower probability of becoming overweight or obese. Students who have access or a view of the natural environment show a higher level of attention than children who do not have this option. Researchers from the Research, Landscape and Human Health Laboratory at the University of Illinois carried out interesting research, concluding that a view of foliage from the window helps girls in puberty with self-discipline.

The provision of space and buildings for leisure and recreation

[45] Partnerství Foundation, 2011
[46] Stiles, 2010
[47]EEAc, 2009

This is probably the best known function of greenery, which involves the direct use for games, sports, and recreation, both organized and informal, active and passive.

- The provision of space for games for children of different age groups
- Providing options for various organized team sports
- Providing options for informal recreation, which does not require special equipment

Access to nature and its use

It is stated that, since humans are a part of nature, and due to the fact that species have evolved over millions of years in the interaction with their natural surroundings, we still need to be in close contact with the world of nature, even though we now mostly live in urban environments. This idea is perhaps best expressed by the biophilia hypothesis, developed by E. O. Wilson. The theory of "biophilia" and the biophilic design strives to reunite the value system of humanity with nature, which will also increase the environmental values and the health of urban residents, thus promoting a sustainable way of life.

Economic benefit

The economic benefit resulting from high-quality public spaces is undeniable and established by a number of studies. For example, CABE (2004) showed in their study "Does Money Grow on Trees?" that green areas increase the value of the other property.

In addition, the production functions of greenery (in particular, community gardens, but also private gardens) also bring economic benefits. It is also important to note that regulatory and environmental functions of green infrastructure have relatively high economic benefits.

Crime rate

A number of studies have shown a direct link between neat public spaces specially with planted vegetation and trees and a decrease in criminal activity.

Structural and aesthetic function

Breakdown, division and merger into an urban structure

Each settlement has its own unique spatial urban structure. More complex structures, such as street networks, building blocks, and urban district, are created from the essential elements made up by plots.

The layout of a developed and undeveloped area is referred to as the form. The traditional form, where individual buildings create a continuous built-up area and streets define the blocks of buildings in the urban structure, is often replaced by the modern form, where solitary buildings are constructed freely in the space. Green infrastructure can play an important role in the division of urban structure, but also in the interconnection the various parts of the municipality and when establishing a settlement with a free landscape.

The role of green infrastructure in ensuring the structure and organization of the settlement is well defined. A municipality may be separated from the surrounding countryside and industrial areas in

this way, and different ways of using the land can also be separated from each other. Such structural open spaces include green strips and concentric green circles, wedged areas of greenery and green corridors, as well as smaller linking areas of greenery, which may take the form of tree-lined streets with a low density of traffic.

In his classic urban planning publication entitled "Image of the City," Kevin Lynch (1960) stated that orientation is important for reasons of efficiency, but also for securing a sense of well-being on the part of the population. Five structural components of the urban environment identified by Lynch (significant elements, nodes, road network, outskirts and boroughs) can be adjusted to a different scale, so that they can be used at different levels of spatial hierarchy on the local/zonal level, at the level of districts or the entire city, and they can also be applied in the design of green infrastructure.

Creation of the spirit of the place, the identity bearer, meanings, and values

Green infrastructure, as well as the whole of the urban landscape, is often an important carrier of the "genius loci" of local history and other values. Open areas in municipalities are important carriers of meanings and values and help to create and reinforce the identity of the individual and the community.

The function of the area's visual enrichment

This function is largely influenced by the quantity and quality of the green infrastructure and the design of the green areas. However, it is important to note that public participation in the planning process also plays a very important role this the context, not just the way the greenery is designed.

Creation of the landscape character and image – landscaping function

Green infrastructure plays an important role in creating the landscape character and image. Landscape image is readable thanks to the arrangement of the components of the landscape's structure. The structure of the landscape itself, which helps create its character, is given by the terrain and important landscape features. Major landscape features are associated both with the look of the landscape and its functioning. Green infrastructure is undoubtedly an important basic land element – whether in the form of forest plants, avenues, solitary trees, non-forest trees, lanes, hedgerows in agricultural land, watercourse greenery, etc.