GREEN INFRASTRUCTURE, BIODIVERSITY AND CLIMATE CHANGE

Snežana Kecman, PhD student

University of Belgrade, Faculty of Forestry

snez.ke@gmail.com

ABSTRACT: Modification of the landscape started with anthropogenic pressure, resulted in a series of negative effects on the landscape, and therefore its abiotic and biotic factors. The ability of nature to adapt and respond to changes that occur, alternate and spread rapidly is considerably reduced. Relevant solution is in the implementation of green infrastructure with the purpose of improving green areas and environmental quality, which is of particular importance for urban areas. Application of modern methods and principles of planning using the potential or/and adding new elements of green infrastructure, enables the formation of a strong and stable network of green infrastructure and sustainable systems. Such systems are capable to respond with their ecosystem services to today's global problems: reduction of biodiversity, climate change, flooding, etc. Green infrastructure has been defined as a strategically planned network of natural and semi-natural areas, designed and managed to deliver a wide range of ecosystem services and protect biodiversity. Well-being and human health depend on ecosystem services, which in turn are dependent on biodiversity. Globally urbanization and climate change posing a significant threat to biodiversity. The relationship of biodiversity, ecosystem services and climate change shows unbreakable connection. Green infrastructure is multifunctional system with abilities to respond, reduce and even neutralize on going changes. Except that, green infrastructure besides ecological benefits, provides a wide spectrum of social and economic benefits for human, and has a very large aesthetic significance in open space.

Key words: green infrastructure, biodiversity, ecosystem services, climate change, landscape planning

INTRODUCTION

Challenges which the 21st century placed in front of humanity are increasing every day. The enormous growth and development of technology and society caused by the Industrial Revolution has significantly and forever changed the landscape (Mamford, 2006). High degree of urbanization and continuous anthropogenic pressuring have resulted in series of negative effects on the abiotic and biotic factors of the landscape and have led to fragmentation of habitats and loss of biodiversity.

Changes in the structure of the landscape and the speed they are happening directly affected the degree of adaptation to modified living conditions to be lower. Some species managed to adapt to new changes, while others succumbed to pressure and disappeared forever (Кецман, 2016). The result is the loss and extinction of a large number species of flora and fauna on the territory of Serbia, but also around the world.

The diversity of flora and fauna ensures the stability of the ecosystem, and also the existence of human. Numerous species are forced to search for new habitats, because of the

reduction and modification of existing biotopes, which is equivalent to reducing the biocenosis. All this leads to the loss of numerous ecosystems, which are a product of biotope and biocenosis, and a total reduction in the biological diversity of the landscape.

The negative influence of human on the landscape in the present is very obvious, and such a continuous influence in the future can bring to the complete loss and degradation of natural areas which are a treasure of biodiversity in the 21st century and of great importance in the fight with climate change. The changes that human made create completely new, unnatural conditions for the life, work and health of human.

Uncontrolled and excessive use of natural resources has led to the development of humanity, industry and generally modern civilization. Consequences such as species disappearance, an increasing number of species threatened by disappearance, fragmentation and disappearance of habitats and ecosystems are the result of increasing degradation of the landscape.

Green infrastructure is an alternative solution to restore balance and respond to climate change, using natural resources through networking to support the environment created by human, providing such economic, environmental and social benefits.

MATERIAL AND METHODS

The research beginning with the searching of published papers and other bibliographic units. It was started search according to key terms related to the thematic which being investigated, but also according to the terms connected to them.

Method is based on analysis, systematization and classification of papers published in leading international journals (which is referred in the Web of Science) and the other bibliographic units.

In the first phase, the search of published papers according to key terms relating to the issue of research. Primarily, the published papers that contained the terms: “green infrastructure”, “biodiversity” and “climate change” in the abstract, title or as a keyword were collected. Then, the research of collected works had been execute in combination with the terms: “ecosystem”, “ecosystem services”, “habitats”, “landscape planning”, “climate”, “temperature change”, “global climate change”, “diversity”, “biological diversity”, “heterogeneity”, “landscape”, “landscape planning”.

In the second phase, the works were classified in four categories: 1) green infrastructure, 2) biodiversity, 3) ecosystem services and 4) climate change.

Farther research has been concentrate on the published paper and bibliographic units which results are in the highest correlation with the purpose of the research theme.

RESULTS AND DISCUSSION

Green Infrastructure

"Green infrastructure" is a term that appears more and more frequently in land conservation and development discussions across the country and around the world. Green infrastructure means different things to different people depend on the context in which it is used (Benedict and McMahon, 2002).

As a concept, it began to be used more intensively in the late nineties of the 20th century, in order to take a leading position in the last few years with planners and designers dealing with spatial development (Florida Greenways Commission, 1994). With the increasing use of the term, there was a need for defining green infrastructure. It can be concluded that the definition exists in the same number as the authors dealing with the concept of green infrastructure.

Sublimation of the most important items from some of the known definitions, the green infrastructure would be:

Strategic planning of a high quality network which connects natural areas, but also other open spaces, with the concept based on the establishment of a national or European Ecological Network (NATURA 2000, Emerald) in rural and urban environments, to preserve the values and functions of natural ecosystems, whose ecosystem services enable reduction and adaptation to climate change, while at the same time providing a wide range of environmental, economic and social benefits (Benedict and McMahon, 2006; Ahern, 2007; European Commission, 2013; Васиљевић *et al*., 2014).

However, from all definitions, the definition of the European Commission can be distinguished, as definition which is complete: Green Infrastructure can be broadly defined as a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings (European Commission, 2013).

The significance and essence of green infrastructure is sublimated in the above definitions. However, the maximum benefit will be provided if been following and respecting the ten principles of green infrastructure.

Next ten guiding principles and strategies have been identified as crucial to the success of green infrastructure initiatives. These principles together provide a strategic approach and framework for conservation that can advance the sustainable use of land while ensuring an interconnected system of green spaces that benefit people, wildlife and the economy (Benedict and McMahon, 2002; Benedict and McMahon, 2006).

Ten principles of green infrastructure according to Benedict and McMahon (2006) are:

1. Connectivity is key: Linkage is essential for natural systems to function properly and for wildlife to thrive, has demonstrated by Conservation Biology. The strategic connection of ecosystem components is crucial to maintaining the values and ecosystem services of natural systems and to maintaining the health and diversity of wildlife populations. Vital to success also is linkages between the staff and programs of different agencies involved in green

infrastructure planning (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

2. Context matters: Predicting and understanding change in native ecosystems and landscapes require analysis of the context in which exist ecosystems - the physical and biological factors of the surrounding area. Nothing happen in a vacuum and that the study of content alone is not enough when dealing with natural systems, emphasizes by landscape ecology (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

3. Green infrastructure should be grounded in sound science and land-use planning theory and practice: From the theories and practices of disciplines such as landscape ecology, conservation biology, landscape architecture, urban and regional planning, geography and civil engineering ensures an appropriately balanced and integrated ecological, social, cultural and practical basis for any green infrastructure initiative (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

4. Green infrastructure can and should function as the framework for conservation and development: Community can plan for conservation needs and determine where to direct development and new growth in the most efficient manner, by prioritizing green infrastructure. Green infrastructure provides the framework for future growth, and ensuring for future generation significant natural resources (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

5. Green infrastructure should be planned and protected before development: Planning green infrastructure identifies critical ecological linkages and hubs in advance of development. This helps to provide that restoration, which is less efficient and more expensive than natural protection, is minimized in place of protection (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

6. Green infrastructure is a critical public investment that should be funded up front: Green infrastructure need to be: planned, designed and funded following the same access used for built infrastructure such as waterlines, bridges, roads, etc. (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

7. Green infrastructure affords benefits to people and nature: Numerable benefits arise from a green infrastructure access, including lessening the need for gray infrastructure, freeing public funds for other community needs and lessening sensitivity to fires, floods, and other natural disasters (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

8. Green infrastructure respects the desires and needs of landowners and other stakeholders: Green infrastructure does not request all land to be in public control or ownership. Green infrastructure should be presented as a concept that will help plan development. Also, she should consider the perspectives of various stakeholders in the private, public, and non-profit sectors (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

9. Green infrastructure requires making connections to activities within and beyond the community: Green infrastructure affords opportunities for and can build on programs related to everything from historic heritage to Smart Growth, to brownfield development, to outdoor recreation, to flood mitigation. Green infrastructure has a look beyond political borders to focus on the natural landscape (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

10. Green infrastructure require long-term commitment: Green infrastructure documents and plans should be considered strategic "living" documents for amending and updating. This involved residual flexible and longsighted mechanisms and opportunities for funding (Benedict and McMahon, 2006; Coastal Regional Commission, 2014).

Green infrastructure is not a program, but it is a well-organized and planned strategy that does not represent a short-term solution. It is a process that lasts and requires long-term commitment. It represents an interdisciplinary approach based on ten planning principles that function at several spatial scales (Table 1).

Table 1. Typical green infrastructure assets and their associated scales

Local, neighbourhood and village scale	**Town, city and district scale**	**City-region, regional and national scale**
Street trees, verges and hedges	Business settings	Regional parks
Green roofs and walls	City/district parks	Rivers and floodplains
Pocket parks	Urban canals	Shorelines
Private gardens	Urban commons	Strategic and long distance trails
Urban plazas	Forest parks	Forests, woodlands and community forests
Town and village greens and commons	Country parks	Reservoirs
Local rights of way	Continuous waterfronts	Road and railway networks
Pedestrian and cycle routes	Municipal plazas	Designated greenbelt and strategic gaps
Cemeteries, burial grounds and churchyards	Lakes	Agricultural land
Institutional open spaces	Major recreational spaces	National parks
Ponds and streams	Rivers and floodplains	National, regional or local landscape designations
Small woodlands	Brownfield land	Canals
Play areas	Community woodlands	Common lands
Local nature reserves	(Former) mineral extraction sites	Open countryside
School grounds	Agricultural land	
Sports pitches	Landfills	
Swales, ditches		
Allotments		
Vacant and derelict land		

Source: Landscape Institute, 2009; European Environment Agency, 2011

Green infrastructure consists of several components (Figure 1) that work together to preserve a network of natural processes. These components are (Williamson, 2003):

Nodes - represent basis of the network and provide space for plants and animals species. Their centers are the key areas that form the core of the network and provide habitats of essential importance for sensitive species, include all sizes and shapes (Williamson, 2003; Benedict & McMahon, 2006).

Sites - are smaller than hubs and can be networked, but also they have not to be networked. As such can contribute to social and ecological values like: habitats for some species, recreation for people, etc. (Williamson, 2003; Benedict & McMahon, 2006).

Corridors - connect hubs and thus ensure the spread of seeds and pollen, the migration of plants, as well as the movement of animals, but also the preservation of historical sites and provide the possibility of recreation (Williamson, 2003; Benedict & McMahon, 2006).

These components in landscape could be representing by assets cited in the Table 1. Depending of the spatial level forests could represent hubs, private gardens, green roofs or pocket park could represent sites, and rivers or canals could represent corridors.

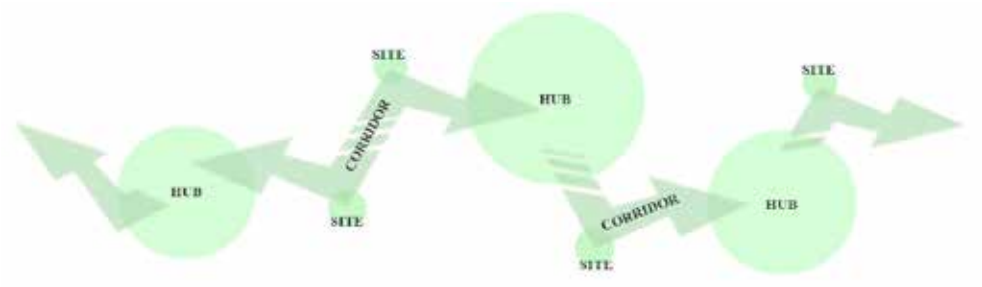

Figure 1. Green infrastructure network components (schematic diagram)
Source: Кецман, 2016

It is noticeable that the hubs, sites, and corridors differ significantly, with form which they occupy in space, their ownership, size and function. Although the protection of natural systems and the conservation of biodiversity through networking is one of the primary goals of green infrastructure, it is represent a complex system whose components can enhance the human health and quality of living conditions, but also have historical, cultural, economic or social significance.

Biodiversity

The notion of biodiversity has been introduced into the environmental terminology about twenty years ago on the proposal of an ecologist, and today it is generally accepted in everyday life, science and practice. Biodiversity or biological diversity is, according to the most accepted definition, the totality of genes, species, ecosystems and landscapes on Earth (Norse and McManus, 1980; Radović, 2005).

Biodiversity includes several organizational levels: genetic, species and ecosystem level, each of them has its spatial and time continuity on the planet Earth (Radović, 2005):

- Genetic diversity: represent the diversity of DNA structures between individuals of the same species, because of each individual has a specific and unique combination of genes which is unrepeatable (Radović, 2005).

- Species diversity: represent the diversity and specificity of all species on the planet Earth, from the very origin of life up till now (Radović, 2005).

- Ecosystem diversity: represent the diversity at a level higher than the species. That is diversity of: habitats (abiotic components), life communities (biotic components), ecosystems and landscapes (Radović, 2005).

Biodiversity organizational levels are interconnected. Loss of species leads to loss of ecosystems, and loss of ecosystem leads to loss of biodiversity. The loss of biodiversity is influenced by many factors, but common to all factors is - a human.

The basic factors that lead to loss of biodiversity are expressed by the acronym HIPPO (Brennan and Withgott, 2005) derived from the word Habitat alteration; Invasive species; Pollution; Population growth; Overexploitation (Radović, 2005).

Multifunctional concept as green infrastructure with combination of their assets and creating network of green space could preserve and improve biodiversity. Components of green infrastructure such as: hubs, sites and corridors is represent more different green place in space like a: rivers, forests, lakes, nature reserves etc. which is very important parts for biodiversity.

Biological resources are the basis of life on planet Earth. Their importance is immeasurable (in relation to other resources) and as such like that should be preserved. However, in the world of global change, biodiversity and the functioning of ecosystems are seriously jeopardized by the fragmentation of habitats, and other abiotic and biotic factors, which the main cause is human activity in the region (Radović, 2005; Gökyer, 2013).

The fundamental significance of biodiversity is reflected in the complexity of the overall life form on planet Earth, which as such represented the basis of the existence of each individual ecosystem, biome and the entire biosphere, thus enabling the survival and evolution of each species (flora, fauna) and also of man. Applied significance is reflected in the fact that the evolution of man and entire human civilization is based on the use of biological resources (Radović, 2005).

Biodiversity is related to ecosystem services through a variety of mechanisms operating at different spatial scales; he regulates the rates, the state and the stability (in many cases) of ecosystem processes fundamental to most ecosystem services (Cardinale *et al.*, 2012; Mace *et al.*, 2012; Balvanera *et al.*, 2016).

Due to the complexity of the links between biodiversity and ecosystem services, monitoring biodiversity alone is not sufficient to understand the status and trends of the services it provides. Monitoring annual changes in the state of ecosystems and determining trends in ecosystem services, in fact, can contribute to our understanding of changes in biodiversity and inform on the basic dynamics of the complex interactions between ecosystems and societies (Díaz *et al.*, 2015; Balvanera *et al.*, 2016).

Ecosystem Services

Ecosystems are communities formed by the interaction between living (biocenosis) and non-living organisms (biotope). The benefits which human beings have from both part of ecosystems and benefit from ecosystem is in many cases known as - ecosystem services.

Though the term ecosystem services is fairly new (among the first uses appears to be Ehrlich and Mooney, 1983), the idea is quite old (Polasky, 2011).

Definition of ecosystem services:

Ecosystem services are the benefits provided to humans through the transformations of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services e.g. clean air, water, and food (Constanza *et al*., 1997; Department of the Environment, Water, Heritage and the Arts, 2009).

Four types of ecosystem services can be distinguished (European Environment Agency, 2011):

- Supporting services have an indirect impact on people or occur over a very long time, whereas changes from the other services (regulating services, provisioning services, cultural services) have relatively direct and short-term impacts on people. These services provide habitats for species and to maintenance of genetic diversity. Habitats (biotope) enable to plants and animals everything they need for survival. They differ from the ecosystem to the ecosystem as well the species in them. However, all species do not spend all type of their development life cycles on the same habitat, than further migrate (birds, mammals, fish, insects, etc.). In that case, their survival is directly dependent on each of the next habitats, and the preservation of natural ecosystems and the provision of habitats for native flora and fauna is a very important role of green infrastructure. This is requirement to the maintenance of genetic diversity, where some habitats are known to be more diverse, since they have a large number of species or a larger number of life communities (biocenosis), and are considered to be “key points” of biodiversity (European Environment Agency, 2011).

- Provisioning services are products obtained from ecosystems such as food, raw materials, fresh water and medicinal resources. Food products are mostly obtained from agricultural lands, marine and freshwater systems, but also from forests which wild food is often unfairly ignored. In addition to food in the forests, but also in other places with available vegetation can find various raw materials such as wood, biofuels and vegetable oils. Also, fresh water plays an important role in the global hydrological cycle, but also the healing resources, for which all ecosystems is potentially suitable source (European Environment Agency, 2011).

- Regulating services represent the benefits obtained from the regulation of ecosystem processes such as local climate and air quality, carbon sequestration and storage, moderation of extreme events, waste-water treatment, erosion prevention and maintenance of soil fertility, pollination and biological control. These services removing pollutants from the atmosphere provide them with shade and affect the rainfall. They act locally, regionally and globally. Improves local and regionally climate and air quality, also contributing to the conservation of energy. At the global level they eliminate and stock of carbon and harmful pollutants from the atmosphere (carbon dioxide, carbon monoxide, etc.) and thus affecting the improvement of the quality of the environment. Also, living organisms affect the reduction of natural

disasters including: floods, storms, avalanche and landslides, affect the prevention of erosion processes and the process of degradation of soil, which is essential for plant growth and the good functioning of the total ecosystem. Ecosystems also perform biological control through the activities of predators and parasites (birds, bat, axes, etc.) of various pests and diseases that attack plants, animals and humans (European Environment Agency, 2011).

- Cultural services represent non-material benefits people obtain from ecosystems such as recreation and mental and physical health, tourism, aesthetic appreciation and inspiration for culture, art and design, and spiritual experience and sense of place. These services have a role in maintaining the health of (psychic and physical) people. They also manifest in the spheres of tourism through research and understanding of various cultural, historical, natural and other values (eco-tourism, cultural tourism, etc.). They are a source of aesthetic inspiration for culture, art, design and can promote aesthetic quality of urban and suburban areas. It provides a spiritual experience and creates a sense of place through natural features such as forests, mountains and caves that are considered sacred through human history and have religious significance (European Environment Agency, 2011).

Humanity derives considerable benefits from the products of biodiversity, but also from services of ecological systems, such as pollination, erosion control and water purification. The relationship between ecosystem services and biodiversity is complex, but in general, most ecosystem services are degraded or reduced if the biodiversity of an ecosystem is substantially reduced. Most ecosystem services are provided by natural systems, however human become aware of their importance and value only when they are reduced or lost (National Research Council, 1999).

Natural systems mostly provide ecosystem services that human beings uses for free, except them suburban and urban systems also can provide some of these services, but not all. Improving urban and suburban areas and provide almost all ecosystem services is possible with applying the concept of green infrastructure.

All ecosystem services such as: supporting services, provisioning services, regulating services and cultural services are of great importance to human. They provide to human: environmental, economic and social benefits. But, the most important role of ecosystem services is in their adaptation to climate change and their mitigation.

Climate Change

There are several reasons why plants and animals are less able to adapt to the current phase of global warming one of it is the very rapid pace of change.

Climate on Earth is constantly and always changing. Until the beginning of the Industrial Revolution, the climate changed as a result of changes in natural circumstances. However, today the term climate change is used when we are talking about climate change that has occurred since the beginning of the 20th century, and they were created as a result of human activities (Antonijević *et al.*, 2013).

The urbanization process has resulted that the areas with vegetation (which provide shade, evapotranspiration, retain atmospheric waters, and have storage and infiltration function, etc.) are replaced with irregularly built surfaces, which resulted in significant changes (Cvejić *et al.*, 2011).

The evidence for rapid climate change is compelling: global temperature rise, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining Arctic sea ice, extreme events, and ocean acidification (NASA – Global Climate Change).

Climate change is perhaps the greatest challenge humanity has ever faced. It affects every corner of our planet – from the poles to the tropics, and from the mountains to the oceans. People and nature worldwide are already feeling the effects: water supplies are shrinking, extreme weather events increasing in frequency and intensity, forests burning, and coral reefs dying (Bates *et al.*, 2009).

Climate change is a global problem, but the consequences will be felt on regional and local levels. Estimates also suggest that these changes will have significant influence for urban areas, because over 50% of the world's population and 80% of Europe's population today living in cities (Cvejić *et al.*, 2011).

Climate change mitigation includes action which need to being applying on local, regional and global level. The most important is beginning. Easiest is to start from the smallest - local level, and then extend the action to other bigger spatial levels. For example, in cities just one tree could change microclimate condition in one garden. More trees or the others type of plants in one street, park or other open spaces in cities could do much more.

The presence of trees and other assets of green infrastructure (Table 1) in the space alter the environment by moderating climate, conserving water, improving air quality and harboring wildlife. By using trees and others type of plants in the cities, it is possible to mitigate the heat-island effect caused by buildings and pavement in urban areas. Green infrastructure with their assets could control climate by moderating the effects of sun, rain, and wind especially in urban areas, where is it more necessary than in suburban areas (Coastal Regional Commission, 2014).

Climate change represents serious threats to quality of life, urban infrastructure and entire urban and suburban systems. Anomalous climate events and trends will increasingly be affected to poor countries, but also the rich ones (World Bank).

Climate change presents huge challenges but also and opportunities for development. Those problems need to be solved in an integrated way. The world needs to produce food for nine billion people by 2050, reducing global temperature, emissions, floods, erosion process, etc. and increasing natural systems and conserving biodiversity (World Bank Group, 2016). That is possible with implementation of green infrastructure concept, whose the basis is ecosystems with their services. Regulating services of ecosystems have an important role in the adaptation and mitigation of climate change.

CONCLUSION

A unique solution to the global problems of today, which is reflected in climate change, biodiversity reduction, fragmentation of the landscape, loss of ecosystems, in various pollutions (water, air, land) and increasing degraded space in urban and rural areas, is a strategic concept of spatial development - green infrastructure.

The concept of green infrastructure can be applied at several spatial levels: local, regional and global. It is based on landscape ecology principles and its immeasurable significance is reflected in the ecosystem services it provides. If ten basic principles of green infrastructure being respect, this concept could be key solution for establishing a disturbed natural balance.

The most important feature of green infrastructure is its multifunctionality, thanks to which have the potential to deliver a wide range of benefits (environmental, economic, social) to society. Whole green infrastructure network delivers much more benefits than individual elements of green space.

Benefits of green infrastructure for biodiversity is in creating new habitats for species (forest, parks, etc.), connecting existing habitats (with hedges, canals, etc.) and create possibilities for migrating species between different habitats.

One more benefits of green infrastructure its adaptation and mitigation to climate change. Mitigate urban heat-island with shading and evapotranspiration of green elements (trees, shrubs, etc.) and also reducing atmospheric carbon-dioxide. Introducing new green elements bring to strengthening ecosystem and their resilience to climate change.

Permeable green surfaces permits for the infiltration and absorption of snow (melt onsite) and rainwater, and improve surface water run-off, on that way reduce the risk of flooding, and also can be prevented soil erosion. Using some type of plants (e.g. reed beds) it possible removal of pollutants from water.

Besides, green infrastructure enabled food production on allotments, gardens and agricultural land with keeping it land potential (safeguarding of soil). Also, green infrastructure can enabled recreation, health and well-being for the human, and offer opportunities for tourism, training, education and social interaction.

The results of numerous research presented in this paper demonstrate the enormous potential of green infrastructure in mitigating and adapting cities to climate change, preserving and improving biodiversity, and the ability to provide ecosystem services. Thanks to ecosystem services green infrastructure can provide economic, environmental and social benefits. Investment in green infrastructure, in use and development of ecosystem, contributes to biodiversity objectives, smart growth and green economy.

Green infrastructure is a strategy planned network of green spaces which contribute to improvement, development and preservation biodiversity and environment. Ecosystems of those spaces provide services (ecosystem services) which help in adaptation and mitigation of climate change.

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