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Climate Change Training Modules Series 12

GREEN INFRASTRUCTURE SOLUTIONS COMBAT CLIMATE CHANGE IN CITIES

Modules
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TO COMBAT CLIMATE CHANGE IN CITIES SOLUTIONS

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COMBATING IN CITIES
SOLUTIONS

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ABBREVIATIONS

C	Carbon
CoM	Covenant of Mayors *Mayors' Contract*
ITU	Istanbul Technical University
KENTGES	Integrated Urban Development Strategy and Action Plan
NO_2	Nitrogen dioxide
O	Ozone
PM	Particulate Matter
SO_2	Sulfur dioxide
US	United States *United States of America*

SUMMARY

Most of the world's population lives in cities and this rate is increasing. Climate change causes sudden and unexpected weather events on earth. Cities are the areas where the impacts of climate change are felt most intensely. These impacts are as an increase in the heat island effect, air pollution, heat waves and water scarcity, change in precipitation regime, increase in the number of dry days, and rainwater causing floods or overflows.

Ecosystems provide many benefits to humans and other living things in their environments. These benefits, which arise as part of the ongoing natural processes in ecosystems, are defined as ecosystem services. Regulatory ecosystem services provided by ecosystems have an important role in reducing the impacts of climate change in cities and increasing the resilience of cities against these impacts. These services are the benefits derived from ecosystem processes in which ecosystems act as regulators (e.g. improving air and soil quality, climate regulation, reducing the impact of natural disasters such as floods and landslides, disease control, water purification, waste management, pollination/pollination, biodegradation control of harmful species).

The high density of built-up areas in cities makes them vulnerable to the impacts of climate change. It is possible to reduce the negative impacts of sudden and unexpected weather events caused by global climate change and to make cities resilient to these impacts by protecting and/or increasing the benefits provided by ecosystems. Ecosystem services provided by a network of interconnected natural, semi-natural and cultural areas (green infrastructure system) that preserve ecosystem values and functions (high ecological quality) in cities play an important role in mitigating the impacts of climate change.

Making the green infrastructure system a part of the spatial planning process, ensuring that the components of this system include stormwater management solutions, protecting the fragile ecosystems of cities, and developing rational solutions to improve the ecosystem services provided by green spaces will contribute positively to making the city resilient and resilient to climate change impacts.

1. GREEN INFRASTRUCTURE SOLUTIONS TO COMBAT CLIMATE CHANGE IN CITIES

The earth we live in is a living organism and, like all living things, it needs certain temperature conditions to survive in a healthy way. Human-induced effects that disrupt the composition of the atmosphere cause the temperature in the world to increase. Unfortunately, the functioning of natural systems on earth is being damaged due to the fact that the atmospheric temperature has increased by one degree compared to the 1800s due to the change in the climate outside of its natural order. The life of all living things in the world depends on the healthy functioning of ecological processes and cycles on earth.

Most of the world's population lives in cities and this proportion is projected to increase. It is possible to reduce the negative impacts of sudden and unexpected weather events caused by global climate change in the areas where we live and to make cities resilient to these impacts with the benefits provided by ecosystems.

1.1. Green Infrastructure System and Components

With the impact of urbanization, construction and infrastructure demands for the creation of new residential and commercial areas put serious pressure on natural ecosystems and urban green areas. The cities of our country are predominantly composed of building areas with multi-storey high density buildings. Within this texture, the proportion of green areas, which are mostly small and isolated areas between building islands, in the city is quite low.

Healthy and livable cities are those that have a balanced distribution between green space and building area, and have an open-green space system (green infrastructure) in which green areas with high ecological qualities coexist.

Green infrastructure is defined as a network of interconnected natural, semi-natural and cultural spaces that preserve ecosystem values and functions (Benedict, 2000; European Commission, 2013). This network of fragments (centers) and corridors includes natural areas such as forests, shrublands, meadows, wetlands, river corridors, and semi-natural and cultural components such as parks, sports fields, school gardens, campuses, personal and institutional gardens, rooftop gardens, vertical/vertical gardens, zoos, botanical gardens, agricultural lands, cemeteries, planted roads, etc. (Figure 1, Table 1).

Figure 1: *Integration of Green Infrastructure Components into Urban Landscapes (Arup, 2019)*

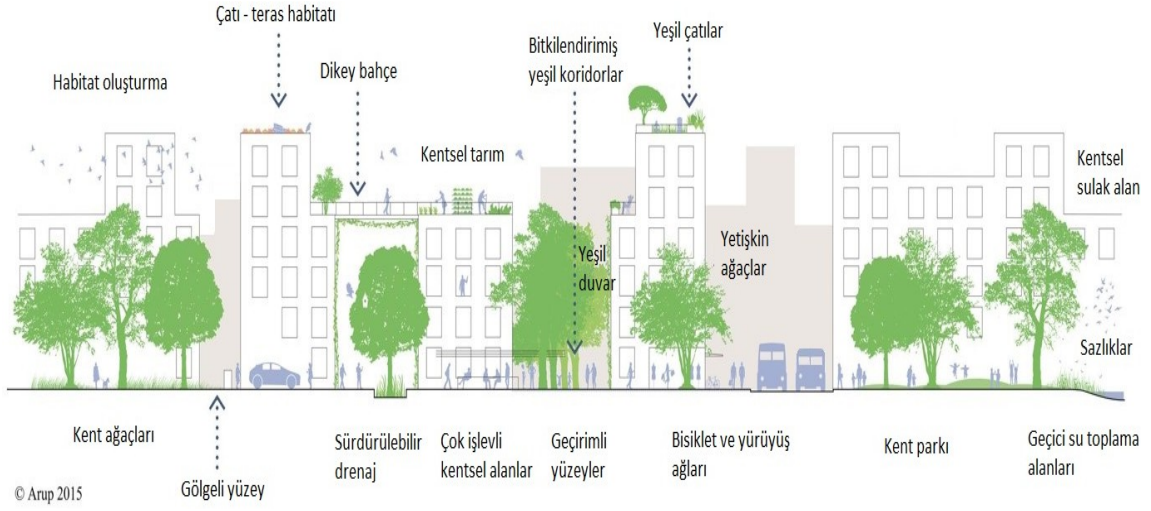


Table 1. Components of Urban Green Infrastructure	
	**Natural areas** in urban areas are areas covered with natural vegetation such as forests, shrublands, empty plots covered with herbaceous plants, wetlands. These areas contain a variety of natural plant species of different sizes and ages and are rich in biodiversity.
	**Urban parks** are green spaces that offer recreational opportunities to the urban population, including natural and cultural ecosystems of various sizes.
	**Squares** are open gathering areas in the city used for different purposes.

Table 1. Components of Urban Green Infrastructure	
	**Private or institutional gardens** are green areas rich in plant density and species diversity.
	**Botanical gardens** are plant collections that contain different plant communities together.
	**Agricultural areas** can take the form of large plots of commercially produced land, orchards or small-scale hobby gardens. Agricultural land contains a variety of annual and perennial plants that are not found in other green areas.
	**Cemeteries** are large green areas with dense vegetation including mature trees in cities. They provide habitats for many species.
	**Planted parking lots** are areas created by planting or afforesting open parking areas in cities with various methods.

Table 1. Components of Urban Green Infrastructure	
	**School gardens** and educational campuses are areas that include educational buildings, playgrounds and sports fields, and may have vegetation.
	**Green roofs** reduce solar radiation through vegetation cover, reduce the speed of rainwater and provide insulation.
	**Vertical gardens** are formed by covering vertical structural elements such as buildings, walls and fences with various plants, reducing energy consumption in buildings.
	**Road trees** on sidewalks, medians and planted lanes create linear corridors in cities. They are the connecting elements of the open green space system.
	**River corridors** are natural corridors that bring together terrestrial and aquatic ecosystems. have important roles in the water cycle and stormwater management.

Table 1. Components of Urban Green Infrastructure	
	These structures, whose **water channels are** mostly created by human hands, are corridors used for recreation and transportation purposes.

2. SERVICES

With its vegetation, green areas cool the air, reduce the heat island effect, capture and store carbon, clean the air by removing pollutants, enrich the soil with organic materials, provide food and shelter wildlife, and support biodiversity, They have many functions such as preventing rainwater from entering surface runoff, feeding groundwater and surface water resources, reducing wind and rainfall erosion, filtering noise, reducing energy consumption, providing recreational opportunities, and increasing the real estate value of land (Forman, 2014). These ecological, socio-cultural and economic functions to protecting the health of the urban population and improving the quality of life.

Ecosystems provide numerous benefits to humans and other living things in their environments. All of these benefits, products and services that occur as part of the ongoing natural processes in ecosystems are defined as **ecosystem services**. They are classified into four groups: provisioning services, regulating services, habitat or supporting services and cultural services (MEA, 2005).

The ecosystem services provided by each component of the green infrastructure system vary depending on the ecological characteristics of these areas (location, size, spatial distribution, vegetation structure, density, etc.). It is important that cities are woven with green networks, in other words, that the components of green infrastructure are in physical connection with each other. **The ecosystem services provided by the green infrastructure system, which includes green areas with high ecological qualities that are designed to form functional connections with each other, reduce the effects of climate change.**

Regulatory ecosystem services provided by ecosystems have an important role in mitigating the impacts of climate change in cities and increasing the resilience of cities against these impacts. These services are the benefits provided from ecosystem processes in which ecosystems act as regulators. Regulatory services include improving air and soil quality, climate regulation, reducing the impact of natural disasters such as floods and landslides, disease control, water purification, waste management, pollination/pollination, biodegradation control of harmful species (MEA, 2005).

2.1. Improving Air Quality

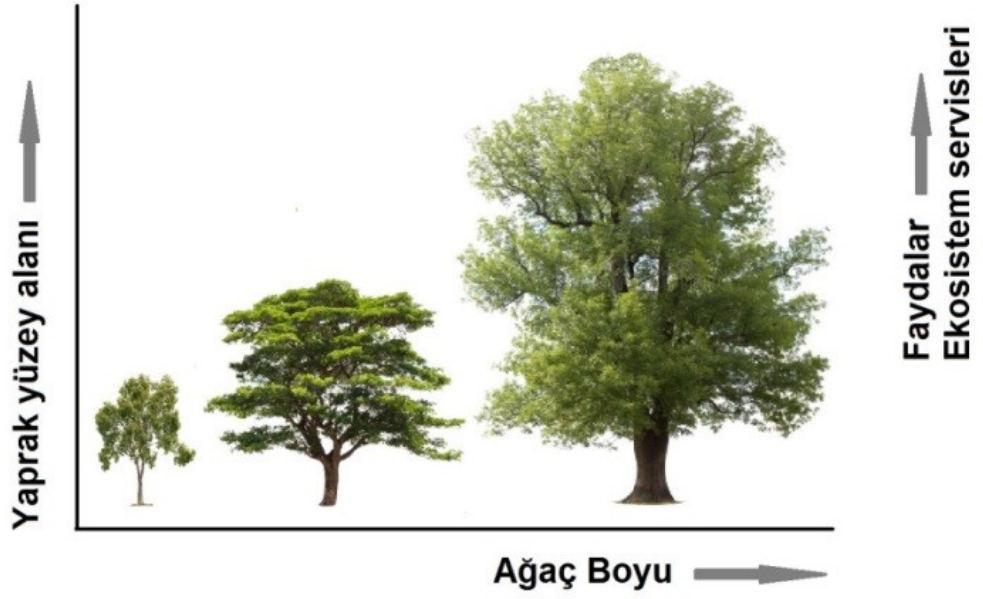
Air pollution has become a common problem in many cities today. Polluted air causes many health problems, especially respiratory and cardiovascular diseases. People living in cities have a higher incidence of these diseases. Especially the elderly and children are at risk in these disease groups.

Pollutants exist in the atmosphere as particles (PM-particulate matter) or gases (C-carbon, NO_2-nitrogen dioxide, O-ozone, SO_2-sulfur dioxide). Particulate matter is one of the most important pollutants affecting human health. These substances suspended in the air are referred to as PM2.5 (size less than 2.5 μm) and PM10 (size 2.5-10 μm) according to their particle size (Scott et al., 2016).

Trees and plants improve urban air quality by removing pollutants from the atmosphere (Nowak & Dwyer, 2000). Trees have the ability to filter pollutants from the air by inhaling them or retaining them on their leaf surfaces. Trees capture carbon from the atmosphere through photosynthesis and store it in wood tissue. After the death of its organs or itself, the stored carbon returns to the atmosphere. Long-lived trees are capable of storing more carbon than short-lived trees. Pollutants sequestered on leaf surfaces remain on the plant until the tree sheds its leaves or the leaves are washed away by rainfall.

The function of trees to improve air quality is directly proportional to the size of the canopy cover. The air purification function of green areas with large-leaved trees with a wide crown structure is high (Roupsard et al., 2013) (Figure 2).

Figure 2: *Relationship between Tree Size and Ecosystem Services Provided*[1]



[1] See https://www.emeraldnecklace.org/park-overview/emerald-necklace-map/

2.2. Climate Edit

Light energy from the sun hits the surfaces of the earth and turns into heat energy. Structural surfaces such as concrete, asphalt and metal heat up with solar energy during the day and heat their immediate surroundings. The surface temperature is high in areas with poor vegetation cover, roads, buildings, roofs and parking lots. Due to the high density of buildings, urban areas are several degrees warmer than their surrounding rural and less developed areas. This microclimatic situation is defined as a heat island (Roth, 2013).

Green spaces are an important factor in controlling urban temperatures. Plants, especially trees, affect the climate of their environment. Trees cool urban surfaces by transpiration and shading. Tall vegetation and high crown density increase shading and transpiration functions, which leads to a cooler environment. Green areas covered with grass, shrubs and trees of the same size have different surface temperatures and cooling effects on the atmosphere. Among these areas, the cooling effect of the area covered with broad-leaved trees is higher than the others. The heat island effect is low in cities where the density of qualified (high ecological quality) green areas is high, the ratio of built-up area/green area is low, and green infrastructure components are regularly distributed. A low heat island effect means that road and building surfaces heat up less in summer and cool down less in winter. This reduces energy consumption for heating and cooling systems in buildings and vehicles.

2.3. Improving Soil Quality - Biological Degradation

Soil is a precious natural resource and a living organism that takes centuries to form. The presence of microorganisms, soil organisms and fungi in the soil increases biodegradation and enriches the soil with nutrients. This is an indicator of a living and healthy ecosystem.

In cities, the soil surface is largely covered by buildings. As with soils in rural landscapes, natural processes continue in soil layers in urban landscapes. However, the physical and chemical structure of the soil in cities differs from the soils in natural areas. Construction activities and underground and aboveground transportation systems cause soil layers to be compacted and prevent soil aeration. In addition, leakage of chemical materials such as lead, fuel oil, oil, detergent from transportation, industrial and domestic wastes into the soil, salting in winter, chemical pesticide and fertilizer applications used in green areas pollute the soil, damage soil organisms and microorganisms, and impoverish the soil.

In soils with vegetation, plant roots provide soil aeration and water infiltration into the soil. The mixing and decomposition of organic materials such as branches, leaves, fruits and flowers into the soil feeds soil organisms, enriches the soil in terms of nutrients and increases microorganism activities.

Removal of organic materials such as branches, leaves, fruits and flowers that fall on the soil surface in urban green areas leads to impoverishment of the soil in terms of nutrients and consequently to a decrease in the number of soil organisms.

2.4. Pollination - Pollination

Pollination is vital for the sustainability of ecosystems and living communities (UNEP, 2010). Maintaining the balance of ecosystems depends on the healthy and sustained relationship between plants and pollinating pollinators. In this respect, pollinator insects are a key component of global biodiversity (Potts et al., 2010).

Areas where tall and old trees with a wide crown cover, trees, shrubs, shrubs and vining plants in different forms that show diversity in terms of leaf, flower and fruit color, flowering, leafing and fruiting at different times of the year are of high ecological value (Coşkun Hepcan et al., 2015). Green areas with high ecological quality contain bird, rodent, winged and insect species that provide pollination/pollination, which are not found in many parts of the city. These species enrich the biodiversity of green areas and the city.

2.5. Flood and Flood Prevention

Water that infiltrates into the soil and is not used by plants may run parallel to the surface under the soil and feed a nearby water body such as a stream or lake, or it may infiltrate deeper and reach the ground water. Vegetation, especially trees, reduces the velocity of rainwater, allows water to pass through the soil and reduces the amount of water that enters surface runoff. Maintaining the natural crown form of trees is very important in terms of slowing down the velocity of rainwater and its infiltration into the soil.

Changing the topographical structure due to urbanization, decrease in permeable surfaces and increase in impermeable surfaces, disregarding/ignoring the natural drainage pattern, turning river beds into concrete channels, narrowing their cross-section or closing them completely,

The natural movement of water causes the flow system to change, the water cycle to be interrupted, and ground and surface water resources to be unable to be fed. This situation often leads to the inability to drain the water during rainfall, causing roads and streets to be covered with water. Changing the natural beds of rivers in and around the city has a negative impact on river ecology and interrupts ecological processes. Streams that flow in their natural bed and have riparian vegetation cover function as channels where runoff water is collected. The vegetation cover and organisms on the water bank and within it allow the water to be filtered. In streams that are enclosed in concrete channels, the flow rate and microorganism structure of the water differ and the self-cleaning function of the water system is eliminated.

Most of the precipitation falling in cities passes to surface runoff in impermeable areas. Due to extreme climatic events, cities receive large amounts of rainfall in a short period of time and the amount of runoff increases. In cases where the amount of runoff exceeds the capacity of water collection systems, it can lead to floods and floods. Since cities generally do not have a separate stormwater collection system, the runoff is collected through wastewater (sewage) systems. This results in the loss of large amounts of usable water as wastewater. In cities with rainwater harvesting systems, this water is utilized in two ways. In some cities, it is conveyed to water bodies such as the sea and rivers. In this case, the aim is to remove the water from the city as quickly as possible and reduce the load on the treatment plant. In cities where treatment is targeted, collected rainwater is conveyed to biological channels or wetlands where biological treatment processes will take place (Strom et al., 2013). Similarly, wetlands act as sponges, helping to retain water and prevent flooding.

3. MANAGEMENT

Green infrastructure is planned, implemented and managed at different scales. Planning can be based on regional (river corridors, natural ecosystems), watershed, city (urban parks, wide tree-lined boulevards, groves), neighborhood (neighborhood and district parks, planted streets and avenues) and site (rain gardens, vertical gardens, stormwater vegetation strips) scales.

Implementation and management is a costly and long-term process that requires many actors to work together in harmony. However, this cost is no more than the budget spent on the construction and maintenance of gray infrastructure components such as transportation and communication lines, clean and waste water systems in cities. Since the completion of the implementation process requires time and budget, these works are programmed in phases.

Although local and central governments are mainly responsible for the management of green infrastructure components, the participation of civil society organizations, local people and volunteers in the management stages contributes to the adoption and protection of practices and increases the chances of success. In addition, by raising awareness and developing solutions to raise public awareness, users can own and protect green infrastructure components.

In the management process, rules for operation and supervision are set and in some cases solutions are developed, such as expropriation or long-term leasing of land. These areas also need to be regularly monitored for maintenance and improvement.

The management of green infrastructure also mapping green areas, identifying biodiversity, identifying diseases and problems and developing solutions, and maintenance and monitoring. In this context, rules for the maintenance and management of city-specific green infrastructure components are defined and guidelines are prepared.

Cities such as Tokyo, Seattle, Portland, Eugene, New York and New Jersey have successful practices in stormwater management. The details of the practices to be carried out in stormwater management in these cities are defined **in stormwater management** guidelines (NYSSMDM, 2005; Hinman, 2013; NJSM, 2004; CPSMM, 2016). These
Workshops are organized at regular intervals to introduce the guidelines, provide information on techniques and practices, and bring together experts, practitioners and users.

Vancouver, Toronto, New York, San Francisco, Portland, Londra, Barselona kentlerinde kent içinde kullanılacak yol ağaçlarının tür seçimi, dikim, bakım koşulları vb. kural ve standartları **yol ağacı** rehberlerinde belirtilmiştir (Stret Tree Guidelines Vancouver, 2011; NYC, 2016; Toronto Street Trees, 2010).

In the cities of Albuquerque (New Mexico, USA) and Las Virgenes (California, USA), which have arid climatic conditions, drought-tolerant native vegetation species and details on how these species can be used are given in **arid landscaping guides** (Las Virgenes Municipal Water District, 2017).

Mapping the green infrastructure components of cities and processing them into information systems provides important data for management studies. In particular, **the** inventory **of** green areas and road **trees**, the processing of these data into information systems, and the regular updating of these data facilitate green infrastructure management activities to a great extent. In cities such as Rome, Portland, Eugene, Seattle, New York, London, London, Amsterdam and Rotterdam, the location, age, height and general condition of trees are monitored and transactions are carried out through this system.

Similarly, the preparation of **a biodiversity inventory** enables the determination of measures to be taken for the protection and improvement of biodiversity in cities. Biodiversity inventories have been prepared in many cities such as Toronto, London and Vancouver.

The management of green areas is not only the responsibility of local governments. There are also rules to be applied in privately owned areas. For example; regular mowing of herbaceous plants and grasses, keeping their height below the specified level, observing invasive species and combating them with recommended ecological methods in case of detection, not polluting water resources, etc. rules are determined by regulations.

Privately owned green spaces have an important role in the protection of ecosystems in urban landscapes (Ramos-González, 2014). In some cases, non-governmental organizations purchase and manage ecologically important areas in and around the city in order to prevent their conversion to urban uses such as housing and to ensure their preservation. For example, "Birdlife International" has acquired a large number of wetlands in Europe, particularly in the UK and the Netherlands, to protect of natural ecosystems.

Similarly, in Eugene, USA, the Rivers to Ridges Partnership has been protecting wetlands and natural grasslands through acquisition (expropriation) or long-term leasing for more than 20 years, and has developed successful solutions to improve ecosystems through management efforts. In this process, open-green spaces representing different landscapes and habitats have been transformed into a region-wide green/ecological network system (West Eugene Wetland Partnership, 1995; The Rivers to Ridges Partnership, 2013). These non-governmental organizations also provide support to science and researchers by carrying out scientific projects in these areas with the support of national and international funds.

The Dutch government has also expropriated or long-term leased some land to ensure the creation and protection of ecological corridors in the process of implementing the national ecological network system.

In addition to these, some practices are carried out in order to increase the awareness of the urban population about green areas and their benefits and to ensure the development of conservation awareness. Award and certificate programs have been developed by various national or international organizations to encourage local governments and city dwellers to improve the quality of life in cities and to create a green space system.

The European Commission has developed the "**European Green Leaf**" award system for cities with a population of 20,000-100,000 and the "**European Green Capital**" **award** system for cities with a population of more than 100,000 in order to support local governments that produce ecological solutions and work towards increasing the standard of living by respecting the environment. Cities wishing to apply for the prize are encouraged to apply for the award in the areas of adaptation to climate change, biodiversity, protection of natural resources, air and water quality.

The projects and practices are developed by making investments in the fields of improvement, clean energy and environmental management. These practices provide ecological, economic and socio-cultural benefits to cities.

Similarly, **the Green Flag Certificate** was developed in 1996 to set a national standard for parks and green spaces in the UK and has since spread around the world. Award
green spaces for biodiversity, health,
security, accessibility, Care, participation and management criteria. Apart from these, there are supports practices that develop ecological solutions in privately owned green spaces. For example, private property in the UK belonging to
areas (housing garden) can be used flooring quantity and Material specifications are defined by regulations and details are specified in the guide booklet. More than 5 square meters in these areas wide impermeable
The use of paving material subject to special authorization. In addition, increasing the permeable surfaces of the pavements used incentivized through tax breaks (DCLG, 2008; Permitted Paving, 2013).

Similarly, in Portland, Seattle and Philadelphia, owners of applications that incorporate solutions that reduce impervious surfaces benefit from tax incentives. Portland also offers other incentives. For example, owners of projects with ecological roofs and trees over 4.5 meters tall are awarded cash prizes to be used during the implementation phase. In addition, the city's stormwater management practices also provide incentives for water retention.

capacity, water flow rate, and effectiveness in pollution treatment, and successful projects are supported with up to 100% budget support during the implementation phase or 35% reduction in stormwater management taxes under the **Clean River Rewards (**GI Case Studies, 2010).

4. EXAMPLES FROM AROUND THE WORLD

cities around the world that have developed, planned and implemented a green infrastructure strategy. The Emerald in Boston (USA) forms the basis of this approach (Figure 3). This park system, where nine parks are connected by river corridors and linear parks, was created in the 18th century. This park system, which includes pedestrian and bicycle paths covering an area of approximately 445.06 ha, aims to protect natural ecosystems with nature-based solutions and to bring users together with nature in the city.

Successful implementations also Stockholm, London, Portland and Baltimore. In Stockholm, efforts to improve the environmental quality of the city began in 1976. 95% of the population has access to green spaces less than 300 meters away. In 2010, Stockholm was awarded the title of Europe's first green capital, and smart growth models against climate change have been developed in the city, taking into account the city's growth forecast for 2040.

Figure 3: *Emerald Necklace*[2]

In the so-called Climate-Smart Model, which is planned to be applied to new development areas, pedestrians, bicycle users and public transportation are prioritized in urban transportation. In addition, in order to protect the natural and agricultural ecosystems in the city and its immediate surroundings, the use of harmful chemicals in these areas has been banned, and biological control and organic farming practices have been encouraged. Green infrastructure and ecosystem services maps have also been integrated into the city plans (Jones, 2018) (Figure 4).

In London, the open space and park system approach, which aims to establish connections between green spaces in and around the city, emerged in 1943. Subsequently, with the plans prepared in 1992, 2004, 2008 and 2012, this system was developed by taking into account the objectives of protecting natural ecosystems and biodiversity and ensuring accessibility by creating pedestrian and bicycle routes. The city's

47% green areas. Open spaces account for 60% (Figure 5).

Figure 4: *Stockholm Yeęil Infrastructure Map*[3]

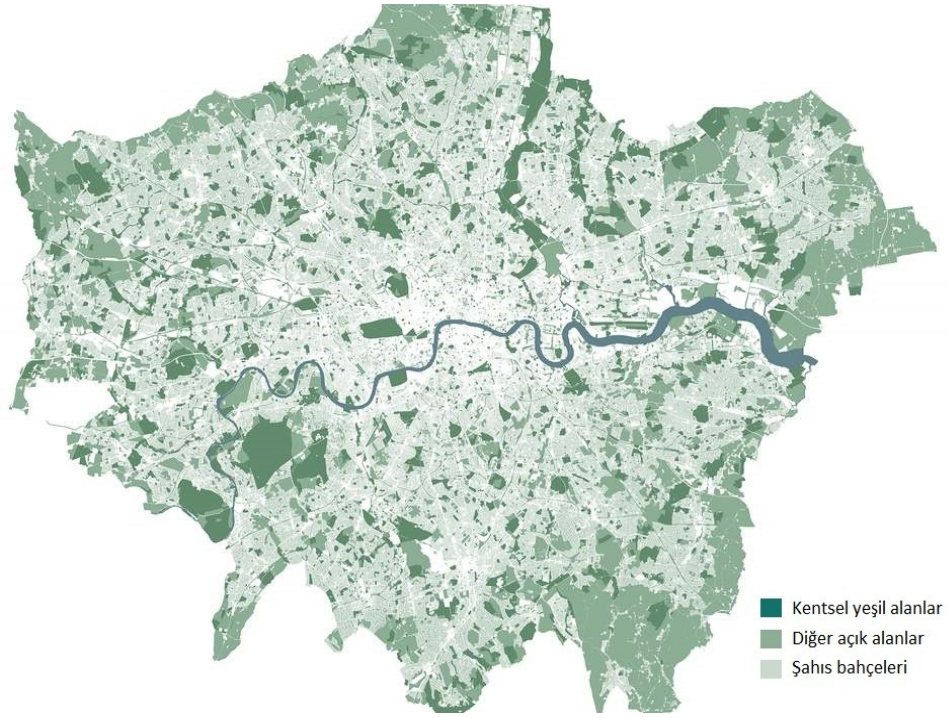
[2] See https://www.emeraldnecklace.org/park-overview/emerald-necklace-map/

[3] http://www.cardiff.ac.uk/archi/research/cost8/case/greenblue/stockholmgreen.html

The city of Portland is one of the most comprehensive and advanced green infrastructure projects in the USA. Within the scope of green infrastructure development works, it is aimed to create green areas with homogeneous distribution throughout the city, including plants with a wide canopy cover, and priority is given to the areas of the city with high building density.

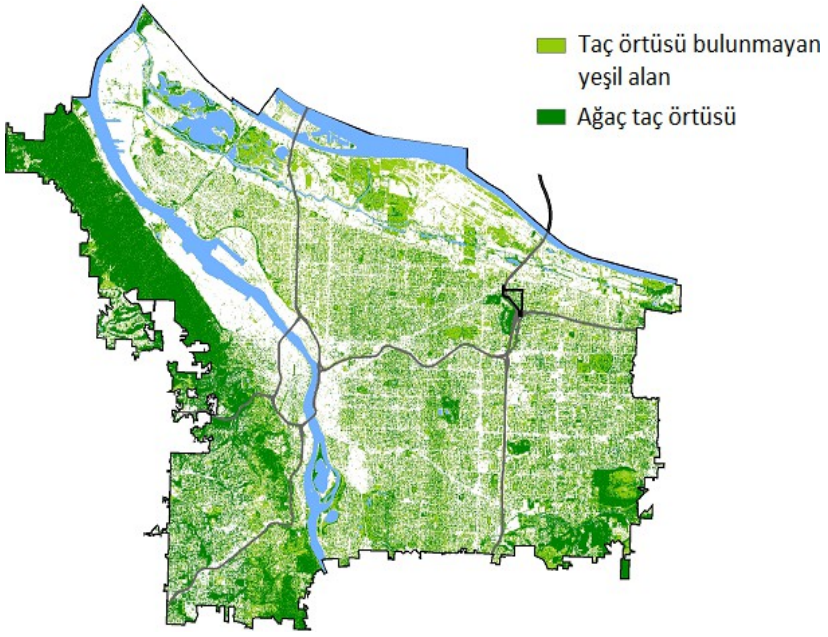
given. With the Green Streets Project, projects and practices were developed to create green corridors by afforesting streets, increase biodiversity and manage stormwater. Tree crown cover was increased to 26% of the city (Figure 6).

Figure 5: *Map of the London Open Space System*[4]



[4] See https://www.gigl.org.uk

Figure 6: *City of Portland Tree Canopy Cover Map*[5]



In addition, the watershed management project aims to protect water ecosystems, prevent pollution and increase biodiversity. The success level of these solutions that increase the resilience of the city regularly monitored through monitoring programs.

In Baltimore in 2010, an open space program was launched to create green infrastructure components in parts of the city in need of renewal, and 700 vacant parcels were transformed. The city also aims to increase tree canopy cover, which covers 28% of the city is planned to increase to 40% by 2037.

Almost all of them have in common increasing biodiversity, improving air and water quality, stormwater management, improving the quality of life of users and human health, and producing recreational solutions for environmental management.

In many cities, the level of ecosystem services provided by green infrastructure is estimated and solutions are proposed to improve these ecosystem services to improve urban ecology and quality of life.

[5] See https://www.portlandoregon.gov/bes/article/509607

5. MANAGEMENT INFRASTRUCTURE

The impacts of global climate change are manifested in the form of extreme weather events. Unlike the usual climate regime, sudden, unexpected weather events occur, and unlike the precipitation regime, short or long periods of heavy rainfall occur. This often results in floods and overflows in many cities.

The high number of impermeable surfaces in cities to changes in the natural flow system of water, interruption the water cycle, and inability to nourish underground and surface water resources. Rainwater entering surface runoff becomes polluted and transmits this pollution to water resources, contaminating water reserves. By retaining the rainwater, the natural flow system of the water is maintained in a suitable way.

rainfall, which aims to be transmitted to water resources

water management has become a priority for many cities around the world

The term "sponge city" has emerged as a result of recent studies and research on this subject. A sponge city is defined as a city where ecological solutions are developed to reduce the flow of polluted water in the management of rainwater, to retain, filter and transmit water to water resources by natural methods. In these cities, impervious surfaces are reduced, permeable roads and surfaces are increased, and structures such as rain gardens, water retention ditches, roof gardens and ponds are used to convey rainwater to natural systems. In sponge cities with successful solutions and practices, the frequency and severity of floods decrease, water quality improves, and groundwater and surface water resources are nourished (Xu et al., 2018). Many cities are developing and implementing policies to become sponge cities.

In cities with arid climatic conditions, the amount of clean water used is higher than the amount of precipitation the city receives. Therefore, the supply of water resources is very important. In stormwater management, it is aimed to control surface runoff water and convey (manage) it to water resources with nature-based solutions. Stormwater management systems can be achieved through the creation of green infrastructure components that include rational solutions such as rain gardens, permeable pavements, dry wells, rainwater plant strips, rain ditches (water retention and accumulation ditches), infiltration trenches, green roofs (roof gardens), rain barrels, cisterns, water treatment areas and wetlands, which are built in accordance with the water cycle by taking into account the natural drainage pattern (Karakoçak, 2011; SPSMM, 2016).

5.1. Permeable (Porous) Flooring

It is a type of pavement that can be used on vehicular and pedestrian roads, made of materials such as concrete or asphalt, which has the ability to absorb water and infiltrate it into the soil underneath, allowing water to filter and filter naturally, purify it from pollutants and feed groundwater resources (Figure 7).

Figure 7: *Permeable Flooring Example* [6] [7]

5.2. Rain Garden

Shallow hollow areas where rainwater is directed directly without any treatment and on which native and non-native plants can be grown are called "rain gardens" or "bio-retention areas" (Demir, 2012). The main function of rain gardens is to collect the water that comes with surface runoff after rainfall in areas such as roof gutters, vehicle - walkways, parking lots and to improve water quality by treating it with biological treatment methods (Jaber et al., 2012). With the runoff coming into the rain garden, the water height increases and a ponding occurs.

This ponding varies depending on the intensity of the rainfall, the infiltration capacity of the water into the ground, the vegetation and the structure of the rain garden. Generally, since the velocity of surface runoff is higher than the percolation rate of water, a ponding of 5-10 cm is formed in the first place. This ponded water then slowly percolates from the base of the rain garden towards the soil (Doğangönül & Doğangönül, 2008).

Rain gardens are a simple and cost-effective stormwater management tool for homeowners, municipalities, and other public spaces (Figure 8) to reduce runoff, improve groundwater recharge, and capture non-point source pollutants before they reach receiving waters (Jaber et al., 2012).

[6] http://www.constructionworld.in/News/Pervious-Concrete-Pavement-for-Smart-Cities/90126

[7] See http://www.craftontull.com/insights/insight_posts/view/46/how-do-permeable-pavement-systems-compare

Figure 8: *Rain Garden Example Eugene, US (United)*

5.3. Precipitation Water Plant Strip

Rainwater plants created at the edges of roads and sidewalks to absorb rainwater from curb openings strips have runoff water control, infiltration and filtration functions (Figure 9) (Eugene, 2014).

Figure 9: *Example of a Yağıę Water Vegetated Strip Eugene, US*

They are designed to include area-specific plant species in different shapes and sizes according to the characteristics of the area to be applied. It includes engineering and design solutions that ensure the absorption of water and removal of pollutants with permeable soil structure and natural plant species.

Some strips have water reservoirs that collect excess runoff water. The collected water is used for irrigation of crops or to feed groundwater systems (Eugene, 2014).

5.4. Rain Ditch

A storm ditch (bioswale) is a narrow and long vegetated ditch on the side of a road that collects and retains runoff water and filters out pollutants (Figure 10) (SPSMM, 2016).

Figure 10: *Example of a Rain Ditch in Seattle, US (EPA, 2017)*

5.5. Green Roof

Green roofs are structures on flat or slightly sloping roofs, consisting of vegetation, soil, drainage and waterproof membrane, which retain a portion of rainwater and direct excess water to the stormwater drain (Figure 11) (SPSMM, 2016).

Figure 11: *Yeęil Roof Example Toronto*[8]

[8] http://www.flatrooferstoronto.com/green-roof.html

5.6. Example Applications

In developed parts of cities, solutions for the creation of green infrastructure components are very limited. It is almost impossible to find suitable open spaces to create new green areas. In these areas

- Increasing the amount of vegetation cover by creating vertical gardens, rooftop gardens, or road afforestation,
- urban transformation in a part of the city
  implementing applications that include green infrastructure components,
- In all abandoned industrial areas
  or by creating green infrastructure components by making ecological improvements in some parts,
- A defunct highwayrailroad or
  Solutions can be produced by considering all or some parts of the river beds as corridors.

Successful examples include High line Park (New York), Boston's Rose Kennedy Greenway, South Korea's CheongGye river corridor, Tanner Springs Park (Portland).

5.6.1. High Line Park

The High line is an urban park in Manhattan, New York City, created by the redevelopment of a 1,876-meter-long railroad track on viaducts after its closure. Built in 1934, part of the elevated railroad track was demolished in 1960. A demolition decision was taken for the remaining section in 1980, but with the initiatives of the Friends of the High Line Association founded in 1999, this decision was canceled and a design competition was organized to transform this area into a park. Started in 2006, the park was completed in three phases in 2009, 2011 and 2014 and cost approximately 188 million dollars (FOHP, 2017) (Figure 12).

Figure 12: *High Line Park*[9]

[9] http://juliotapiaphotography.com/highline-park

5.6.2. Boston Rose Kennedy Greenway

In order to create a solution to the traffic problem in Boston, an elevated highway on viaducts was built in the harbor area in 1959, cutting the physical connection between the harbor and the city. Howeverdue to traffic density, air pollution and noise problems, in 1991, after more than ten years of planning, the so-called "Big ", which is the undergrounding of the traffic, was realized.

The project, which aims to create a green corridor in the city, was realized. Completed in 2008, the 2.4 km long project, which cost approximately 1.7 million dollars and is described as the most comprehensive project in the US due to the creation of a system of underground tunnels, has transformed Boston into a pedestrian-friendly city. The project also developed solutions for stormwater management and biodiversity enhancement (ASLA, 2013) (Figure 13).

Figure 13: *Rose Kennedy Yeęil Road 2002-2007 (ASLA, 2017)*

5.6.3. CheongGye River

The CheongGye River, which passes through the center of Seoul, was turned into a closed canal in 1971 and a highway and viaduct were built on it. Due to the problems such as air pollution, heat island effect, noise in the city over time and the viaduct's end of life, the road and viaduct were removed between 2003 and 2009, ecological improvement work was carried out on the river bed and the river corridor was reconstructed (Figure 14). Considering the 200-year precipitation data

The implementation cost approximately 380 million dollars.

After the implementation of the project, biodiversity increased, the air temperature on and around the river bank was 3-6 degrees cooler than in other parts of the city, the speed of wind movement increased by 2-7%, and pollutant particles in the air decreased by 35%.

In addition, as the river has become a center of attraction, the number of tourists coming to the city has increased significantly (64000 people/day), land has gained value and new job opportunities have emerged (Lee, 2006).

Figure 14: *CheongGye River Before and After Ecological Restoration (Lee2006)*

5.6.4. Tanner Springs Park in Portland

Located in the Pearl District northwest of Portland, the wetland area was filled in the late 1880s to create an industrial zone. Abandoned in 1960, a large-scale urban renewal project was initiated in 1994 to transform this area into a residential neighborhood. In this idle area, Tanner Spring Park was created by excavating a parcel of approximately 3700 m^2. Completed in 2002 at a cost of 3.6 million dollars, the park's lowest code is 6 meters below the old lake floor.

on the site. The design of the park aims to recreate the pre-industrial meadow and wetland ecosystem to emphasize the ecological history of the region. The park, created in a contaminated industrial area, is considered as an example of "sustainable park design and management experience". In the area where the park is located, surface runoff rainwater is collected in the park. The water is filtered using natural methods and ultraviolet light in the wetland habitat without any chemical application and is transmitted to the river system (Figure 15).

Figure 15: *Tanner Spring Park Before and After Ecological Restoration*[10]

[10] http://www.landezine.com/index.php/2013/03/tanner-springs-park-by-atelier-dreiseitl/

Reducing the impacts of climate change in cities

In addition to creating new green areas for the purpose of as well as flood defenses that can prevent flooding during heavy rainfall. protection systems are also being developed. One of the best examples is **the Flood Control System, G-Cans Project** (G-Cans Project, Kasukabe, Saitama, Greater Tokyo Area), which was prepared for the Saitama area in the north of the city to prevent flood disasters in Tokyo during rainfall and typhoons. Initiated in 1992 and completed in 2009, the project created a system of massive tunnels and reservoirs under the city. The system, consisting of five 32-meter diameter and 65-meter high shafts connected by 6.5 km of tunnels running 50 meters underground, 1.5 billion Euros. G-Cans' main stormwater reservoir, called the "underground temple", is 177 meters long, 78 meters wide and 25 meters high. The reservoir has 59 columns, each weighing 500 tons, with the capacity to discharge 200 tons of water per second into the Edogawa river, connected to a 10MW pump. In the calculations of the water retention and conveyance capacity of the flood protection system, rainfall values that can occur once in 200 years were taken into account (C- Cans Project, 2009).

6. EXAMPLES TURKEY

There is no holistic example in Turkey where green infrastructure is implemented in a way that includes ecological solutions, but small-scale point solutions are produced on a project basis.

The "Adaptation to Climate Change through Rain Harvesting Project" carried out by the Landscape Research Association (PAD) in partnership with Çankaya Municipality and Humanitarian Earth Association and supported by the IVth Environmental Grant Program was completed in 2017. Within the scope of the project, an "Introductory Guide to Rain Harvesting Practices" was prepared in order to raise awareness about the importance of rainwater retention in urban and rural landscapes, to introduce application techniques and to share examples (Tokuş & Özdemir, 2017). In order to transfer the project experiences to practice, Çankaya Municipality working to ensure technical and physical transformations that will enable nearly 500 parks across the district to be irrigated with stored rainwater.

With the arrangement made in 2018 in the central campus of the Ministry of Environment and Urbanization, permeable concrete was applied on the walkway and a rain garden was created in the green area by the road. The aim was to discharge surface water into the green area and rain garden (Figure 16-17). The Ministry is working on similar applications in the gardens of public institutions.

Figure 16: *Ministry of Environment and Urbanization Yerleękesi Rain Garden Application*[11]

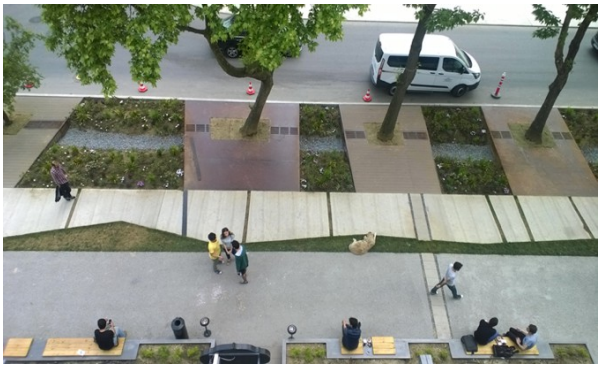
Figure 17: *Ministry of Environment and Urbanization Permeable Concrete Application*[12]

[11] See https://mpgm.csb.gov.tr/yagmur-hasadinda-kucuk-ama-etkin-bir-adim-yagmur-bahceleri-haber-228890

[12] https://mpgm.csb.gov.tr/yagmur-hasadinda-kucuk-ama-etkin-bir-adim-yagmur-bahceleri-haber-228890

In addition, within the scope of green campus practices, water management solutions were developed in landscape designs at Istanbul Technical University (ITU) Ayazağa Campus, and rain ditches (biological channels) were created to retain rainwater on walkways (Figure 18).

Figure 18: *ITU Ayazaga Campus Biological Channel Example*[13]



Izmir Metropolitan Municipality is working on developing green infrastructure strategies at the metropolitan regional scale. These strategies, which prioritize river corridors that establish a physical relationship with the city and its immediate surroundings, have not yet been translated into large-scale comprehensive plans and integrated into physical plans. Projects are being prepared to develop point solutions in some parts of the city. URBAN GreenUP, supported by the Horizon 2020 program, is one of them. The project aims to increase biodiversity, manage stormwater and improve air quality through nature-based solutions in three sample areas.

Unfortunately, well-intentioned practices cannot bring a permanent solution to the problem due to the lack of holistic approaches to the creation of a green infrastructure system.

[13] See https://www.hetpeyzaj.com/

7. LAWS AND REGULATIONS TURKEY

In our country, the standard of "10 m^2active green space per person" defined in the Regulation on the Principles of Plan Construction of the Zoning Law No. 3194 is taken into account in urban green space planning. This should also be taken into consideration in implementation.

In the Country Spatial Strategy Plan, open green spaces are classified as a social infrastructure component. It is stated that "open green space system" should be included in the plan notes of spatial plans. Within the scope of the implementation of landscape architecture objectives in the current spatial planning process, the definition of the open green space system, its types and its functions can be focused on more. The scope of the definition of "Open Green Space System" can be expanded and "Green Infrastructure" practices can be brought to the forefront in the implementing legislation.

In the Integrated Urban Development Strategy and Action Plan (KENTGES 2010-2023), which is a roadmap for central and local administrations on urbanization and zoning issues, the concept of "Open-Green Space System" is included among the strategies. In the plan, it is envisaged to make arrangements that protect existing green areas in settlement areas and recommend open and green areas system in spatial plans. In this context, it is emphasized that legal arrangements should be made for the development of planning and design standards and the preparation of guidelines.

Due to the lack of legal regulations, urban open green space planning and design is isolated from urban development plans and is carried out on a limited scale at the zoning parcel level and at the initiative of municipal councils (Yılmaz, 2010).

The Ministry of Environment and Urbanization prepared Urban Design Guidebook for Local Governments in 2015. The terms "open and green space, green space system, green network" are mentioned in different sections of this handbook, but their definitions, contents and components are not explained.

Published on June 23, 2017 in the Official Gazette and entered into force, the "Regulation on Stormwater Collection, Storage and Discharge Systems" is one of the pioneering steps taken regarding stormwater management in cities. The Regulation, which includes the procedures and principles regarding the planning, design, project design, construction and operation of stormwater collection, storage and discharge systems prepared by the Ministry of Environment and Urbanization, aims to design and construct an applicable model for Turkey with all its elements. The regulation also aims to contribute to the efforts to eliminate the problems experienced in the realization of infrastructure investments and services, to establish standards for the harmonious and effective operation of the data infrastructure, and to develop implementation tools (Official Gazette, 2017). However, the regulation does not specify that these systems, which include stormwater management solutions, are components of green infrastructure and should be integrated into green space systems.

7.1. Recommendations for Turkey's Cities

In order to include the concept of "Open-Green Space system or Green Infrastructure" in the legislation where the country plan levels and implementation provisions are included, the relevant laws, regulations and specifications (Zoning Law,

It would be appropriatethe necessary arrangements (Building Inspection Law, Municipal Law, Planned Areas Type Zoning Regulation, Regulation on the Principles of Plan ConstructionEngineering and Architectural Services Specification, etc.) (Yılmaz2010).

Although issuing regulations is the first step towards solving the problem, it is necessary to ensure that the regulations are properly implemented and monitored. In this context, with the cooperation of central and local governments, it is necessary to develop area-specific rainfall water management hand booklets for each city or district.
/Preparation of guidelines will increase the chances of success in implementations. The Rain Garden Preparation Guide, which includes the procedures and principles regarding the implementation of rain gardens prepared by the Ministry of Environment and Urbanization in April 2018, is a good example of this. This guide will be a useful and guiding resource for local governments and practitioners.

Classification of green areas according to their square meter per capita size is an important problem for the creation of qualified green areas in cities. Green areas should be evaluated according to their ecological qualities and spatial distribution, not according to their areal size. The ecological quality of an area on its size, form, species diversity (plant and animal) and species density. As the number, density and mass of natural plants increase, the ecological quality of the area increases. Similarly, the ecological value of areas with a gradual vegetation consisting of trees, shrubs, shrubs and ground covers of different species, sizes and ages is high (Coşkun Hepcan et al., 2015). On the other hand, lawns, which are widely used in cities, are ecologically poor areas and are defined as "ecological deserts" in the scientific literature because they contain one or a few species, require constant watering, chemical fertilizers and pesticides for their cultivation and maintenance (Forman, 2014). The ecological qualities of green spaces are characterized by the ecosystem

determines the type and quantity of services. The main principle should be **the creation of a green infrastructure (open-green space) system with high ecological qualities and a balanced distribution within the urban fabric.** In this context, it should be aimed to develop a holistic approach to improve the ecological characteristics of open-green areas.

Each city has its own unique climate, natural, cultural, demographic and ecological characteristics, green space planning-design policies and practices. Therefore, it would be appropriate to develop measures based on the unique values of cities.

First of all, mapping the existing green infrastructure components and identifying the missing components of the system will provide important data for determining planning strategies. Solutions can be developed to complete the missing components. For example;

- Urban corridors can be created by planting trees on streets, avenues, sidewalks and around the railway tracks
- Public buildings that create a heat island effect in the city
  also by using trees with wide crowns in privately owned parking lots, the heat island effect created by these areas can be reduced.
- The physical conditions of cities are conducive to tree planting
  In sections where it is not possible, wheeled plant containers (parklets) can be used to increase the canopy cover
- Flooding of dry stream and river corridors
  They can be handled together with their beds and organized as green corridors through ecological improvement works. Especially in cities with rivers and canals, these solutions can be developed
- Urban transformation, urban green infrastructure
  solutions can be developed, unfortunately, it is unfortunate that this could be an opportunity to prevent point solutions that aim to renovate buildings to make them resilient.

cannot pass. However, urban transformation practices should be planned and implemented in a way to include an open green space system at neighborhood, district or larger scales in order to create livable, healthy and planned cities. In addition, in order to create new green areas, it is necessary to find resources to eliminate ownership problems and to cover expropriation costs.

A stormwater management program should be prepared and solutions such as rain gardens should be made widespread throughout the city. The Ministry of Environment and Urbanization's goal of creating rain gardens in the gardens of public institutions and organizations is an opportunity for strengthening green infrastructure and water management in cities. The scope of this target can be expanded to include the gardens of private organizations, educational and health institutions, and residential areas.

Guidelines should be produced that include site-specific solutions of urban green space system components at local scale and details of design, implementation and management. These guides can be prepared at the scale of district municipalities. For example;

- Guides with design and implementation details for pavements, roads, medians, etc. that include water management solutions
- Guidelines should be prepared including plant species, sizes, maintenance and management rules to be used in areas such as near buildings, sidewalks and medians in the city.

In order to encourage local governments to prepare these guidelines, legal arrangements can be made to transform the Manual for the Preparation of Urban Design Guidelines from advisory to mandatory.

In addition, recording the existing vegetation in cities, especially in areas under the responsibility of local governments, taking an inventory of park and road trees, and processing the data into digital databases (information systems) will provide great convenience for the protection, management and maintenance of these trees. Encouraging the participation of volunteers from the local community in these inventory studies will contribute positively to raising awareness and developing conservation consciousness.

Determining the ecosystem services provided by green areas will facilitate taking measures to provide the services needed in the city . In order to increase the ecosystem services provided by green areas, it would be appropriate to develop solutions to improve the ecological qualities of these areas. Preserving natural ecosystems as much as possible and producing nature-based solutions will increase the resilience of these areas. **For example, wetlands act as sponges, helping to retain water and prevent flooding.** The presence of wetland ecosystems in the vicinity of the city increases the resilience of the city. Therefore, it is very important that they are protected and not converted to other uses.

In our country, most of which is under the influence of arid and semi-arid climate, there are many natural plant species resistant to heat and drought. Preferring native plants that can survive in arid conditions instead of foreign/exotic plants that require a lot of water and maintenance in landscape architecture applications in cities will contribute to the development of successful solutions in the process of adaptation to climate change (Dilaver, 2014; Barış, 2014).

In addition to these, solutions can be developed to increase the number of trees with wide crowns, height and mass in cities as much as possible. **Trees whose crown cover is reduced by unnecessarily hard pruning lead to the breakdown of the resistance of cities against climate change and make them unstable.** Many cities in the world, such as Toronto, London, Rome and Sydney, which are working on taking measures against climate change, aim to "increase the number of trees and tree canopy cover in the city". Unfortunately, in many cities in our country, street, road and park trees are pruned to the point that they have almost no crown cover, or they are cut down and removed from their environment. This practice, which negatively affects the health of trees and reduces the benefits they provide, also hinders local governments' goals of creating livable cities. In order to eliminate this dilemma, in addition to training the personnel responsible for maintenance and management, legal arrangements such as the preparation of regulations can be made by the central government or guidebooks containing technical solution details can be prepared by local governments.

The ecosystem services provided by green areas increase when the ecosystems in these areas are healthy. For this reason, it would be appropriate to abandon the use of chemical fertilizers and pesticides, which cause soil and water pollution and harm human health, and to develop ecological and biological control methods in the maintenance of green areas. In the cities of our country, similar targets can be developed to the policies of many cities such as Paris, London, Cambridge and Portland to clean their green areas from chemical pesticides. In this context, local governments, the Ministry of Environment and Urbanization, NGOs and volunteer participants can cooperate and develop "clean environment" projects.

Permeable concrete or asphalt can be used instead of impermeable materials in areas where possible in the city. In the cities of our country, school gardens are largely covered with impermeable surfaces and the vegetation cover in these areas is very poor. "Green campus" projects supported by national or international funds can be developed in partnership with the Ministry of National Education, the Ministry of Environment and Urbanization, local governments and non-governmental organizations in order to improve the ecological qualities of school gardens, reduce the proportion of hard surfaces such as concrete and asphalt and enrich them in terms of vegetation.

Implementing incentives such as tax deductions or reward systems for green infrastructure in cities will make these solutions attractive and raise awareness.

Providing trainings to increase the knowledge and awareness of technical staff working in units responsible for the maintenance and management of green areas on climate change adaptation solutions will increase success. Similarly, raising the awareness of local people will contribute to raising conservation awareness. For this reason, it is important to share the practices in various ways such as social media and local press. The solutions implemented in Portland can be taken as an example. A walking and cycling route was defined that includes different types and scales of stormwater management solutions in the city. In this way, it is possible for local people and tourists to see the practices and benefits on site.

Many cities around the world are working to mitigate the effects of climate change. Izmir Metropolitan Municipality has become a party to the Covenant of Mayors (CoM) established by the European Commission and aims to reduce carbon emissions by 20% by 2020 (SEAP, 2016).

In order to mitigate the negative impacts of climate change in cities, it is not enough to take measures only at the source, such as reducing greenhouse gas emissions. In addition, ecosystem services should be prioritized in the development of green space planning, design and management strategies. These rational solutions for the improvement of ecosystem services will contribute to the protection and improvement of the fragile ecosystems of cities and to making the city resilient and resilient to the impacts of climate change.

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