Birpinar M.E., Tuğaç C. (2021) Water management with green infrastructures in ensuring sustainability of Turkish cities pp. 144-157. In Gastescu, P., Bretcan, P. (edit, 2021), *Water resources and wetlands*, 5th International Hybrid Conference Water resources and wetlands, 8-12 September 2021, Tulcea (Romania), p.235
Available online at http://www.limnology.ro/wrw2020/proceedings.html Open access under CC BY-NC-ND license
5th International Hybrid Conference Water resources and wetlands, 8-12 September 2021, Tulcea (Romania)

WATER MANAGEMENT WITH GREEN INFRASTRUCTURES IN ENSURING SUSTAINABILITY OF TURKISH CITIES

Mehmet Emin BİRPINAR[1], Çiğdem TUĞAÇ[2]
[1] Turkish Republic Ministry of Environment and Urbanization – Ankara, Yıldız Technical University Civil Engineering Department – İstanbul, Turkey. *E-mail: mehmeteminbirpinar@gmail.com*
[2] Turkish Republic Ministry of Environment and Urbanization, General Directorate of Environmental Management, Climate Change and Adaptation Department – Ankara, Turkey. *E-mail: cigdemtugac@gmail.com*

Abstract. In addition to the rapid growth and expansion of cities, the pressure created by the increasing population on natural resources is now taking place at a rate above the carrying capacity of the environment. Cities are highly dependent on ecosystem services, that is, the resources that nature provides to sustain our existence. Water has a privileged place within these sources. Water is a basic resource for life and for all human activities. It is also irreplaceable in terms of the ecosystem and the services it provides. Water is a resource where the negative effects of climate change are already beginning to be seen and could directly threaten the security of states. The vulnerability of water to changes in the climate system is paramount because climate change directly affects the water cycle. Extreme weather events due to climate change can cause sudden, unexpected events unlike conventional climate regimes. This also changes the rainfall regime. This situation causes urban floods in cities where rainfall becomes more frequent, resulting in loss of property and lives. In urban areas where the rainfall regime is decreasing, conversely, it causes water scarcity. In the cities, especially the large number of impermeable surfaces affects the natural flow system of water. Changes in the water cycle prevent the feeding of underground and above-ground water sources. Rainwater, which cannot pass underground at the appropriate time, is contaminated during its stay on the surface then pollute the water reserves. It is observed that urban infrastructure systems are increasingly handled with an integrated approach to create sustainable cities that are resilient to the negative effects of climate change and green infrastructure solutions are developed in order to ensure the sustainability of water. One of the most important features of a city resilient to the climate change is providing effective water management and providing quality water to its citizens. The aim of this study is to address the strategies and green infrastructure solutions that need to be implemented by taking into consideration the issue of sustainable management of water resources in cities, especially in the context of climate change. In the study, it was resulted that reaching to the cities resistant to climate change in today's conditions depends on the sustainable management of natural resources that are directly affected by global warming, the determination of green infrastructure strategies and the determination of appropriate adaptation actions by considering local characteristics. Another result obtained from the study is that in line with the evaluations made on the basis of geographical regions and urban areas in Turkey, water management in Turkey will gain more importance in the coming years with the effect of climate change. In this context, the consideration and dissemination of green infrastructure solutions, especially on the basis of basins and in urban areas, will increasingly come to the fore with their recreational, cultural and biodiversity values, health benefits and supports to disaster risk management by increasing resilience of the settlements.
Keywords: Water, climate change, green infrastructure, urban resiliency.

1 INTRODUCTION

Climate change, one of the most important issues on the international agenda today, is a multidimensional problem. The studies carried out under the leadership of the United Nations (UN) on combating the negative effects of climate change has dimensions that affect climate change policies not only at international but also at national and local scales. The greenhouse gas mitigation commitments made by countries under the UN Framework Convention on Climate Change (UNFCCC) and the Paris Agreement are very important. However, in the UN NDC Synthesis Report published in February 2021, it was emphasized that they are not enough to overcome the climate crisis (UNFCCC 2021). Even if greenhouse gas emissions are reduced globally, current emissions in the atmosphere will continue to affect the world. In this regard, today climate change adaptation activities come to the fore and include less exposure to and benefit from climate-induced changes where possible, and are determined by local conditions (IPCC 2018). In this context, today cities, where human activities are concentrated, are considered with importance and Nature-based Solutions (NbS) and green infrastructure (GI) are increasingly used in many countries, including Turkey, within the scope of climate change adaptation actions (UNFCCC 2020).

NbS is an essential part of the solution to achieve climate resilience and reveals the importance of nature in combating climate change. Adequate investment in NbS contributes to reducing the cost of negative consequences of climate change, creating new jobs opportunities, and increasing urban resilience against climate change (Canals and Marín 2019: 8). Within the scope of NbS, GI is defined by the European Commission as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (EC 2013: 3).

In the literature, it is seen that there are studies in which evaluations are made in terms of the benefits of GI to urban areas from different perspectives and these benefits are evaluated within the scope of case studies. As emphasized in these studies, GI have important functions in urban areas (OECD 2020: 6). Liu and Jensen (2018) evaluated the relationship between GI and urban water management in the context of case studies. They demonstrated the benefits of combining GI with traditional grey engineering solutions in terms of reducing the urban water footprint and conserving water. In the aforementioned study, it was concluded that cooperation between sectors and stakeholders is important in extending GI approach to the urban area (Liu and Jensen 2018: 126). Everett et al. (2015) also discussed the potential benefits of using blue and green infrastructure elements in cities. In the study, it was concluded that a significant paradigm change is needed in policies and practices in order to realize the many benefits that can be increased, such as reducing the risk of flooding in cities, breaking the urban heat island effect and providing recreation opportunities of the blue and green infrastructure elements, which are increasingly used to meet the objectives of urban water management, and that all parties should work together (Everett et al. 2015: 50). Another study that deals with GI in the context of Disaster Risk Management (DRR) is Carter et al.'s (2018) study in the Urban Mersey Basin in North West England, revealing the contribution of GI in the context of disaster management in flooded areas (Carter et al. 2018).

In the study carried out by Stefanakis (2019), the role of wetlands as a GI element in urban water management was discussed, and it was concluded that wetlands have important environmental and economic advantages with their functions such as protection against floods, storm water management, water treatment, habitat creation, recreation and education opportunities (Stefanakis 2019). In another study by Ellis (2013), this time a broader GI approach in urban sustainable surface water management was considered together with micro and mezzo-vegetative drainage systems. Evaluation conducted within the scope of the UK using GIS and remote sensing revealed that it is important to include GI solutions in planning (Ellis 2013: 24). In the study conducted by Rowe et al. (2016) in New Jersey, a survey was conducted on the practices and barriers to GI at the municipal level. As a result of the survey, it was determined that the most common GI solution to reduce the runoff of rainwater on the surface is rain gardens. As an important result of the study, adaptation to climate change was not seen as the primary objective by the municipalities in the implementation of the aforementioned application and financing was identified as an important obstacle in the dissemination of GI solutions (Rowe et al. 2016).

Pitman et al. (2015) evaluated the contribution of GI to climate change adaptation within the context of South Australia. It was concluded that GI includes multiple benefits such as human health and well-being, urban liveability, effective water management, economic development, urban agriculture and biodiversity conservation (Pitman et al. 2015: 112). In addition, by De la Sotaa et al. (2019), the contribution of urban forests and urban agricultural activities in Spain applied within the scope of the EU's LIFE Program to combating climate change and reducing greenhouse gasses as GI elements was discussed. It was concluded that the type of urban GI selected in the study provided significant differences in this context (De la Sotaa et al. 2019: 151). In addition to these studies, Seddon et al. (2020) emphasized that there is a need for an administrative paradigm change that will enable sustainable development and the dissemination of NbS solutions in overcoming climate and biodiversity crises (Seddon et al. 2020). In their studies, Zuniga-Teran et al. (2020) and Alhassan et al. (2020) emphasized the difficulties encountered within the scope of GI solutions, and revealed that appropriate techniques should be used and green governance should be ensured in the effective implementation of GI (Zuniga-Teran et al. 2020; Alhassan et al. 2020).

As mentioned in the above studies in the literature, GI solutions create carbon dioxide sinks, protect biodiversity, protect from flood risks, mitigate the impact of floods after heavy rains, and are used as urban recreation areas outside of these disaster times. They are also useful in soil management and wastewater treatment. GI are more cost-effective than traditional gray infrastructure solutions and can serve for a longer period of time. For this reason, they are considered as a complementary or alternative to technical solutions (O'Farrell and Anderson 2010: 59; Rusche et al. 2019: 2).

In line with these considerations, the aim of the study is to address the strategies and GI solutions that need to be implemented by taking into consideration the issue of sustainable management of water resources in cities, especially in the context of climate change.

2 METHODS

The relational research model was used as the study method. It is aimed to establish the relationship between GI solutions and ensuring the sustainability of water resources against climate change, especially in urban areas (Figure 1).

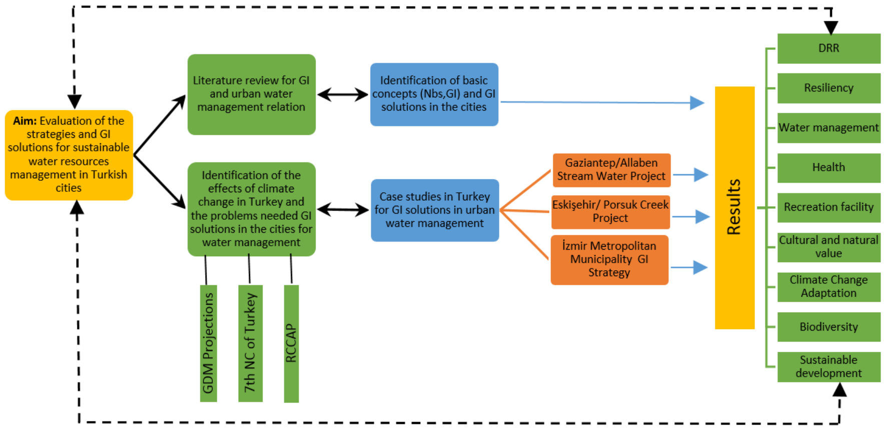


Figure 1. Conceptual method flowchart

The evaluations were made with the regional climate projections produced for Turkey until 2100 by the General Directorate of Meteorology (GDM) according to the Intergovernmental Panel on Climate Change (IPCC) scenarios, based on the CMIP5 project global models HadGEM outputs using the dynamic downscaling method in the RegCM4 model. These projections were also used in the 7th National Communication of Turkey submitted to the UNFCCC Secretariat prepared under the coordination of the Ministry of Environment and Urbanization (MoEU). Projections were made for the years 2016-2099 with reference to the period 1971-2000 (Figure 2). When the results of the outputs for all scenarios were evaluated together, it was predicted that temperatures would increase by an average of 2-3°C, the numbers of consecutive dry days would increase, and rainfall would decrease significantly. These are important results that reveal the importance of water management, which is the focus of this study (MoEU 2018a).

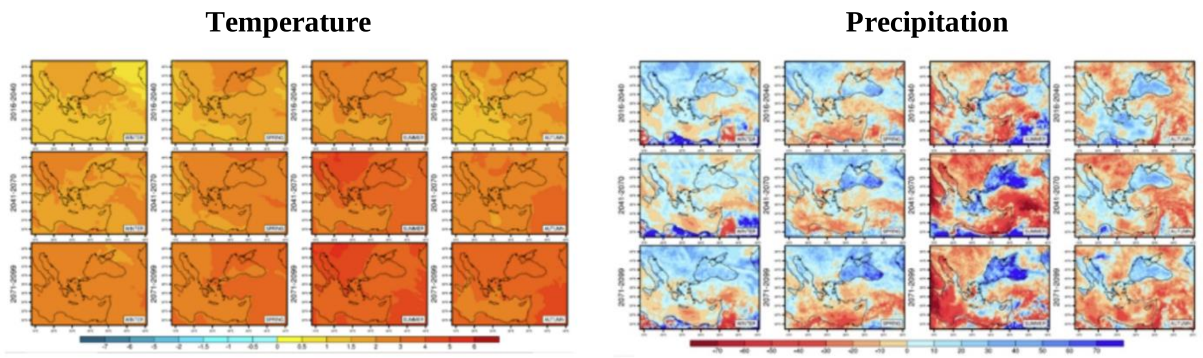


Figure 2. HadGEM2-ES RCP4.5 Temperature and Precipitation Projections-20 km (MoEU 2018a: 131)

3 CONCEPTUAL FRAMEWORK

Entire societies live dependent on ecosystems. Factors such as climate and land use changes caused by human activities affect ecosystems and the services they offer. This is an issue that increases and exacerbates disaster risks. In combating these effects, NbS are defined as actions involving the improvement and restoration of nature in line with conservation, management and ensuring climate resilience (IDB, 2020: 9). In climate change adaptation and DRR, GI is an important approach in the context of NbS, plans and strategies, and GI forms a hybrid structure of NbS together with ecosystem services (Diepetri and McPherson 2017: 99; Eggermont et al. 2015; OECD 2020: 6). Ecosystem services contained in this definition refer to all the processes, benefits and products that the ecosystem offers for human existence. Water, air, food and cultural/spiritual values obtained from nature are within this scope. These opportunities provided by the natural environment are important not only for humans, but also for all living things. Therefore, the planning approach based on ecosystem services, which also takes into account natural functioning and the factors affecting it, should be preferred. Studies show that well-managed ecosystems and services offer cost-effective solutions to reduce disaster risks (Albayrak 2017; EC 2013; EEA 2014: 18).

GI on the other hand, contains various natural and semi-natural entities as a network system consisting of interconnected elements, including all kinds of green and blue components (Figure 3). Many natural elements such as coastal salt marshes, oyster reefs, mangroves, coral reefs, and dunes can be considered within the scope of GI. In addition, all water bodies, lakes, rivers and streams, as well as the sea and oceans, are considered as blue infrastructures. Since there are places such as coastal areas, forests, beaches, wetlands, which are areas where water and land meet, these places are considered with importance in climate change adaptation and DRR studies but they are GI areas under urbanization pressure. In urban areas, GI also include all elements from street afforestation to large parks, pocket parks to cemeteries, small streams, lakes and sports facilities. Today, green walls and green roofs have been added to this list as modern GI elements (EEA 2014; Haase 2017:111).

Figure 3. Potential components of GI (EC 2021)

GI has the functions of reducing the heat island effect in cities, providing rainwater drainage in order to prevent floods, providing recreational opportunities, protecting physical and psychological health and ensuring pollution control, creating new employment areas and supporting economic development as well as increasing the quality of urban life. In a study conducted in the United States, it has been calculated that street afforestation is three to six times more efficient in rainwater management than drainage systems per US $ 1000 invested. In the same study, the cost of urban GI was US $ 8 million and US $ 250 million was saved in gray infrastructure costs (IDB 2020: 7; Diepetri and McPherson 2017: 100). In the context of NbS development and adaptation to climate change, it is important to apply GI as hybrid systems (Figure 4) with gray, namely hard or engineering techniques and blue infrastructures. Because they complement each other (Diepetri and McPherson 2017: 94-96; Grimm 2016).

Figure 4. Hybrid systems, green, grey and blue infrastructure are considered together (Martin et al. 2021: 3)

The proportion of built and impermeable surfaces in cities is generally higher than green and soil areas, which increases the vulnerability of cities to the effects of climate change and disrupts the water cycle. Underground and surface water resources cannot be fed sufficiently (Figure 4). Rainwater, which flows rapidly on the surface, gets polluted in the urban area and transfers this pollution to water reservoirs. In addition, high volumes of rapidly moving water damage the riverbeds that it reaches with pressure, create erosion and cause habitat loss. The increase in sediment also causes the clogging of drainage channels. Floods in urban areas are also responsible for significant loss of life and property (Konyalı and Çay 2020: 668; CA-NEMO 2021).

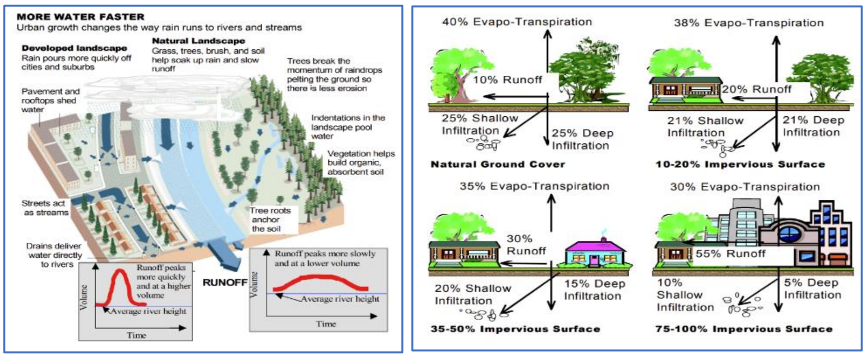
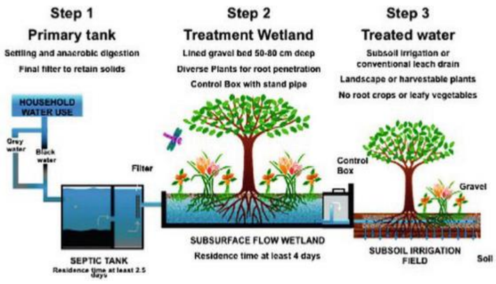


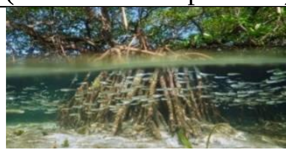
Figure 4. Changes in water cycle by urbanization (CA-NEMO 2021: 2)

Today, 'sponge city' approach is adopted for effective urban water management. Sponge cities include an infrastructure system where large amounts of water are drained and slowly returned to nature or used where necessary. In this context, permeable surface coating materials are used in cities, green roofs, rainwater tanks and rain gardens are designed and GI system is developed to allow water cycle (Chan 2018; Fuldauer 2019). GI solutions in the context of ensuring water management in cities, which are the subject of this study, are shown in Table 1.

Table 1. GI solutions supporting the water cycle in cities (Flint 2019; Fuldauer 2019; Furlong et al.2018; Hepcan 2019: 20; IDB 2020; Khan 2018; Konyalı and Çay 2020: 673; MoEU 2018b; Urban GreenUp 2021a,b)

GI Solution	Content	Display
Planted swales and retention ponds	Swales are shallow, flat bottom, planted open channel systems and are often used to reduce the flow rate of water. Biodiversity, aesthetics and landscape values are quite high. It can also be used to drain roads and parking lots from rainwater in cities. Retention ponds are NbS that provide additional storage capacity that prevents runoff during rains, and an existing natural pit can also be used for this purpose.	 **Figure 5.** Swales (sustainabletechnologies.ca 2021)

Floodable parks	These parks are designed to allow stormwater to be stored in a risk-free manner and to allow controlled release and/or drainage after the flood is over.	 **Figure 6.** Floodable Parks (Furlong et al. 2018)
Green filter areas	The fall of rainwater or irrigation water from the surface along the soil profile with the effect of gravity is called infiltration. It is used to separate major pollutants such as industrial facilities or roads and walk axles and to create barriers between them. In this context, pocket parks, street trees, green walls are considered and they are important not only in the context of water management but also in reducing air pollution.	 **Figure 7.** Green filtration (IDB 2020)
Natural waste water treatment	It refers to natural wastewater treatment systems created with the support of water plants within the scope of elements such as wetlands and ponds.	 **Figure 8.** Natural water treatment (Khan 2018)
Hard drainage sidewalks / Porous floors	It is a type of flooring produced from hard material in small pieces or completely porous material that gives water directly to the soil.	 **Figure 9.** Porous floors (Aouf 2016)
Green pavements	Green pavements are plantable GI that provide drainage of water as low-cost solutions and provide the opportunity to use in different ways in the context of urban design.	 **Figure 10.** Green pavements (Urban GreenUp 2021c)
Cool pavements	Cool pavement are pavements that can be disassembled and reflect sunlight. In addition to reducing the urban heat island effect, they stay cool thanks to their porous structure and the water and air they contain.	 **Figure 11.** Cool pavement (Aouf 2016).

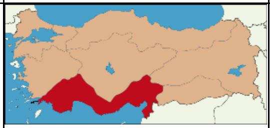
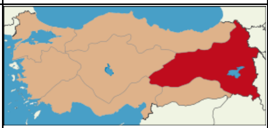
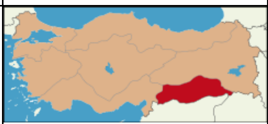
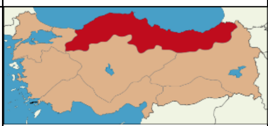
Green roads for cyclists and pedestrians	They are permeable GI systems that allow the flow of water and are made suitable for use on the axles used by cyclists and pedestrians.	 **Figure 12.** Cycle green paths (Urban GreenUp, 2021d)
Green buildings, green roofs and rain water harvesting	They are the GI elements that are formed especially on the roofs and hold a part of the precipitation water thanks to the vegetation, soil, drainage and waterproof coating components. In addition, systems for efficient use of water are established in green buildings.	 **Figure 13.** Green roofs (Vijayaraghavan, 2016)
Renaturalization of the water channels	These are GI's, where concrete wall systems that disrupt the natural outflow of water are removed in line with flood prevention and are instead installed with modular and plant-containing systems that enable the natural flow of river beds.	 **Figure 14.** Channel renaturalization (Urban GreenUp 2021d)
Protection of coastal ecosystems	In the prevention of flood risks in coastal cities, it is necessary to protect the mangroves, wetlands, floodplains and swamps, which are important parts of coastal ecosystems, to create buffer zones and to protect water quality.	 **Figure 15.** Mangroves (Flint 2019)
Urban forests	These forests provide effective drainage with their water retention capacity, especially in urban floods, and significantly support gray infrastructures. In this respect, it is very important to protect and develop forest areas and wooded areas in cities.	 **Figure 16.** Urban forests (Hilten 2018)
Rain gardens	These gardens are considered as shallow basins that are built to collect, store and filter and purify the flowing water and contain porous soil structure and natural vegetation.	 **Figure 17.** Rain Garden (MoEU, 2018b)

4 THE GEOGRAPHICAL REGIONS, CITIES IN TURKEY AND GI SOLUTIONS

According to IPCC reports, the Mediterranean macroclimate region, including Turkey, is one of the most vulnerable regions in terms of climate change impacts (IPCC 2021). On the other hand, water consumption in Turkey increases with population growth and urban activities (Karlı and Artar 2021: 145). Annual usable water per capita amounted to 1,652 m^3 in 2000, 1,544 m^3 in 2009 and 1,346 m^3 in 2020. Turkey is among the countries experiencing water stress, when its per capita water potential is considered. It reveals the importance of water management and the necessity of a basin-based approach in Turkey (Birpınar and Tuğaç 2018; SHW 2021).

Considering that each geographical region in Turkey will face different problems in the context of climate change, Regional Climate Change Action Plans (RCCAP) prepared by MoEU for seven geographical regions and announced in February 2021. In the RCCAP, in parallel with the meteorological observations above, it is seen that the problems related to water management (Table 2) come to the fore due to the problems of excessive rainfall and drought and require DRR measures (MoEU 2021a).

Table 2. Findings in the context of water and disaster management in Turkey's geographical regions (MoEU 2021a)

Region	Location	Findings in the Context of Water and Disaster Management
The Mediterranean Region		Annual rainfall in the region tends to decrease. However, there are records of sudden heavy rains. Accordingly, floods and overflows are important problems, and the issue of drainage comes to the fore. Rainwater harvesting should be expanded in the region in the context of GI, swales and floodable green areas should be developed to protect wetlands from rising sea water levels.
The Eastern Anatolia Region		Changes in the region's rainfall patterns reveal the risk of flooding due to sudden record levels of rainfall, while long periods without rainfall present a drought problem this time. In addition, extreme snowfalls and variable weather conditions in the region require the use of permeable and climate-resistant flooring in the context of GI.
The Aegean Region		Annual average precipitation in the region tends to decrease and water stress is expected. There is an increase in the number of consecutive dry days. Sudden and heavy rainfalls are a major threat. GI solutions should be developed to protect the groundwater resources from the increasing sea level on the shoreline and to address floods caused by sudden rainfalls.
The South-eastern Anatolia Region		Temperatures in the region are very high and trigger vigorous evaporation. It is the region with the highest risk of drought and desertification. There are areas of severe erosion. The number of rainy days decreases significantly. However, sudden heavy rains that suppress suddenly cause floods. The prominent GI in the region is rainwater harvesting.
The Central Anatolia Region		It is the geographic region with the least rainfall. It is expected that the amount of rainfall will decrease and the number of consecutive dry days will increase. There is an important sinkhole formation due to underground water intakes. Sudden heavy rainfalls can be seen. Protection of wetlands, inventory of underground and surface water resources and rain harvesting are important.
The Black Sea Region		The region receives the most precipitation in Turkey and there is a serious increase in the number of days with heavy rain. Floods, overflows and landslides are experienced in the region. It is important to develop effective basin management and GI solutions such as swales, permeable floors and green roofs. Streambeds should not be narrowed by walls in the Region.
The Marmara Region		In the Region, an increase in temperatures and irregularities in precipitation is predicted. The region is vulnerable to floods and storms with increasing severity and is the region where the most flood disasters are seen after the Black Sea Region. GIs for floods and sea level rise should be designed and hybrid solutions should be considered in water supply and wastewater management.

The different local characteristics of the geographical regions in Turkey bring along solutions that differ in the context of NbS and GI. In this respect, Regional and Urban NbS Catalogs are developed by MoEU together with UNDP under Climate Promise Programme (UNDP 2020). In addition, Enhancing Adaptation Action in Turkey Project is carried out with EU-IPA funds and impact and risk analyzes are made based on geographical regions. The grant component of the project has been opened to local governments and different stakeholders on climate adaptation, including water management (EU et al. 2021; MoEU 2021b). Another project that can be addressed in the context of climate change and water management and made at the regional level is the Climate Change Impact on Water Resources Project completed in 2016 by the repealed Ministry of Forestry and Water Affairs. With the project, 25 hydrological basins in Turkey were considered and drinking and utility water in cities, rainwater harvesting, water pricing as well as climate change adaptation actions in the main sectors of agriculture and industry were determined (MoFWA 2016).

In the upcoming period in Turkey, management and storage of water will become even more important, especially in urban areas. In this context, by MoEU; (1) Regulation on Stormwater Collection, Storage and Discharge Systems was published in 2017, (2) Rain Gardens Preparation Guide was published in 2018 (MoEU, 2018b), (3) In 2019, the 2020-2023 National Smart Cities Strategy and Action Plan was announced (MoEU 2019), (4) With the amendment of the Regulation dated January 23, 2021, rainwater collection system has become mandatory in buildings to be built on parcels over 2000 m². For the buildings to be built in areas smaller than 2000 m², the decision is left to the local administrations, (5) Green areas are rapidly increased with public gardens, ecological corridors, and afforestation works.

In addition to these studies in Turkey, there are also GI-focused projects directly carried out by local administrations. The following headings include examples of the said projects.

4.1 Gaziantep Metropolitan Municipality/Alleben Stream Water Project

The green corridor project was initiated by the Metropolitan Municipality in 2019 in order to open the narrowed bed of the Alleben Stream in Gaziantep and turn it into a living element of the city and it was aimed to contribute GI. By allowing the natural flow of the Alleben Stream in an area of 350 meters long and approximately 200 thousand square meters in line with flood and hydrological analyzes, it is aimed to purify the stream bed from pollution, protect existing trees and add new ones, create a green corridor (Figure 18), and give the city an important recreation area with permeable surface coatings (Gaziantep Metropolitan Municipality 2019).

Figure 18. Gaziantep / Alleben Stream Project and Green Belt (Gaziantep Metropolitan Municipality 2019)

4.2 Eskişehir Metropolitan Municipality/Porsuk Creek Project

In Eskişehir, Porsuk Creek divides the city center into two parts and forms a green corridor. Along Porsuk Creek, projects have been developed to design a green axis connecting the city center with a large urban recreation area City Park with a green area of 150.000 m^2 on an area of 257.000 m^2. While Porsuk could be used for drinking and irrigation water until 1980, it was polluted due to domestic and industrial wastes. In this direction, the Porsuk Creek Coastal Transformation Project has been developed along the 10 km coastline in order to improve the parts of the creek in the city, make it resistant to disasters such as floods, and prevent leakage from irrigation channels. With the project, the city has gained both an important green and cultural infrastructure and an important recreation axis (Figure 19). The project made it to the finals in the World Urbanism Competition organized by WRI in 2018. (Arslantaş et al. 2020: 8; kentselstrateji.com 2021; WRI 2019).

Figure 19. Eskişehir Porsuk Creek Coastal Transformation Project (kentselstrateji.com 2021; Eskişehir Metropolitan Municipality 2018)

4.3 İzmir Metropolitan Municipality/GI Strategy

The preparation of the GI Strategy started in 2017 by the Izmir Metropolitan Municipality. By Strategy, development of hybrid blue-green-gray infrastructure solutions, establishment of coast-city relationship, and in the context of Horizon 2020-Urban GreenUp Project, at which İzmir selected as the pioneer city together with Liverpool and Valladolid, making GI applications such as, vegetated swales and retention pools, permeable pavements and pocket parks (Figure 20) were aimed. The prepared GI Strategy has been handled in the context of the gulf, basin and sub-basins (Izmir Metropolitan Municipality 2021a; Urban GreenUp 2021f, g). In the GI Strategy, in line with water management, issues such as (1) water potential map, urban streams master plan, preparation of groundwater resources map, (2) repair of water beds, (3) protection of rain and surface waters in relation to the groundwater system came to the fore (İzmir Metropolitan Municipality 2021b).

Figure 20. İzmir GI Solutions (İzmir Metropolitan Municipality 2021b)

The proliferation of examples such as the above that make water management possible in urban areas in Turkey and the handling of GI as NbS together with gray infrastructures in this context are important strategies that stand out even more in a process where the negative effects of climate change are predicted to continue increasingly.

5 RESULTS AND DISCUSSION

Evaluations made on the basis on the climate related problems both in geographical regions and urban level in the study reveal that water management in Turkey will become even more important in the coming years. In this context, the handling of GI solutions, especially in urban areas, will come to the fore more and more in order to achieve success in combating climate change in Turkey.

Given that urbanization increases impermeable surfaces, fossil fuel use, deforestation, and ecosystem degradation, these factors also pose risks to water resources. Underground water sources cannot be adequately fed, and the water cycle cannot be adequately completed. In the context of climate change adaptation and DRR, hybrid approaches in which GI is tackled with blue and grey infrastructures are required to be developed as part of the NbS. Developing a basin-based approach in ensuring efficiency in water management often necessitates cooperation between different administrative scales. For developing no regret GI solutions, it is essential to base on detailed analysis studies beforehand. Adequate investment in NbS and GI will help reduce the financial consequences of climate change and will contribute to the creation of new jobs, increase the resilience of livelihoods, and reduce people's poverty. Another aspect affecting the success of GI practices is the development of governance and cooperation at all levels.

As can be seen from the study, there are GI practices in cities in Turkey, but it seems that they should be expanded. In particular, it is necessary to evaluate in more detail the calculations of the returns of these studies and the expected gains of the outputs of GI projects carried out in urban areas in the context of water management. In the context of adaptation to climate change, the short, medium and long-term results of these GI solutions, alone or together with hybrid solutions, need to be addressed further. In addition, it is essential to address the issue of financing needs, which is an important problem area for local governments in the dissemination of GI solutions. In this direction, this study should be reconsidered in the coming years in order to see whether the GI solutions that are expected to become widespread in new urban areas in Turkey give the expected effect.

6 CONCLUSIONS

GI solutions support ecosystem services, biodiversity and access to fresh water, improved livelihoods, healthy nutrition and food security and urban resilience, as well as they also contribute to the achievement of the objectives of the UN Sustainable Development Goals (SDGs), the Paris Agreement, the UN Habitat New Urban Agenda and the UN Sendai Framework for DRR. Considering the efforts carried out by local administrations in Turkey in the context of combating climate change, limiting greenhouse gas emissions and adaptation, it is seen that the actions are concentrated on solid waste and waste-water treatment, transportation, buildings and settlements, energy efficiency and renewable energy practices, increasing carbon retention and drainage capacity through land use planning and green-gray infrastructures. Implementation of climate change adaptation and GI practices by those who know the specifications of the local area undoubtedly provides much more effective and practical solutions. GI practices, which are one of the important agenda items of the G20, the OECD and the UN, are also one of the most important issues for Turkey in the context of combating climate change at the local level. However, it is important to provide the national and international technical, financial and capacity building supports to local administrations in line with the implementation of GI. In today's conditions, reaching climate change resilient cities depends on sustainable management of natural resources directly affected by global warming, the determination of GI strategies and appropriate adaptation solutions considering local characteristics.

REFERENCES

Albayrak, İ. (2017). *Ekosistem Servislerine Dayalı Mekansal Planlama Yaklaşımı: Ömerli Havzası Örneği [Spatial Planning Approach Based on Ecosystem Services: The Case of Ömerli Basin].* Retrieved from OBANET website: http://obanettr.org/default.asp?baslik=ekosistem_servislerine_dayali_mekansal_planlama_yaklasimi_omerli_havzasi_ornegi&page=2&a=173&b=1&c=173. Accessed 15 April 2021 [in Turkish]

Alhassan, İ., Bartsch, K. and Sharifi, E. (2020). Green infrastructure needs green governance: Lessons from Australia's largest integrated stormwater management project, the River Torrens Linear Park, *Journal of Cleaner Production,* **261**(4).

Aouf, R. S. (2016). *The Climate Tile by Tredje Natur Aims to Stop Cities Flooding*. Retrieved from De Zeen website: https://www.dezeen.com/2016/12/29/climate-tile-tredje-natur-stop-cities-flooding-urban-design-climate-change/?hcb=1. Accessed 10 April 2021

Arslantaş, F., Sanalan, K.C. ve Çil, A. (2020). *Şehirlerde Yeşil Altyapı ve Doğa Tabanlı Çözümler İyi Uygulama Örnekleri [Green Infrastructure and Nature Based Solutions in Cities Good Practice Examples]*, DKM, Ankara 118p. [in Turkish]

Birpinar, M. E., Tuğaç, Ç. (2018). Impacts of climate change on water resources of Turkey, pp. 145-152. In Gastescu, P., Bretcan, P. (Eds.) *Conference Proceedings Water resources and wetlands, 5-9 September 2018, Tulcea Romania,* 312p.

CA NEMO (2021*). How Urbanization Affects the Water Cycle.* Retrieved from NEMO California Partnership website: https://www.waterboards.ca.gov/rwqcb2/water_issues/programs/stormwater/ISDC/Nemo_Fact_Sheet.pdf Accessed 10 April 2021

Canals, V. P. and Lázaro M. L. (2019). *Towards Nature-based Solutions in the Mediterranean*, IUCN Centre for Mediterranean Cooperation, Spain, 58p.

Carter, J. G., Handley, J., Butlin, T. and Gill, S. (2018). Adapting cities to climate change – exploring the flood risk management role of green infrastructure landscapes, *Journal of Environmental Planning and Management,* **9**, 1535-52.

Chan, F. K. S., Griffiths, J. A., Higgitt, D., Xu, S., Zhu, F., Tang, Y., …Thorne, C. R. (2018). "Sponge City" in China—A breakthrough of planning and flood risk management in the urban context, *Land Use Policy,* **76**(2018), 772-778.

De la Sotaa, C., Ruffato-Ferreira, V. J., Ruiz-Garcia, L. and Alvarez, S. (2019). Urban green infrastructure as a strategy of climate change mitigation. A case study in northern Spain, *Urban Forestry and Urban Greening,* **40,** 145-51.

Diepetri Y. and McPherson, T. (2017). Integrating The Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction. In N. Kubish, H. Korn, J. Stadler ve A. Bonn (Eds.), *Nature-Based Solutions to Climate Change in Urban Areas* (pp. 91-109). Cham: Springer.

Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., … Le Roux, X. (2015). Nature-based solutions: new ınfluence for environmental management and research in Europe, *GAIA-Ecological Perspectives for Science and Society*, **24**(4), 243–248.
Eskişehir Metropolitan Municipality (2018). *Eskişehir Dünya Kentleri İle Zirve İçin Yarışıyor [Eskişehir Competes with Cities of The World for Peak]*. Retrieved from Eskişehir Metropolitan Municipality website: https://www.eskisehir.bel.tr/icerik_dvm.php?icerik_id=4394&cat_icerik=1&menu_id=24. Accessed 15 April 2021 [in Turkish]
European Commission (2013). *Green Infrastructure (GI)-Enhancing Europe's Natural Capital-COM (2013) 249 final*, EC.
European Commission (2021). *The forms and Functions of Green Infrastructure*. Retrieved from European Commission website: https://ec.europa.eu/environment/nature/ecosystems/benefits/index_en.htm. Accessed 15 April 2021
European Environment Agency (2014). *Spatial Analysis of Green Infrastructure in Europe,* Publication Office of the European Union, Luxembourg, 56p.
European Union, MoEU and UNDP (2021). *Enhancing Climate Adaptation Action in Turkey Project.* Retrieved from EU, MoEU and UNDP webpage: https://iklimeuyum.org/en/home/. Accessed 2 May 2021
Everett, G., Lawson, E. and Lamond, J. (2015). Chapter 3: Green Infrastructure and Urban Water Management. In D. Sinnett, N. Smith and S. Burgess (Eds.), *Handbook on Green Infrastructure Planning, Design and Implementation* (pp. 50-66). Elgar Online Publishing.
Flint, R. (2019). *Celebrating Mangroves – The Super Ecosystem of the Tropics.* Retrieved from IUCN website: https://www.iucn.org/news/marine-and-polar/201907/celebrating-mangroves-super-ecosystem-tropics. Accessed 12 April 2021
Fuldauer, E. (2019). *China's Sponge Cities Are Turning Concrete Green to Combat Flooding.* Retrieved from Tomorrow City website: https://www.smartcitylab.com/blog/urban-environment/chinas-sponge-cities-are-turning-concrete-green-to-combat-flooding/. Accessed 12 April 2021
Furlong, C., Uittenbroek, C., Gulsrud, N., Termes-Rife, M., Dodson, J. and Skinner, R. (2018). *Understanding the Role of the Water Sector in Urban Liveability and Greening Interventions Case Studies on Barcelona, Rotterdam, Amsterdam, Copenhagen and Melbourne,* RMIT University Centre for Urban Research, Melbourne, Australia, 44p.
Gaziantep Metropolitan Municipality (2019). *Şahin Müjdeyi Verdi; Alleben Deresi Özüne Kavuşacak [Şahin Give the Good News: Allaben Stream Will Meet Its Essence].* Retrieved from Gaziantep Metropolitan Municipality website: https://www.gaziantep.bel.tr/tr/haberler/sahin-mujdeyi-verdi-alleben-deresi-ozune-kavusacak. Accessed 15 April 2021 [in Turkish]
Grimm, N., Cook, E. M., Hale, R. L. and Iwaniec, D. M. (2016). A Broader Framing of Ecosystem Services in Cities: Benefits and Challenges of Built, Natural, or Hybrid System Function. In K. C. Seto, W. Solecki, C. A. Griffith (Eds.), *The Routledge Handbook of Urbanization and Global Environmental Change* (pp. 203-212). New York: Routledge/Taylor & Francis Group.
Haase, D. (2017). Urban Wetlands and Riparian Forests as a Nature-Based Solution for Climate Change Adaptation in Cities and Their Surroundings. In N. Kubish, H. Korn, J. Stadler ve A. Bonn (Eds.), *Nature-Based Solutions to Climate Change in Urban Areas* (pp. 111-121). Cham: Springer.
Hepcan, Ç. C. (2019). *Green Infrastructure Solutions as Part of Climate Change Adaptation in Cities,*.MoEU, Ankara, 40p.
Inter-American Development Bank (2018). *Increasing Infrastructure Resilience with Nature-based Solutions (NbS).* IDB, Washington, 52p.
IPCC (2018). *Special Report: Global Warming of 1.5 ^{O}C.* IPCC, 616p.
IPCC (2021). *Reports.* Retrieved from IPCC website: https://www.ipcc.ch/reports/. Accessed 10 May 2021
İzmir Metropolitan Municipality (2021a). *Yeşil Altyapı Nedir? [What is Green Infrastructure?].* Retrieved from İzmir Metropolitan Municipality website: http://izmirdoga.izmir.bel.tr/tr/yesilAltyapiHakkinda/1/8. 15 April 2021 [in Turkish]
İzmir Metropolitan Municipality (2021b). *Su Alanları [Water Areas].* Retrieved from İzmir Metropolitan Municipality website: http://izmirdoga.izmir.bel.tr/tr/suAlanlari/4/14. 15 April 2021 [in Turkish]
Karlı, Ö. R. G. and Artar, M. (2021). Kentsel su yönetiminde araç olarak su ayak izi ve mavi-yeşil altyapı [Water footprint and blue-green infrastructure as a tool in urban water management], *Ege Univ. Ziraat Fak. Derg.*, **58**(1), 145-162 [in Turkish]
Kentsel Strateji (2021). *Eskişehir Kent Merkezi Kentsel Dönüşüm Projesi [Eskisehir City Center Urban Transformation Project].* Retrieved from Kentsel Strateji website: https://www.kentselstrateji.com/wp-content/uploads/T-14_EskisehirPorsuk.pdf. Accessed 8 April 2021 [in Turkish]

Khan, N. (2018). *Natural Ecological Remediation and Reuse of Sewage Water in Agriculture and Its Effects on Plant Health*. Retrieved from Intechopen website: https://www.intechopen.com/books/sewage/natural-ecological-remediation-and-reuse-of-sewage-water-in-agriculture-and-its-effects-on-plant-hea. Accessed 8 April 2021

Konyalı, D. C. and Çay, R. D. (2020). Sürdürülebilir yağmursuyu yönetimi kapsamında yeşil altyapı sisteminin değerlendirilmesi: Fırınlarsırtı TOKİ Konutları (Edirne) yerleşimi için bir öneri, *Kent Akademisi,* **13**(4), 668-687.

Liu, L. and Jensen, B. (2018). Green infrastructure for sustainable urban water management: Practices of five forerunner cities, *Cities*, **74,** 126-133.

Martin, J. G. C., Scolobig, A., Linnerooth-Bayer, J., Liu, W. and Balsiger, J. (2021). Catalyzing innovation: governance enablers of nature-based solutions, *Sustainability*, **13**(4), 1-24.

MoEU (2018a). *Turkey's Seventh National Comminicaiton*. MoEU, Ankara, 261p.

MoEU (2018b). *Yağmur Bahçesi Uygulama Kılavuzu [Rain Garden Application Guide].* MoEU, Ankara, 54p. [in Turkish]

MoEU (2019). *2020-2023 Ulusal Akıllı Şehirler Stratejisi ve Eylem Planı [2020-2023 National Smart Cities Strategy and Action Plan]*. MoEU, Ankara, 658p. [in Turkish]

MoEU (2021a). *Regional Climate Change Action Plans*, MoEU, Ankara, 240p.

MoEU (2021b). *Inauguration of the Enhancing Adaptation Action in Turkey Project.* Retrieved from MoEU-IPA website: https://ipa.gov.tr/HaberDetay/Turkiye%E2%80%99de-Iklim-Uyum-Eyleminin-Guclendirilmesi-Projesinin-Acilisi-Gerceklestirildi_2269. Accessed 12 April 2021

MoFWA (2016). *İklim Değişikliğinin Su Kaynaklarına Etkisi Projesi Proje Nihai Raporu Yönetici Özeti [Climate Change Impact on Water Resources Project Final Report-Executive Summary]*, MoFWA, Ankara, 389p. [in Turkish]

OECD (2020). *Nature-based Solutions for Adapting to Water-Related Climate Risks, OECD Environment Policy Papers, No. 21*. OECD Publishing, Paris, 30p.

O'Farrell, P. J. and Anderson, P. M. L. (2010). Sustainable multifunctional landscapes: a review to implementation, *Current Opinion in Environmental Sustainability,* **2,** 59-65.

Pitman, S. D., Daniels, C. B. and Ely, M. E. (2015). Green infrastructure as life support: urban nature and climate change, *Transactions of the Royal Society of South Australia,* **139**(1), 97-112.

Rowe, A. A., Rector, P. and Bakacs, M. (2016). Survey results of green infrastructure implementation in New Jersey, *Journal of Sustainable Water in the Built Environment*, **2**(3).

Rusche, K., Reimer, M. ve Stichmann, R. (2019). Mapping and assessing green infrastructure connectivity in European city regions, *Sustainability,* **11**(1819), 1-12.

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A. and Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges, *Philosophical Transactions of the Royal Society B,* **375**(1794), 1-12.

SHW (2021). *Toprak-Su Kaynakları [Soil-Water Resources].* Retrieved from SHW website: https://www.dsi.gov.tr/Sayfa/Detay/754#. Accessed 12 April 2021 [in Turkish]

Stefanakis, A. I. (2019). The role of constructed wetlands as green infrastructure for sustainable urban water management, *Sustainability*, **11**(24), 1-19.

Sustainable Technologies (2021). *Swales.* Retrieved from Sustainable Technologies Evaluation Program website: https://wiki.sustainabletechnologies.ca/wiki/Swales. Accessed 12 May 2021

UNDP (2020). UNDP's Climate Promise. Retrieved from UNDP website: https://www.undp.org/content/dam/climatepromise/documents/Climate%20Promise-COVID-Brochure-2pager.pdf. Accessed 12 February 2021

UNFCCC. (2020). *Increasing Resilience Through Natural Solutions*. Retrieved from UNFCCC website: https://unfccc.int/news/increasing-resilience-through-natural-solutions. Accessed 21 January 2021

UNFCCC (2021). *Nationally Determined Contributions Under the Paris Agreement Synthesis Report by the Secretariat,* FCCC/PA/CMA/2021/2.

Urban GreenUp (2021a). *Deliverables Overview*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/insights/deliverables/d1-1---nbs-catalogue.kl. Accessed 21 January 2021

Urban GreenUp (2021b). *Solutions*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/solutions/. Accessed 21 January 2021

Urban GreenUp (2021c). *Green pavements – Green Parking Pavements*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/solutions/green-pavements--green-parking-pavements.kl. Accessed 21 January 2021. Accessed 21 January 2021

Urban GreenUp (2021d). *Cycle-Pedestrian Green Paths*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/solutions/cycle-pedestrian-green-paths.kl. Accessed 21 January 2021

Urban GreenUp (2021e). *Channel Re-Naturalization*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/solutions/channel-re-naturalization.kl. Accessed 21 January 2021

Urban GreenUp (2021f). *Front Runners: İzmir*. Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/cities/front-runners/izmir.kl. Accessed 21 January 2021

Urban GreenUp (2021g). *Expected Impacts.* Retrieved from Urban GreenUp website: https://www.urbangreenup.eu/cities/front-runners/izmir/expected-results.kl. Accessed 21 January 2021

Van Hilten, L. G. (2018). *Urban Forests Make Megacities More Environmentally Sustainable.* Retrieved from Elsevier website: https://www.elsevier.com/connect/atlas/Urban-forests-make-megacities-more-environmentally-sustainable. Accessed 12 April 2021

Vijayaraghavan, K. (2016). Green roofs: a critical review on the role of components, benefits, limitations and trends, *Renew Sustain Energy Rev*., **57**, 740–52.

WRI (2019). *Eskişehir Urban Development Project.* Retrieved from WRI website: https://prizeforcities.org/project/eskisehir-urban-development-project. Accessed 10 April 2021

Zuniga-Teran, A. A., Staddon, C, De Vito, L., Gerlak, A. K., Ward, S., Schoeman, Y., Hart, A., Booth, G. (2020). Challenges of mainstreaming green infrastructure in built environment professions, *Journal of Environmental Planning and Management*, **63**(4), 710-35.