

DEVELOPING URBAN DESIGN INPUTS TO ENHANCE THE
FUNCTIONALITY OF THE GREEN AREAS IN CITIES FROM ECOSYSTEM
SERVICES PERSPECTIVE: THE CASE OF ÇANKAYA DISTRICT IN
ANKARA

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FETHİYE ARSLANTAŞ

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ECOSYSTEM SERVICES PERSPECTIVE: THE CASE OF ÇANKAYA
DISTRICT IN ANKARA**

submitted by **FETHİYE ARSLANTAŞ** in partial fulfillment of the requirements
for the degree of **Master of Science in Urban Design in City in Regional Planning,**
Middle East Technical University by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Serap Kayasü
Head of the Department, **City and Regional Planning**

Prof. Dr. Müge Akkar Ercan
Supervisor, **City and Regional Planning, METU**

Dr. Uğur Zeydanlı
Co-Supervisor, **City and Regional Planning, METU**

Examining Committee Members:

Prof. Dr. Can Bilgin
Department of Biology, METU

Prof. Dr. Müge Akkar Ercan
Supervisor, **City and Regional Planning, METU**

Prof. Dr. Nilgöl Karadeniz
Landscape Architecture, Ankara University

Date: 10.09.2021



I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Last name : Arslantaş, Fethiye

Signature :

ABSTRACT

DEVELOPING URBAN DESIGN INPUTS TO ENHANCE THE FUNCTIONALITY OF THE GREEN AREAS IN CITIES FROM ECOSYSTEM SERVICES PERSPECTIVE: THE CASE OF ÇANKAYA DISTRICT IN ANKARA

Arslantaş, Fethiye

Master of Science, Urban Design in City and Regional Planning

Supervisor: Prof. Dr. Müge Akkar Ercan

Co-Supervisor: Dr. Uğur Zeydanlı

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The quality of urban environments and the health of citizens have an essential connection with urban green areas through ecosystem services (ES). However, the rapid urbanization in cities has threatened ES provision and causes a series of social and environmental challenges. ES concept is a tool that represents a comprehensive understanding of these challenges and that promotes developing planning strategies towards more liveable, sustainable, and resilient cities. To that end, this thesis aims to investigate planning and design inputs for urban green areas to maximize the current capacity of needed ES to improve human health and wellbeing. It uses and examines the district of Çankaya in Ankara as the case study. A literature review on ES helped to define primary beneficiaries of related ES. This research examines existing urban green sites in the Çankaya district, their spatial distribution, and mapping their ES quality using geographical information systems software (ArcGIS). Spatial analysis results were handled with the analysis tool which was developed within the scope of the thesis. Based on the analysis tool results, this

research proposes design inputs within the ES perspective to improve the functionality of selected urban parks in the Çankaya district of Ankara.

Keywords: Ecosystem Services (ES), Urban Ecosystem Services (UES), Urban Nature, Urban Green Space, Urban design, Çankaya, Ankara



ÖZ

EKOSİSTEM HİZMETLERİ PERSPEKTİFİNDEN KENTLERDE YEŞİL ALANLARIN İŞLEVSELLİĞİNİ ARTTIRMAK İÇİN KENTSEL TASARIM GİRDİLERİ GELİŞTİRİLMESİ: ANKARA, ÇANKAYA İLÇESİ ÖRNEĞİ

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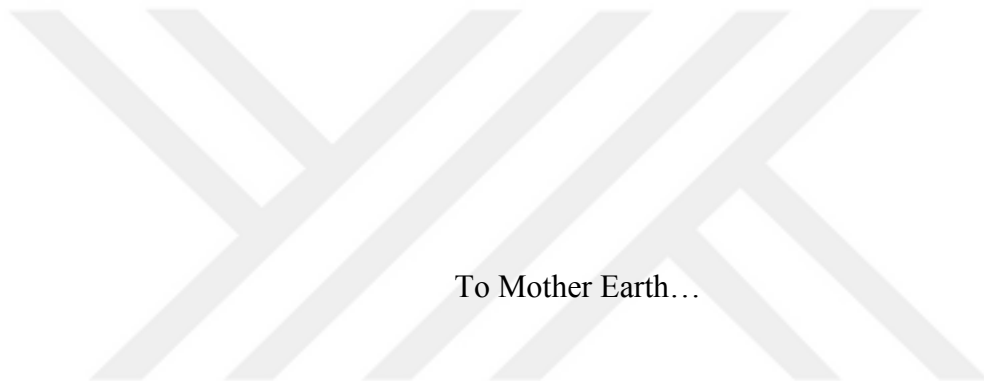
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Kentsel çevrenin kalitesi ve kentlilerin sağlığı, yeşil alanların sunduğu ekosistem hizmetleriyle önemli bir bağlantıya sahiptir. Bununla birlikte, hızlı kentleşme, ekosistem hizmetinin arzını tehdit etmekte ve bir dizi sosyal ve çevresel sorunlara yol açmaktadır. Ekosistem hizmeti konsepti, bu zorlukların kapsamlı bir şekilde anlaşılmasını temsil eden ve daha yaşanabilir, sürdürülebilir ve dayanıklı şehirlere yönelik planlama stratejileri geliştirmeyi destekleyen bir araçtır. Bu amaçla, bu tez, insan sağlığını ve refahını iyileştirmek için ihtiyaç duyulan EH'nin mevcut kapasitesini en üst düzeye çıkarmak için kentsel yeşil alanlara yönelik planlama ve tasarım girdilerini araştırmayı amaçlamaktadır. Bu araştırma, çalışma alanı olarak Ankara ili Çankaya ilçesini kullanmakta ve incelemektedir. EH ile ilgili bir literatür taraması, ilgili EH'nin birincil yararlanıcılarının tanımlanmasına yardımcı olmuştur. Bu araştırma, Çankaya ilçesindeki mevcut kentsel yeşil alanları, mekansal dağılımlarını ve EH kalitelerinin coğrafi bilgi sistemlerini (CBS) kullanarak haritalandırmasını incelemektedir. Mekansal analiz sonuçları, tez kapsamında geliştirilen analiz aracıyla ele alınmıştır. Bu araştırma, analiz aracının sonuçlarına

baęlı olarak Ankara'nın ankaya ilçesinde seilen kentsel parklarda EH perspektifinde işlevsellięini geliřtirmeye yönelik tasarım girdilerini önermektedir.

Anahtar Kelimeler: Ekosistem Hizmetleri, Kentsel Ekosistem Hizmeti, Kent Doğası, Kentsel Yeřil Alan, ankaya, Ankara





To Mother Earth...

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CLC	CORINE Land Cover
CN	Curve Number
CORINE	Coordination of Information on the Environment
DEM	Digital Elevation Model
EEA	European Environment Agency
EPA	U.S. Environmental Protection Agency
ES	Ecosystem Services
EU	European Union
EVI	Enhanced Vegetation Index
GHG	Greenhouse gases
GI	Green Infrastructure
GIS	Geographical Information System
ICT	Information and Communications Technology
IPBES	Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MA	The Millennium Ecosystem Assessment
METU	Middle East Technical University

NASA	The National Aeronautics and Space Administration
NDBI	Normalized Difference Built-up Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
PM	Particulate Matter
SAVI	Soil Adjusted Vegetation Index
SBA	Service Benefitted Areas
SPU	Service Provider Units
TEEB	The Economics of Ecosystems and Biodiversity
UES	Urban Ecosystem Services
UGI	Urban Green Infrastructure
UNEP	United Nations Environment Programme
URBES	Urban Biodiversity and Ecosystem Services
UTR	Urban Temperature Regulation
VOC	Volatile organic
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Problem Context

The Millennium Ecosystem Assessment (MA) (2003) defined Ecosystem Services (ES) as "the benefits people derive from ecosystems". MA put the notion on the global agenda and established a critical link between the importance of biodiversity conservation and the challenges in meeting the United Nations Millennium Development Goals (TEEB, 2010). The term "biodiversity" refers to a wide range of life on Earth at all levels, including genes and ecosystems, the evolution of life-sustaining ecological and cultural processes (AMNH, n.d). In other words, ES are the goods and services that biodiversity provides (UNEP, 2008).

ES are the vital services that people need to sustain their life. Urban nature with surrounding natural areas is the major ES provider. IPBES defined good quality of life (2019) as the state of mind that most people have when they reach their full potential. It is a realm of security and mutual trust that depends on the various aspects of their lives. It also includes accessing to food, energy, water, health, freedom of choice and action. Most of the mentioned components have direct relation with ES provision.

Rapidly increasing population and urbanization have affected ES and biodiversity within urban areas (Güneralp et al., 2013). According to the United Nations report (2014), over half of the world's population (54 percent) live in urban areas. If current trends continue, global urban population is expected to double up to 6.5 billion approximately, reaching 66 percent by 2050. Besides the majority of the world population live in urban areas, most of the UES are consumed in cities.

With the increasing size of population, urban areas around protected areas will increase, and it will affect biodiversity and ES both directly through physical expansion over land, and indirectly due to land use and human behaviours within urban areas (Güneralp et al., 2013).

In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*, Fragkias et al. (2013) revealed five major important trends in urbanization process that have an impact on biodiversity and ES.

“Trend 1: The physical extents of urban areas are expanding faster than urban populations.”

In the global context, urban areas are growing twice as fast as the urban population (Seto et al., 2011). Thus, the proportion of covered by hard surfaces is also increasing more quickly than the urban population. From an urban morphological viewpoint, peri-urban areas generally include a higher proportion of provisioning ES land with agriculture, pastures, and forests than urban areas. In a social context, agrarian society mostly takes place in peri-urban lands. Producing and maintaining crops and farmland is their main economic activity. Their lifestyle, cultural and production activities are negatively affected by the rapid expansion of urban lands over peri-urban lands.

“Trend 2: Urban Areas Modify Their Local and Regional Climate”

Urbanization also causes changes in climate and ecosystems. Land-use changes in and around urban areas have a considerable impact on temperature and precipitation (Seto & Shepherd, 2009). The conversion of natural surface to a hard-surface, storing heat in walls, anthropogenic heat, air pollution, and three-dimensional urban geometry are causing factors of urban heat island effect (Ryu & Baik, 2012).

The dense concentration of urban activities (i.e., anthropogenic activities) such as transport, industrial production, and the heating way in houses also contributes to increasing heat in urban areas. According to Smith et al. (2009), buildings are the main emitter contribution to total emissions with 60%; road traffic with 32% and

metabolic sources with 8% in Manchester City. As can be noted from this research, anthropogenic activities' contribution to increasing heat level of cities change according to cities' concentration of these activities. Nonetheless, Fan & Sailor (2005) suggest that the estimated energy consumed because of anthropogenic activities impact is 1-3°C to the urban heat island effect.

Dense anthropogenic activities in urban areas are parallel with the high concentration of producing aerosols, pollution, and carbon dioxide (Pataki et al., 2007). Aerosols have a cooling and warming effect, depending on the types. There is strong evidence that urbanization affects precipitation variability, which is called the "urban rainfall effect" (Shem & Shepherd, 2009).

"Trend 3: Urbanization Increases Demands on Natural Resources"

Expansion of the urban built area surface causes an increase in resource consumption especially water, energy, timber. At the same time, mainly agricultural lands; with chain effect on habitat, biodiversity, and ES will be affected directly and indirectly (Seto et al., 2013). Small changes in the urban lifestyle and consumption patterns saving measures on energy and materials to be applied at the building scale can reduce the need for resources and energy on larger scales with a knock-on effect.

"Trend 4: Urban Expansion Is Increasing Near Biodiversity Hotspots"

While urban areas are expanding rapidly, they also threaten critical habitats in terms of biodiversity. It is predicted that 1.8% of all biodiversity hotspot areas will be destroyed because of urban expansion (Seto et al., 2012b).

"Trend 5: Urbanization Influences the (Green) Economy"

In the future, it is expected that urbanization will be mostly in developing economies countries. These countries are less committed to improving biodiversity and ES and pay less attention to conservation issues. In these areas, international capital, especially multinational companies, international real estate companies, and private real estate actors will shape the developments (Seto et al., 2010).

Brauman et. al (2007) give a sight to better understand the spatial relation between ES supply and consumption. They quoted that:

“As human population densities increase, there is often a spatial mismatch between the places where humans use ecosystem services and the location of ecosystems that produce them. Because of this, feedbacks to ensure the continued provision of services may not exist. Moreover, risk of impairment is greatest in areas where land conversion happens most rapidly, often the same places where people depend most directly on ecosystem services. Some ecosystem services are transportable, whereas others are not. Identification of key ecosystem service source areas would aid in ensuring continued delivery.” (Brauman et. al, 2007: page 82)

Areas where field degradation and field character change are mostly places where cities and human population are concentrated. The places that are most dependent on services are areas where people population is much more concentrated. It is possible to draw the following conclusion that the transformation of these natural areas into the environment is much more within the city.

Human life is dependent on nature and the ES provided by nature. In the city, some services are even more critical for different social groups. Vulnerable groups in the city, such as the elderly, children, or those working in sectors whose economic production directly depends on nature, will be much more affected by this change. The areas where we communicate with nature in the city are undoubtedly green infrastructure elements such as urban parks. These areas are an opportunity in terms of the potential of providing service to the city dwellers. It is possible to use these areas most beneficially for citizens by enhancing the ES provision degree, increasing the ES quality and ES sustainability.

Today, strengthening urban ES in green areas enable us to develop new urbanization policies to improve life quality of citizens. It is becoming increasingly important to consider these urbanization trends and policies for urban decision-makers.

Alternative tools in urban planning and design can help to reduce stress on urban green areas and support the provision of needed ES they provide.

1.2 Aims and Objectives of the Research, and the Main Research Questions

Most of the studies on ES in the literature have focused on ecosystems in out of urban context, and they missed to consider the interaction of nature and citizens. On the other hand, in urban design context, green areas are mostly mentioning as public space, and their socio-ecological functions are neglecting.

This research aims to discuss the importance of ES in urban areas through green areas and investigate planning and design inputs for urban green areas to maximize the current capacity of needed ES to improve human health and wellbeing. It addresses two main research questions. The first research question is: ***to what extent urban ecosystem services promote the life quality of citizens?*** This question will help to create an overall understanding importance of UES, urban green areas as ES providers and beneficiaries defined by the theoretical background of the study. Furthermore, it will provide comprehensive input for the second question ***How can be maximized the contribution of the green areas into urban environment via effective planning of the ES?*** The study's sub-questions are (1) *what the relationship between ES and urban planning and design* (2) *how to measure spatial distribution of ES and primary beneficiaries* (3) *how to enhance the green spaces current ES provisioning capacity via design.*

Answers to these sub-questions will guide the general theoretical and conceptual framework to define the role of ES in urban context and give planning and design inputs.

1.3 Research methodology

The study aims to develop design inputs in urban design field by combining the ES mapping work produced within the scope of the EU project called Nature and Cities (numbered: TR2015/DG/01/A5-02/138) with the educational information in the urban design master's program. This EU project is supported by “Turkey - EU Civil Society Dialogue V” coordinated by the Ministry of Foreign Affairs, Directorate of European Union, and program which was granted IPA II-2015, under call for proposals EuropeAid/139354/ID/ACT/TR (TR2015/DG/01/A5-02). The project was coordinated by Nature Conservation Centre (DKM) within the partnership of Eurosite Association.

ES mapping study of Çankaya District, which is an output of the project, was used as data in order to determine the current potential of the services offered by the parks within the scope of the thesis. The contribution of this thesis is to present urban design inputs that will increase this potential in accordance with the needs.

The study explores the benefits of ES, the identification of the primary beneficiaries of these benefits, and the urban design inputs that can be applied to increase the utilization of ES via enhancing ES capacity. Within the scope of the study, an analysis tool was developed to test whether the ES provided by the park meets the needs of the primary beneficiaries. The tool also contributes to determine the urban design inputs that can be applied in the park. In this context, although ES mapping was not prepared in this research scope, selection of ES, data collection and preparation process, and mapping techniques for each ES were presented in the research. In this manner, it enabled the analysis and synthesis made within the scope of the study to be handled with a more holistic approach and evaluated on the same ground.

This research uses convergent parallel mixed method approach to provide a complete understanding of research problem. This approach is a concurrent approach that conducts the simultaneous collection of qualitative and quantitative data, followed

by analyzing two components independently, and interpreting the data together (Creswell & Pablo-Clark, 2011).

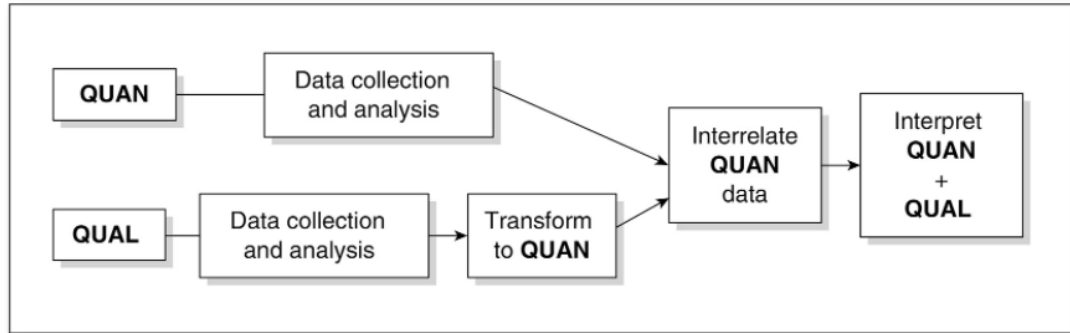


Figure 1. 1. Convergent parallel mixed method approach (Edmonds and Kennedy, 2017; page 4)

A literature review on UES initially was conducted to answer the very first research question that is: "*what extent UES promote the life quality of citizens?*". According to selected ES types which will be explained in the third chapter of this research, a set of qualitative data was collected to learn about how citizens are utilizing UES. Afterwards, benefits of UES, and urban design inputs in literature are defined with deductive method.

Secondly, this research developed ES maps to present the current ES potentials in order to answer the second research question that is: "*How can be maximized the contribution of the green areas into urban environment via effective planning of the ES?*", current ES potential was presented via ES mapping study. Land cover maps were produced by superimposing the remote sensing images and urban plans to define service provider units (SPU) and service benefitted areas (SBA). Without changing the content, materials are manipulated through juxtaposition, overlapping, and layering. By integrating diverse data obtained from multiple maps, these technical processes have the ability to generate a comprehensive framework and coherent representation (Yavuz, 2018). Data classification and validation for landcover classes was done by comparing the data with spatial data set which is produced with controlled classification method.

One of the most important resources in the study is the outcome of the mapping process. This section provides information on the mapping techniques utilized on various mapping ES, the materials used in the mapping process, and the research material analysis approach. In this spatial modelling, both quantitative data collected and collected qualitative data converted into quantitative data through using the software of ArcGIS.

Thirdly, an analysis tool that will be detailed explained in Chapter 3 of this research will be employed to be tested on a selected 9 urban parks as the cases of this research. The case areas are particularly selected to understand whether some spatial, morphological, and natural differentiation effects on ES provisioning capacity.

Case study method is defined by Yin (1984, p.23) as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used.”

1.4 Structure of Thesis

This thesis consists of five Chapters. Chapter 1 introduces this research by defining its main research problem, aims and objectives, research questions and research methodology. Chapter 2 develops the theoretical framework on the literature on ES, its importance and relation with the disciplines of urban planning and design. Chapter 2 also explains urban green areas from the UES perspective, by discussing UES in terms of its benefits and primary beneficiaries. Thus, it provides a basis for revealing urban design inputs to enhance the ES provisioning capacity for specific services Chapter 3 defines the research methodology of this study. It explains the data collection and assessment strategy extensively. The methods of the analysis tool developed within the scope of the thesis are given in this Chapter. Chapter 4 presents the findings of this research, and finally, Chapter 5 summarizes the findings of the research, makes discussions on the findings of the research, makes suggestions on

the urban design inputs regarding UES, and limitations of the research. Last but not the least, this part includes the suggestions for the future research.



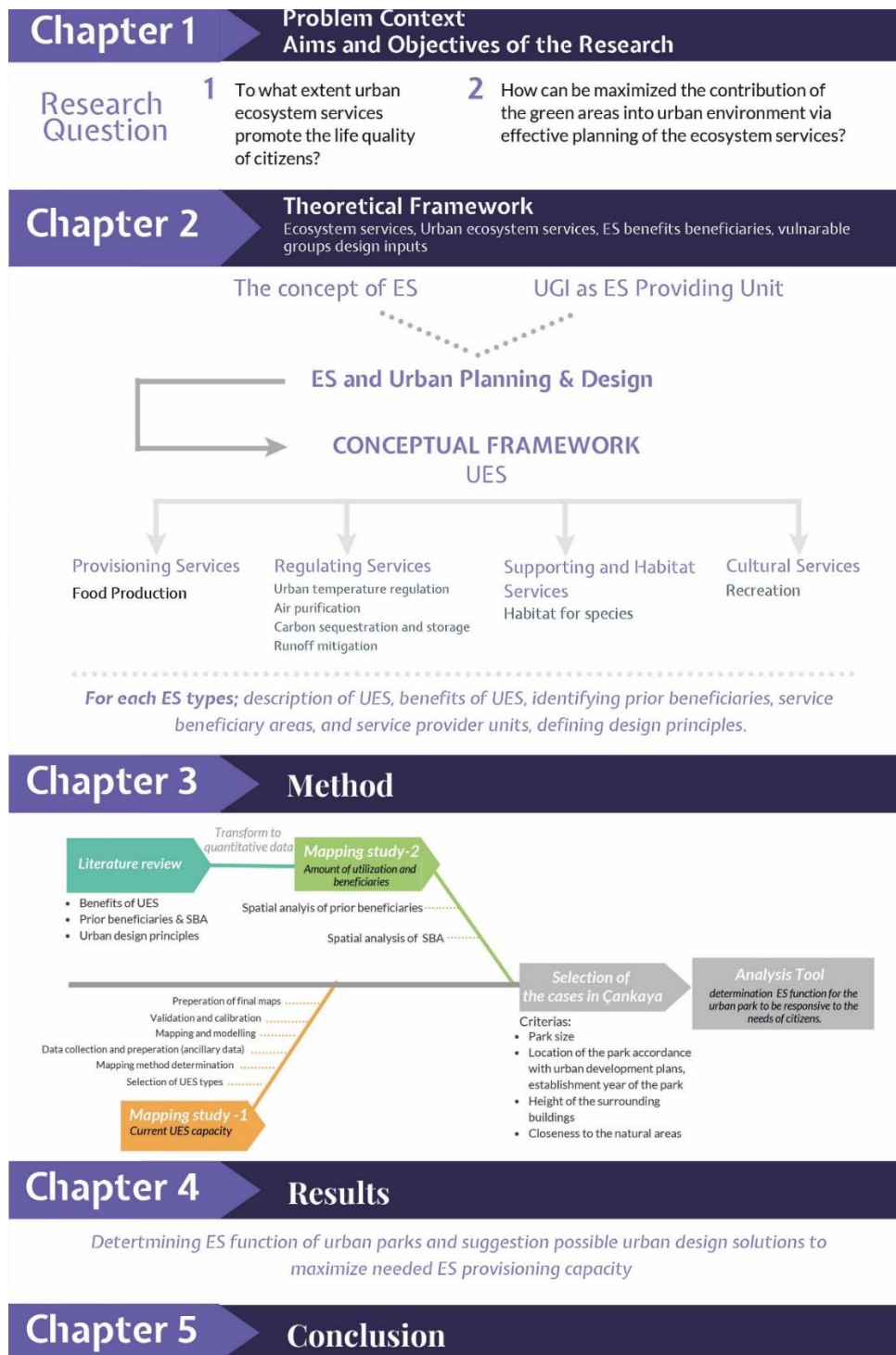


Figure 1. 2. Configuration of Thesis

CHAPTER 2

THEORETICAL FRAMEWORK

This chapter aims to provide a theoretical framework to answer the two main questions:

- To what extent UES promote the life quality of citizens?
- How can be maximized the contribution of the green areas into urban environment via effective planning of the ES?

Hence, this chapter starts with a discussion of ES concept and investigates ES classification and valuation methods. Next, it focuses on urban green areas from UES perspective. After that, UES are discussed as a tool in city planning and design on different scales with examples from other countries. Finally, selected UES are profoundly discussed in the context of their benefits, and primary beneficiaries. In addition, design indicators are defined to enhance provisioning capacity for each specified ES in urban park context. The chapter concludes with a final remark and presents a brief table showing the main findings of Chapter 2.

All in all, this chapter presents a base knowledge about classification and description of UES by giving samples at different scales in a social-ecological context in order to provide a comprehensive understanding to the later parts of the research. In addition, it presents the general urban design inputs that are likely to increase the capacity of providing the determined ES. These inputs are described at street, park and building scales to better show and explain their relationships with urban parks.

2.1 The Concept of Ecosystem Services (ES)

Ecosystem Services (ES) has become an essential concept to link the functioning of ecosystems to human welfare benefits (Fisher et al., 2009). Moreover, it draws attention to the fact that people associate their dependence on ecological life support systems. Over the last years, the papers addressing ES in the literature have increased exponentially, and some of the scholars have defined ES as an approach to think about and assessing the nature-society relationship (Lele et al., 2013).

According to Gomez et al.'s (2009) reviews on the historical development of the conceptualization of ES, Westman first introduced the origin of ES in modern history with the term “nature’s services” in the late-1970s. Afterwards, Ehrlich and Ehrlich firstly used the term “ecosystem services” in 1981. They have drawn a utilitarian frame that the benefits of ecosystem function as services increase public interest in biodiversity conservation with making more informed policy and management decisions (Westman, 1977; Ehrlich and Ehrlich, 1981; Fisher et al., 2009). In 1997, Daily described ES as “conditions and process”, besides “actual life-support functions”. Then, Costanza, et al. (1997) defined ES as “the benefits human populations derive, directly or indirectly, from ecosystem functions”.

The most remarkable publication that mentions the significance of ES concept, Millennium Ecosystem Assessment (MA) involving more than 1300 scientists, was published in 2003 (Fisher et al., 2009). According to MA (2003), the ecosystem’s contribution to human well-being is called “ecosystem services”. MA introduced the concept on the global agenda and created an essential connection between the necessity of conserving biodiversity and the challenges in meeting to United Nations Millennium Development Goals (TEEB, 2010).

Urban ecosystems provide vital services for citizens (McDonald & Marcotullio, 2011). People need ecosystems. Ecosystems contribute to human well-being in various ways. They provide the necessary resources for food, water, shelter, and energy. Also, they regulate the conditions (e.g., temperature, water quality) in which people live, work, play and, most fundamentally, underpin the underlying processes (e.g., primary production) and cycles (e.g., carbon cycle, water cycle) that support life.

In the context of urban planning, urban ecosystems consist of built infrastructure and the ecological infrastructure that water and vegetation in or near the built environment play an essential role in serving ES at different spatial levels (building, streets, neighborhood, and region) (Gomez et al., 2013). Ecological infrastructure including blue and green spaces (natural and semi-natural areas such as parks, cemeteries, gardens, yards, urban allotments, urban forests, single trees, green roofs as green spaces; wetlands, streams, rivers, lakes, ponds as blue spaces) both can locate in urban and peri-urban areas (EEA, 2011). In the study, the main focus of UES is on services provided within urban parks.

2.1.1 Classifying Urban Ecosystem Services

MA and The Economics of Ecosystems and Biodiversity (TEEB) have a great impact on the development of ES concept in the literature (McGranahan et al., 2005; TEEB, 2011). In these two publications, ES in urban areas have been grouped, and it has attracted attention as part of the critical discussion on green infrastructure (GI) (DG Environment, 2012). Nevertheless, in comparison to other ecosystems such as wetlands and forests, UES receive insufficient attention (Gómez-Baggethun and Barton, 2013)

Although there is still uncertainty regarding the number of ES, the “MA Report,” which is one of the most important publications on this subject, grouped ES in four

major categories: provisioning, regulating, supporting and cultural services (MA, 2005).

TEEB Manual for Cities: Ecosystem Services in Urban manuals for Cities (2011) focuses more specifically on ES in cities. This report classifies ES relevant to cities with examples (Table 2. 1). Similar to MA (2005), it also defines the types of ES as provisioning services, regulating services, habitat or supporting services and cultural services.



Table 2. 1. Ecosystem categories and types relevant to cities. (TEEB, 2011, page: 4-5)

Ecosystem Service	Service Icon	Service description	Example
Provisioning services: Ecosystem services that describe the material or energy outputs from ecosystems.			
Food		Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems, but marine and freshwater systems, forests and urban horticulture also provide food for human consumption.	In Havana, Cuba (1996), a significant proportion of the urban population's food was produced within urban gardens, including 8,500 tons of agricultural produce, 7.5 million eggs and 3,650 tons of meat (according to a review by Altieri, 1999).
Raw materials		Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.	Non-timber forest products such as rubber, latex, rattan and plant oils are very important in trade and subsistence – the annual global trade in such products is estimated to amount to US\$11 billion (Roe et al. 2002).
Fresh water		Ecosystems play a vital role in providing cities with drinking water, as they ensure the flow, storage and purification of water. Vegetation and forests influence the quantity of water available locally.	Estimates of the value of the services of a South African mountain fynbos ecosystem with an area of only 4 km ² indicated that water production was the biggest contributor to the total value of the system. The value was estimated to range from approximately US\$4.2 million to 66.6 million in 1997, according to how well the system is managed (Higgins et al. 1997).
Medicinal resources		Biodiverse ecosystems provide many plants used as traditional medicines as well as providing raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.	80% of the world's people are still dependent on traditional herbal medicine (WHO 2002), while the sale of medicines derived from natural materials amounts to US\$57 billion per year (Kaimowitz 2005).
Regulating services: The services that ecosystems provide by regulating the quality of air and soil or providing flood and disease control, etc.			
Local climate and air quality regulation		Trees and green space lower the temperature in cities whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.	In Cascine Park in Florence, Italy, the urban park forest was shown to have retained its pollutant removal capability of about 72.4 kg per hectare per year (reducing by only 3.4 kg/ha to 69.0 kg/ha after 19 years, despite some losses due to cutting and extreme climate events) (Paoletti et al. 2011). Harmful pollutants removed included O ₃ , CO, SO ₂ , NO _x and particulate pollutants as well as CO ₂ .
Carbon sequestration and storage		Ecosystems regulate the global climate by storing greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues; thus acting as carbon stores.	Urban trees too, are important in carbon sequestration: in the United States, their annual gross carbon sequestration amounts to 22.8 million tons of carbon per year (as calculated in 2002) (Nowak and Crane 2002). This is equivalent to the entire USA population's emissions in five days. This sequestration service is valued at US\$460 million per year, and US\$14,300 million in total.
Moderation of extreme events		Ecosystems and living organisms create buffers against natural disasters, thereby preventing or reducing damage from extreme weather events or natural hazards including floods, storms, tsunamis, avalanches and landslides. For example, plants stabilize slopes, while coral reefs and mangroves help protect coastlines from storm damage.	In the case of the Californian Napa City, USA, the Napa river basin was restored to its natural capacity by means of creating mudflats, marshes and wetlands around the city (TEEBcase by Almack 2010). This has effectively controlled flooding to such an extent that a significant amount of money, property, and human lives could be saved.
Waste-water treatment		Ecosystems such as wetlands filter effluents. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.	In Louisiana, USA, it was found that wetlands could function as alternatives to conventional wastewater treatment, at an estimated cost saving of between US\$785 to 34,700 per hectare of wetland (in 1995) (Breaux et al. 1995).

Table 2. 1 (continued)

Ecosystem Service	Service Icon	Service description	Example
Regulating services: Continued			
Erosion prevention and maintenance of soil fertility		Soil erosion is a key factor in the process of land degradation, desertification and hydroelectric capacity. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well-functioning ecosystems supply soil with nutrients required to support plant growth.	A study estimated that the total required investment to slow erosion to acceptable rates in the USA would amount to US\$8.4 billion, yet the damage caused by erosion amounted to US\$44 billion per year. This translates into a US\$5.24 saving for every US\$1 invested (Pimentel et al. 1995).
Pollination		Insects and wind pollinate plants which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats.	Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee (Klein et al. 2007).
Biological control		Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.	Water hyacinth was brought under control in southern Benin using three natural enemies of that plant (De Groot et al. 2003). Whereas the biological control project cost only US\$2.09 million in present value, its accumulated value is estimated to amount to US\$260 million in present value (assuming the benefits stay constant over the following 20 years), representing a very favourable 124:1 benefit cost ratio.
Habitat or Supporting services: These services underpin almost all other services. Ecosystems provide living spaces for plants or animals: they also maintain a diversity of plants and animals.			
Habitats for species		Habitats provide everything that an individual plant or animal needs to survive: food, water, and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements.	In a March 2010 article (IUCN 2010), IUCN reports that habitat loss is the single biggest threat to European butterflies, and may lead to the extinction of several species. Habitat loss was said to occur most often as a result of changes in agricultural practice, climate change, forest fires, and expansion of tourism.
Maintenance of genetic diversity		Genetic diversity (the variety of genes between, and within, species populations) distinguishes different breeds or races from each other, providing the basis for locally well-adapted cultivars and a gene pool for developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as 'biodiversity hotspots'.	In the Philippines, an initiative to conserve local varieties of rice aided in the development of rice strains that are better adapted to local conditions - giving greater yield, a quality seed supply, and decreasing dependence on plant breeders - at a much lower cost than that of formal plant breeding (SEARICE 2007).
Cultural services: These include the non-material benefits people obtain from contact with ecosystems. They include aesthetic, spiritual and psychological benefits.			
Recreation and mental and physical health		Walking and playing sports in green space is a good form of physical exercise and helps people to relax. The role that green space plays in maintaining mental and physical health is increasingly becoming recognized, despite difficulties of measurement.	A review article examined the monetary value of ecosystem services related to urban green space, based on 10 studies, including 9 cities from China and 1 from the USA (Elmqvist 2011). It reported that on average, 'Recreation and Amenity' and 'Health effects' contributed a value of US\$5.882 and US\$17.548 per hectare per year respectively to the total average of US\$29.475 per hectare per year provided by the seven identified ecosystem services in the various studies.
Tourism		Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008 global earnings from tourism summed up to US\$944 billion. Cultural and eco-tourism can also educate people about the importance of biological diversity.	Based on the amounts of money people spent on travel and local expenditure in order to visit Coral reefs in Hawaii, it was estimated that the value associated with these reefs amounted to US\$97 million per year (TEEBcase by van Beukering and Cesar 2010). This implies that reef tourism resulted in significant income generation for individuals, companies, and countries.
Aesthetic appreciation and inspiration for culture, art and design		Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.	Prehistoric rock art of southern Africa, Australia, and Europe, and other examples like them throughout the world, present evidence of how nature has inspired art and culture since very early in human history. Contemporary culture, art and design are similarly inspired by nature.
Spiritual experience and sense of place		In many parts of the world natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.	In the example of the Maronite church of Lebanon, the church committed to protecting a hill in their possession, comprising rare remainders of intact Mediterranean forest, independent of scientific and legal arguments, because this was in line with Maronite culture, theology and religion (Palmer and Finlay 2003).

2.1.2 Ecosystem Services Value

In the literature on ES, there are various value typologies including ecological, economic, social, cultural, spiritual, symbolic, therapeutic, insurance and place values (OpenNESS, 2014). Moreover, it is emphasized that the separation of the valuation is hard to define. According to Gómez-Baggethun and his friends (2013), the values addressed to ES are grouped into **three broader categories**: monetary, social and cultural values, and insurance values.

Monetary value of ES is an environmental assessment from an economic point of view (Yengué, 2017). Financial valuations are confined to priced products and services, which only cover a small portion of ES (Gómez-Baggethun et al., 2013). It includes calculating the numerical importance of specific ES and the value of an improvement in/loss of such services under various scenarios (TEEB, 2011). For example, cost-saving using engineering methods reduces air emissions or property destruction caused by natural obstacles to environmental extremes (URBES, 2013). Similarly, the loss of water regulation services due to land-use changes in city catchments necessarily involves building expensive water purification plants (Daily and Ellison, 2002). A recent study about the monetary valuation on urban runoff management by urban green space in Finland shows that leaving green space saves a significant amount of money rather than construction (Silvennoinen et al., 2017). Study results show that in catchments with a high concentration in land-use, a lower proportion of green space, and high runoff control costs, the ecosystem service value was generally higher. Monetary value is varied from 90,000 to 270,000 € ha⁻¹ depending on the proportion of impervious area.

Sociocultural values include human behavior and understanding of ecosystem services by non-monetary ranking methods (MA, 2003). People's attitudes and behavior toward environments and the services they provide are influenced by their moral, spiritual, educational, aesthetic, place-based, and other beliefs toward the urban world (MA, 2003). As Chiesura (2004), Chan et al. (2012) and Gómez-Baggethun et al. (2013) indicate, place values, sense of community and belonging,

physical and mental wellbeing, community cohesion, and educational values are highly correlated with the group of cultural ES. According to Higuera et al. (2013), citizens who are unable to spend money to preserve environmental resources might also be able to give social support for protection and conservation activities.

Insurance value is nature's contribution to being high toleration and resiliency to unexpected natural events in terms of resiliency and adaptability. For instance, food production in cities has played an important role in terms of food security and urban economy at certain times in some geographical regions, especially in times of economic and political crisis (Barthel & Isendahl, 2013).

2.2 Urban Green Infrastructure (UGI) as Ecosystem Services Providing Units

Urban Green Infrastructure (UGI) is the major ES providers in the city. European Commission (2013a: page number 3) describes UGI as: *“Urban green infrastructure is 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 such as water purification, air quality, space for recreation and climate mitigation and adaptation.”*

In ES context, urban green areas refer to service providing units (SPU). Vandevallé et al. (2013) describe these units as *“the components of biodiversity necessary to deliver a given ES at the level required by service beneficiaries”*. SPU represents the minimum unit to take into consideration UES supply. Different typologies of the green spaces have different capacities (Zardo et. al., 2017). Analyzing SPU covers the typology and spatial distribution of urban green infrastructure. Moreover, the size of SPU is an important variable affecting the performance to supply the service (Zardo et. al., 2017).

The broad list of potential UGI was grouped under three different scales by Landscape Institute in 2009 (Table 2. 2):

- Local, neighborhood and village scale
- Town, city, and district scale
- City-region, regional and national scale

Table 2. 2. GI grouped into three different scales (Landscape Institute Green infrastructure: connected and multifunctional landscapes, Page:4)

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

Table 2. 3. Assessment of ecosystem services provided by green infrastructure and nature-based solutions at different implementation scales
(Retrieved from Arslantaş, et. al. 2020, page: 112, 113)

Implementation Scale	Green infrastructure and nature-based	Provisioning services					Regulating services					Cultural services			Supporting services
		Food production	Fresh water	Wood	Medicines	Urban temperature regulation	Air purification	Water purification	Pollination	Noise reduction	Carbon sequestration	Rainoff mitigation	Recreation	Ecotourism	Habitats for species
Building, street	Domestic garden	X			X	X	X		X	X					X
Building, street	Rain garden	X			X	X	X	X	X			X	X		X
Building, street	Permeable pavement					X						X			
Building, street	Green facade					X	X	X	X	X					X
Building, street	Green roof	X			X	X	X		X	X		X			X
Building, street	Green parking lot					X	X		X						
Street, neighborhood	Street trees	X				X	X	X	X	X	X	X	X		X
Street, neighborhood	Sustainable urban drainage systems					X	X	X				X			
Neighborhood	Community food growing area	X			X	X	X		X	X	X	X	X		X
Neighborhood	Neighborhood park	X				X	X	X	X	X	X	X	X		X
Neighborhood	Urban park	X				X	X	X	X	X	X	X	X		X
Neighborhood	Botanic garden				X	X	X	X	X	X	X	X	X		X
Neighborhood	Fruit garden	X			X	X	X	X	X	X	X	X			X
City, region	Green corridors					X	X	X	X	X	X	X	X		X
City, region	Water channel		X			X		X				X	X	X	X
City, region	Streams		X			X		X				X	X	X	X
City, region	Forest	X		X	X	X	X	X	X	X	X	X	X	X	X
City, region	Agricultural land	X			X										

2.3 Ecosystem Services and Urban Planning & Design

To maintain liveable, sustainable, and resilient cities, it is consequently important to preserve, restore, and enhance urban ES (McPhearson et al. 2015; Botzat et al. 2016; Frantzeskaki et al. 2016). As the city population grows, it becomes increasingly important to maintain healthy and functioning ecosystems in order to meet the growing demand for ES in a sustainable manner (Geneletti et. al., 2019).

ES in cities is influenced by urban planning in many ways (Cortinovis, 2018). Firstly, UES provision is highly dependent urban ecosystem' spatial distribution and availability. Therefore, strategic decisions during the urban planning process directly effect on UES (Langemeyer et. al. 2016). Secondly, urban planning affects urban population and urban functions' distribution by defining land use' spatial arrangement. This process impacts on the demand for UES (Baro et. al. 2016). Thirdly, urban planning actions made by the planning authorities can also affect who may benefit from UES. For this reason, It is necessary to consider protect and enhance ES benefits.

2.4 Urban Ecosystem Services

Admittedly number of studies about ES classification and valuation methods has significant place in the literature. This study focuses on selected 7 UES types. The selection criteria are mostly based on data availability and social indicators of social needs for ES. More detailed information about selection of ES types will be discussed under the Chapter 3 in the study. On the scope of the study, selected UES types are indicated in the Table 2. 4.

Table 2. 4. Selected UES types

PROVISIONING SERVICES	Food production
REGULATING SERVICES	Urban temperature regulation
	Air purification
	Climate regulation
	Runoff mitigation
HABITAT OR SUPPORTING SERVICES	Habitats for biodiversity
CULTURAL SERVICES	Recreation

2.5 Provisioning Services

Provisioning ecosystem services are including products that people get from ecosystems directly. Supplying of food, water, biomass, and fiber can be sample of these services. Provisioning services is most of the examined ES type in the literature (Martínez-Harms, M. J. et. al., 2012).

In the Millennium Assessment Report (2005), products that obtained from ecosystem are listed as *food* (derived from plants, animals, and microbes), *fiber* (materials included wood, jute, cotton, silk and wool), *fuel* (wood, dung and other biological materials serve as energy source), *genetic resources* (including genes used for animal, plant breeding and biotechnology), *biochemical*, *natural medicines and pharma-ceuticals*, *ornamental resources* (animal and plant products) and *fresh water*. In the document, ES is listed as *food*, *raw material*, *fresh water* and *medical resources*.

The amount of provisioning services consuming in cities is increasing more rapidly than population growth (MA, 2005). Because between the dates 1960 and 2000 world population has doubled, production of food %160 increased; on the other hand, this ratio was four times in developing countries (MA, 2005).

2.5.1 Food Production

Food production in cities was formally recognized for the first time and contribution of health and wellbeing benefits were highlighted in United Nations International Conference on Human Habitats in Istanbul, 1996.

When considering consuming – producing food ratio in cities, only a small part of the demand for food supply by the citizens is met from the food produced in the urban area. The provisioning services potential in rural areas is more than urban areas. Definitions and supplying amount are varying between countries, regions, and cities. However, it takes important place in food producing and supplementary income (McGranahan et al., 2005).

Urban agriculture may have in many typologies including community or allotment garden, private garden, easement garden, rooftop gardens or green roofs, peri-urban agriculture (Lin et al., 2017). The food demand of the city is met mostly from agricultural lands close to the city periphery. Horticultural activities in urban areas are called “urban gardens” (Camps et al., 2016). Urban gardens can occupy building balconies, windows, rooftops, walls, vacant lots, allotments, school courtyards, and urban parks.

Although cities are generally externally dependent on food supply, there are also self-sufficient examples in the world. For example, urban agriculture has an important place in terms of supplying food and cities’ economy in Cuba. Especially, after the Russian Economic Crisis, typology of the urban agriculture has changed. Called “organoponicos” which are using productive landscapes instead of wastelands have emerged. Urban and peri-urban agriculture is taking crucial place in Havana. Beside the different types of farms located in Havana; State Farms for Producers Consumption “*Autoconsumos Estates*”, Community Gardens (plots) “*Huertos Populares*”, Community Gardens (intensive cultivation garden) “*Huertos Populares (Huerto Intensivo)*”, Urban Community Garden “*Organoponico os Populares*”, and High Yield Urban Gardens “*Organoponicos de Alto Rendimiento*”

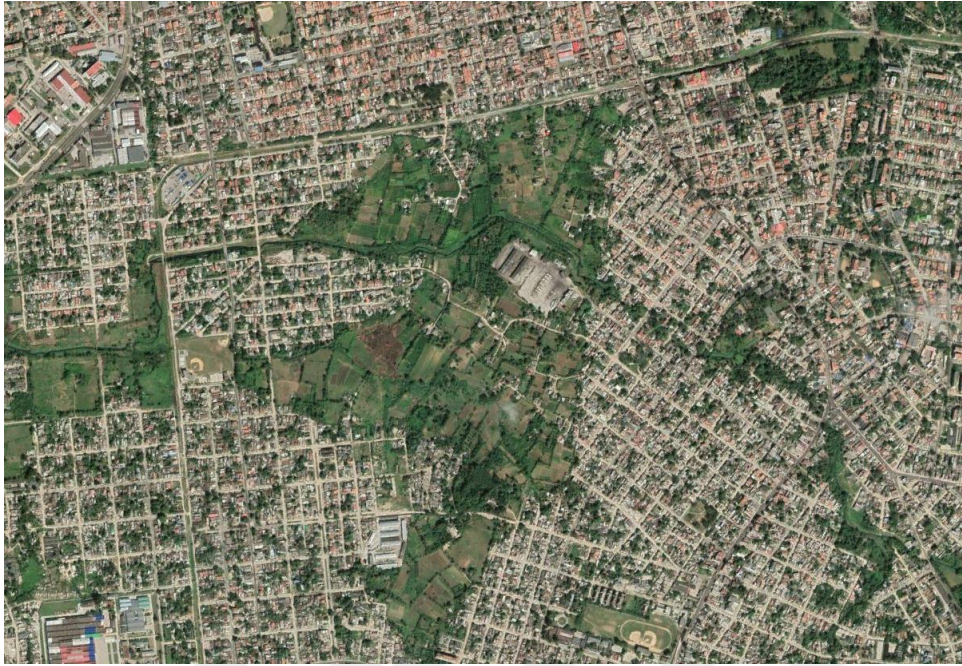


Figure 2. 1. Urban agriculture in Havana city. (Image taken from Google EarthPro, 21.07.2019)



Figure 2. 2. Plot farming in Havana. (Photo Credit: Arnoud Joris Maaswinkel)

Urban gardening has also contributed to ecosystem services provision. Increasing food production in urban areas has multiple benefits for citizens. According to a study conducted by Barthel et al. (2013), ecosystems services generated by urban gardening were listed as “supply of fresh vegetables, crops, fruits and berries, production of fertile soil, recycling of waste by composting and reduced food transport and packaging, seed dispersal, pollination, genetic library maintenance of crop varieties, natural insect pest regulation, surface water drainage, regulation of microclimate, learning/memory arenas about food production and local ecologies, mnemonic features in urban landscapes related to food security”.

Moreover, urban gardening activities can improve the social cohesion in city (Anguelovski, 2013), enhance the quality of life via promoting healthy and active lifestyle (Van den Berg et al., 2010), provide recreation areas and decrease the stress level (Breuste and Artmann, 2014), and make people more aware of living environment via environmental education opportunities (Shava et. al., 2010).

Urban agriculture areas are places where citizens can directly benefit and develop their experience on growing food practice. In this respect, increasing the contact with nature provides many benefits. It also provides ES that cannot be directly observed.

Benefits of food production in urban areas

Nutrition and food security

The World Bank (1986) defined food security as “access by all people at all times to enough food for an active healthy life.” Food production in urban areas, urban agriculture, has played an important role in terms of food security and urban economy at certain times in some geographical regions, especially in times of economic and political crisis (Barthel & Isendahl, 2013). On the other hand, global crisis such as climate change, public health crisis or financial crisis affect not only certain geographies but also worldwide. United Nations Food and Agricultural Organization draws attention to urban food system importance in times of COVID-19 pandemic, urban food systems strongly impact the food security and nutrition for urban population because of dealing with food availability, accessibility, and affordability (2020).

According to Barthel et al. (2013), urban gardening is a way to transfer collective knowledge of how to grow food, thus create local ecological and social response capacity against major collapses in urban food supplies.

Bellows et al. (2008) claim that 10x10 meter plot, located in a 130 day temperate growing season can meet the need of a household’s yearly vegetable needs including necessary nutritional requirement for healthy living. Urban areas have the potential significant amount of food cultivation including urban parks.

Education opportunities

Urban agriculture enables to attract group of people from different lifestyles, age-groups and ethnicities (Bendt. et al., 2013). For example, mentorship training where

young people can learn from experienced gardeners, has important place in transmitting both embodied and tacit knowledge (Barthel et. al., 2013). It leads a venue where children and adults can learn about ecological processes, biodiversity and producing food (Blaine et al. 2010).

School-garden programs have important health effects on young people (Bellows, A. et. al., 2008). With urban agriculture, young people have chance to be familiar with good and healthy food habits, and aware of reducing obesity and chronic disease. Moreover, these programs teach a skill and enhance their social, physical, and mental abilities (Bellows, A. et. al., 2008).

A growing body of literature has examined that young people's interest in urban agriculture can relieve stress, improve concentration and curiosity on courses, assist collaboration and cooperation, improve good relations with peers or others, improve self-confidence and self-sufficiency and other personal development skills (Rogers, 2018).

Health benefits

In recent years there has been a growing interest in correlation between fresh food and health. In the literature, many studies show that the primary motivation of why farmers grow their own food and buyers purchase locally grown products is the freshness of products (Bellows et al., 2008). As cited in Bellows and her friends' study, during 5-10 days of transportation, the products lose their nutritional value by about 30-50% (2008). Enriched nutrition can also help to mitigate the disease better (Zeeuw et al., 2001).

According to a study by Wolch and friends (2011, as cited in Hand et al., 2016), lack of connection with nature impacts on children's health and wellbeing, relation with increasing obesity, especially in early childhood period. As Wolch and friends (2011) noted that disconnection with nature negatively affects to cognitive well-being, such as ability to problem solving or evaluation of risks (Kuo and Taylor, 2004). In early childhood period, experiences are very significant to create a lifelong

connection with nature. It might result to have motivation to conserve nature (Wells and Lekies, 2006).

In Bellows and her friends' study, gardening activities and food production was discussed as good exercise for health. Reducing coronary heart disease especially for menopausal women and elderly men (Bietz and Doren, 2004), diabetes and glucose tolerance for adults and elderly men (Van Dam et al., 2002). Moreover, as cited in Bellows and her friends' study (2008), gardening activity increase strength and endurance of the muscle in activity-reduced person such as pregnant women, cancer survivors and those who have sedentary lifestyle (Evenson KR, et al. 2004; Irwin 2004; Rolland et al. 2004; Wannamethee and Shaper 2001; Wannamethee et al. 2000; Anonymous-B 1995).

Among older people, gardening is mutually supported activity that combating social isolation and develop their social network, thus contribute to enhance quality of life with improving individual's emotional, physical, and spiritual renewal (Milligan et al., 2004).

As mentioned previously, in addition to the directly observable benefits offered by urban gardens, there are also benefits that support human health because of ecosystem processes. Those are listed in Barthol and his friends study (as sourced from in Bolund and Hunhammar, 1999; Miller, 2005; Ernstson et al., 2010a) as "production of fertile soil, recycling of waste by composting and reduced food transport and packaging, seed dispersal, pollination, genetic library maintenance of crop varieties, natural insect pest regulation, surface water drainage, regulation of microclimate, learning/memory arenas about food production and local ecologies, mnemonic features in urban landscapes related to food security".

Social cohesion and integration

Urban gardens have many social and cultural benefits in multiple dimensions. They provide a space that support social contact and active participation. According to Lin and her friends (2017), it is an effective tool for improving social cohesion and

bridging racial divides by bringing people of different ages, races, and income levels together. They provide a teaching, learning and education venue for experienced gardeners, young and old people (Barthel et. al., 2013), help bridge the gap between consumers and producers (Specht et al., 2013), learning to work collectively which leads to develop social skills, widen their social network (Stocker and Bernett, 1998). Moreover, urban gardening activities have connection with preventing crime, support cultural diversity, enhance community strength and promoting active citizenship (Warner and Hansi, 1987; Murphy 1999, as cited in Lin et al., 2017).

2.6 Regulating Services

In the Millennium Assessment Report (2005), regulating ES is described as “the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification.”

2.6.1 Urban temperature regulation

According to the European Environment Agency (2012), heat waves are the deadliest natural disaster to affect people in Europe. In urban areas, urban heat island effect intensifies further the heat stress resulting from heat waves (Zhao et. al., 2018). Urban area mostly concentrated on built structures such as buildings, roads and other infrastructure absorb and re-emit the solar radiation more than natural environment such as green areas, forests, and water bodies (EPA, 2020). Urban areas become an “island” of higher temperatures than surrounding areas. The temperature difference can be up to 10°C (Oke, 1982). UHI mechanisms described by Oke in 1982 shown in the Figure 2. 3.

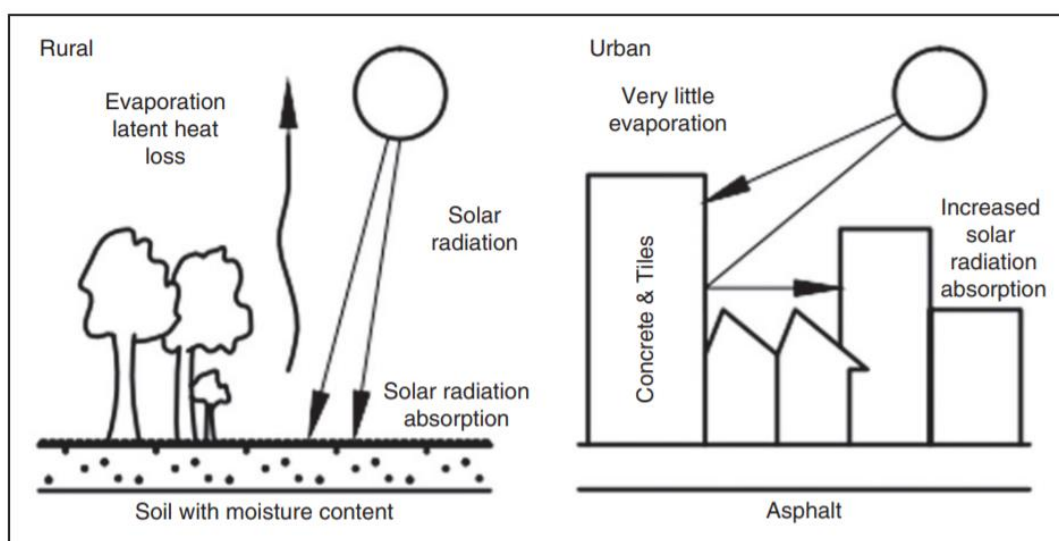


Figure 2. 3. Urban Heat Island mechanism (Resource: Pochee and Johnston, 2017; page 731)

Urban heat island form because of meteorological, morphological, and human factors aggravating heat impacts (EEA, 2012). The details of these factors are given in Table 2. 5.

Table 2. 5. Factors determining the strength of the urban heat island effect and its impact (Resource: European Environment Agency, 2012)

Meteorological factors	Morphological factors	Human factors aggravating heat impacts
Radiation Temperature Wind speed	Geographical location and topography Vegetation and water areas High building mass Presence of impervious cover Structure that hinders ventilation	Urbanisation with a high share of built-up land and impervious areas Population density Little shadowing Insufficient building insulation Additional heat production due to production processes, transport, heating etc.

In a study conducted in Manchester, (Smith et al, 2009) found that buildings are the dominant emitters with contributing 60% of the waste heat energy in the city; 32% of road traffic and 8% of human metabolic heat emission. Waste heat energy constitutes an important part of the total energy (solar and anthropogenic energy). It increases urban heat island effect between 1 °C and 3 °C (Fan and Sailor, 2005). The highest temperature in the city is generally high-density urban area with tall buildings, lack of green spaces and large amount of anthropogenic heat result of burning fossil fuels, transportation, and industrial process (EEA et al., 2008).

International Union for Conservation of Nature (IUCN) participated in Urban Biodiversity and Ecosystem Services (URBES) research project in 2012, which aims to bridge the knowledge gap on the role of urban biodiversity and ecosystem services for human well-being. Within the scope of the project, 4 different cities were examined and compared in order to examine the effect of green infrastructure in the city on climate regulation (Figure 2. 4). Accordingly, it is seen that there is the least cooling potential in Berlin and Salzburg city centers. The main reason for this is the dense urban texture, the abundance of impermeable surfaces and the scarcity of urban forest areas compared to the cities of Helsinki and Stockholm.

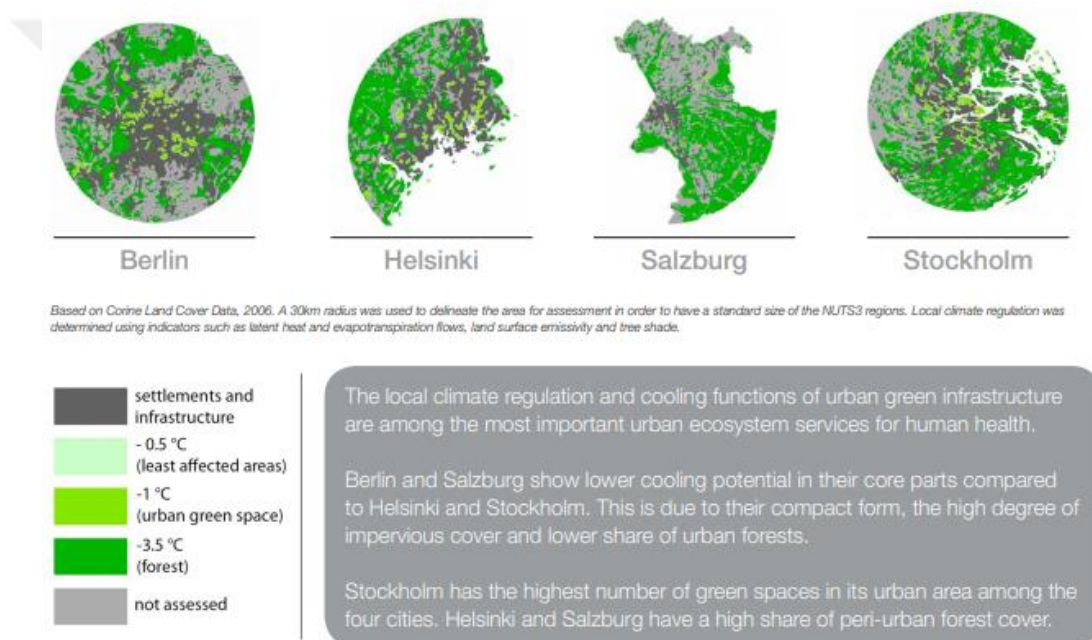


Figure 2. 4. Reduction of heat island effect in different cities (Resource: URBES Project fact sheet)

Green areas in cities are the essential components that provide climatic regulation together with water surfaces. Water absorbed in plants uses heat as it evaporates, thereby cooling the air (Nowak and Crane, 2000). At the same time, trees also reduce the heat load in the city because they reflect the sun radiation and form a shadow surface. Another factor is that the green areas are the airways that facilitate the ventilation of the city. An increasing number of studies have found that urban

temperature regulation is one of the most critical ecosystem services that trees provide to urban areas (McPhearson, 2011).

Along with features such as the presence and maturity of trees, leaf surface, crown closure, the green area size, height of the building, and density of urban fabric surrounding the green area also affect the capacity of decreasing urban heat island effect.

UHI causes problems, such as relative humidity change, energy consumption increase, and thermal sensation for urban residents (Lee, 2019). Urban temperature regulation service has direct and indirect benefits for urban residents.

Benefits of urban temperature regulation in urban areas

Decreasing energy consumption

International Energy Agency report (2018) provided the shares of residential energy consumption by end use in selected countries in 2018 (Figure 2. 5). Based on this data, space heating is the major use of energy in residents with the share of 53%. The building size, household income, and building characteristics influences the energy consumption in residential areas.

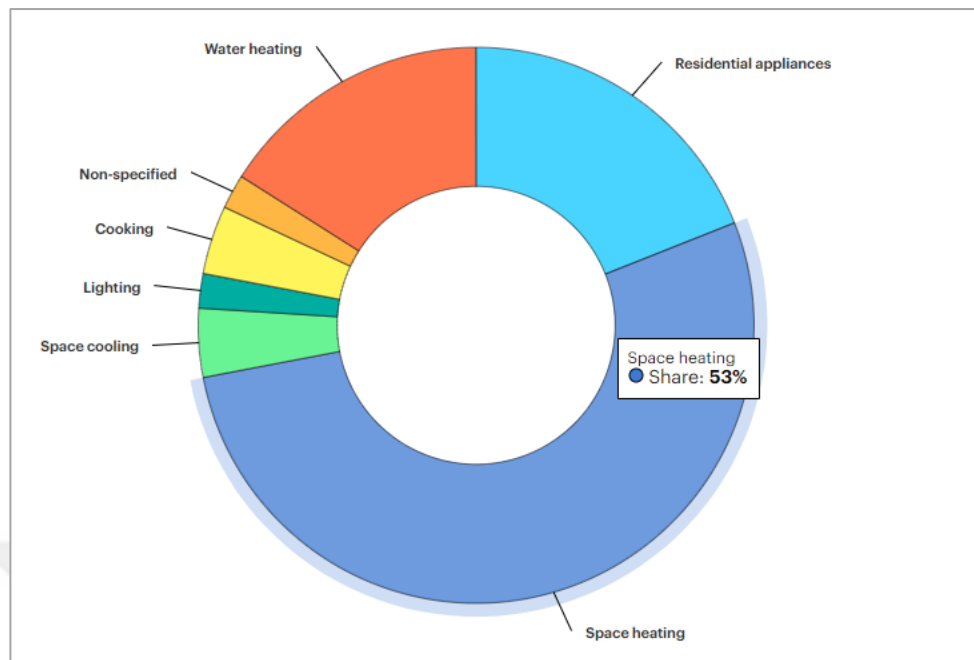


Figure 2. 5. Shares of residential energy consumption by end use in selected IEA countries, 2018 (IEA, 2018)

While the shade of the tree impacts saving cooling energy consumption, the wind-shielding effects of the tree decrease both heating and cooling energy use (Akbari et al., 2001). In an experiment made by Parker (1981, as cited in Akbari et. al., 2001), the effect of adding trees and shrubs on the energy consumption of a building was tested in Florida. According to the results, adding trees and shrubs reduce cooling-electricity by up to 50%.

Health benefits (reducing heat-related illness)

Urban temperature regulation service reduces heat-related illness because certain demographic groups are more sensitive to heat stress than others. Hence, they need for urban temperature regulation service higher than the average. **Young children (<5)** and **the elderly (>65)** are vulnerable groups based on their higher sensitivity to heat stress (Basu and Samet 2002; Kenny et al. 2010; Kabisch et al. 2017; Cortinovis and Geneletti 2018). Gronlund and his friends (2015) have been found that there is a correlation between extreme heat and cardiovascular mortality among the elderly by area-level characteristics such as less green space. Another study conducted by

Arnberger and his friends in 2017 analyzed the green space preference of the elderly people on hot days. The study shows that the coping behavior to avoid heat stress is visiting green space which provides shadow and including water components, with easily accessible and cooler environments than their home.

2.6.2 Air purification

Air quality is the main concern of European Union (EU). Several policy tools have been introduced at the European level to enhance air quality in metropolitan areas. Over the last two decades, most of the policies have focused on controlling anthropogenic emissions of air pollutants from specific sources and sectors (Baró et al., 2014). Urban natural areas reduce the concentration of chemicals in the atmosphere and ensure air purification.

Benefits of air purification in urban areas

Improving air quality

In research conducted in 2014, Baro and his friends highlighted the contribution of ecosystem services provided by urban forests in Barcelona to enhance the quality of life in the city via improving the air quality and climate change mitigation. In the study, city-based emissions (road transport, residential and tertiary, industry and energy generation, and port activity) and background pollutions (recorded by the monitoring stations in the city) were used to determine the pollution levels in the city. According to the study, annual total air pollution removal by air pollutant was estimated at 305.6 t with monetary value of 2.38 million USD year⁻¹ by urban forests of the municipality of Barcelona in 2008.

Pollutant parameters and their sources are given in Table 2. 6.

Table 2. 6. Pollutant parameters and their source (Union of Chambers of Turkish Engineers and Architects Chamber of Environmental Engineers, 2018)

Pollutants	Source
SO ₂	Burning of fossil fuels Emissions from vehicles
NO ₂	Emissions from vehicles High temperature combustion
Particulate Matter (PM)	Industry Burning of fossil fuels Emissions from vehicles Agricultural and secondary chemical reactions
CO	Incomplete combustion Emissions from vehicles
O ₃	nitrogen oxides emitted from vehicle, industrial activities, and volatile organic (VOC) compounds react to sunlight

Health benefits (reducing breath-related illness)

According to research conducted by Makri and Stilianakis in 2008, fetuses and children, the elderly, and persons with pre-existing diseases group are more vulnerable to the damaging health effects of air pollution. The effects of different air pollutants on human health can be different. Pollutant parameters and effects are given in the Table 2. 7.

Table 2. 7. Pollutant parameters and their effects (Union of Chambers of Turkish Engineers and Architects Chamber of Environmental Engineers, 2018)

Pollutants	Effects
SO ₂	Respiratory diseases Acid rain
NO ₂	Eye and respiratory diseases Acid rain
Particulate Matter (PM)	Cancer, cardiovascular disease Respiratory diseases Increase in infant mortality
CO	Decrease in the oxygen carrying capacity of the blood by combining with the hemoglobin in the blood Death
O ₃	Respiratory system problems Eye and nose irritation Asthma Immune system disorders

According to World Health Organization, PM pollutant level is the current best indicator to measure health effect of ambient air pollution (WHO, 2014a). As Table 2.7 shows, exceeding PM level in cities cause cancer, heart disease, respiratory illnesses, and increases infant mortality.

According to research conducted in Columbia University, there is a direct correlation between the number of trees in the neighborhood and allergy and asthma diseases (Lovasi et al., 2008). The study also showed that the addition of 343 trees per square kilometer reduces the incidence of asthma among children aged 4 to 5 years, by 24 to 29%.

2.6.3 Climate Regulation

Carbon sequestration is defined as the process of capturing and storing atmospheric CO₂. In carbon cycling process, most CO₂ emission appear from urban areas or related with urban dweller's activities. According to the Intergovernmental Panel on Climate Change (IPCC), greenhouse gases (GHG) emitted from four main sectors: energy; industrial processes and product use; agriculture, forestry, and other land use; and waste (2006). As cited in Dodman article, the main sectors, sub-sectors, and assessed GHG was given in the Table 2. 8 (2009).

Table 2. 8. Sectors and gases assessed for national greenhouse gas inventories (Resource: Dodman, 2009: page 187)

Sector	Sub-sectors	Greenhouse gases assessed
Energy	• Stationary combustion • Mobile combustion • Fugitive emissions • CO₂ transport, injection and geological storage	• Carbon dioxide • Methane • Nitrous oxide • Hydrofluorocarbons • Perfluorocarbons
Industrial processes and product use	• Mineral industry emissions • Chemical industry emissions • Metal industry emissions • Non-energy products from fuels and solvent use • Electronics industry emissions • Emissions of fluorinated substitutes for ozone-depleting substances • Other product manufacture and use	• Sulphur hexafluoride • Nitrogen trifluoride • Trifluoromethyl sulphur pentafluoride • Halogenated ethers • Other halocarbons
Agriculture, forestry and other land use	• Forest land • Cropland • Grassland • Wetlands • Settlements • Other land • Emissions from livestock and manure management • N₂O emissions from managed soils, and CO₂ emissions from lime and urea applications • Harvested wood products	
Waste	• Solid waste disposal • Biological treatment of solid waste • Incineration and open burning of waste • Wastewater treatment and discharge	

SOURCE: Intergovernmental Panel on Climate Change (2006), *Guidelines for National Greenhouse Gas Inventories*, Cambridge University Press, Cambridge.

The presence of significant carbon-retaining areas (carbon sinks) such as forests, peatlands, oceans, and lakes regulate the release of greenhouse gases into the

atmosphere and ensures the regulation of the climate both locally and globally. High concentration of CO₂ and other GHG cause increase in atmospheric temperature. Excess of CO₂ have direct connection in terms of heating the air in the atmosphere and creating pollution. So that, climate regulation ecosystem service has also direct relation with regulating urban temperature and air purification ecosystem services. Suggested design inputs for both services are valid for climate regulation.



Benefits of climate regulation services in urban areas

Carbon mitigation

Cities are responsible for 75% of the global CO₂ gases emission because of transportation and building activities (UNEP, n.d). The role of urban trees is acting as a sink of CO₂ by storing excess carbon as biomass and fixing carbon during photosynthesis (McPherson and Simpson, 1999). The term carbon mitigation is used to refer to reduce emission of and stabilize the levels of GHG in the atmosphere (NASA, n.d). Vegetation and soil in urban green space are successful to remove CO₂ from the atmosphere and storing carbon (Linden et. al., 2020). The carbon retention of trees also changes according to factors such as climatic conditions, genetic features, physical properties (height, diameter, etc.) and volume increases of the tree species (Pamukçu-Albers et al., 2018).

Health benefits

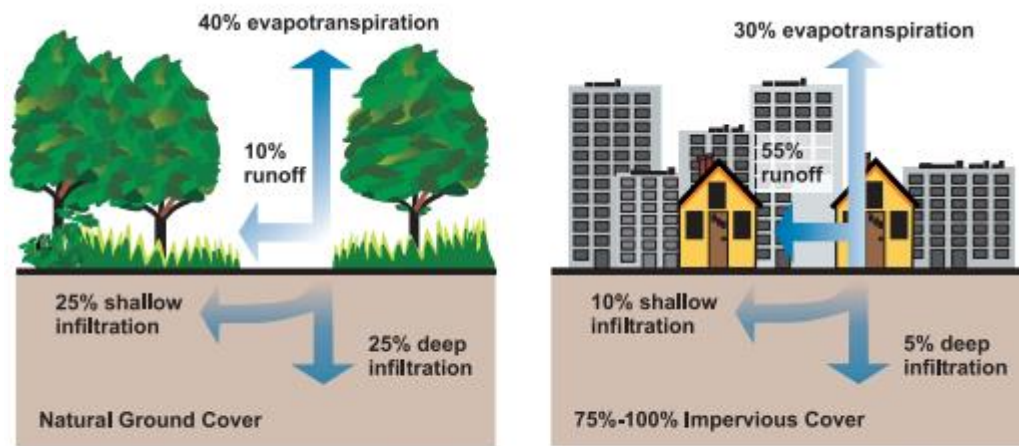
Because CO₂ is main contributor to air pollution, the health benefits of climate regulation service is parallel to *air purification* service which is discussed in previous section.

2.6.4 Runoff mitigation

Among the important regulating ES are the facts that natural elements in an area affect the water holding capacity of that area and consequently the decrease of floods. In urban areas, impermeable surfaces (asphalt, concrete, marble, etc. flooring materials, and buildings) become a barrier for water to reach the soil, thus reducing soil absorption and increasing surface flow. It is called urban runoff. In urban areas with 50 to 90% impermeable surface, 40 to 83% of precipitation flows as surface water flow; this rate may fall up to 13% in forest areas (Bonan, 2002).

For example, in New York City, only trees on the streets hold 28 million tons of rainwater annually (Peper et al., 2007). In cities, water retention landscapes are

designed to regulate precipitation water. While the risk of floods is reduced by these structures which emit rainwater, spread, reduce the flow rate, and increase the absorption by the soil, the water requirement of the vegetative tissue of the city can be met from the precipitation water. Although rain gardens are the most typical example, road trenches, excavation-filling slopes, or collecting water reservoirs or larger-scale cisterns are examples. For example, green roofs can hold rainwater up to 25% to 100% depending on depth and roof slope (Oberndorfer et al., 2007).



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

Figure 2. 6 Relationship between impervious cover and surface runoff. (Resource: EPA, 2003: 1)

In addition to directly damage of heavy rainfall, urban runoff also leads to series of cascading events on transportation, wastewater, electricity, and water. Cascading events from floods is described as situations where floods have a single or many detrimental effects on the operational capability of other urban infrastructures and their services (Hilly, et. al. 2018).

Benefits of runoff mitigation in urban areas

In this study, benefits of runoff mitigation service areas will refer to prevent cascading effects in heavy rainfalls.

The study which aims is presenting a framework for analyzing cascading effects from flood events mentioned as starting point for some common services and their interdependencies in the Figure 2. 7 (Hilly, et. al., 2018).

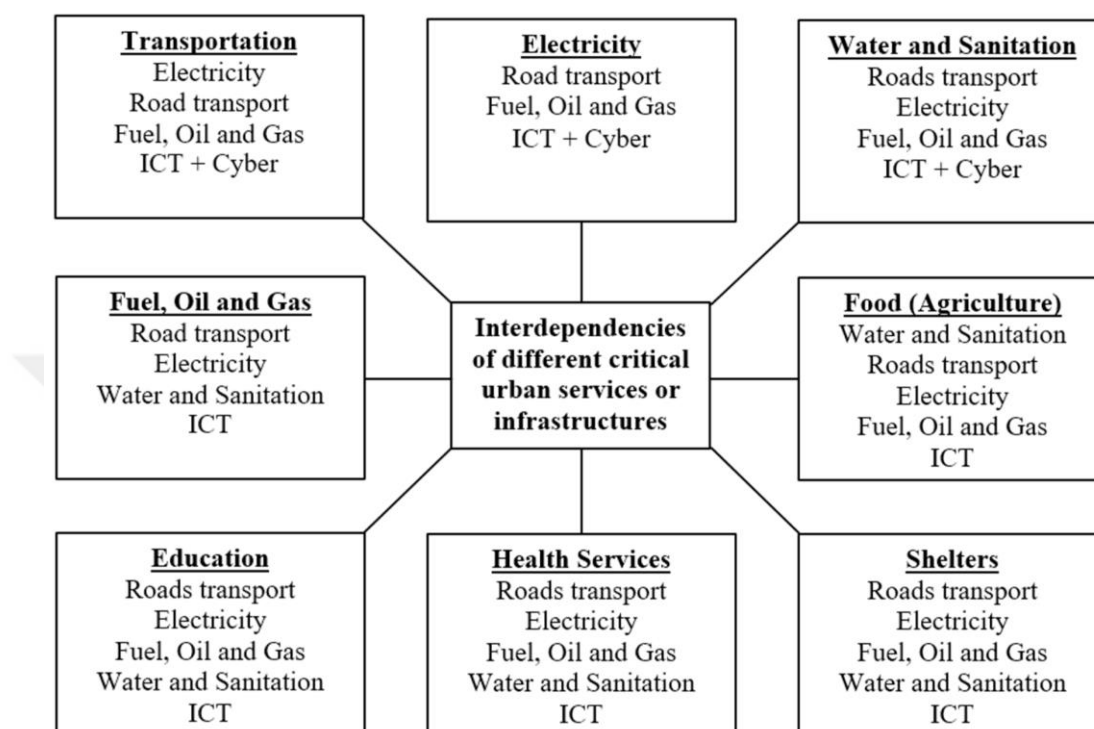


Figure 2. 7. Example of interdependencies between critical urban services and their infrastructures (Resource: Hilly et. al., 2018; page:2)

Impact on water supply services

Urban runoff carries the main pollutants which sourced into four categories: activity-related (road transport emissions), land cover-related (buildings and infrastructure), behavior related (pesticide and fertilizer use), plus atmospheric deposition (AD) (Petrucci et. al., 2014). These pollutants directly mixed into streams and rivers, where they seriously harm to human health and ecosystems. Minimizing runoff leads preventing water bodies from the pollution, and protect water quality and groundwater sources (EPA, 2003).

Impact on transportation services

The frequency of flooding in cities has a negative affect on vital urban infrastructure, public services, productivity, and inhabitants' livelihoods. It has considerable impact on driver behavior causing traffic congestion more serious (Zhu et al.,2018). It causes increasing travel distance, cost, and time. As a result, it effects economic and social activities aimed at the destination (Hilly, 2018). Traffic congestion due to urban runoff also affect the business interruptions, extra CO₂ emissions and increased fuel usage. More importantly, emergency services used for vital situations in the city, such as fire trucks, ambulances, and police cars, can be delayed due to traffic delays.

Impact on power supply services

During flood, power units are impacted. This will cause other services to be disrupted. According to Hill et al. (2018), the following are some of the most common effects of power outages: parts of telecommunication systems have been disrupted; problems as a result of high temperatures and cooling such as air-conditioning usage; unless backup generators are available, this will have an impact on perishable foods; traffic delays caused by traffic light outage; disruption of water and sewerage services (pumping stations power failure).

2.7 Supporting and Habitat Services

Habitat is described as a natural environment with physical boundaries that allows vital activities of species such as food, breeding, migration, and expansion. Ecosystems provide everything a single plant or animal needs to survive. Urban ecosystems have an essential place for migrant species such as birds, amphibians, bees, and butterflies (Müller et. al., 2010).

Green areas' naturalness impact on people has been investigated in Gothenburg, Sweden (Knez et. al., 2018). According to the research, it has been determined that people's attachment, closeness, belonging, establishing an emotional connection

with the place, cognitive levels (remembering, thinking) are higher in the areas where the naturalness is high.

Enhancing the capacity of supporting and habitat services is direct and indirectly related with other UES.

2.8 Cultural Services

Cultural services are services that focus on people's interactions with nature. Cultural services are non-material benefits that directly related to the feelings people get from nature, aesthetic experiences, inspiration, and happiness from activities in nature. According to the URBES project, cultural ES are among the most important services offered in urban areas. Because people value spiritual, educational, and aesthetic values, cultural ES are often the most intimate connections between people and the environment.

Because cultural ecosystem services are directly related with human experience, it has become unclear to measure, type and number of services. They contribute human health and well-being, fostering social cohesion, and developing sense of place.

2.8.1 Recreation

Recreation is all the activities that people voluntarily carry out in order to meet their needs such as pleasure, satisfaction, peace and entertainment in their spare time (Pigram, 1983). Recreation services is described in the Common International Classification of Ecosystem Services (Haines-Young and Potschin, 2013) as an important service that benefit people through enhancing the physical health (via e.g. exercise); and psychological and emotional well-being. In other words, the natural environment contributes to people experiencing and enjoy nature.

Ecological characteristics affects the recreational value of the park (Gómez-Baggethun et al., 2013). In the study, recreational and ecological values of the park is associated with the habitat services.

Since recreation ecosystem service is based on spending time in nature and connecting with nature, its benefits are parallel to the food production service. In the study, education opportunities, health benefits, and social cohesion and integration benefits were also accepted as recreational service. As mentioned in previously in food production benefits, spending time in nature contributes to relieve stress, improving concentration, enhancing social, physical and mental abilities. Therefore, recreational service has positive impact on *increasing workforce and productivity* indirectly.

2.9 Urban design strategies to enhance ES capacity in urban parks

In this section, the strategy to increase the capacity of each selected ES is discussed separately and the urban design inputs that will increase the service are presented. The determination of urban design inputs has been based on the development of the ecosystem function. For these reasons, in each section, firstly, the definition of ecosystem function and its relationship with ecosystem service are given. As mentioned in the previous sections, ES is defined by Brown et al. (2007) as “the specific results of ecosystem functions that either directly sustain or enhance human life.”

In the study, urban design inputs are given in three different scales. These are urban, street and park scales. The main purpose of giving in this way is that green areas in the city should be considered holistically in order to increase the potential of providing ES. There are similarities between ecosystem functions in different ES. For example, climate regulation ES is highly related to air purification ES in terms of air pollution resulting from anthropogenic activities increases carbon and other gases. In addition, it is also related with reducing UHI in context of these gases

condense in the city and cause the air to warm up. So that, the strategy and urban design inputs to improve climate regulation ES provision directly cover the other two ES.

2.9.1 Decreasing UHI effect via increase cooling capacity

To reduce urban heat stress, ecosystem functions that will increase the cooling effect at city, street and park scale can be used as design input. There are three ecosystem functions that influence the cooling capacity of GI: ***evapotranspiration (ETA)***, ***absorbing solar radiation (shading)***, and ***air flow and heat exchange (wind)*** (Geneletti et. al., 2019). The most significant contributors to the cooling impact of UGI are shading and evapotranspiration (Skelhorn et. al., 2014).

According to Urban Heat Island Strategy for City of Vienna prepared by Vienna Municipality (2018), there is comprehensive urban design actions to decrease UHI in the city. These actions are evaluated and presented as urban design inputs that will support the ecosystem function.

To support air circulation in urban scale, ***UGI networks connection*** in and around to city is essential. The creation and maintenance of axial corridors can support urban air circulation and provide fresh air for surrounding areas. Especially, connecting corridors between peri-urban areas which agricultural and forestry areas are located can promotes to cool air. It's important to consider how the geography of the surrounding area affects the air temperature. For example, forests and greenspace promotes generation of cool air, and slopes and hillsides support airflow. In fact, geographically based downdrafts and mountains are important sources of fresh air, and airflow contributor for urban areas. They also help remove greenhouse gases and improve air quality. Because the built environment elements, such as high-story buildings negatively effect on air flow, there should be ***avoided to building blocks parallel to slopes***.

With a high heat storage capacity, water can help lower temperatures in large, deep, and still bodies of water. The temperature difference between the day and night is generally lower. Also, it can contribute to the overall humidity in the environment. In urban scale, **increasing UGI along the waterways**, and avoiding built infrastructure can help to cool air flows.

A water-permeable layer can be built over a porous surface to provide waterproofing for pavements. Also, breathable materials can be used to prevent water evaporation. Increasing permeable surfaces inside the park and streets encourage in-situ rainwater evaporation. Some examples of **permeable surfaces** which are shingle grids, gravel lawns, bark chippings, and pebbles can be used to prevent water evaporation. For areas where porous concrete is preferred, wood blocks or timber grids are also suitable.

More water component creation, such as outdoor pools, and water-playgrounds for children, fountains increase water evaporation. Collecting water in **retention ponds, swales, and lakes** helps to increase evaporation. **Infiltration ponds** are used to collect rainwater that flows into water-permeable embankments. The plants then evaporate the water. This produces a beneficial microclimate. Water conservation measures help minimize the burden on the sewer system and treatment plants.

Urban vegetation can be irrigated using various systems such as **rain gardens**, underground water storage, and roof run-off. The maintenance of green spaces and vegetation can be adapted to the varying heat loads. It is necessary to water and irrigation to maintain plant functions.

Tree canopy coverage, size and soil cover are the three different components of UGI that related with shading and ETA (Geneletti et. al., 2019). The term "Urban Tree Canopy" (UTC) refers to "the layer of tree leaves, branches, and stems that provide tree coverage of the ground when viewed from above." (USDA, 2019). **Large-canopy trees** have more shading capacity. Shading capacity has direct relation with tree canopy size. So that, one side or double side of the street with deciduous trees can reduce street heating.

In building scale, to preventing from heat storage and reducing solar radiation, **lighter-colored buildings, greening façades-walls-roofs** and **water-based cooling (such as blue roofs)** can be implemented. Blue roofs provide thermal storage and cooling, and it can retain rainwater during heavy rainfall events.

Some of the design inputs also helps to support other ecosystem services. Such as green corridors, creating new connections, enable to walking, cycling and other non-motorized activities (recreational services); increasing connectivity between different habitats (supporting habitat services) transition of animal species; improvement of current green ad open spaces habitat quality; support to remove pollutants (air purification services).

2.9.2 Enhancing air quality

To improve air quality, ecosystem functions that will increase the air purification effect at city, street and park scale can be used as design input. There are two ecosystem functions helps to reduce air pollutants: **deposition and dispersion**.

Urban vegetation can help minimize air pollution by changing the speed and distance of pollutants traveling across the city. This process is known as dispersion. Urban vegetation can reduce air pollutants by taking a small portion of their emissions. This process is known as deposition and is usually less important for reducing air exposure than dispersion (Greater London Authority, 2019).

In urban scale, **green corridors** lead to air flow and helps to reduce exposure to air pollution. **Vegetation barriers** such as trees and shrubs located near-road can provide a semipermeable barrier to main airflow carrying air pollutants. It also increase the extending the distance between human and air pollutant source such as motorized-vehicles (Hewitt et. al., 2019). Thick vegetation may merely produce air turbulence, but a thinner cover may allow air to pass through and support air filtration (Bolund and Hunhammar, 1999).

By a process known as deposition, urban vegetation generally eliminates a few percent of pollutants. When pollution settles on the surface of a leaf, it gets cleared from the air. This mechanism is less significant than dispersion for minimizing exposure to air contaminants in the urban environment. (Greater London Authority, 2019).

In **roadside vegetation**, air purification performance between plant and tree species varies between species. Particularly, trees in the city have been shown to be important in capturing air pollutants (Aylor et al. 2003). For example, deciduous trees have higher performance in capturing air pollutant particles than evergreen trees. Different particle size fractions also vary between species according to leaf width and waxy presence (Dzierzanowski et al. 2011). At the same time, daily (day and night changes), monthly (changes in sunbathing hours) and annual (seasonal changes) affect the performance of plants and trees to absorb daily pollutants. In addition, fossil fuel consumption for heating seriously reduces the air quality of the city in winter season. Coniferous trees have a greater filtering capacity than deciduous trees due to the higher overall surface area of their needles (Stolt, 1982). Since coniferous trees do not shed their leaves in winter, they have a greater capacity to hold air pollutants throughout the year. As a result, a **mix of species** appears to be the best option (Bolund and Hunhammar, 1999).

According to the study (Currie and Bass, 2008), trees and shrubs are more effective at reducing air component than **green walls** and **green roofs**. However, **shrubs** and **intense green roofs** are the most cost-effective alternative in high-density areas with limited space for trees.

2.9.3 Supporting climate regulation

Carbon sequestration and storage by fixation in photosynthesis that contributes to climate mitigation (Gomez et. al., 2013). By storing extra carbon as biomass during photosynthesis, urban trees acting as CO₂ sinks. Because the quantity of CO₂ retained

by trees is proportional to their biomass, increasing the number of trees in urban areas might possibly delay the accumulation of atmospheric carbon. As a result, tree-planting initiatives are an appealing alternative for climate change mitigation in cities (Gomez et. al., 2013).

CO₂ excesses have a direct link to heating the air in the atmosphere and causing pollution. As a result, the ecosystem service of climate regulation is linked to the ecosystem services of controlling *urban temperature* and *air purification*. For climate regulation ES, the suggested design concepts for both services are applicable.

2.9.4 Enhancing runoff mitigation

Percolation and regulation of runoff and river discharge are ecosystem functions that contribute to runoff mitigation in cities. Filtration of water through soil and plant helps to purify it and lowers the quantity of water and contaminants that run untreated into storm drain systems and local waterways.

Restoration works to be carried out on the flood plains in the lower basin will allow to prevent damages and losses caused by flood events in urban, sometimes in regional scale (Demirbaş Çağlayan et. al. 2020).

Instead of grass, using ***native vegetation*** has multiple benefits such as conserving native plant species, enhancing quality of water, and support wildlife habitat. This method of lawn replacement works by capturing rainwater that's collected by the plants. This method can also be used when soils are not ideal for infiltration.

A ***bioretention area*** is a type of ***rain garden*** that's designed to reduce the pollutants, collect, and store water when it cannot easily pass through the soil. These areas are usually bigger and more durable than traditional rain gardens.

In building scale, instead of draining onto the pavement, roof gutters can be directed to areas where the water can be filtered and reused. Having ***disconnected downspouts*** helps conserve the water that flows into local streams and wetlands.

A rain barrel or cistern is a type of water storage device that collects rainwater from a gutter downspout. It is called **water harvesting**. It is commonly used to store it temporarily for irrigation or to keep it from mosquitos.

Permeable pavements are durable and can withstand rain. They can be made from various materials such as concrete, asphalt, and porous concrete. It can be used in combination with other sustainable solutions such as rain gardens and bioretention areas.

Green roofs are designed to retain water and release the water via evaporation. They can be installed over an existing roof. These roofs feature a load-bearing capacity that can handle rain and provide a great environmental benefit such as cooling/heating energy use (as mentioned in UHI section) and support wildlife habitat.

Some of the plant species can purify runoff water via **helophyte filters** which is planted with reeds and works as biological treatment. It works by attracting bacteria that live in the roots. The primary functions of the reeds are to aerate the roots and extract nitrates and phosphorus (Aquarama, 2011).

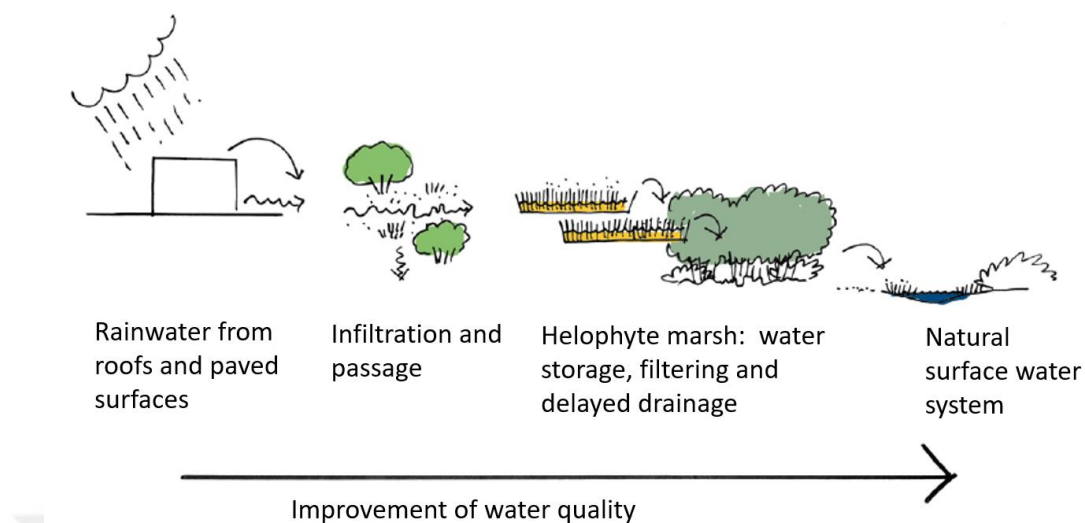


Figure 2. 8. The principle of the natural water system (Tilburg Municipality, 2020: Nature and Cities Project, Green Infrastructure and Nature Based Solutions Workshop 2020)

2.9.5 Supporting habitat for biodiversity

Creating habitats for birds and insects is important to preserve biodiversity and provide educational function to the human being in an urban environment (Persson & Smith, 2014). A suitable habitat may offer breeding and overwintering grounds for a wide range of species, contributing to a variety of ecosystem services year after year (Persson and Smith, 2014).

SFEI's (San Francisco Estuary Institute) published report (2019), aims to develop a scientific approach to supporting nature in cities, and synthesizes global research on urban ecosystems. According to the report, there are seven key elements in multiple scales to support biodiversity in urban areas. These elements are related with Patch size (size of green areas), Corridors (connection with green areas), Matrix Quality (the quality of green areas to support biodiversity), Habitat Diversity (distribution of habitat types), Native Plant Vegetation, Special Resources, and Management. In my study, these first six elements are implemented as design inputs to support habitat for biodiversity.

A study published in 2015 (Beninde et al.) identified the size of green areas as one of the most important factors in determining the level of biodiversity in urban green areas. **Larger green area size** supports more species to sustain their life in terms of finding adequate resources. In addition, larger population can help prevent local extinction and population crashes. It can also support more species if its size is less isolated. Similar-sized patches can also support biodiversity if they have a low edge area and are less isolated than their core area (Soga et al., 2014). Low edge area, such as **square or circular form of green areas** have more core habitat and less perimeters. Thus, it increases the probability of survival of the species sensitive to the area (SFEI, 2019).

High connectivity between green areas is one of the most important elements to support biodiversity in urban areas (Beninde et al., 2015). **Green corridors** with less barriers support to species move freely to access resources, gene flow and present suitable conditions during their different life stages (SFEI, 2019). Green areas connectivity can be provided with **greening streets, riparian corridors, wildlife crossings, and greenways**.

Creating habitats can be done in many ways. Some of these include putting up **birdhouses or feeders** to attract small bird species. A good place to set up an insect hotel is a sunny and sheltered location, close to a plant with good pollinated opportunities. An exposed nest box can offer a better environment for building a nest, but it can also be very attractive to predators (Persson and Smith, 2014).

Greenspace's capacity to support biodiversity depends on the quality of the surrounding habitats. High-quality habitats are associated with a greater diversity of species (Goddard et al., 2010). Greening techniques can improve the quality of the urban landscape by increasing the diversity of plants and trees along streets and in resident's gardens (SFEI, 2019). Tree canopy size, richness and abundance of native plants has been found to improve biodiversity (SFEI, 2019). Vertical green areas with high complexity of vegetation such as shrubs, existence of large trees, water component and special resources can improve to enhance the quality of green areas

to support biodiversity (Belaire et al., 2014). Considering all these, are **street trees**, **raingardens**, **bioswales**, **bioretention basins**, **green roofs**, and **green façades** are urban design elements to effect quality of green areas.

Habitat diversity can increase the number of species because it allows them to access resource multiple habitat types as take up more space and resources. Creating a diversity of habitat types, such as riparian vegetation will provide resources to wider range of species even highly specialized to one habitat type (SFEI, 2019).

Preferring **native plants** rather than lawn for plantation, can contribute to diversity of wildlife better (SFEI, 2019), improve soil conditions by facilitating nitrogen cycling, regulation pH and other chemicals (Dahlgren et al., 1997), and enable interdependent interactions between microbial populations (Dahlgren et al., 2003) and other plants. Native plants need less fertilizer, and water.

Because all species are dependent on water, **water component** are greatly related with higher biodiversity (Beninde et al., 2015). They serve as hubs for various terrestrial and aquatic species (Hill et al., 2017).

According to Yin (2017), **dead trees** are good habitats for various plants and animals. It can also be used to create a habitat for insects. It can be hung from a tree branch to create a shelter for animals.

2.10 Concluding Remarks

Based on previous theoretical discussion, there are several points and concepts highlighted as a guide for next chapters of this research. First, understanding natural and green areas in the city from an ES perspective requires an insight about the definition, classification, and value of ES. Nature alone meets all the needs that can ensure the continuity of human life.

UGI and NBS, as part of GI, is the main ES providers in urban areas. Urban parks are the component of UGI and defined as SPU in this study. Anthropogenic activities

in cities directly or indirectly affect ES delivery negatively. There are many diseases that affect people's health and well-being due to lack of ES. In addition, it causes disruptions in essential urban services. It is so critical to conserve, repair, and enhance UES in order to maintain livable, sustainable, and resilient cities.

This study focuses on 7 selected services which are food production, urban temperature regulation, air purification, climate regulation, runoff mitigation, habitats for biodiversity and recreation.

In this chapter, the importance of each selected ES is discussed over benefits to urban services and human-welfare. Each services' benefits were grouped under broader categories. In the study, the people most affected by the lack of these ecosystem services and the most vulnerable urban services were identified as the primary beneficiaries. With the light of this chapter, *primary beneficiaries* related demographic characteristics, their use of land and their place of residents tried to be revealed.

The possible urban design strategies is defined for each services. This strategy includes GI and NBS solutions in three different scales which are urban, street and park. Although ES are examined in separate groups, they are closely related to each other. Therefore, the design inputs to increase the capacity of some services may also apply to another service.

It has been concluded from the literature review that food production in the city will not meet the need if it is not handled at city or region scale. So that, design inputs are presented only for parks that will be possible to implement for food production. However, it was added as a design input by considering solutions to support food production in the city.

Since enhancing **habitat service for biodiversity** service supports the healthy habitats and continuity of ecosystems, it has been revealed that the urban design inputs for this service is *cross-cutting* issue to suggest for each park.

Cultural ecosystem services are directly related to people's experiences in nature. Therefore, different usage functions were defined according to primary beneficiaries instead of presenting the urban design inputs that will increase **the recreation service**. Because it includes human-nature connection, this service is also highly related with food production service.

Food production in urban areas provide *nutrition and food security, education opportunities* via transferring tacit knowledge (Barthel et. al., 2013), learning about ecological processes, biodiversity and producing food (Bellows, A. et. al., 2008), being familiar with good and healthy food habits; teach a skill and enhance people social, physical, and mental abilities (Bellows, A. et. al., 2008), relieving stress, improving concentration, assisting, collaboration and cooperation in social life, improving personal development skills in young people (Rogers, 2018); *health benefits* via having high nutritional value (Bellows et al., 2008), good exercise for health, reducing coronary heart disease especially for menopausal women and elderly men (Bietz and Doren, 2004), reducing diabetes and glucose tolerance for adults and elderly men (Van Dam et al., 2002), increasing strength and endurance of the muscle in activity-reduced person (Evenson KR, et al. 2004; Irwin 2004; Rolland et al. 2004; Wannamethee and Shaper 2001; Wannamethee et al. 2000), combating social isolation, developing social network, improving emotional, physical, and spiritual renewal (Milligan et al., 2004); and *social cohesion and integration* via bridging racial divides by bringing people of different ages, races, and income levels together (Lin et.al., 2017), learning to work collectively (Stocker and Bernett, 1998), connecting between consumers and producers (Specht et al., 2013), preventing crime, supporting cultural diversity, enhancing community strength and promoting active citizenship (Warner and Hansi, 1987; Murphy 1999). Since food production in cities is related to both the experiences of the citizens and the product obtained as a result of their experience, it has been handled a little differently than other selected ecosystems.

Benefits of **urban temperature regulation** service are *decreasing energy consumption* via decreasing both heating and cooling energy use (Akbari et al.,

2001), *health benefits* via providing cooling affect for people who have higher sensitivity to heat stress, reducing cardiovascular disease mortality rate (Gronlund et.al., 2015).

Air purification services in urban area provide *improving air quality* through removing city-based emissions (road transport, residential and tertiary, industry and energy generation, and port activity). Low quality of air leads to reduction of life quality standards, and negatively impacting *health*.

Climate regulation service allows to *improve health* and providing *carbon mitigation* in urban areas. Because CO₂ is a major air pollutant, climate regulation and air purification ES benefits were evaluated in the same perspective in the study.

Runoff mitigation service was linked to preventing cascading effects of heavy rainfall. It contributes to preventing the consequences of runoff in urban areas. These consequences were grouped under three categories. These ara impact on water supply, transportation and power supply services

Habitat for biodiversity service is directly and indirectly affect to other services, because its related with habitat's health.

The discussions provided in Chapter 2 helped the author in (1) benefits of selected ES (2) identifying prior beneficiaries for each ES (3) urban design inputs to increase ES provision capacity in three different scales. While first two instruments will be an input of analysis tool which will be discussed in next chapter, 3rd will be used according to analysis tool results.

Table 2. 9. UES benefits, benefit explanations and prior beneficiaries.

	Benefits	Benefit explanations	Prior beneficiaries
Food Production	Nutrition and food security	transfer collective knowledge of how to grow food, thus create local ecological and social response capacity against major collapses in urban food supplies (Barthel et al. 2013) Food production in urban areas; urban agriculture; has played an important role in terms of food security and urban economy at certain times in some geographical regions, especially in times of economic and political crisis (Barthel & Isendahl, 2013).	Everyone
	Education opportunities	Transferring tacit knowledge (Barthel et al., 2013) Learning about ecological processes, biodiversity and producing food (Bellows, A. et. al., 2008) Being familiar with good and healthy food habits; teach a skill and enhance their social, physical, and mental abilities (Bellows, A. et. al., 2008) Relieving stress, improving concentration, assisting collaboration and cooperation, improving personal development skills in young people (Rogers, 2018)	Elderly people Young people
	Health benefits	High nutritional value (Bellows et al., 2008) Good exercise for health. Reducing coronary heart disease especially for menopausal women and elderly men (Bietz and Doren, 2004) Reducing diabetes and glucose tolerance for adults and elderly men (Van Dam et al., 2002) Increasing strength and endurance of the muscle in activity-reduced person (Evenson KR, et al. 2004; Irwin 2004; Rolland et al. 2004; Wannamethee and Shaper 2001; Wannamethee et al. 2000) Combating social isolation, developing social network, improving emotional, physical, and spiritual renewal (Milligan et al., 2004).	Elderly people Young people
	Social cohesion and integration	Bridging racial divides by bringing people of different ages, races, and income levels together (Lin et al., 2017) Bridge the gap between consumers and producers (Specht et al., 2013) Learning to work collectively (Stocker and Barnett, 1998) Preventing crime, supporting cultural diversity, enhancing community strength and promoting active citizenship (Warner and Hansi, 1987; Murphy 1999)	Citizens who are from different backgrounds, educational areas, adaptation of newcomers to the neighborhood

Table 2. 9. UES benefits, benefit explanations and prior beneficiaries. (continued)

Benefits	Benefit explanations	Prior beneficiaries
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Recreation	Increase in workforce and productivity	spending time in nature contributes to relieve stress, improving concentration, enhancing social, physical, and mental abilities	workers, students
Urban temperature regulation	Decreasing energy consumption for heating and cooling	Saving cooling energy consumption, decreasing both heating and cooling energy use (Akbari et al., 2001)	High heating and cooling energy needed areas High-risk areas where be affected by high and low temperature
	Health benefits	Cooling affect for people who have higher sensitivity to heat stress Reducing cardiovascular disease mortality (Gronlund et al., 2015)	Young children (< 5) and the elderly (> 65) are vulnerable group to heat (Basu and Samet 2002; Kenny et al. 2010; Kabisch et al. 2017; Cortinovis and Geneletti 2018).
Air purification	Improving air quality	Removing city-based emissions (road transport, residential and tertiary, industry and energy generation, and port activity)	High concentrated city-based emission sources
	Health benefits	Low quality of air leads to reduce life quality standards, and negativeley impact on health	Fetuses and children, the elderly, and persons with pre-existing diseases group are more vulnerable to damaging health effects of air pollution (Makri and Stilianakis, 2008) High level of air pollutant concentration causes cancer, heart disease, respiratory illnesses, and increases infant mortality (WHO, 2014a); allergy and asthma diseases (Lovasi et al., 2008).
Climate regulation	Carbon mitigation	Reducing emission of and stabilize the levels of GHG in the atmosphere (NASA, n.d)	
	Health benefits	Low quality of air leads to reduce life quality standards, and negatively impact on health	Fetuses and children, the elderly, and persons with pre-existing diseases group are more vulnerable to damaging health effects of air pollution (Makri and Stilianakis, 2008) High level of air pollutant concentration causes cancer, heart disease, respiratory illnesses, and increases infant mortality (WHO, 2014a); allergy and asthma diseases (Lovasi et al., 2008).

Table 2. 9. UES benefits, benefit explanations and prior beneficiaries. (continued)

Benefits	Benefit explanations	Prior beneficiaries
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Runoff mitigation	Impact on water supply services	Urban runoff carries the main pollutants which harm to human health and ecosystems	Road transport emission, buildings and infrastructure, pesticide and fertilizer use, and plus atmospheric deposition are main four sources of the pollutants (Petrucchi et. al., 2014). business interruptions, extra CO ₂ emissions and increased fuel usage delays in emergency services air conditioning usage, telecommunication systems, backup generators, impact on perishable foods, traffic delays, water, and sewerage services disruption (Hill et. Al., 2018)
	Impact on transportation services	Increasing travel distance, cost, and time	
	Impact on power supply services	Due to power units' disruption results power outages	

Table 2. 10. Urban design inputs to enhance the specified ES capacity.

	Design input		
	Urban	Street	Park
Urban temperature regulation	UGI networks connection avoiding to building blocks parallel to slopes increasing UGI along the waterways	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred rain gardens swales planting large canopy trees in one or double side of the streets lighter-colored buildings, greening façades-walls-roofs and water-based cooling (such as blue roofs) vegetation barriers roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred collecting water in retention ponds, swales, and lakes infiltration ponds rain gardens planting large canopy trees Inside the park, buildings are suggested with lighter-colored, vegetation barriers
	green corridors	roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees	roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees
Air purification	UGI networks connection avoiding to building blocks parallel to slopes increasing UGI along the waterways	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred rain gardens swales planting large canopy trees in one or double side of the streets lighter-colored buildings, greening façades-walls-roofs and water-based cooling (such as blue roofs) vegetation barriers roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred collecting water in retention ponds, swales, and lakes infiltration ponds rain gardens planting large canopy trees Inside the park, buildings are suggested with lighter-colored, greening façades-walls-roofs and water-based cooling (such as blue roofs)
	restoration in flood plains in the	lawn replacement with native plants	lawn replacement with native plants

		roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs	blue roofs)
Runoff mitigation	restoration in flood plains in the lower basin	lawn replacement with native plants bioretantion areas rain gardens disconnection downspouts water harvesting permeable pavements green roofs, green façades, green walls	lawn replacement with native plants plants with helophyte filters bioretantion areas rain gardens disconnection downspouts water harvesting permeable pavements green roofs, green façades, green walls
Habitat for biodiversity	larger green areas square or circular form of green green corridors riparian corridors creating	greening streets wildlife crossing greenways planting high tree canopy sized trees native plants	birdhouses or feeders planting high tree canopy sized trees rain gardens bioswales bioretantion basis green roofs, green façades, green walls leaving dead trees in green areas water component



CHAPTER 3

ANALYSIS TOOL INPUTS

3.1 Research Method

This study is designed to answer how contribution of the urban parks can be maximized to the urban environment via effective planning of ES. To investigate how current UES potential meets citizens' need, an analysis tool is developed. The analysis tool aims to determine an ES function for the urban park to be responsive to the needs of citizens. It guides the determination of urban design inputs that will support to increase capacity of ES function. The analysis tool consists of two main components: i. *ES current capacity*, and ii. *Amount of utilization and beneficiaries*.

An assessment of the *current capacity of ES* in Çankaya was calculated through a six-step process via mapping study in the scope of the EU project that has been mentioned in Chapter 1. These steps are: selection of ES types, mapping method determination, data compilation, mapping and modelling, validation and calibration, and preparation of final maps. Within the scope of the study, ecosystem services are prioritized and selected according to expert's feedbacks, quality, and resolution of existing and accessible data sets. The study is focused on 7 types of ES. These ES are food supply, reduction of a heat island effect, air purification, climate regulation, runoff mitigation, habitats for species, and recreation.

The benefits are categorized under 6 UES with deductive method. Food production (nutrition and food security, education opportunities, health benefits, social cohesion, and integration); urban temperature regulation (decreasing energy consumption for heating & cooling, health benefits); air purification (improving air

quality, health benefits); climate regulation (carbon mitigation, health benefits); runoff mitigation (impact on water supply services, transportation services and power supply services); and recreation (education opportunities, health benefits, social cohesion and integration, increase in workforce and productivity). As inferred from the literature review, habitats for species service is directly related with naturalness, this ES services is accepted as a criteria that can be maximize for every park for healthier environment. The design parameters possible solutions to increase the service delivery capacity of the 7 UES have been determined by considering the benefits and vulnerable groups.

3.2 Research Design

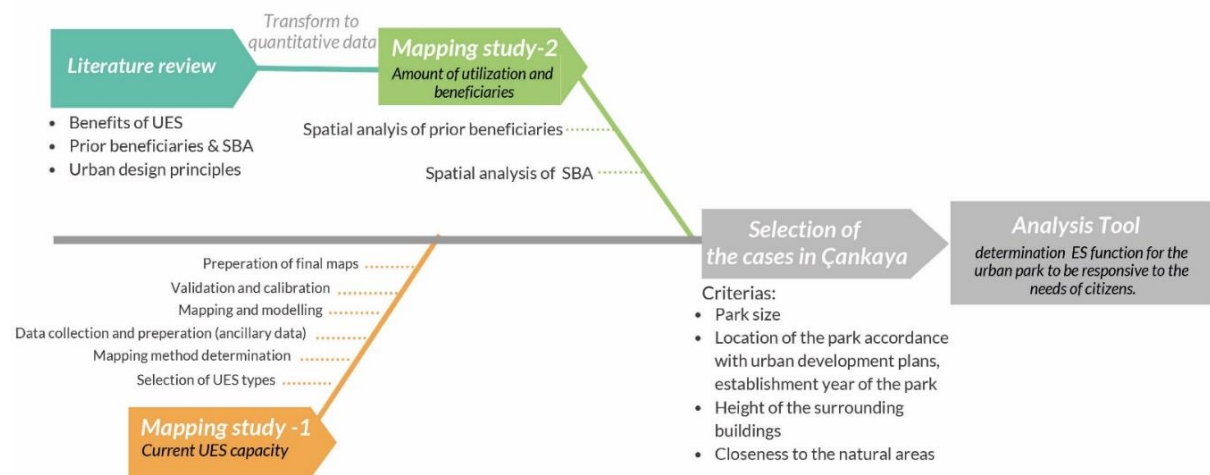


Figure 3. 1. Research techniques, tools and their role

3.3 Site selection

This study asked: “How can be maximized the contribution of the green areas into urban environment via effective planning of the ecosystem services?” To answer this research question, 9 urban parks were selected from different neighborhoods. All selected parks have different layouts and topological relations.

Rapid urbanization in cities, also in Ankara, has threatened ES provision, and causes series of social and environmental challenges. So that, while selecting the study sites, urbanization process, and ecological values were considered.

- i) park size
- ii) location of the park accordance with urban development plans, establishment year of the park
- iii) the height of the surrounding buildings
- iv) closeness to the natural areas

3.3.1 Natural Components of Ankara

The city of Ankara is located between North Anatolia and Konya Plain. It was settled on a rocky area which is surrounded by a mountain belt. The east of the city is located in Kızılırmak and the west is in the basin of Sakarya River. Çubuk Stream, İncesu Stream and Hatip Stream (Bent Stream), which are important water resources of the city. These important streams feed the Ankara Stream, which flows along the east-west axis of the city and originates from the Sakarya River. The geomorphology of Ankara, which began on a hilltop surrounded by two river channels, resembles as a 'calyx' type surrounded by ridges (Yavuz, 2018).

The height difference in different quarters of Çankaya varies over a thousand meters. This active topography also allowed the formation of many valley systems and seasonal streams. The most important surface water asset in the area is Eymir Lake. İncesu Stream, which springs from Elmadağ, flows through the İmrahor Valley and feeds Eymir Lake. Almost all Eymir Lake's waters are supplied by Mogan Lake, which is the southwest neighbor of the area. These two lakes are connected to each other by an underground channel. In addition, the ponds, and wetlands along the Imrahor Valley, the 50. Yıl DSİ Pond in the METU Campus, the ponds in the Bilkent and Hacettepe University campuses constitute other water assets. Mogan Lake,

Eymir Lake and their surroundings are included in the Mogan Lake Important Nature Area and Bird Area.

3.3.2 Brief information of Çankaya and Urban Park Selection

Çankaya, in addition to being the central district of the capital Ankara, is one of the most crowded districts in Turkey. Although the resident population in 123 neighborhoods is 921,999 the daytime population exceeds two million. Over one hundred thousand university students' study at 10 foundation and 8 public universities (Çankaya Municipality, 2019).

According to the data obtained from Çankaya Municipality in 2019, there are a total of 471 parks under the responsibility of Çankaya Municipality. The distribution of these parks by first 10 neighborhoods is as shown in the table below Table 3. 1.

Table 3. 1. Number of parks by neighborhood (Çankaya Municipality,2019)

Neighborhood name	Number of urban parks
Ahmet Taner Kışlalı	22
Ümitköy	21
Birlik	18
Mutlukent	18
Oran	15
Çiğdem	14
Yaşamkent	12
100.Yıl	10
Dodurga	10
İşçi Blokları	10

In terms of urban parks' location in Çankaya, the west and east of METU Campus contain parks with different characteristics and urban development. East of Çankaya

is relatively newly developed urban area. In this area, parks are larger and have fewer children's playground compared to other neighborhoods. The parks in the northwest of the city, close to the city center, are older in terms of their establishment.



Figure 3. 2. Three areas in Çankaya which includes different characteristic of urban parks.

The size of 421 parks in Çankaya varies between 0.01 ha and 49.4 ha. There are 280 parks in between 0.01 and 0.4 ha. Since the selection of relatively smaller parks in the calculation of ES delivery will negatively affect the accuracy of the study, these parks are excluded from the selection criteria. According to the relative area size value, the parks are grouped as small (0.4 – 2 ha), medium (2 – 10 ha) and large (larger than 10 ha.). Secondly, urban parks which have high proportion of grass areas, built surfaces and no trees were excluded. Because some of the parks' responsibilities are in Metropolitan Municipalities, those are neglected. As the study focuses on the ES offered by urban parks, 11 rural neighborhoods within the borders of Çankaya Municipality was also excluded in the selection criteria.

The largest park in the district is Dikmen Vadisi. Then comes the Ellinci Yıl Parkı with 13.95 ha. These two parks were selected as large-sized. Then, the parks from 3 different part of the province were examined by considering urban development plans of Ankara, height of the surrounding buildings, and closure to other urban parks. Details of the spatial characteristics of selected parks will be discussed in 4th Chapter. These features are important to quantify ES capacity in terms of different spatial, morphological, and natural differentiation.

Kurtuluş Parkı, Ellinci Yıl Parkı and Münzeviler Parkı are located in north of Çankaya. The parks are about 1 km from each other. Kurtuluş Parkı and Ellinci Yıl Parkı have similarities in terms of forms, establishment years and large size categories. Münzeviler Park is similar to 50. Yıl Parkı is similar to Kurtuluş Parkı in terms of being in a residential area and urban texture. Kurtuluş Parkı is closer to the city center and surrounded by various land use. Muharrem Kaleli and Ahmed Arif Parkı are in small-sized parks.

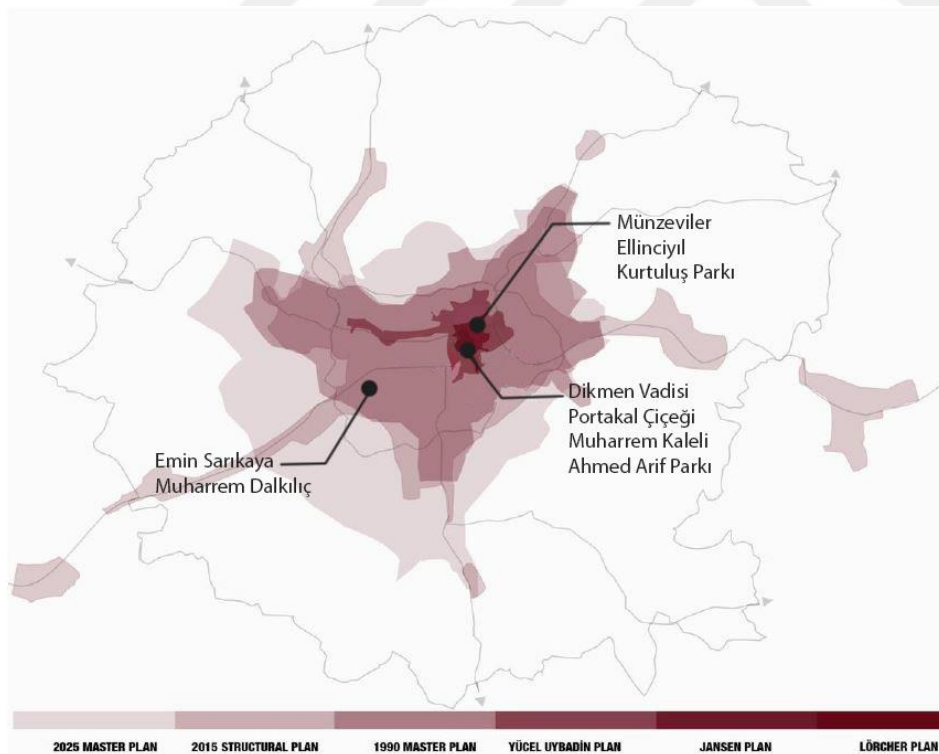


Figure 3. 3. Macroform development of Ankara and selected urban parks (Resource: Kalkanlı, 2019: page 90, Retrieved by the author, 2021)

Dikmen Vadisi, Portakal Çiçeği, Muharrem Kaleli and Ahmed Arif Parkı are located in East side of METU. This area is an older settlement compared to parks in west side of METU. Dikmen Vadisi is the largest parks among selected parks. The establishment years are similar with Portakal Çiçeği Parkı. As Dikmen Vadisi is a valley, it covers a continuous and large area. The land use around it is diverse.

Emin Sarıkaya and Muharrem Dalkılıç Parkı are in relatively newly developed urban areas. While the form of the parks is similar with rectangular shape, sizes are various. Muharrem Kaleli Park is one of the elements that ensure the continuity of green space in this area. While Emin Sarıkaya is in an area with dense residential texture, there are also natural areas around it. The variety of land use around the park is similar.

Table 3. 2. Selected Urban parks and features

Name of the park	Neighborhood	Locational	Size (ha)	Size Category	Establishment Year
Ellinci yıl	50.Yıl	North – east of Çankaya	13.95 ha	Large	1970
Ahmed Arif Parkı	Öveçler	East of METU	1.49 ha	Small	2000
Dikmen Vadisi	İlkadım, Ayrancı and Güzeltepe	East of METU	49.5 ha	Large	1994
Emin Sarıkaya	Koru	West of the METU	2.95 ha	Medium	Before 2000
Kurtuluş Parkı	Fidanlık	North – east of Çankaya	11.46 ha	Large	1980
Muharrem Dalkılıç Koşu Yolu	Ahmet Taner Kışlalı	West of METU	1.90 ha	Small	2003
Muharrem Kaleli	Ata	West of METU	0.89 ha	Small	2009
Münzeviler	Ertuğrulgazi	North – east of Çankaya	1.84 ha	Small	2000
Portakal Çiçeği	Aziziye	East of METU	5.38 ha	Medium	1991

3.4 Data Collection and Preparation

Within the scope of the study, ES are prioritized and selected according to expert feedbacks and the availability of existing accessible data sets. Food production, urban temperature regulation, air purification, climate regulation, runoff mitigation, habitats for biodiversity, and recreation services were mapped.

Ancillary data was collected and information about data with definition, scale, access of data and related ES were shown in Table 3. 3.



Table 3. 3. Ancillary data used in ecosystem service mapping

	Scale/ details	Definition, explanation	Data access	Scope	ES
Corine Land Cover (CLC) 2012. Version 20	1/25.000	“Copernicus is a European program for monitoring the Earth, in which data is collected by Earth observation satellites and combined with observation data from sensor networks on the earth’s surface.”	Open source	Europe	Land cover map Food supply
Çankaya Municipality Land use Plan	1/25.000	This plan includes both projections and current statue of the land uses.	Subject to permission	District	Land cover map Recreation
The Sentinel-2 Global Land Cover (S2GLC)	10*10 m resolution	S2GLC project was founded by the European Space Agency (ESA) in 2017. The dataset is delivered with 10 m spatial resolution with thematic legend composed of 13 land cover classes.	Open source	Global	Landcover map (to validate data) Air purification Climate regulation Runoff mitigation Habitats for species
	30*30 m resolution		Open source	Global	Urban temperature regulation
Çankaya District Governorship, 2019. District Directorate of Agriculture and Forestry 2019 Activity Briefing Report.	Statistical data		Subject to permission	District	Food supply

Google Maps	Variable	Google Maps is a consumer application and web mapping platform developed by Google. Satellite images, aerial photos, street maps, 360° interactive panoramic views of streets, real-time traffic conditions, and route planning for walking, driving, flying, and taking public transportation are all available.	Open source	Global	Validation
Landsat 8 Data	Band 10	Landsat 8 Data Bands 10 is called thermal infrared, or TIR. Instead of measuring the temperature of the air, the band values are based on ground temperature. So that, it is often much hotter. (Loyd, 2013)	Open source	Global	Urban temperature regulation
Yandex Map	Variable	“Traffic by time of day” tool was used.	Open source	Global	Air purification (vehicle emissions)
Digital Elevation Model (DEM)					Runoff mitigation (Slope) Runoff mitigation (Roughness)
Worldclim	1 km ² resolution	The dataset of spatially interpolated monthly climate data for global land areas at approximately 1 km ² resolution (Fick and Hijmans, 2017)	Open source Global		Runoff mitigation
E-bird	Database, citizen-science	E-bird is a web based birdwatching database that provides scientists, researchers, and	Open Source	Global	Habitats for species

Çankaya Province Ecosystem Services Mapping Workshop	Participants	naturalists with real-time data on the distribution and abundance of bird species. database from throughout Turkey since 2002 can store records of volunteer citizen science project is an example. A workshop reports was produced within the scope of Nature and Cities Project supported by the program “Turkey - EU Civil Society Dialogue V” . Food production areas were marked on maps by representatives of municipalities, public institutions, NGOs, academicians who is also city dweller of Çankaya, and headmen of Çankaya rural neighborhoods.	Open Source	District	Food Production Validation
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3.4.1 Land cover map

1:25000 scales Çankaya Municipality Development Plan (2018) has more than 100 different layers. In the planning hierarchy and the legislation, these layers including parks, settlement, commercial, housing, industrial areas, recreational areas, and other areas. However, those layers only cover the urban area. Grouping of land cover and land use data at the rural areas was done by using CORINE 2012 data set. In the scope of the study, this two data was gathered and grouped into three level.

Level 1 covers natural environment and built environment. At level 2, natural environment and built environment classified according to sectors. Natural environment includes natural green areas, urban green areas, and semi-natural green areas. Built environment includes service area, residential area, mining area, industrial area, and transportation. At level 3, further detail is provided as possible (Table 3. 4) according to ecosystem and land use type details. The resulting classes and the areas they cover in Çankaya district and their percentages are shown in the table.

Table 3. 4. The resulting classes and the areas they cover in Çankaya (reproducing land-cover data with Municipality Development Plan and CORINE 2012 data set.)

LEVEL 1	LEVEL 2	LEVEL 3	Area Coverage (ha)	Percentage
Natural environment	Natural areas	Steppe	11362	26.20%
		Rocks	1318	3.00%
		Riparian vegetation	67	0.20%
		Lake	146	0.30%
		Forest	2662	6.10%
		Reedbed	134	0.30%
		Open forest	1909	4.40%
	Urban green areas	Urban green areas	3002	6.90%
	Semi natural areas	Plantation	740	1.70%
		Vineyards and orchards	7	0.02%
		Pasture	637	1.50%
		Irrigated farming	236	0.50%
		Agriculture	10732	24.70%
Built environment	Service area	Working area	2038	4.70%
		Education facilities	1024	2.40%
		Public services	8	0.02%
		Sanitary facilities	216	0.50%
		Tourism area	13	0.00%
	Residential area	Low density urban fabric	3493	8.10%
		High density urban fabric	3258	7.50%
	Mining	Mining	141	0.30%
	Industrial area	Industrial area	140	0.30%
	Transportation	Transportation	84	0.20%

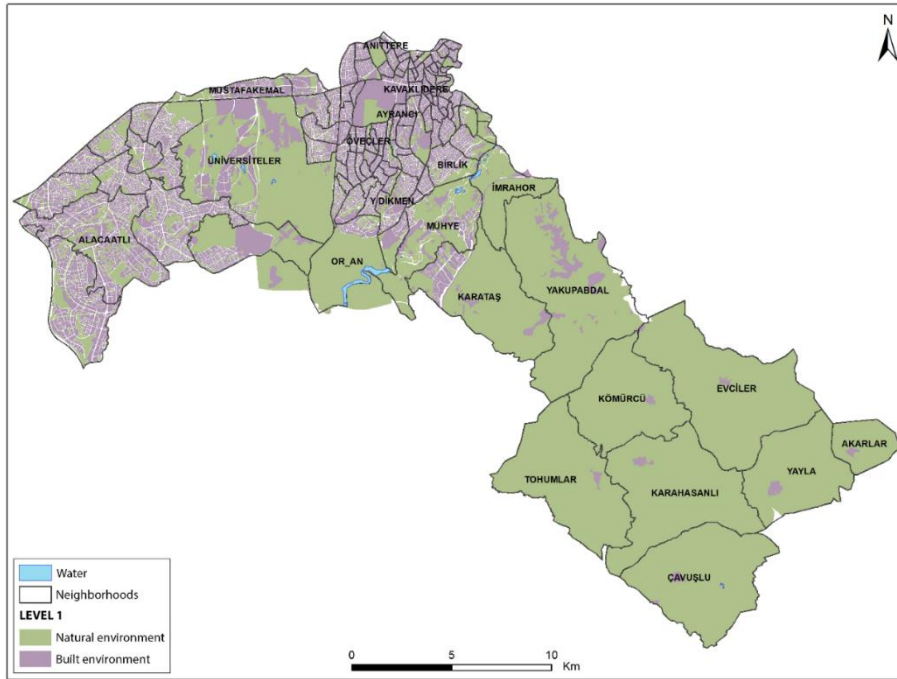


Figure 3. 4. Landcover map (Level 1)

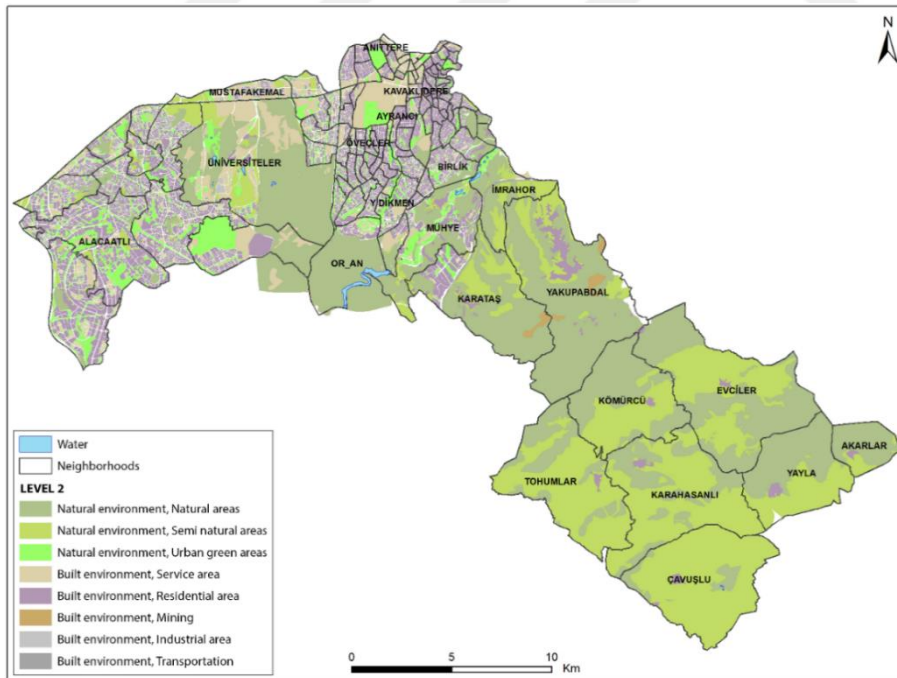


Figure 3.5. Landcover map (Level 2)

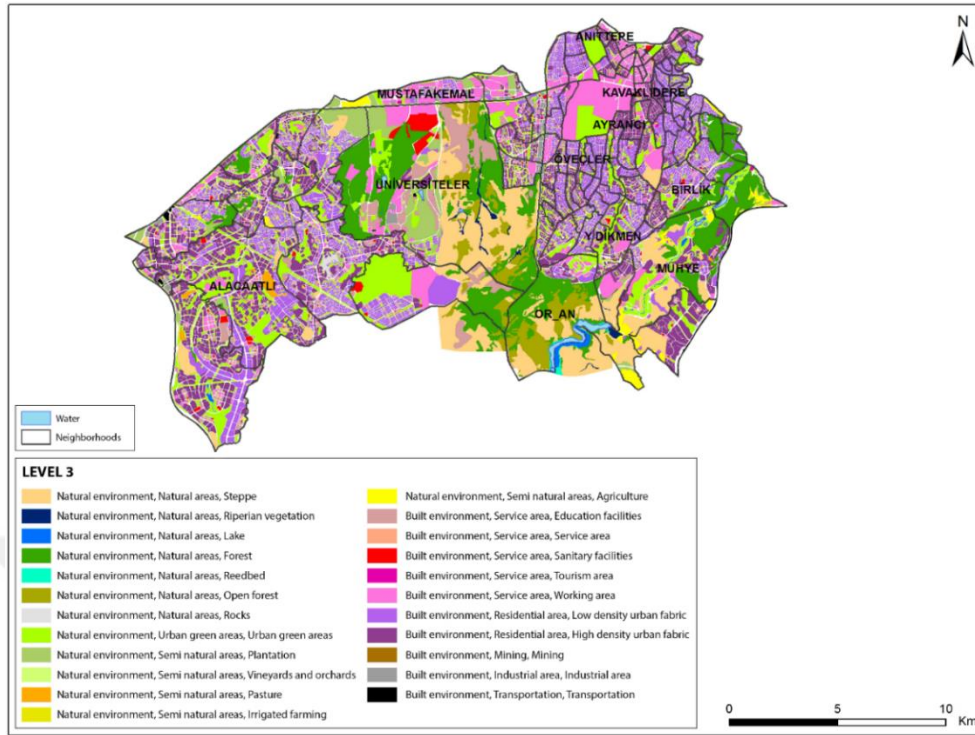


Figure 3.6. Landcover map (Level 3)

Çankaya Municipality Development Plan includes future projections as well as the current situation. For this reason, to determine the current status of Çankaya, controlled classification has been made with using random variables (Breiman, 2001) method. The accuracy of the data depends on the mapping of the services. For example, while recreation services focus on spatial distribution and cover of green areas data, climate regulation service is focusing on surfaces covered with coniferous leaves and broadleaf trees, and steppe area. Therefore, the validation of Level 3 data is especially important. Using remote sensing techniques, a land cover map of 10*10 m was produced, and services were mapped using this data set. This data was used to map all services except food supply and recreation services (Demirbaş Çağlayan et. a. 2020).

In the classification study, Sentinel-2 multispectral satellite images of the European Space Agency (ESA) were used. Sentinel-2 is a satellite image with high spatial (10m-20m-60m) and temporal resolution (5-6 days). Images were analyzed using

Google Earth Engine Platform (Gorelick et al.2017). A total of 812 images of Çankaya covering the years 2016-2019 were used.

Phenological cycles in vegetation are one of the features frequently used in land cover classification. Images from different seasons of the year were used to capture these phenological changes. For example, it is convenient to use autumn images to distinguish deciduous trees and coniferous trees, and spring summer images to distinguish forests and steppes. For this reason, October-November images and April-May images were passed through a cloud filter within the scope of the study. The median values of the bands specified in Table 3. 5 were calculated within these periods.

Table 3. 5. Bants used for the Sentinel 2 gallery and their features

Bant	Spatial resolution (m)	Wavelength	Description
B2	10	496.6nm (S2A) / 492.1nm	Blue
B3	10	560nm (S2A) / 559nm	Green
B4	10	664.5nm (S2A) / 665nm	Red
B5	20	703.9nm (S2A) / 703.8nm	RE 1
B6	20	740.2nm (S2A) / 739.1nm	RE 2
B7	20	782.5nm (S2A) / 779.7nm	RE 3
B8	10	835.1nm (S2A) / 833nm	NIR
B11	20	1613.7nm (S2A) / 1610.4nm	SWIR 1
B12	20	2202.4nm (S2A) / 2185.7nm	SWIR 2

Vegetation indices are one of the most used tools in classifying ecosystems, vegetation cover, and determining the amount of biomass (Meyer et al. 2019). Vegetation indices are usually band combinations calculated by the ratio of bands to each other. NDVI (Normalized Difference Vegetation Index), which is one of the most used indices, uses the red wavelength used by plants in the photosynthesis process and the near-infrared wavelength it reflects after photosynthesis. High values

in the index are indicative of healthy vegetation structure and efficient photosynthesis function. The indices and formulas calculated using remote sensing images are given in Table 3. 6., and the NDVI spring image is given in Figure 3. 7.

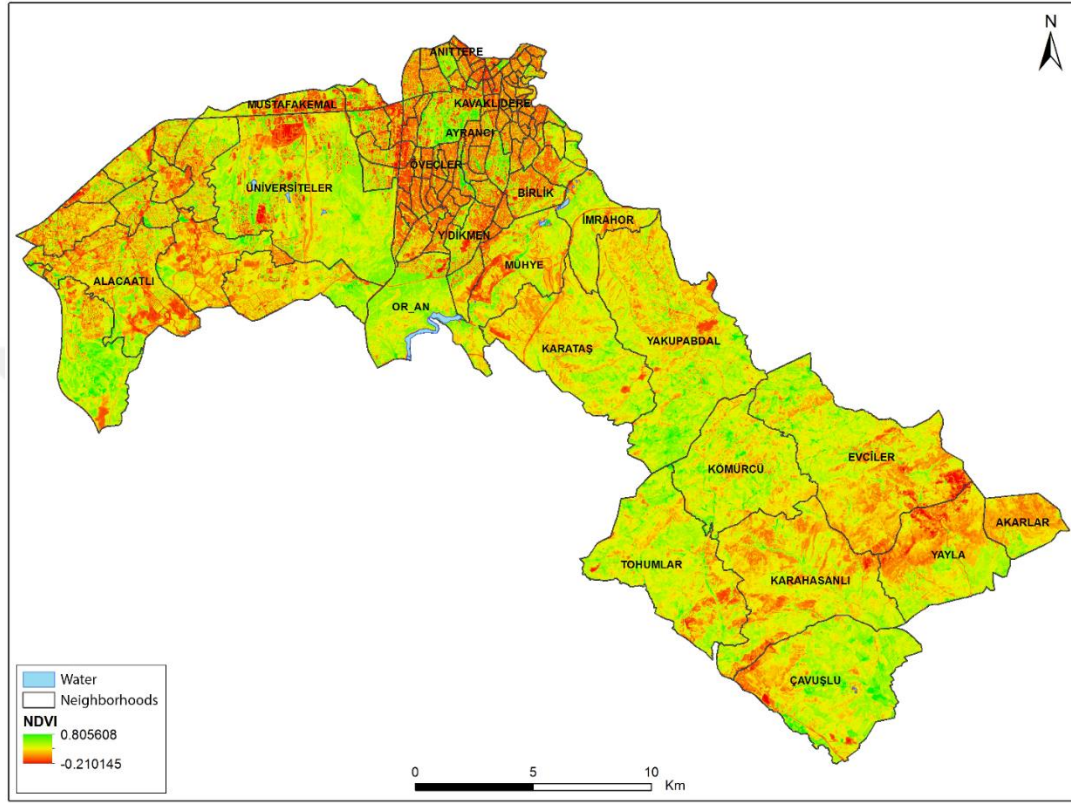


Figure 3. 7. The map showing the NDVI index calculated for Çankaya (obtained from 2016-2019 spring images)

Table 3. 6. Spectral indices and formulas calculated using Sentinel 2 bands

Index		Resource	Formula
NDVI	Normalized Difference Vegetation Index	Rouse et al., 1974	$(B8 - B4) / (B8 + B4)$
EVI	Enhanced Vegetation Index	Jiang et al., 2008	$(B8 - B4) / (B8 + 2.4 * B4 + 1)$
SAVI	Soil Adjusted Vegetation Index	Huete, 1988	$(B8 - B4) * 1.5 / (B8 + B4 + 0.5)$
NDWI	Normalized Difference Water Index	Ji et al., 2019	$(B8 - B11) / (B8 + B11)$
NDBI	Normalized Difference Built-up Index	Zha et al., 2003	$(B11 - B8) / (B11 + B8)$

Nine spectral bands, five vegetation indices were randomized using 28 variables in total, calculated for two seasons. Variables model was established, and 86% accuracy was achieved with the cross-validation method. Model verification showing the error matrix is as in Table 3. 7.

Table 3. 7. Classification error matrix

	Built environment	Steppe	Lawn	Coniferous trees	Water	Agricultural lands	Deciduous trees	Classification accuracy (%)
Built environment	26	3	0	1	1	1	1	79
Steppe	1	26	0	0	0	3	0	87
Lawn	0	0	30	0	0	0	0	100
Coniferous trees	2	0	0	24	0	0	4	80
Water	2	0	0	0	17	0	1	85
Agricultural lands	0	3	0	0	0	27	0	90
Deciduous trees	0	2	1	3	0	0	24	80

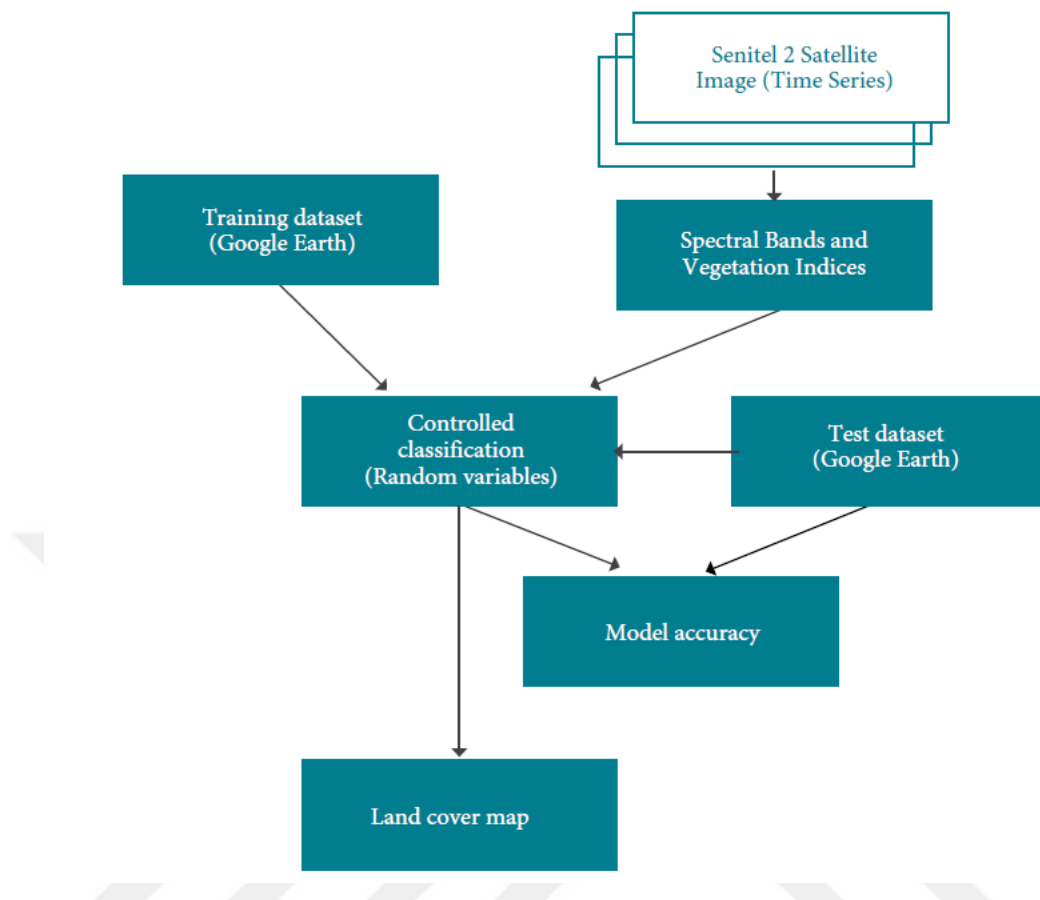


Figure 3. 8. Controlled classification method

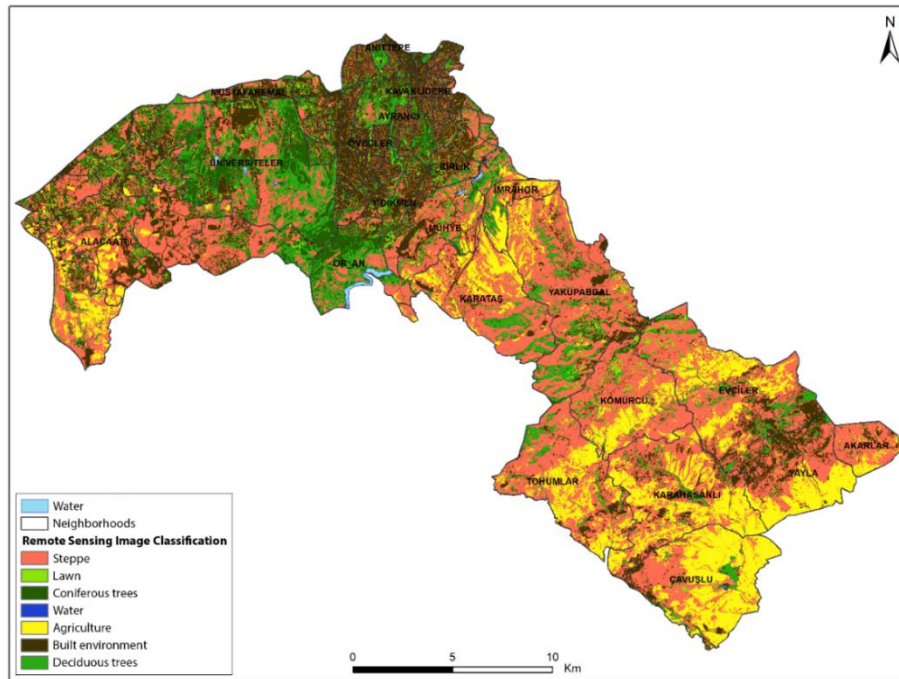


Figure 3. 9. Landcover map produced with controlled classification

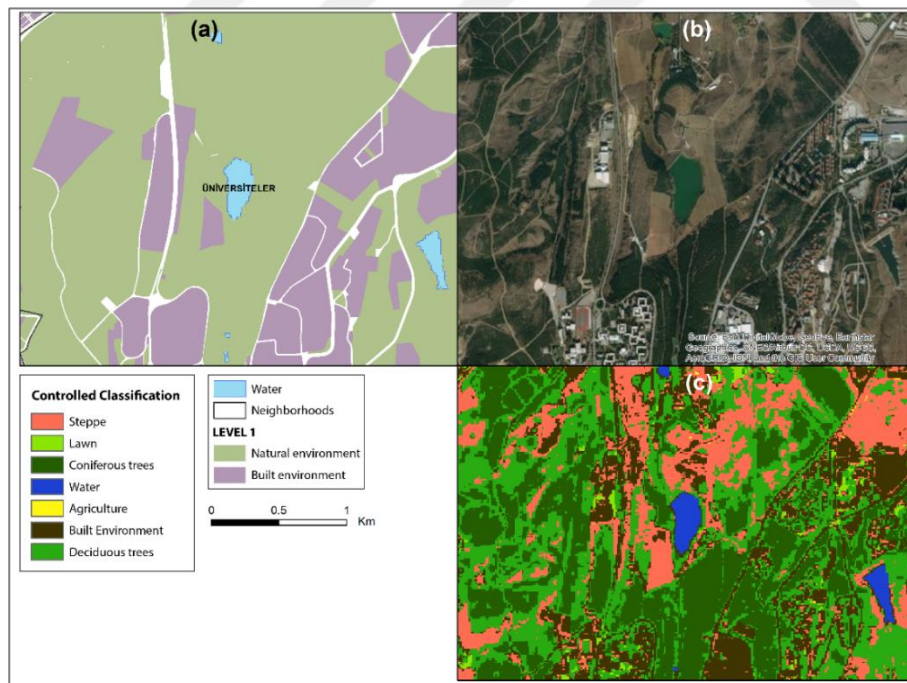


Figure 3. 10. Differences between generated landcover map

3.5 Preparation Ecosystem Services Maps (ES Capacity)

3.5.1 Food production

Referring backwards and forwards in the study, while food production takes place in agricultural areas, fruit gardens and pastures in rural, it is mostly carried out - from building scale to neighborhood scale - windows, balconies, rooftop gardens, green walls, allotments, school courtyards, vacant lots, and urban parks in cities.

Food production SPU were produced using **two different sources of information**. *The first one* is Regenerated Landcover Map (Level 3). As mentioned in data collection and preparation part of the study, this map was produced from Çankaya Municipality Development plan and CORINE Land Cover (CLC) 2012. Since CORINE data set is a reliable source providing information especially on agricultural production, this regenerated map was used (Demirbas Çağlayan et. al. 2020). Regenerated Landcover Map (Level 3) has four type of classes which including food production SPUs. These are vineyard and orchards, pasture, irrigated farming, and agriculture lands (Table 3. 4).

The second one is a District Directorate of Agriculture and Forestry 2019 Activity Briefing Report which has statistical data. In the report which was prepared by Çankaya District Governorship (2019), agriculture (wheat, barley, chickpea) and animal husbandry statistical data was presented. In the study, this data was transformed into spatial data in ArcGIS software.

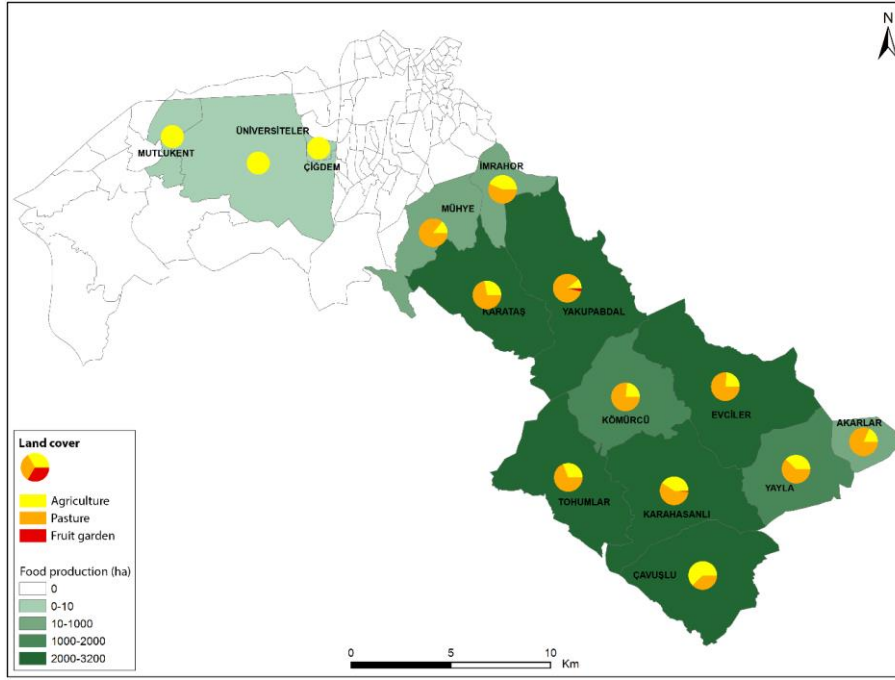


Figure 3. 11. Synthesis of food production SPU and valuation of the food production service at the neighborhood level

3.5.2 Urban temperature regulation

Method developed by Huang et al. (2019) was used to create surface temperature model. In the method, atmospheric calibration was applied. Landsat 8 thermal band (Band 10) 30-meter spatial resolution obtained from LANDSAT Satellite data was used. First, this method estimates the influence of atmosphere on surface thermal radiation. Second, such influence is subtracted from the total thermal radiation received by the satellite sensor (15), thereby the surface brightness temperature is obtained. Third, the surface brightness temperature is converted into its corresponding LST.

The process of creating surface temperature model is shown in Figure 3. 12.

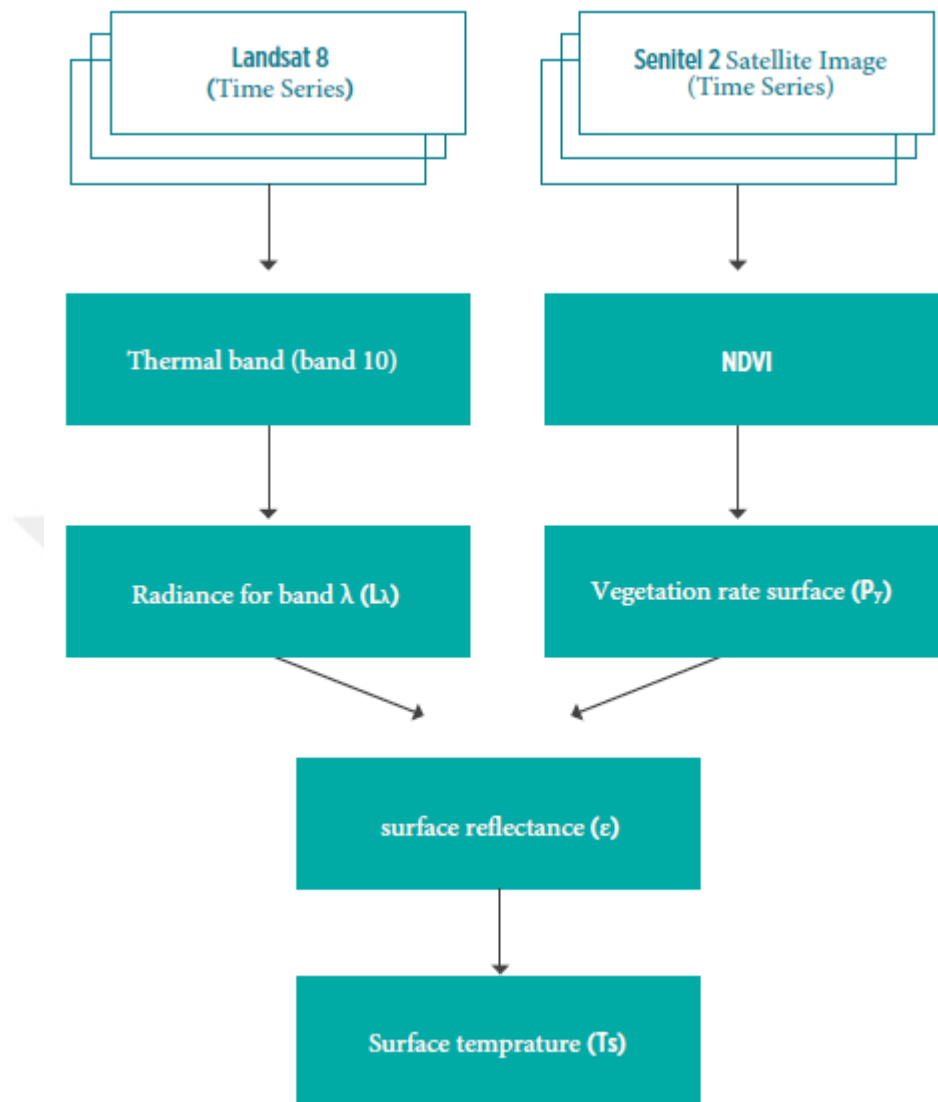


Figure 3. 12. Preparation of the surface temperature model

Band 10 reflects radiation values in the upper atmosphere. The data is stored in digital number codes (DN). Various corrections and calculations were made from DN values to thermal values (Figure 3. 13.).

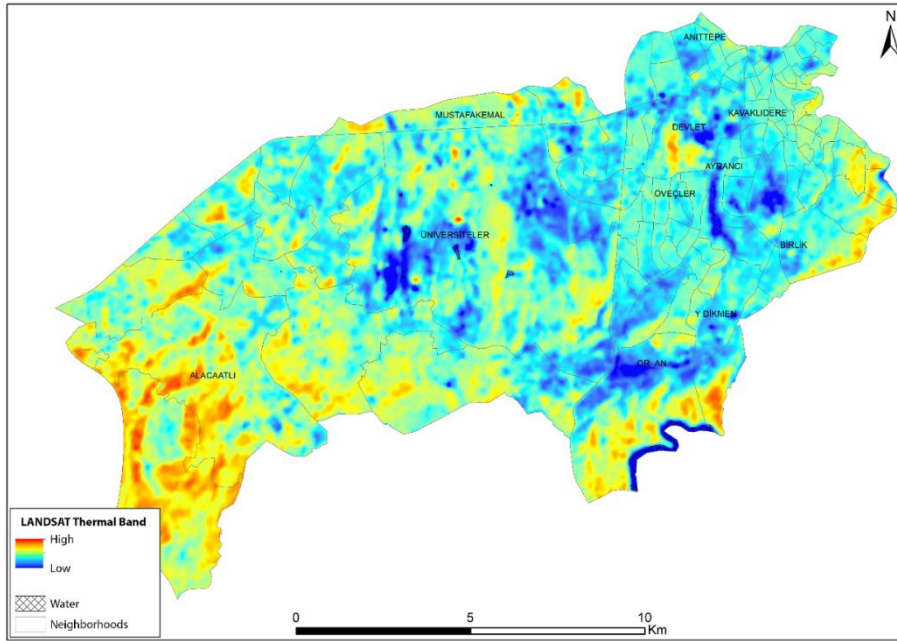


Figure 3. 13. Landsat Thermal bant

The NDVI layer obtained from the Sentinel 2A image was used in the calibration. NDVI image and Landsat thermal bands at different resolutions were brought to the same resolution with sub scaling (10 m).

The following procedures were followed in modeling the surface temperature (Demirbaş Çağlayan et. al. 2020):

1. Vegetation ratio (P_v) surface was obtained using NDVI.
Formula: $P_v = (NDVI - N_s) / (N_v - N_s)$
2. Classified land use and land cover surface; divided into three classes as urban area, natural area and water. Different coefficients were used for each land cover.
3. By using these two surfaces, the radiation coefficient (ϵ) surface was created. As seen in below, the waters are high, urban area has low radiation coefficient.

$$\text{Urban areas: } \epsilon_b = 0.9589 + 0.086 * P_v - 0.0671 * P_v^2$$

$$\text{Natural areas: } \epsilon_s = 0.9625 + 0.0641 * P_v - 0.0461 * P_v^2$$

$$\text{Water: } \epsilon_w = 0.995$$

$N_s = 0$ (NDVI value of the area without vegetation)

$N_v = 0.8043613$ (Highest NDVI value of the vegetated area)

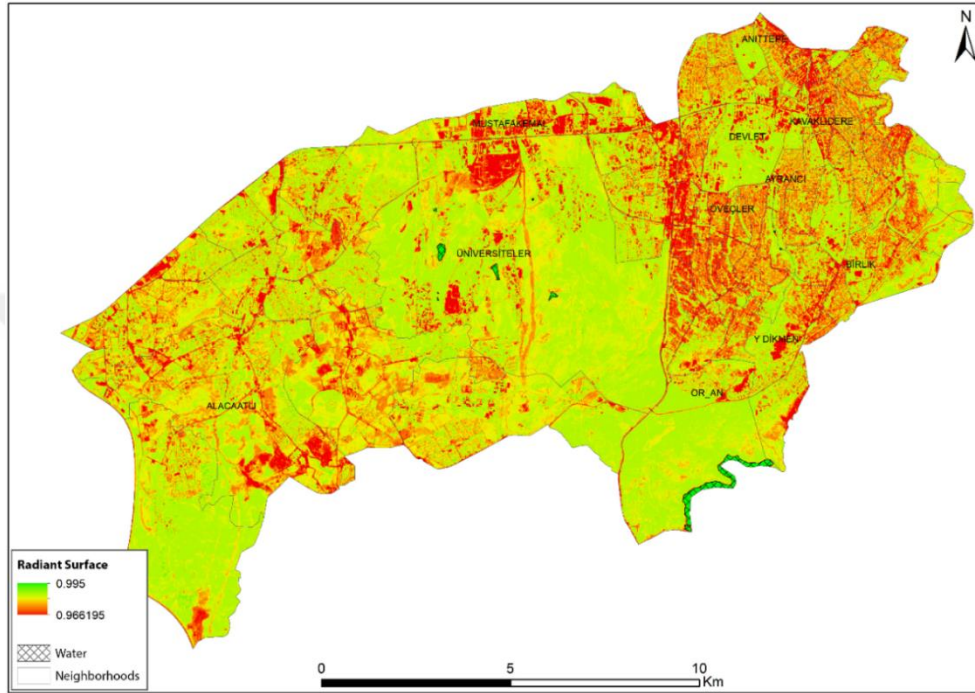


Figure 3. 14. Radiant surface

4. The thermal band image was calibrated using the radiation coefficient surface and atmospheric corrections were made. Then, the surface values were converted to temperature values (Figure 3. 14).

Top-of atmosphere (ToA) spectral radiances: $L\lambda = M_L * Q_{cal} + A_L$

Radiance scaling multiplication factor: $M_L = 3.3420E-04$

Radiance scaling total coefficient: $A_L = 0.10000$

The coefficients are taken from the image guide data. (USGS, 2019)

When the temperature is T , the radiance $B(TS)$ of the black body is:

$$B(TS) = [L\lambda - L_{\uparrow} - \tau \cdot (1 - \varepsilon) L_{\downarrow}] / \tau \cdot \varepsilon$$

ε : Radiation coefficient

$$\tau = 0.9$$

$$L_{\downarrow} = 1.37 \text{ W}/(\text{m}^2 \cdot \mu\text{m} \cdot \text{sr})$$

$$L_{\uparrow} = 0.78 \text{ W}/(\text{m}^2 \cdot \mu\text{m} \cdot \text{sr})$$

Land surface temperature: $T_s = K_2 / \ln(K_1 / B(T_s) + 1)$

$$K_1 = 774.8853 \text{ W}/(\text{m}^2 \cdot \text{sr} \cdot \mu\text{m})$$

$$K_2 = 1321.0789 \text{ K}$$

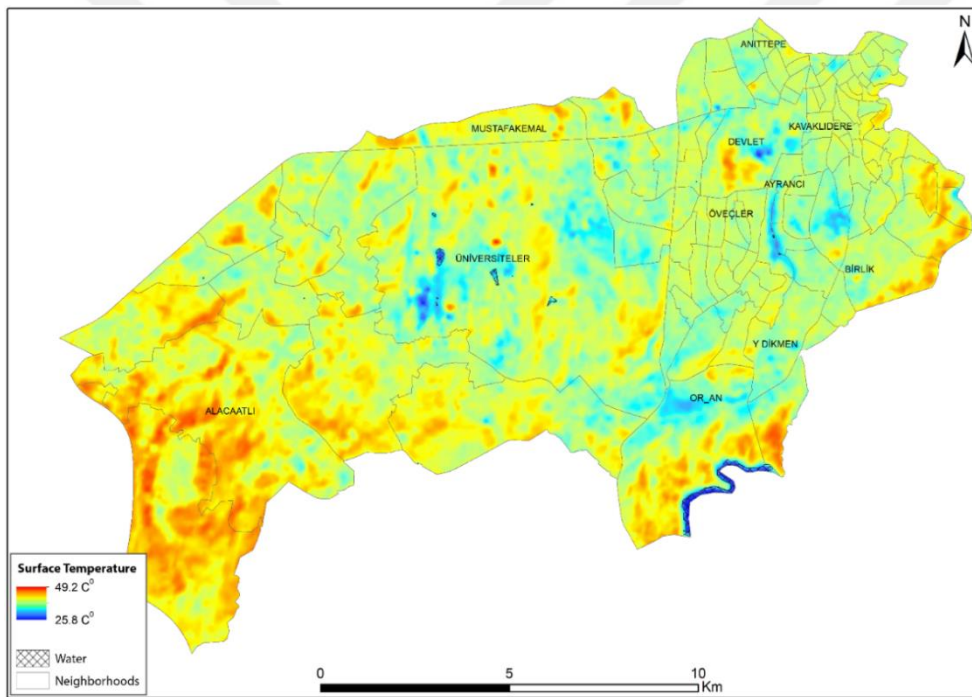


Figure 3. 15. Surface temperature

3.5.3 Air Purification

After grouping the air pollutants at the district boundaries according to their emission sources (Table 3. 8), the distance functions determined with expert opinions are defined as impact zones. Potential air pollutants surface was created using these layers.

Table 3. 8. Pollutant sources and distance functions

Pollutants	Source	Type	Impact distance and function
Traffic	Yandex map was examined for peak hours, traffic density was divided into 3 classes and included in the analysis.	Gas	1.Degree roads: 500 m 2. Degree roads: 350 m 3. Degree roads: 100 m
		Particulate matter	1. Degree roads: 200 m 2. Degree roads: 150 m 3. Degree roads: 50 m
Mining	The mining areas specified in the CORINE 2012 land cover classification have been confirmed by Google Earth images.	Gas	150 m
		Particulate matter	500 m
Industry	The units were selected in Çankaya Development Plan	Gas	1.000 m
		Particulate matter	200 m
Squatter houses	Squatter housing areas were digitized from Google Earth base images.	Gas	800 m
		Particulate matter	400 m

Potential pollution sources was specified in Table 3.8. Figure 3.16 are calculated separately for gas emissions and particulate matter by using the specified distance functions, and the cumulative potential pollution surface has been created.

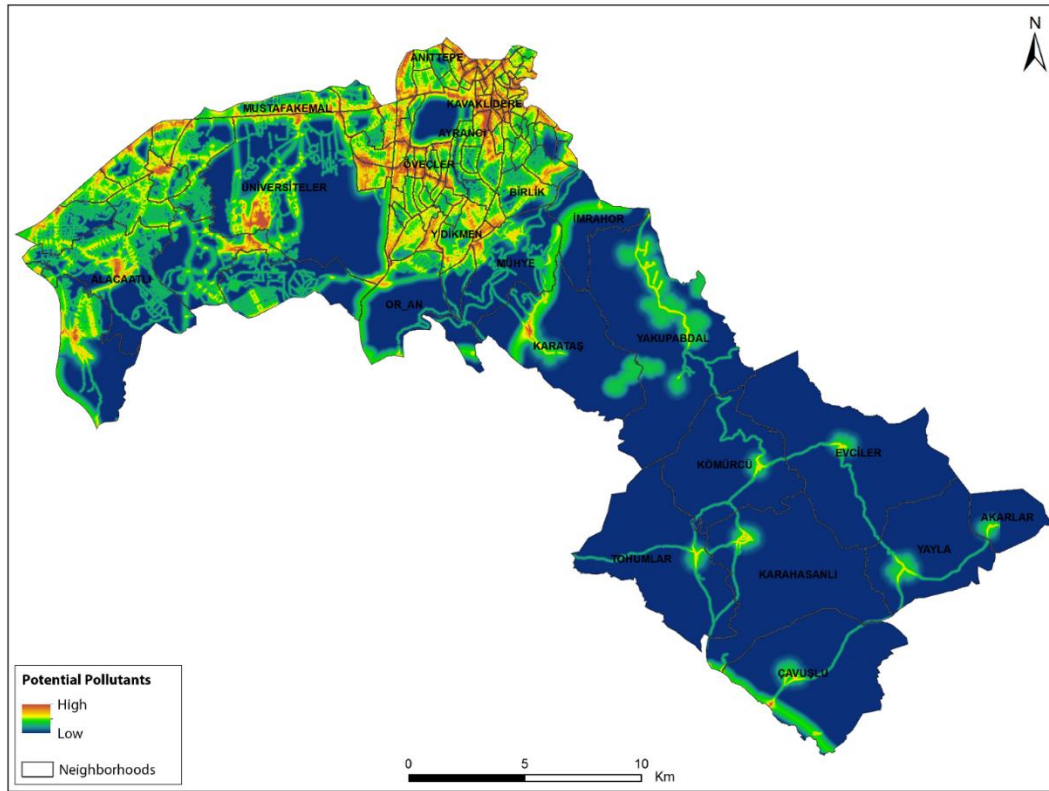


Figure 3. 16. Distribution of potential pollutants affecting air quality

Topographic factors have effect on improving air quality. In the analysis, the valleys were determined by calculating the Topographic Position Index (Jenness, 2006), and graded according to the width and continuity of the valley floors. The valleys built according to their building densities were removed from this surface. At this stage, Google Earth images and floor heights defined in Çankaya Landuse Plan were taken as reference (Yılmaz & Memlük, 2008).

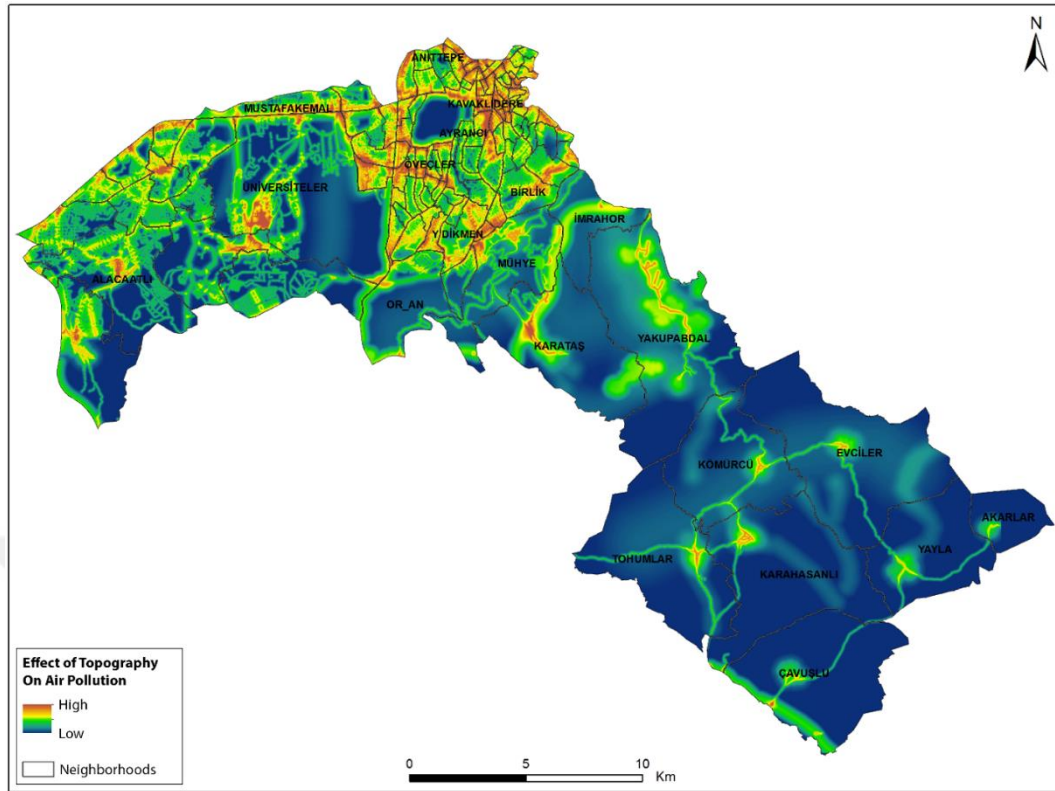


Figure 3. 17. Dispersion model created by considering topographic effects of potential pollutants

In the mapping of air quality, a "deterministic model" has been created that considers the pollutant sources and impact distances only within the district boundaries. Particle holding capacities of coniferous and broadleaf trees were calculated separately and included in the analysis as a factor to reduce the potential pollution load.

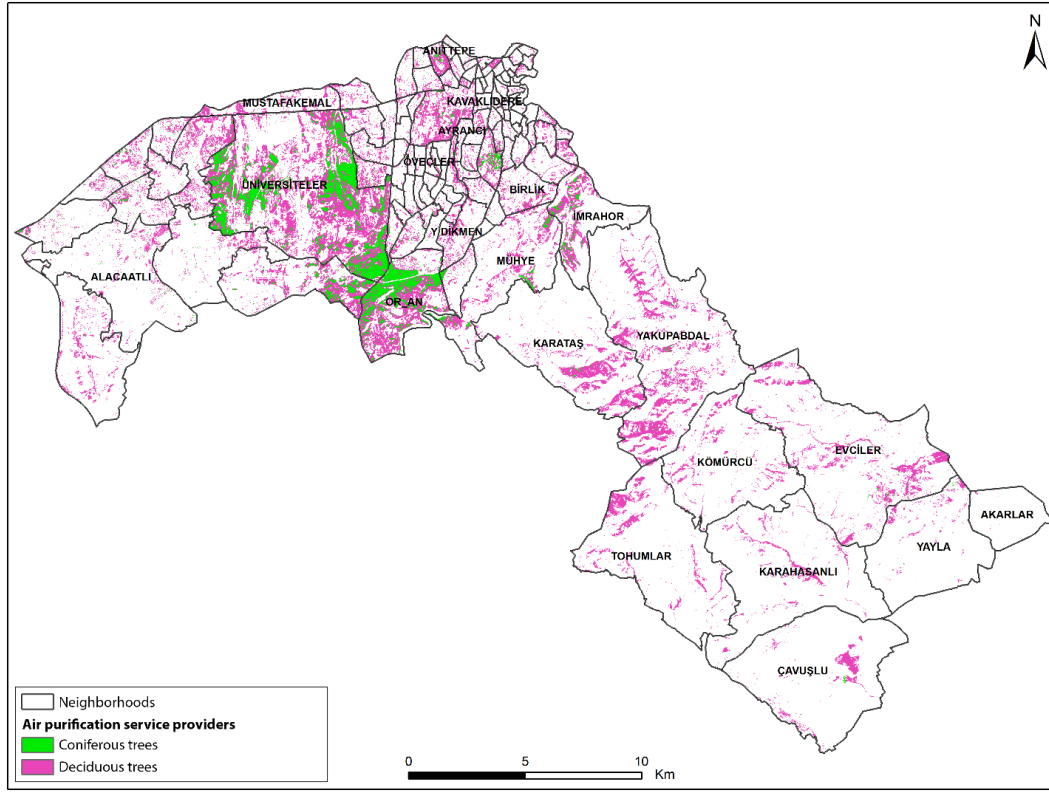


Figure 3. 18. Air purification service providers

$$F_i = V_d * C$$

$$F_{it} = F_i * A * T$$

$$F = \sum_{i=1}^3 F_{it}$$

F: dry deposition fluxes (mg/m²d)

VD: particle deposition velocity (cm/sn)

A: projected surface area of particle (in m²)

T: Time

C: Concentration of pollutants in the atmosphere (mg/m³)

According to dry deposition method (Alphan and Coşkun-Hepcan), the number of particles and gas kept by trees during their vegetation period has been calculated. NO₂, SO₂ and PM₁₀ values was considered the capacity of trees in natural areas to hold pollutants in the atmosphere.

In these equations, the vegetation period of coniferous trees is 365 days, and the vegetation period of broad-leaved trees is 214 days between April and October, and the monthly average rainy days for the period between 1927-2018 (MGM, 2019) are deducted. Accordingly, the time interval (T) was calculated as 262 days for coniferous trees and 159 days for broad-leaved trees.

Dry deposition rate value for SO₂, NO₂, and PM₁₀ has been accepted as 0.64 cm/sec, 0.55 cm/sec and 0.37 cm/sec, (Alphan and Coşkun-Hepcan, 2019). According to the data of the National Air Quality Monitoring Network of the Ministry of Environment and Urbanization Çankaya Station for 2018 (ÇŞB, 2019), SO₂, NO₂, and PM₁₀ 24-hour average values were used (6.35, 66.13, 59.93 µg/m³).

The amount and distribution of service provided by trees is calculated. A 500 x 500 m grids was used to present how the carbon capture service has changed throughout in Çankaya (Figure 3.19.).

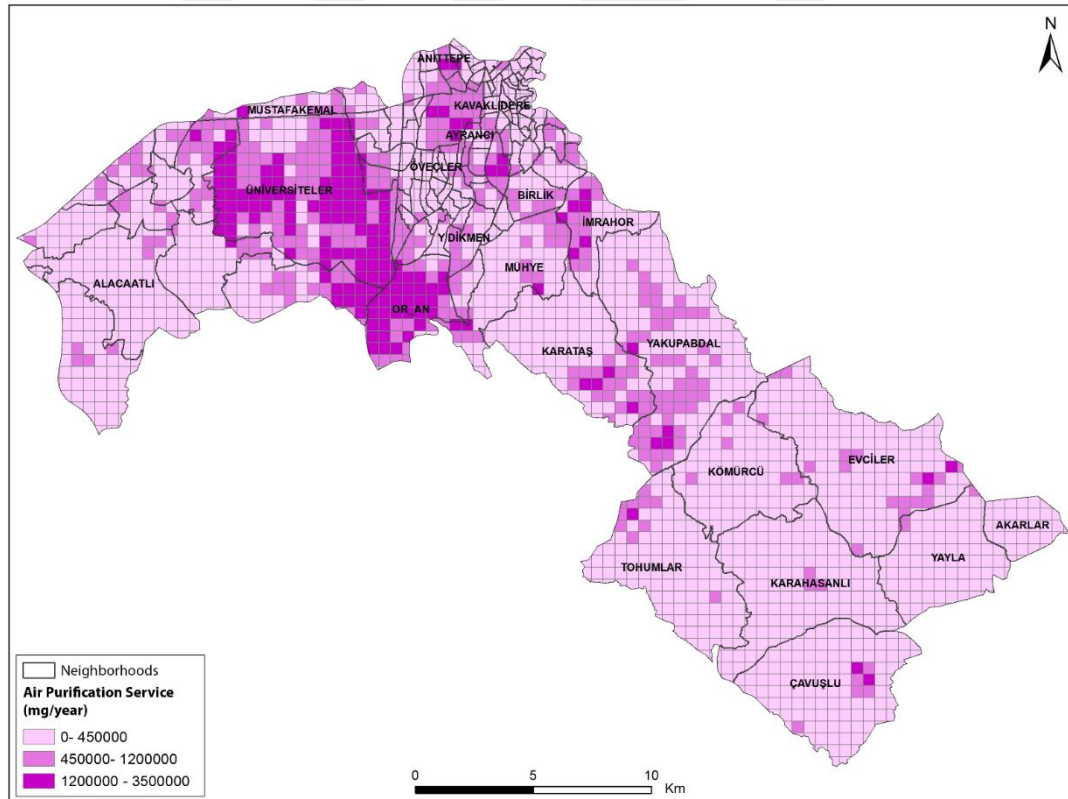


Figure 3. 19. Air purification service (annual capture for SO₂, NO₂ and PM₁₀)

3.5.4 Climate Regulation

Forests and steppes have been identified as carbon sequestrant, climate regulate ecosystems. The "wealth tables" included in the plans of Ankara Forestry Operation Directorate, Ankara and Bala Forest Operation Chief Offices were used in biomass calculations.

Above and underground biomass amounts were calculated using the formulas in Table 3. 9. The average values obtained from the management plan are generalized to the whole district due to the lack of type and wealth data for the city.

Land cover map produced with controlled classification was used to create a distribution of forests and steppes data.

Table 3. 9. Aboveground and belowground biomass and carbon

Aboveground biomass and carbon (tonC/ha)		Reference
Deciduous forest	Volume x 0,717 x 0,48	Tolunay, 2013; NIR Turkey, 2017; OGM, 2017; IPCC, 2006
Coniferous forest	Volume * 0,613 * 0,5386	Güner ve Çömez, 2017
Steppes	0,735 ton C	NIR Turkey, 2017
Belowground biomass and carbon (ton C/ha)		
Deciduous forest	Belowground biomass and carbon * 0,23	IPCC, 2006
Coniferous forest	Volume * 0,613 * 0,5386* 0,179	Güner and Çömez, 2017
Steppes	2,94 ton C	NIR Turkey, 2017

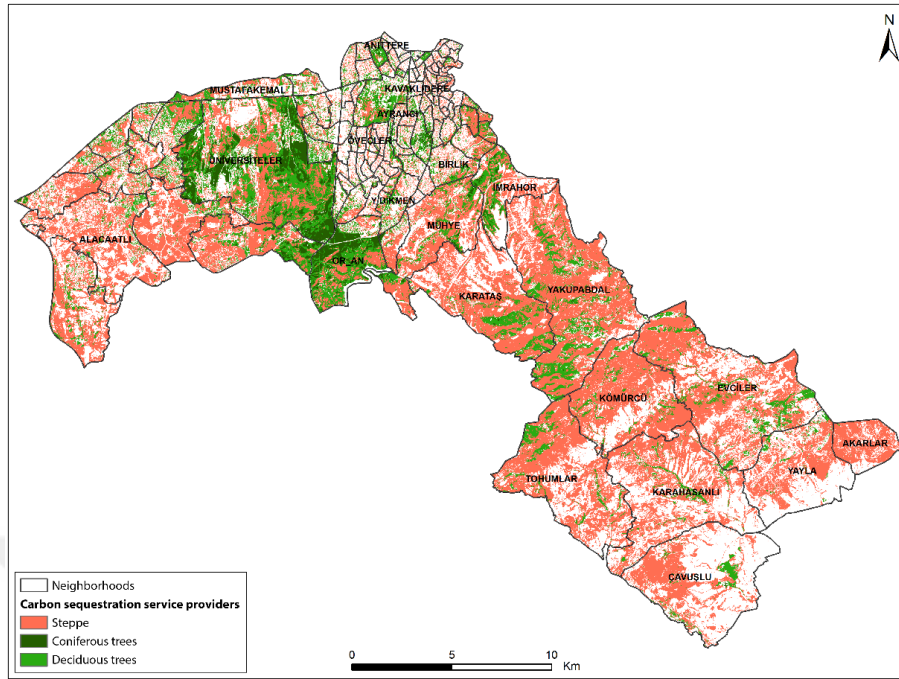


Figure 3. 20. Carbon sequestration, climate regulation, service providers (steppe and forest)

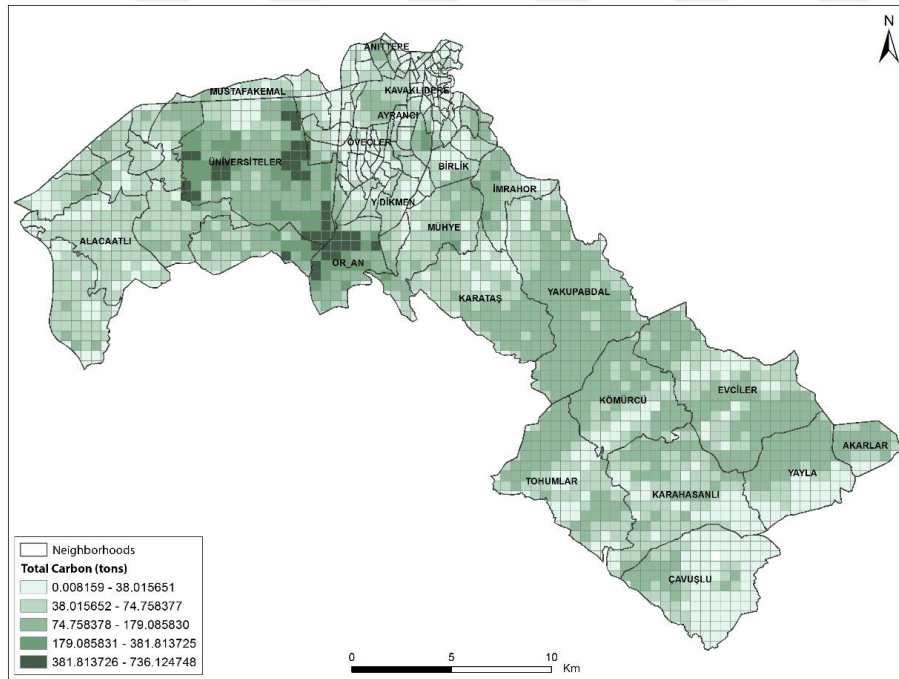


Figure 3. 21. Distribution map of carbon sequestration service in 500 x 500 m squares)

3.5.5 Runoff mitigation

Curve number in the assessment of water retention service (Soil Conservation Service Curve Number (SCS-CN)) method was used (Alphan & Coşkun-Hepcan, 2019; Pamukçu-Albers et al., 2020; Whitford et al., 2001). According to the method, water held in the soil during and after precipitation is evaluated with a curvilinear relationship between precipitation and soil. Surface runoff begins after the soil is saturated with water. The amount of clay and organic matter in the soil and its porous structure and aggregation capacity affect the water holding capacity. Another critical factor is the presence and density of vegetation on the surface. Since there is no plant in the bare areas that reduces water absorption, the water passes to the surface flow after a short time, and since there is no mechanism that stabilizes the soil, the process also triggers erosion. The amount of water passing into the runoff (Q) is generally less than the amount of precipitation (P). If there is no infiltration, the amount of rainfall is equal to the amount of runoff. The amount of permeation is causally related to the slope, soil structure, and vegetation. However, since there is no detailed soil information in Çankaya, the recommended CN (curve number) values in the literature (Zeng et al., 2017) were used considering the land cover information (Table 3.10).

Table 3. 10. CN values used in the study

Landcover	CN (Curve Nंबर)
Impervious area	90
Agricultural area	78
Steppe	69
Forest	65
Water	N/A

The amount of runoff was calculated over the grid system. Each square is 500m * 500 m in size. The surface runoff volume is calculated with the following formula, considering the cover type and the daily maximum rainfall data for many years.

$$Q = \frac{(P - 0.2 * S)^2}{(P + 0.8 * S)}$$

$$S = \frac{2540}{CN} - 25.4$$

$$V_r = Q * A$$

Q: Runoff (mm)

P: Rainfall (mm)

S: Potential maximum retention
after runoff begins

CN: Curve number

A: Drainage area (m²)

V_r: Runoff volume (m³)

SCS-CN method gives the amount of surface flow per unit area by considering the cover information. However, topographic variables such as the basin, slope, topographic position (being located on the valley base), precipitation, and roughness also affect flood and overflow risk. For this reason, an advanced risk analysis that considers the topographic variables have been performed. While creating the risk map, "Analytical Hierarchy Method, One of the Multi-Criteria Decision-Making Methods" was used (Pamukçu-Albers et al., 2018). The method allows multiple factors to be evaluated together by weighing them according to their importance. In the scoring system, sub-factors were assessed, with 1 point in the areas where flood and overflow would have little or no impact, and the areas where the flood could be most effective was 5 points (Table 3. 11) (Pamukçu-Albers et al., 2018).

Table 3. 11. Data and weight scores used in the Analytical Hierarchy Method

Variable	Class	Class degree	Point	Variable	Class	Point
Slope groups	Nearly level	0°-2°	5	Topographic position	Valley	5
	Very gentle slope	2°-12°	4		Lower slope	4
	Gentle slope	12°-20°	3		Middle slope	3
	Strong slope	20°-30°	2		Upper slope	2
	Extreme slope	30°<	1		Ridge	1
Elevations in river basin	Lower basin		4	Roughness	Nearly level	5
	Middle basin		3		Very gentle slope	4
	Upper basin		2		Gentle slope	3
	Upmost		1		Strong slope	2
Rainfall	450-555		2			
	361-450		1			

The slope is a topographic factor that affects water and soil flow in a basin, increasing runoff risk and soil loss. Flat and near-flat areas are the areas most affected by floods. In other words, the flood duration is longer in these areas. All debris and sediment collect in these areas; floods also mostly occur in these areas. The map of the slope groups of Çankaya is shown in Figure 3 .22.

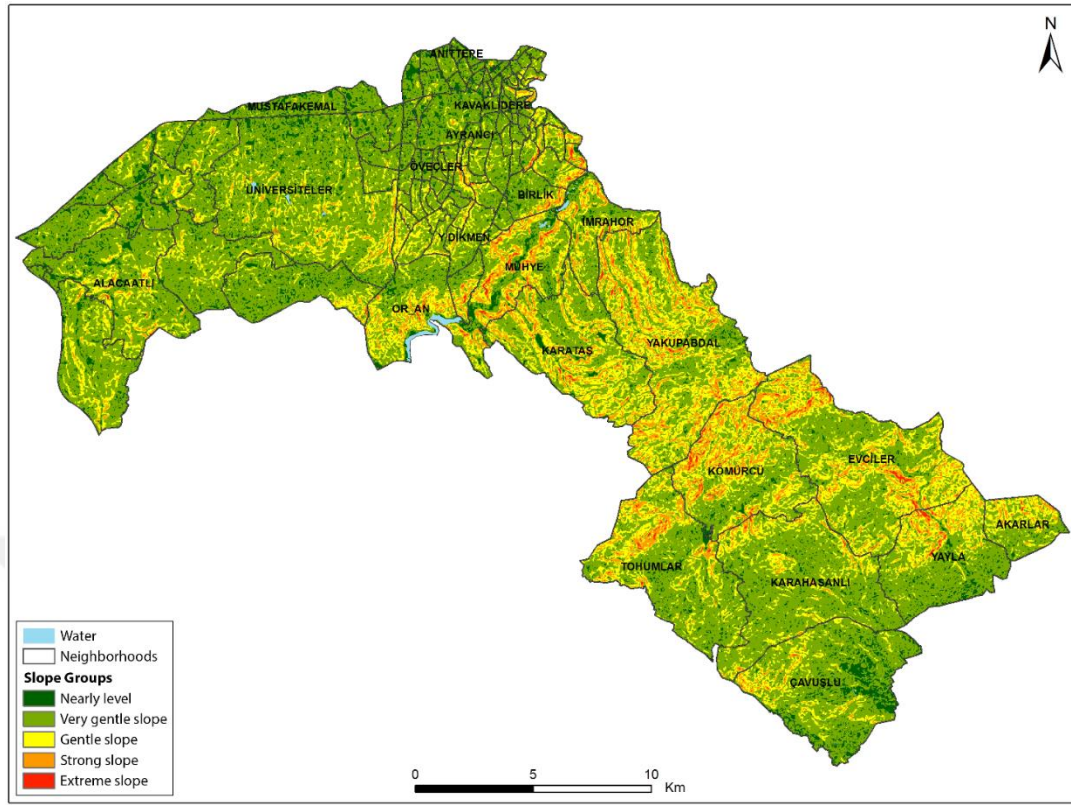


Figure 3. 22. Slope groups map

Precipitation is the climatic factor most affecting floods and overflows in a basin. Generally, there is a linear relationship with altitude of the area. In the study, annual precipitation of the area information was taken from Worldclim 2 dataset which is created by Fick & Hijmans in 2017.

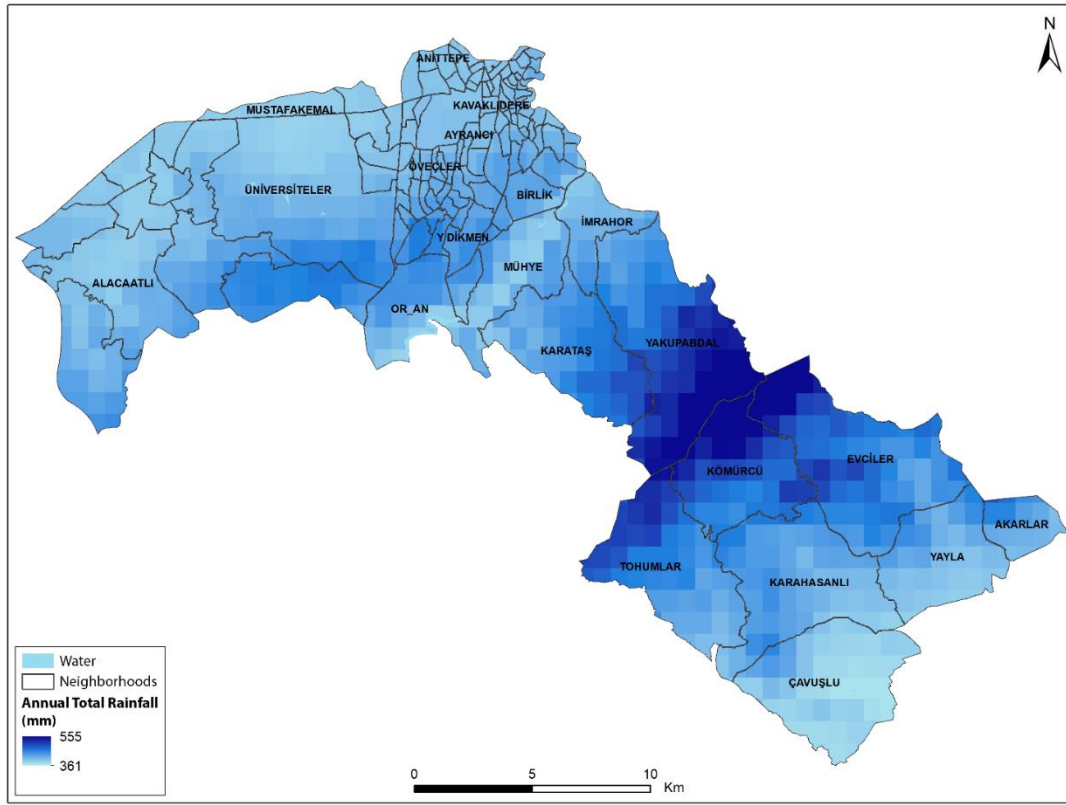


Figure 3. 23. Annual total rainfall map

The roughness was calculated with the formula of Riley Terrain Roughness Index (Riley et al., 1999) using the Digital Elevation Model (DEM). The roughness is divided into four groups; flat and near-flat areas (index value: 0-116) received the highest score in terms of runoff possibility, and areas with a high degree of roughness (index value: 497-671) got the lowest score.

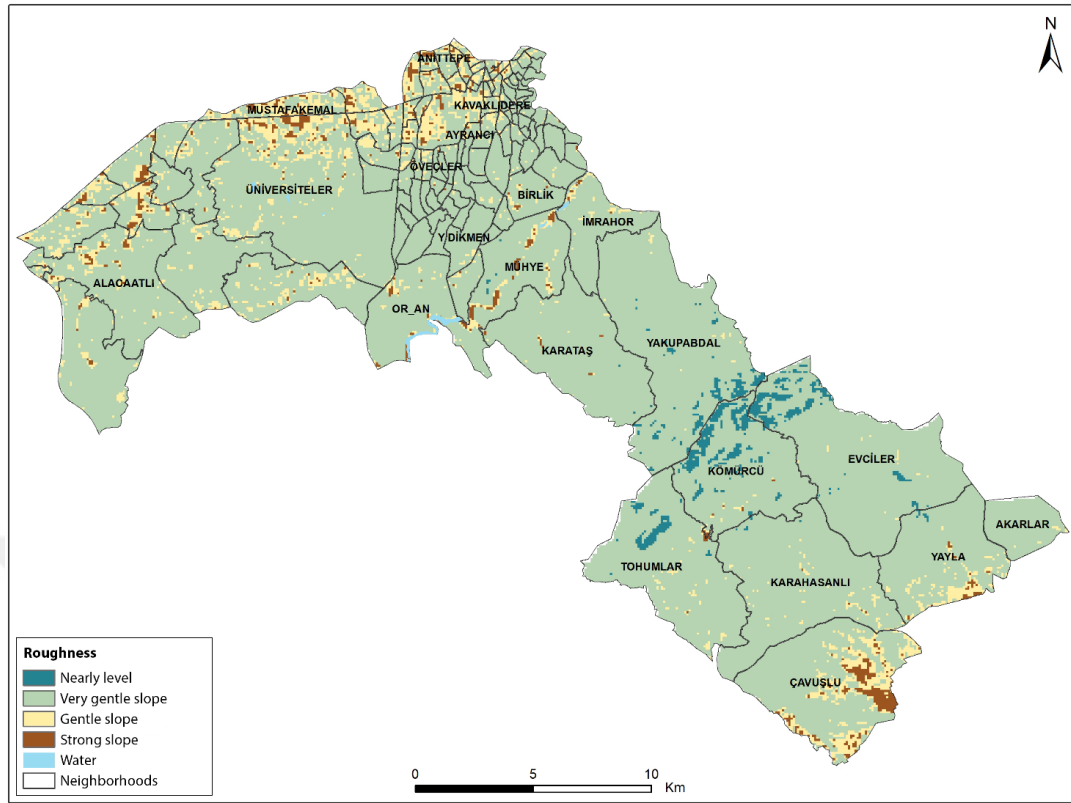


Figure 3. 24. Roughness map

The excess water flows from high slopes to downslope with the force of gravity. Therefore, the water is accumulated at lower elevations.

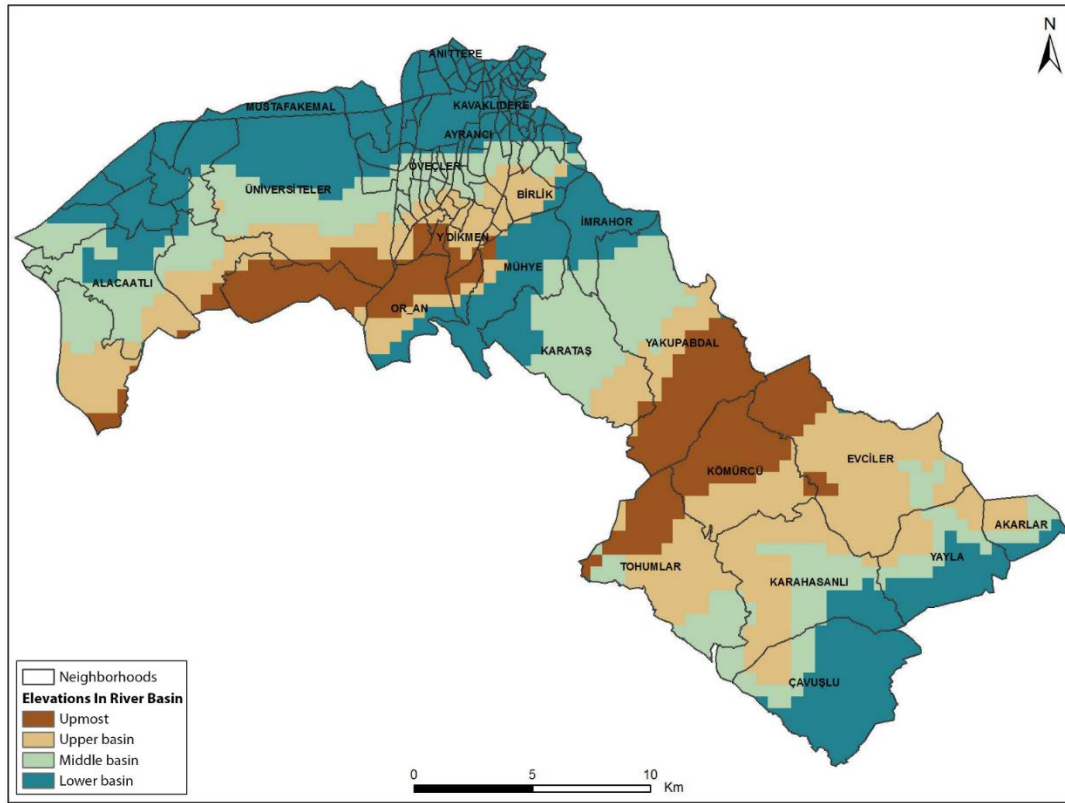


Figure 3. 25. Map showing the relationship of altitude in the basin

In the study, Topographic Position Index developed by Jennes in 2006 was used to classify landforms. According to the topographical location, ridges with the least risk of flood got the lowest score, while the valley floors got the highest score.

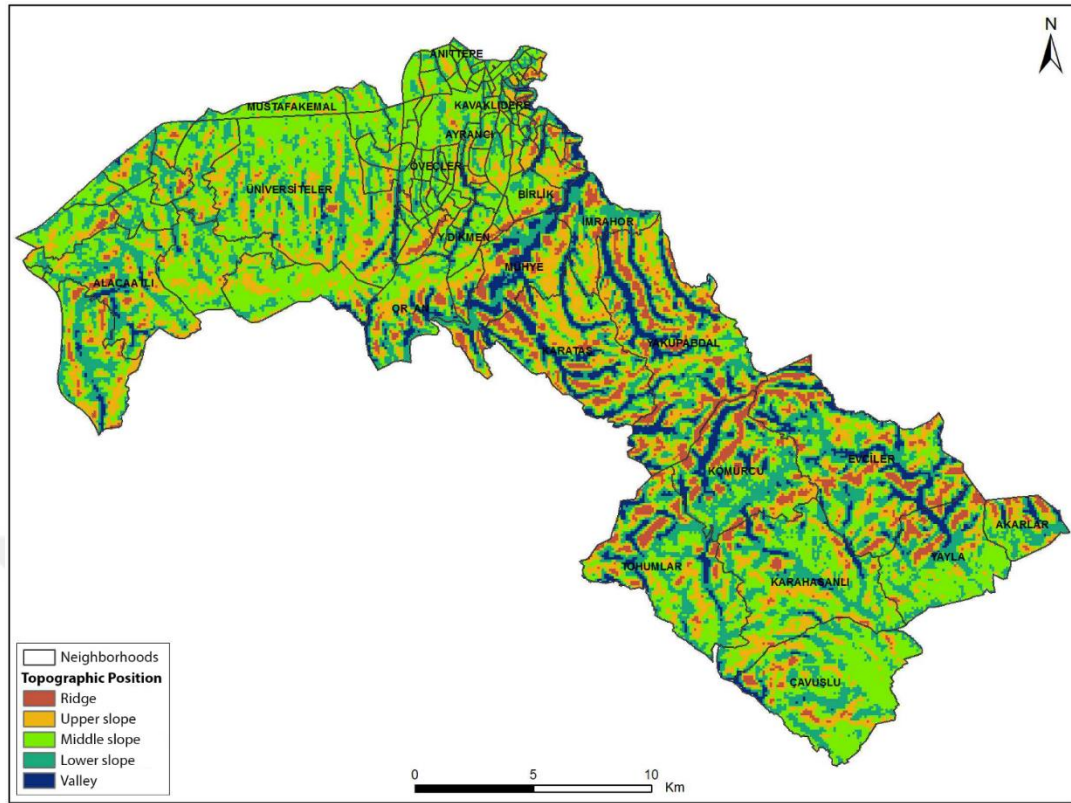


Figure 3. 26. Topographic position map

Flood risk was calculated by considering the specified topographic variables which are slope groups, annual total rainfall, roughness, location of basins and topographic position.

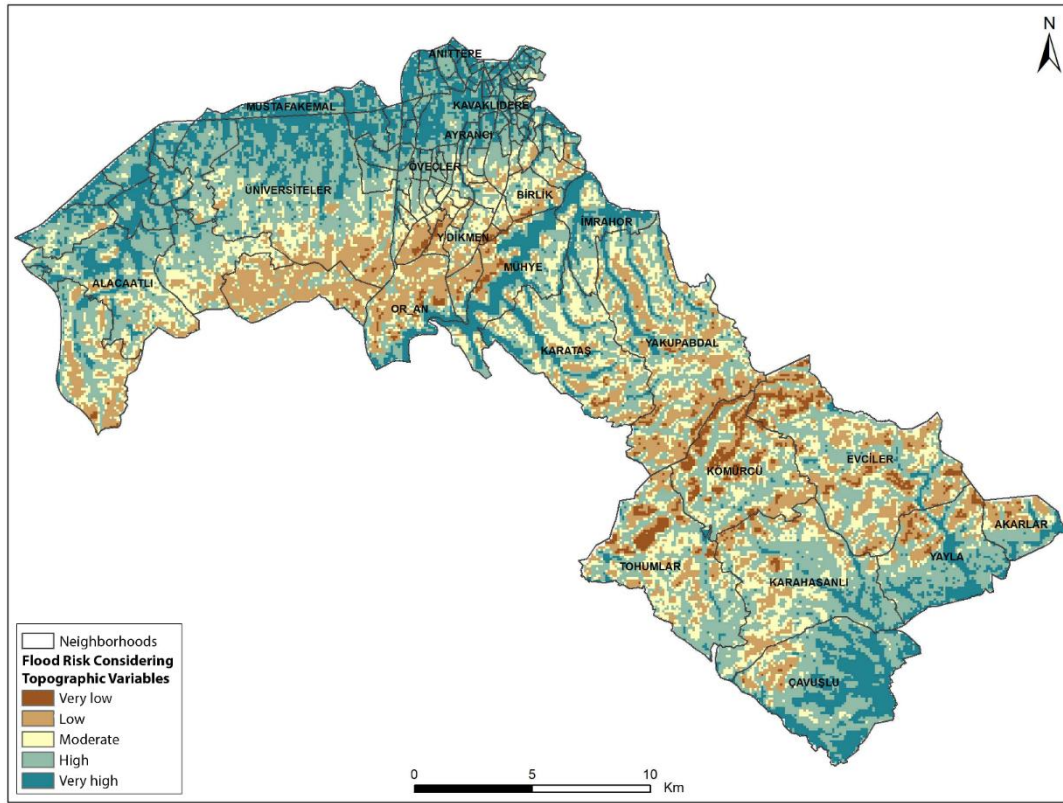


Figure 3. 27. Flood risk considering topographic variables

3.5.6 Habitats for biodiversity

In the study, habitat for biodiversity service was mapped in only park scale on selected parks. Four experts carried out field studies in the parks, scoring the naturalness and richness of vegetation, structural diversity (including grass, bush, tree layers), water availability, development period and rarity of the area. The evaluation was based on the rapid assessment of ecosystems developed by Spellerberg (1994) and the METU Nature Reserve Report (Zeydanlı et al., 1996), and some criteria (such as water availability) were added to the assessment.

Evaluation was made using three different methods to measure habitats for biodiversity service valuation. These are:

- 1- The scores were assigned by experts according to the field observation survey (examining natural vegetation richness, structural diversity of vegetation,

presence of water components, core area size, growing period, frequency)
(Appendices)

- 2- Evaluation of the records collected by bird experts from selected parks.
- 3- Evaluation of e-bird data.

When these data are evaluated, the habitat for biodiversity service of the selected parks is presented as in percentage to relative comparison in the Figure 3. 28.

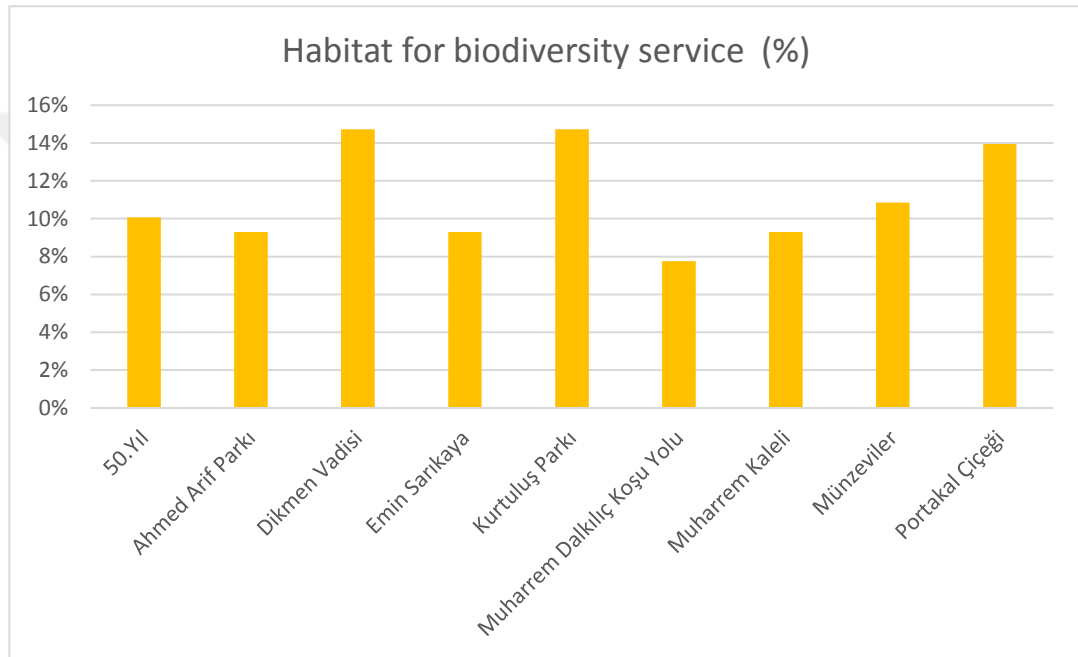


Figure 3. 28. Comparing the provision of habitat for biodiversity ES among selected parks.

3.6 Identifying Primary Beneficiaries (ES Utilization)

With the light of literature review, vulnerable groups for each benefit of ES were identified. The vulnerable group has been considered as the primary beneficiaries of ES. Accordingly, the demographic characteristics of the beneficiaries, their use of land and their places of residence were analyzed. Çankaya Municipality Landuse Plan, Google Maps and statistical data were used in the analysis. Age factor is one

of the most important criteria. In the study, information about age was obtained from these two sources.

For the elderly population, nursing home and elderly rehabilitation center, and for young people, educational units were taken as basis. According to Turkish legislation on Nursing Homes (legislation number: 4414), Elderly Care, and Rehabilitation Centers, elderly people are defined as a person over the age of 60 who is socially and / or poor and in need of protection, care, and assistance.

As stated in the Ministry of National Education Preschool Education and Primary Education Institutions Regulation (legislation number: 19942), children aged 36-68 months (3-6 years) are enrolled in the kindergarten.

According to Turkish Primary Education and Education Legislation (legislation number: 222), attendance age of primary school is 6-14, and secondary school is 14-18 ages. Within the study's scope, the age range of students attending university was assumed as 18-30, and students who are in dormitory units are considered university students.

In the legislation, special education is defined as the places where individuals who need lifelong special education and support due to their deficiencies in mental functions, conceptual, social, practical adaptation, and self-care skills.

In the case of recreation, people living within 300 m from the new parks were considered as beneficiaries (Kabisch et al. 2016; Stessens et al. 2017). Primary beneficiaries in accordance with benefits of UES are derived from the earlier theoretical discussions in Chapter 2. For this purpose, a 300 m buffer was set around the park, and socio-economical features in relation to those ES were identified, quantified, and mapped.

Each ES benefits, its explanations, prior beneficiaries and related units/ areas in landcover map are summarized in the Table 3.12. Vulnerable groups were determined within the area in 300 m buffer around the park (Table 3. 13.). Selected

UES primary beneficiaries' spatial equivalents were adapted from land cover data. Values belonging the parks are presented in Table 3. 14.

Urban temperature regulation service helps to reduce heat island effect. Built structure, such as buildings, roads and impermeable surfaces absorb solar-radiation, and leads to warm up. Impervious areas, high and medium density urban fabric are defined as priority areas as need for UTR service. Because tree shades have positive impact on heating and cooling energy save, high energy needed areas are also highlighted as prior units. Those are, techno park, small industrial areas, industrial areas, power distribution units, heat centers, gas station and fire stations. UTR service also have benefits on reducing heat-related illnesses. According to literature children below 5 age and elderly above 65 age are vulnerable groups based on their heat sensitivity. Kindergardens, nursing home and elderly rehabilitation centers, health centers are selected as primary units.

Air purification service have focused on controlling anthropogenic emissions of air pollutants. Specific sources that leads to increase concentration of chemicals in the atmosphere were defined as primary units/ areas. These are fossil fuel used areas, small industrial areas, industrial areas and intense transportation areas. As outlined in the literature review, pregnant women and children, the elderly, and those with pre-existing illnesses are especially sensitive to the harmful health consequences of air pollution. Fossil-fuel used areas, kinder gardens, nursing home and elderly rehabilitation centers, health centers are selected as primary units. As carbon is one of the air pollutants, these units/areas are also applicable for the primary beneficiaries of climate regulation services.

The benefits of runoff mitigation service areas will be discussed in this research in terms of preventing cascading impacts during heavy rainfalls. In this context, preventing surface runoff also prevents possible difficulties that may occur as a result of heavy rainfall. Possible problems area grouped under three categories. These are impacting on water, transportation, and power supply. As mentioned in literature review, urban runoff carries pesticides and fertilizers used in agricultural activities,

road transport emissions, and polluted particles from buildings and infrastructures. These pollutants can mix to water, and threaten the public and habitat health. Impervious areas, high and medium density urban areas, and intensive transportation areas selected as primary areas. Flooding events increase the travel distance, costs, and time, and it delays the essential services that the city provides. Working areas, health facility areas, urban storage areas, intensive transportation areas and fire station units were selected as primary units/areas. During a flood, power units are affected. This will cause various problems such as air-conditioning usage, traffic delays, and perishable food. Working areas, techno parks, industrial areas, health facilities, power distribution units, technical infrastructure, heat center and intensive transportation areas were also chosen as primary areas/units.

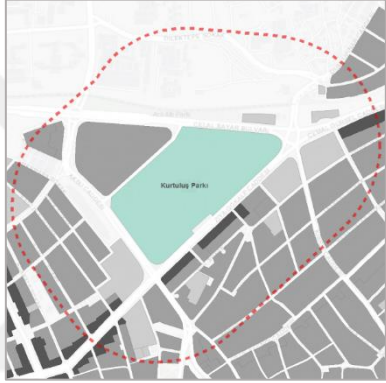
Recreation service is related with people's experiences with and in nature. In this context, food production and recreation services are highly similar. As highlighted in literature review, connection with nature in especially early childhood and for elderly people have positive affect on wellbeing in many ways. It provides education opportunities. Kindergardens, special education areas, primary schools, high school, dormitory areas, universities and Nursing Home and Elderly Rehabilitation Centers selected as primary areas/units. Recreation service has also health benefits such as reducing stress, cognitive development for children, combating social isolation for elderly, improving emotional, physical, and spiritual renewal. The same units/areas are also selected for health benefits. It also contributes social cohesion and integration with bringing people from different ages, races, socio-cultural and economic level. Newly developed areas, kindergardens, special education areas, primary schools, high school, dormitory areas, universities and Nursing Home and Elderly Rehabilitation Centers selected as primary areas/units. It increases workforce and productivity for people who are working, and students. So that, educational units and working units such as commercial areas, industrial area, techno park units were selected.

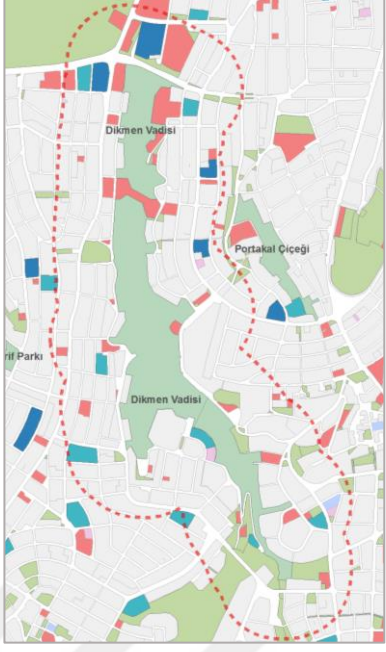
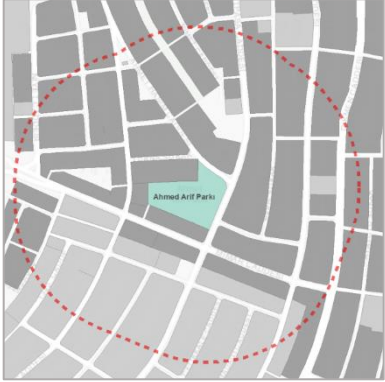
Table 3. 12. ES benefits, benefit explanations, prior beneficiaries and related units/ areas in landcover map

Benefits	Benefit explanations summary	Who, and which units	Related units/area in landcover map
Nutrition and food security		Everyone	Population in neighborhood
Education opportunities	Transferring tacit knowledge (Barthel et al., 2013) Learning about ecological processes, biodiversity and producing food (Bellows, A. et al., 2008) Being familiar with good and healthy food habits; teach a skill and enhance their social, physical, and mental abilities (Bellows, A. et al., 2008) Relieving stress, improving concentration, assisting	Elderly people Young people	Nursing Home and Elderly Rehabilitation Centers (over 60), Kindergarten (3-6 ages) Special education, Primary schools (6-14 ages), High school (14-18 ages), University (18-30 ages), Dormitory (18-30 ages)
Health benefits	High nutritional value (Bellows et al., 2008) Good exercise for health. Reducing coronary heart disease especially for menopausal women and elderly men (Bietz and Doren, 2004) Reducing diabetes and glucose tolerance for adults and elderly men (Van Dam et al., 2002) Increasing strength and endurance of the muscle in activity-reduced person (Evenson KR, et al. 2004; Irwin 2004; Rolland et al. 2004; Wannamethee and Shaper 2001; Wannamethee et	Elderly people Young people	Nursing Home and Elderly Rehabilitation Centers (over 60), Kindergarten (3-6 ages) Special education, Primary schools (6-14 ages), High school (14-18 ages), University (18-30 ages), Dormitory (18-30 ages)
Social cohesion and integration	Bridging racial divides by bringing people of different ages, races, and income levels together (Lin et al., 2017) Bridge the gap between consumers and producers (Specht et al., 2013) Learning to work collectively (Stocker and Barnett, 1998) Preventing crime, supporting cultural diversity, enhancing	Citizens who are from different backgrounds, educational areas, adaption of new comers to the neighborhood	Newly developed residential area, Kindergarten (3-6 ages), Special education, Primary schools (6-14 ages), High school (14-18 ages), University (18-30 ages), Dormitory (18-30 ages)
Decreasing energy consumption for heating&cooling	Saving cooling energy consumption, decreasing both heating and cooling energy use (Akbari et al., 2001)	High heating and cooling energy needed areas High-risk areas where be affected by high temprature High-risk areas where be affected by low temprature	Industrial areas, Small industrial areas Technopark, High density urban fabric, Medium density urban fabric, Power distribution units, Heat centers, Gas stations, Fire stations
Health benefits	Cooling affect for people who have higher sensitivity to heat stress Reducing cardiovascular disease mortality (Gronlund et al.,	Young children (< 5) and the elderly (> 65) are vulnerable group to heat (Basu and Samet 2002; Kenny et al. 2010; Kabisch et al. 2017; Cortinovis and Geneletti 2018).	Health facilities, Nursing Home and Elderly Rehabilitation Centers (over 60), Kindergarten (3-6 ages)

Benefits	Benefit explanations summary	Who, and which units	Related units/area in landcover map
Air purification	Improving air quality	High concentrated city-based emission sources	Fussel fuel used area, Industrial areas Small industrial areas, Intensive transportation area, Heat center
	Health benefits	Footuses and children, the elderly, and persons with pre-existing diseases group are more vulnerable to damaging health effects of air pollution (Makri and Stilianakis, 2008) High level of air pollutant concentration causes cancer, heart disease, respiratory illnesses, and increases infant mortality (WHO, 2014a); allergy and asthma diseases (Lovasi et al., 2008).	Fussel fuel used area, Health facilities Nursing Home and Elderly Rehabilitation Centers (over 60), Kindergarten (3-6 ages)
Climate regulation	Carbon mitigation	Reducing emission of and stabilize the levels of GHG in the atmosphere (NASA, n.d)	Fussel fuel used area, Industrial areas Small industrial areas, Intensive transportation area, Heat center
	Health benefits	Low quality of air leads to reduce life quality standards, and negativeley impact on health Footuses and children, the elderly, and persons with pre-existing diseases group are more vulnerable to damaging health effects of air pollution (Makri and Stilianakis, 2008) High level of air pollutant concentration causes cancer, heart disease, respiratory illnesses, and increases infant mortality (WHO, 2014a); allergy and asthma diseases (Lovasi et al., 2008).	Health facilities, Nursing Home and Elderly Rehabilitation Centers (over 60), Kindergarten (3-6 ages)
Runoff mitigation	Impact on water supply services	Urban runoff carries the main pollutants which harm to human health and ecosystems	Impervious areas (%) (neighborhood scale), High density urban fabric (neighborhood) (%), Medium density urban fabric (neighborhood) (%), Intensive transportation area
	Impact on transportation services	Increasing travel distance, cost and time	Working area (commercial landuse), Health facilities, Technical infrastructure Fire station, Intensive transportation area
	Impact on power supply services	Due to power units disruption results power outages	Working area (commercial landuse), Industrial areas, Small industrial areas Technopark, Health facilities, Urban storage, Technical infrastructure Power distribution units, Heat centers, Intensive transportation area

Table 3. 13. Determination of vulnerable groups around selected parks.

	Density around the park	Landuses around the park
Ellinci Yıl Park		
Kurtuluş Park		
Münzeviler		

Dikmen Vadisi		
Portakal Çiçeği		
Ahmed Arif		

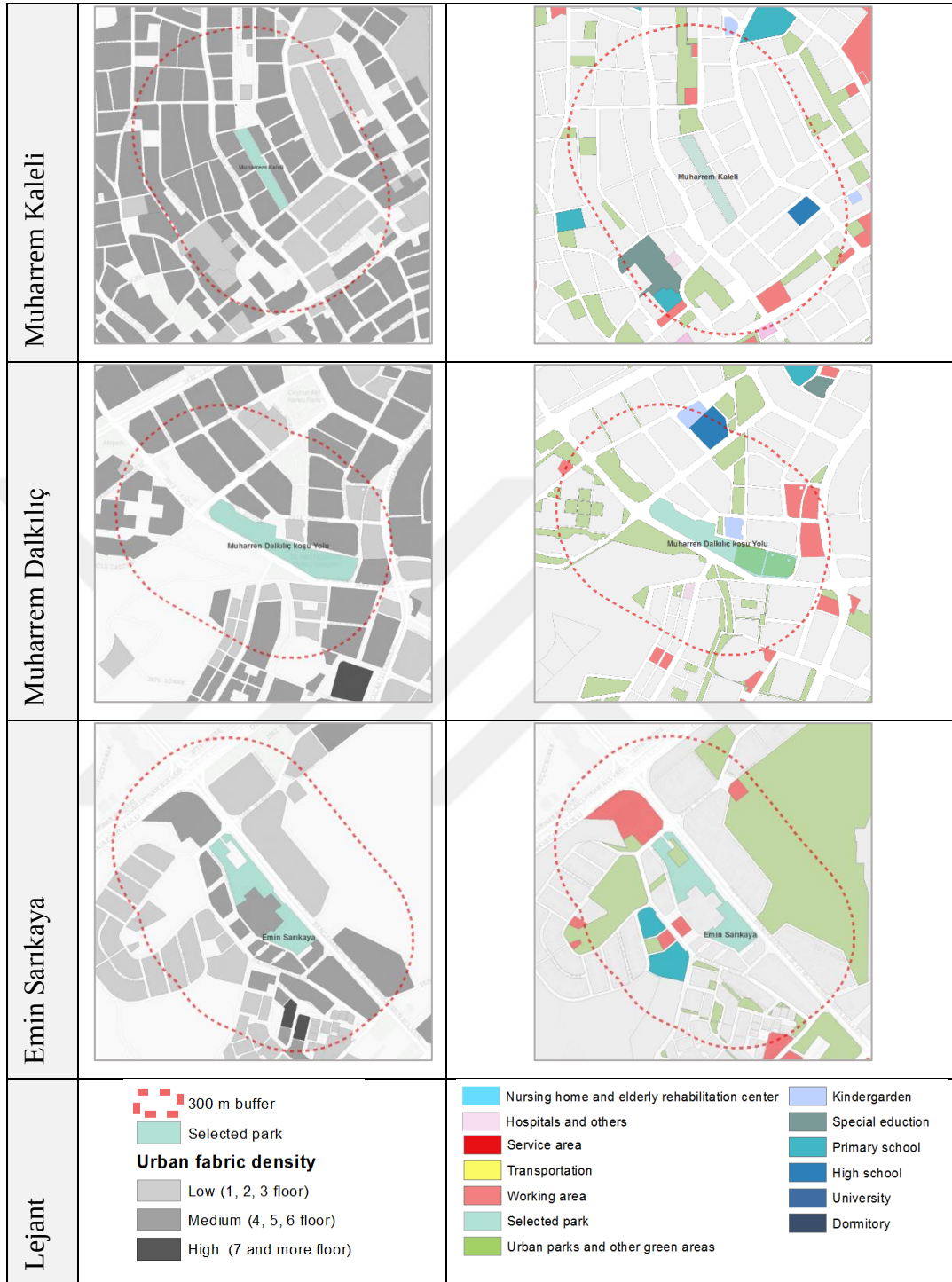


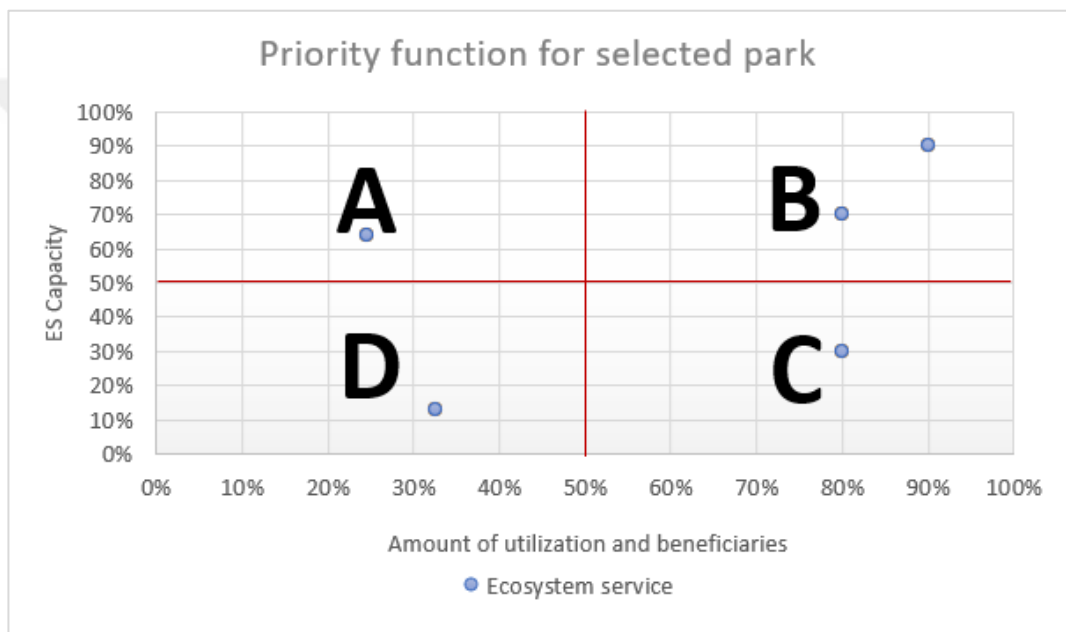
Table 3. 14. Units and priority areas number/coverage used by beneficiaries located within 300 m of the selected park.

	Impervious areas (%) (neighborhood scale)	High density urban fabric (neighborhood) (%)	Medium density urban fabric (neighborhood) (%)	Low density urban fabric (neighborhood)	Newly developed residential area (Y/N)	Fossil fuel used area (Y/N)	Working area (unit)	Small industrial area (unit)	Industrial area (unit)	Technopark (unit)	Kindergarden (0-6 Age) (unit)	Special Education (?) (unit)	Primary school (6-14 Age) (unit)	High school (14-18 Age) (unit)	University (18-30 Age) (unit)	Dormitory (14-30) (unit)	Nursing Home and Elderly Rehabilitation Centers (60 - Age) (unit)	Health facility area (unit)	Sport facilities (unit)	Power distribution units (unit)	Urban storage area (unit)	Technical infrastructure (unit)	Heat center (unit)	Gas station (unit)	Fire station (unit)	Intensive transportation area
Elinciyıl (300 m)	33	0	21	12	0	1	0	0	0	0	0	0	4	0	3	2	0	2	0	0	0	1	0	0	0	4
Kurtuluş Parkı (300 m)	33	6	24	9	0	0	30	0	0	0	1	0	3	1	0	0	0	2	0	0	0	2	0	3	0	12
Münzeviler (300 m)	89	0	85	4	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	6
Dikmen Vadisi (300 m)	63	0	49	14	1	1	17	0	0	0	1	0	9	5	0	0	1	3	2	0	0	0	7	0	2	6
Portakal Çiçeği (300 m)	85	1	77	8	0	0	5	0	0	0	0	0	1	3	0	0	0	2	0	0	0	0	0	0	0	4
Ahmed Arif Parkı (300 m)	32	0	19	13	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	4
Muhammed Arif Parkı (300 m)	82	0	64	18	1	0	1	0	0	0	1	1	2	1	0	0	1	1	0	0	0	0	1	0	1	2
Muhammed Arif Parkı (300 m)	79	1	41	38	0	0	3	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	3	0	1	6
Emin Sankaya (300 m)	65	0	26	39	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	5

3.7 Analysis Tool

The analysis tool was designed to determine the priority ES function of the park. Two inputs (1: ES capacity, 2: ES utilization) were examined to identify the function of each park. In the Y-axis, ES capacity is presented in the X-axis the amount of utilization and beneficiaries were presented. Each marker represented as ES.

Table 3. 15. Analysis tool design (representation)



The diagram is divided into four sections. Each section is defined as areas where two different variables intersect. These sections are titled as A, B, C and D. Accordingly, the area where the ES capacity is high, and the need for ES is low, is “**A part**” that should be protected without interfering with the current situation. “**B part**” is where both variables are the high and should be monitoring. “**D part**” where both variables are low, should be monitoring as Part B. “**C part**” is the area where amount of utilization and primary beneficiaries is high, and ES capacity is low. “**C part**” is the priority part, and the capacity of ES type in this area should be enhanced with suggested urban design inputs.

The demonstration of the analysis tool is given in Tabla 3. 15. Similar graphs were created for each park with the same purpose to identify the function.

As a result of ES mapping, the distribution of ES service belonging to Çankaya district has been revealed. The values obtained from the mapping results were used by presenting them on the park scale. For this, ES values corresponding to the area where the park is located were used. As a result, 6 ES values belonging to 9 parks were obtained. These values are presented in tabular form (Table 3. 16) and converted to percentage values (Table 3. 17) for comparison between parks. For example, the sum of the numerical value offered by the Urban Temperature Regulation service in 9 parks is 540. In order to compare the service offered by the parks within themselves, this value is proportioned to the service provided. Accordingly, the surface area temperature performance of the 50. Yıl Parkı is 80 (Table 3. 16). When a comparison is made between 9 parks, this rate corresponds to 15% (Table 3. 17). In this way, the same calculations were made for other types of ES and parks. These values are represented on the Y axis in the analysis tool.

Table 3. 16. The ratio of the ES provided by the selected parks to the total ecosystem services provision in Çankaya

Name of the park	Neighborhood	Urban temperature regulation*	Air Purification	Climate regulation	Runoff mitigation	Recreation**
50.Yıl	50.Yıl	80	0,06	0,02	0,1	80
Ahmed Arif Parkı	Öveçler	60	0,01	0	0,03	60
Dikmen Vadisi	İlkadım	100	0,43	0,16	0,94	80
Emin Sarıkaya	Koru	40	0,02	0,01	0,02	60
Kurtuluş Parkı	Fidanlık	80	0,12	0,03	0,14	80
Muharrem Dalkılıç Koşu Yolu	Ahmet Taner Kışlalı	20	0	0	0,02	60
Muharrem Kaleli	Ata	20	0,01	0	0,02	60
Münzeviler	Ertuğrulgazi	60	0,02	0,01	0,02	60
Portakal Çiçeği	Aziziye	80	0,04	0,02	0,11	60

*Surface temperature performance (0-100): Average surface temperatures for the evaluated areas were compared. The minimum surface temperature is assumed to be 100 and the increasing temperature is shown with decreasing values.

** Recreational performance (0-100): Number of activities, size, and accessibility inputs were evaluated. For each criterion maximum values were accepted as 100 and averages were taken.

*** Habitat performance (0-100): Size, naturalness, variety, age, rarity, and water availability inputs were evaluated. The maximum values for each criterion were accepted as 100 and the averages were taken.

Table 3. 17. The comparison of ES provided by the selected parks among themselves

Name of the park	Neighborhood	Urban temperature regulation (%)	Air Purification (%)	Climate regulation (%)	Runoff mitigation (%)	Recreation (%)
50.Yıl	50.Yıl	15%	8%	8%	7%	13%
Ahmed Arif Parkı	Öveçler	11%	1%	0%	2%	10%
Dikmen Vadisi	İlkadım	19%	61%	64%	67%	13%
Emin Sarıkaya	Koru	7%	3%	4%	1%	10%
Kurtuluş Parkı	Fidanlık	15%	17%	12%	10%	13%
Muharrem Dalkılıç Koşu Yolu	Ahmet Taner Kışlalı	4%	0%	0%	1%	10%
Muharrem Kaleli	Ata	4%	1%	0%	1%	10%
Münzeviler	Ertuğrulgazi	11%	3%	4%	1%	10%
Portakal Çiçeği	Aziziye	15%	6%	8%	8%	10%

The spatial equivalent of these beneficiaries was obtained from the second mapping study and used as input in the analysis tool. The benefits defined as a result of the theoretical discussion and related landuse units, and relevant inputs expressed in Table 3. 12, Table 3. 13 and Table 3. 14. The finalized summary table is presented in Table 3. 18. These values have been converted to percentages for internal comparison. While making this calculation, first of all, inputs related to ES benefit were collected for each park. These collected values were divided by the total relevant values in other parks. As a result, the values in percent were obtained. The cumulative values of each benefit in terms of percentages for the relevant ecosystem

service are taken. Thus, the need for ES between parks has been defined comparatively (Table 3. 19).

For example, belonging Urban Temperature Regulation service have two defined benefits. One is “decreasing energy consumption for heating and cooling”, and other one is “health benefits”. For this benefits relevant ES utilized number of units and areas are varies between parks. Units and areas associated with these two benefits were collected for each park. Those related numerical values as it follows: 50. Yıl Parkı (56), Kurtuluş Parkı (69), Münzeviler (174), Dikmen Vadisi (119), Portakal Çiçeği (165), Ahmed Arif Parkı (52), Muharrem Kaleli (150), Muharrem Dalkılıç (124), and Emin Sarıkaya (91). Then, the numerical value offered by the Urban Temperature Regulation service were collected. This value is 1000. In order to compare the service offered by the parks within themselves, this value is proportioned for each park separately. As an example, 50. Yıl Parkı have 56 relevant units and areas, the ratio between parks is around 6%.

Table 3. 18. UES benefits and related units/areas belonging 300 m buffer in selected parks

Ecosystem Services	ES benefits	Selected Parks									Total for each benefits	Total for each ES
		Elinciyıl	Kurtuluş Parkı	Münzeviler	Dikmen Vadisi	Portakal Çiçeği	Ahmed Arif Parkı	Muharrem Kaleli	Muharrem Dalkılıç	Emin Sarıkaya		
Urban temperature regulation	Decreasing energy consumption for heating&cooling	54	66	174	114	163	52	147	122	91	983	1000
	Health benefits	2	3	0	5	2	0	3	2	0	17	
Air purification	Improving air quality	5	12	7	9	4	4	2	6	5	54	123
	Health benefits	7	15	7	12	6	4	5	8	5	69	
Carbon sequestration	Carbon mitigation	5	12	7	7	4	4	2	6	5	52	94
	Health benefits	6	6	1	16	3	0	6	2	2	42	
Runoff mitigation	Impact on water supply services	58	75	180	118	167	55	148	127	96	1024	1298
	Impact on transportation services	7	46	7	33	11	6	5	12	10	137	
	Impact on power supply services	7	46	7	33	11	6	5	12	10	137	
Recreation	Education opportunities	9	5	1	16	4	1	6	3	2	47	249
	Health benefits	9	5	1	16	4	1	6	3	2	47	
	Social cohesion and integration	9	5	1	17	4	2	7	3	2	50	
	Increase in workforce and productivity	9	35	1	32	9	2	6	5	6	105	

Table 3. 19. Percentage values of need for UES in selected parks.

Ecosystem Services	Selected Parks								
	Ellinciyl	Kurtuluş Parkı	Münzeviler	Dikmen Vadisi	Portakal Çiçeği	Ahmed Arif Parkı	Muharrem Kaleli	Muharrem Dalkılıç	Emin Sarıkaya
Urban temperature regulation (%)	6	7	17	12	17	5	15	12	9
Air purification (%)	10	22	11	17	8	7	6	11	8
Climate regulation (%)	12	19	9	24	7	4	9	9	7
Runoff mitigation (%)	6	13	15	14	15	5	12	12	9
Recreation (%)	14	20	2	33	8	2	10	6	5



CHAPTER 4

MAPPING ECOSYSTEM SERVICE CAPACITY, UTILIZATION AND BENEFICIARIES ANALYSES OF THE SELECTED PARKS

This study explored the planning and design inputs for urban green areas to maximize the current capacity of needed ES to improve human health and wellbeing. Through mapping study, current ES potential were revealed. With the light of literature review, benefit of ES and their priority beneficiaries were defined. This qualitative data transformed into quantitative data via ArcGIS software through second mapping study. In this way amount of utilization and beneficiaries of ES were detected. With using analysis tool, these two data was organized in percentages for relative comparison.

According to analysis tool, selected parks where the existing potential of ES is low and amount of utilization and beneficiaries are high were determined as ES function for each park. To enhance capacity in accordance with park's ES function, determined urban design strategies were suggested in accordance with the results of Chapter 2.

4.1 Mapping Study 1 Results: Current ES Capacity in Selected Parks

In the study, the value of the contribution of urban parks to the provision of ES for the city was considered. To make a comparison between the parks in terms of ES provision, all the selected parks ES values was calculated in Chapter 3. 7, and presented as percentage for comparison.

These values are represented in a radar chart. A radar chart is a graphical representation of multivariate data that shows the data in a two-dimensional chart with multiple axes (Porter and Niksiar, 2018).

Since Dikmen Vadisi has a larger area compared to other selected parks, provision ES is much higher than other parks. Radar chart of Dikmen Vadisi is shown separately.

According to the chart (see Figure 4. 1), each service is shown in a different color. Kurtuluş Parkı is the park that stands out among 8 parks in terms of its service capacity. If the urban heat island effect is neglected, the temperature should decrease by 1°C every 200 meters in accordance with the relationship between temperature and altitude. Therefore, the green area with the highest temperature among the evaluated areas should be Kurtuluş Park, which is at the lowest altitude. While Kurtuluş Park is expected to be warm due to its location in the district center, Kurtuluş Park has a much lower temperature than expected among the compared areas due to the presence of old trees with wide crowns.

Urban temperature regulation service capacity shown by orange color in the chart is the same in 50. Yıl Parkı, Kurtuluş Parkı and Portakal Çiçeği Parkı. In addition, the size of the park has increased the success in balancing the temperature. For this reason, the performance is low in parks such as Muharrem Kaleli with 0.8 ha, and Muharrem Dalkılıç with 1.9 ha which were evaluated in small size park category.

Air purification, climate regulation and runoff mitigation services have correlation with two factors: (1) Presence of trees in the area, (2) Area size. As the size of the area increases, its vegetation will also increase and this influence service performance. Kurtuluş Parkı, Dikmen Vadisi and 50. Yıl Parkı have the highest score in terms of providing recreation services. Among the reasons for this can be explained by the fact that Dikmen Vadisi is more accessible in terms of size and form, Kurtuluş Parkı and 50. Yıl Parkı are close to the city center and there are dense residential patterns around it.

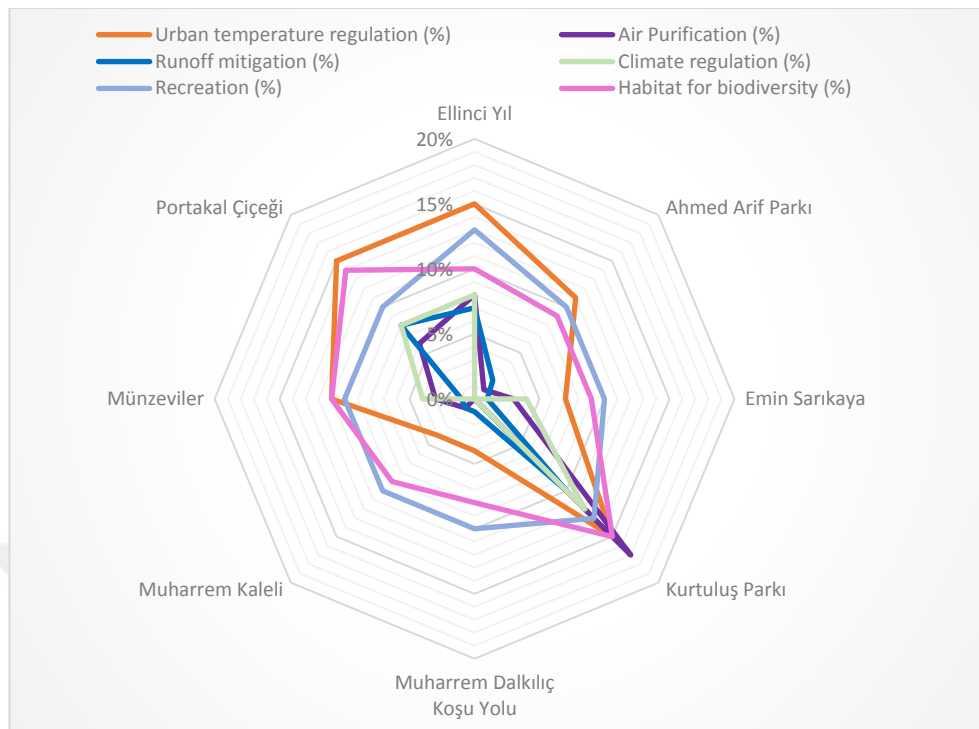


Figure 4.1 The comparison of ES provided by 8 selected parks among themselves

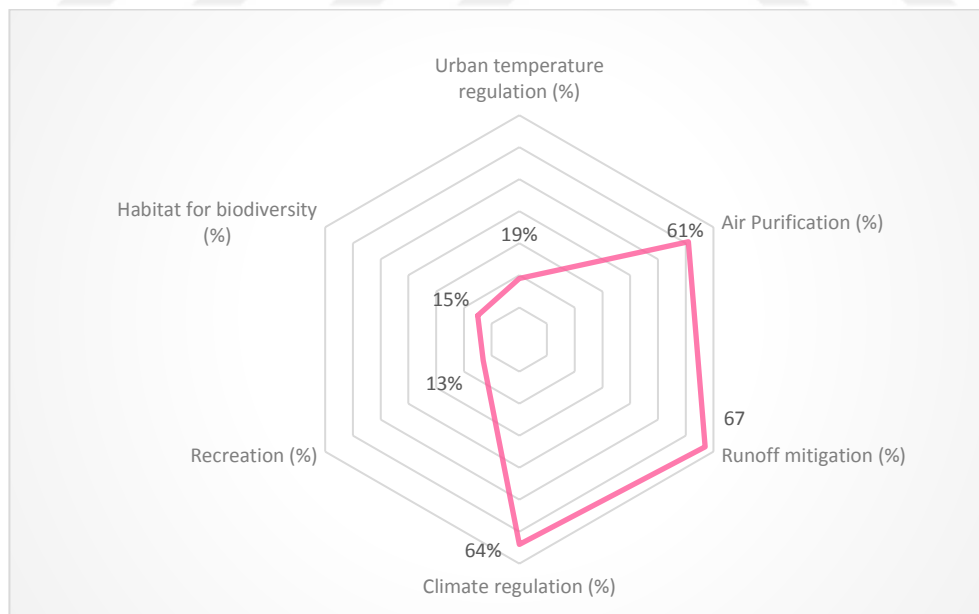


Figure 4.2. ES provision of Dikmen Vadisi

4.2 Mapping Study 2: Amount of Utilization and Beneficiaries

In the study, benefits and primary beneficiaries of selected ES was defined with the light of literature review. The spatial equivalent of these beneficiaries was obtained from the second mapping study and used as input in the analysis tool.

These values are also represented in a radar chart to relative comparison (Figure 4.3). These values are based on the data which is explained in Chapter 3. 7. Amount of needed ES shown in a different color. Accordingly, Dikmen Vadisi steps forward with the need for the recreation and climate regulation services.

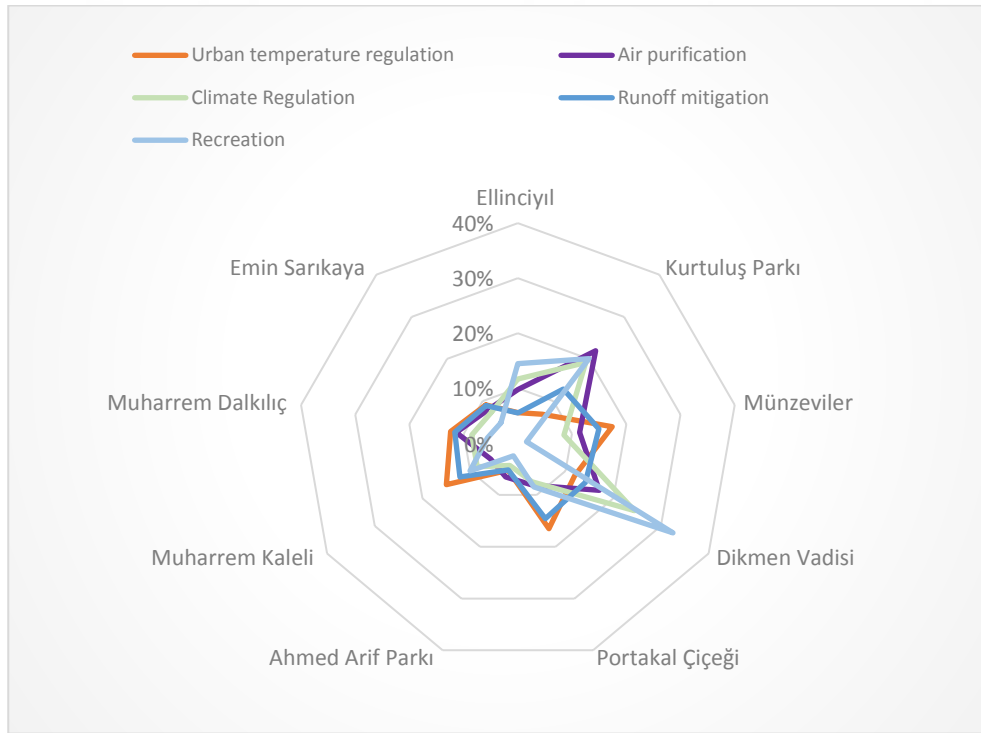


Figure 4.3. The need of ES for selected parks.

4.3 Determination of priority function for selected parks

In this section, how different features of selected parks affect ES provision has been evaluated. Google earth images were taken by using Google Earth Pro software in around 15 years periods to understand changes in urban fabric and give an idea about

future needs. Also, It provides information for squatter housing areas that cannot be determined by plans and remote sensing images. Coal is used for heating in these areas, and coal as fuel has a great contribution to air pollution. It is important to determine these areas because there is a greater need for air purification and climate regulation services.

While examining the parks, attention was drawn to utilization areas and units are in the 300 m buffer of the selected parks which was specified in Chapter 3. 6. In urban design inputs context, such as shape of the park, presence of water components, quantity of trees, tree species; impermeable surfaces, units and facilities in park are important. So that, these features are also mentioned while examining the park.

As mentioned in Chapter 3. 7, analysis tool helps to determine the priority ES function of the park to enhance the needed ES capacity. There are two important inputs which are shown in X and Y axis. ES capacity (y-axis), these values are result of ES mapping process and mentioned in Table 3. 17. ES utilization (x-axis): these values are result of second mapping study, and mentioned in Table 3. 19. As was stated in Chapter 3. 7., where these two variables intersect in a high primary beneficiaries and low ES capacity area is the park's priority function. According to priority function of the park, design inputs which was discussed in Table 2. 9 are given.

4.3.1 Ellinciyl Park

Ellinci Yıl Park is the only park located in 50. Yıl neighborhood. It was established in 1970. The total area of the park is around 14 ha with covering %40 of the neighborhood (see Figure 4. 5). The streets around the park consist of medium-rised (4,5,6 floor) housing. As it is seen in the satellite images took in 2004 and 2020 (see Figure 4. 4), most of the squatter houses seem to have been demolished. Fossil fuel use is still common in this area. This affects the air quality.



Figure 4.4. Satellite images of 50.Yıl Park took in 2004 and 2020 (Google Earth Pro)

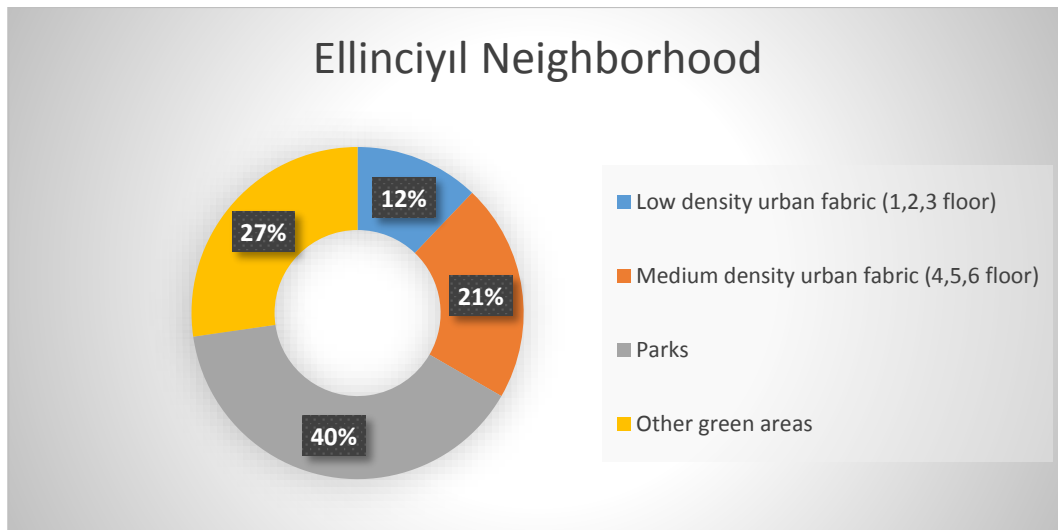


Figure 4. 5. Natural and built environment proportion in 50.Yıl Neighborhood

In Çankaya Municipality Land use Plan, demolished area is planned as urban park. Around the planned park, there will be residential units with medium-rised floor (4,5,6 floor).

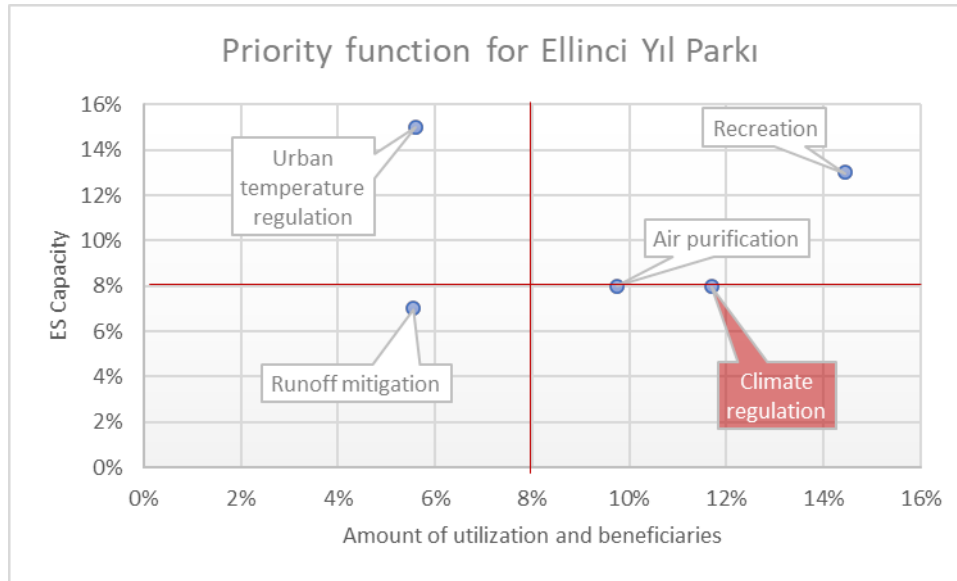
Ankara University is in 300 m buffer of the park. In addition, 2 dormitories and 4 primary school is in the buffer. The Park is close to the selected two other parks and city center.

The park has 2000 m² of grass surface. Although most of the walking areas are covered with permeable surfaces, hard floors are used in some physical activity areas such as sport fields, jogging tracks, or gathering places. There are children's playgrounds in the park with plastic toys and covering rubber surfaces. Planting with high irrigation needs. The park has great water component, artificial pond with around 1800 m², and there is vegetation with high irrigation needs.



Figure 4. 6. General overview of Ellinci Yıl Park (Google Image Street View)

Table 4. 1. Determination of priority ES function for Ellinci Yıl Parkı



According to Table 4. 1, urban temperature regulation service performance should be protected. Recreation, air purification and runoff mitigation services should be monitoring. Climate regulation service is the primary ES function of the park. This service should be enhanced to maximize the utility of the park. Design inputs are given in the Table 4. 2. In urban scale, UGI networks connection, avoiding to building blocks parallel to slopes, and increasing UGI along the waterways can help to enhance climate regulation service performance. In street scale, permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles), using wood blocks or timber grids where porous concrete is preferred, rain gardens, swales, planting large canopy trees in one or double side of the streets, lighter-colored buildings, greening façades-walls-roofs and water-based cooling (such as blue roofs), vegetation barriers, roadside vegetation, mix of deciduous and coniferous tree plantation, green façades, green walls, green roofs, shrubs and intense green roofs in limited space for trees. In park and street scale, permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles), using wood blocks or timber grids where porous concrete is preferred, collecting water in retention ponds, swales, and lakes, infiltration ponds, rain gardens, planting large canopy trees. Inside the park, buildings are suggested with lighter-colored, greening façades-walls-roofs

and water-based cooling (such as blue roofs) nature-based solutions can contribute to enhance carbon mitigation and increase the climate regulation performance.

As mentioned in Chapter 2, urban design inputs for habitat for biodiversity service is cross-cutting issue to suggest for each park. Suggested urban design inputs are shown in the Table 4. 2.

Table 4. 2. Design inputs to enhance carbon mitigation and increase climate regulation performance.

	Design input		
	Urban	Street	Park
Climate regulation	UGI networks connection avoiding to building blocks parallel to slopes increasing UGI along the waterways	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred rain gardens swales planting large canopy trees in one or double side of the streets lighter-colored buildings, greening façades-walls-roofs and water-based cooling (such as blue roofs) vegetation barriers roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred collecting water in retention ponds, swales, and lakes infiltration ponds rain gardens planting large canopy trees Inside the park, buildings are suggested with lighter- colored, greening façades-walls-roofs and water-based cooling (such as blue roofs)

4.3.2 Kurtuluş Parkı

Kurtuluş Parkı is located in Fidanlık Neighborhood with covering 97% of the total park in the neighborhood. It was established in 1980. The streets around the park consist of medium-rise (4,5,6 floor) housing. In the north side of the park, Celal Bayar Boulevard forms the border. As it is seen in the satellite image took in 2004 and 2020, it is not observed a significant change in the form of the park and surroundings (Figure 4. 7). There is also heavy traffic on Celal Bayar Boulevard and other roads surrounding the park during the day.



Figure 4. 7. Satellite images of Kurtuluş Parkı took in 2004 and 2020 (Google Earth Pro)

Commercial areas are densely located in the neighborhood. Hacettepe University hospital is located in a 300 m buffer. In addition, there are 3 primary schools and 1 nursery close to the park. 2 fuel stations are also located here.

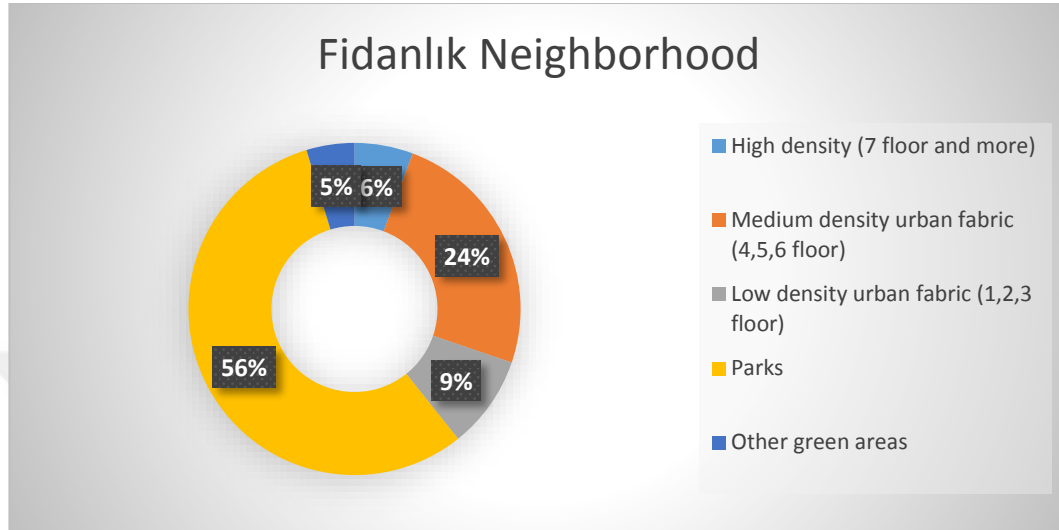


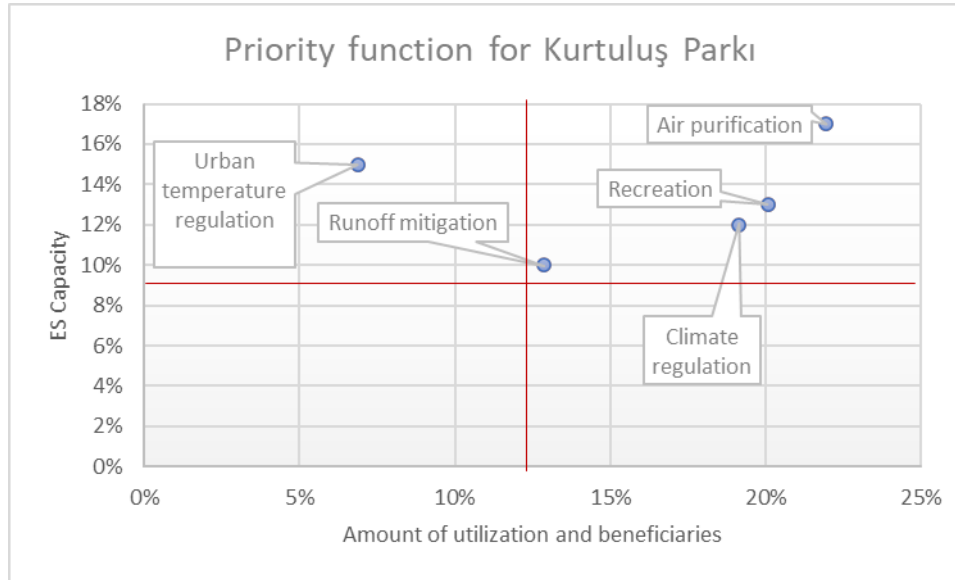
Figure 4. 8. Natural and built environment proportion in Fidanlık Neighborhood

The total surface area of the park is 11.46 hectares with covering 90% permeable surface. There is a commercial facility within this area that visitors can benefit from. The total built structure in the park covers 11.364 m². There is an artificial pond in the park with around 2.000 m². Most of the walking area covers with non-permeable surfaces, and the jogging tracks covers with artificial grass material. There is a children playground in the park. The material of the toys is plastic.

There are large-leaved old trees in the park. In addition, there is mix type tree species with deciduous trees covers 98.000 m² and coniferous trees cover 1.391 m².

Although there are few high irrigation needs-planting areas, grass surfaces cover around 1.000 m² in the park.

Table 4. 3. Determination of priority ES function for Kurtuluş Parkı



According to Table 4. 3, urban temperature regulation and runoff mitigation service performance should be protected. Recreation, air purification and climate regulation services should be monitoring. Urban design inputs belonging habitat for biodiversity service performance should be applied for all parks, as mentioned Chapter 2.

Table 4. 4. Design inputs to enhance habitat for biodiversity service performance.

	Design input		
	Urban	Street	Park
Habitat for biodiversity	larger green areas square or circular form of green areas green corridors riparian corridors creating	greening streets wildlife crossing greenways planting high tree canopy sized trees native plants	birdhouses or feeders planting high tree canopy sized trees rain gardens bioswales bioretention basis green roofs, green façades, green walls leaving dead trees in green areas water component leaving dead trees

4.3.3 Münzeviler Parkı

Münzeviler Parkı is located in Ertuğrulgazi Neighborhood with covering 90% of the total park in the neighborhood. The total area of the park is 1.85 ha. It was established in 2000. The streets around the park consist of medium-rised (4,5,6 floor) housing. As it is seen in the satellite image took in 2004 and 2020, It is possible to see the trees in the park develop in years (see Figure 4. 9). There are mixed-type tree species in the area, and 90% of all covers with deciduous trees (13.580 m²). In addition, inferred from the image, most of the squatter area which is located south of the park have been replaced by medium-density urban fabric (4,5,6 floor). It is observed that there are still squatter housing with fossil fuel use in the area.



Figure 4. 9. Satellite images of Münzeviler Parkı took in 2004 and 2020 (Google Earth Pro)

Residential areas are densely located in the neighborhood. 1 primary school is located in a 300 m buffer.

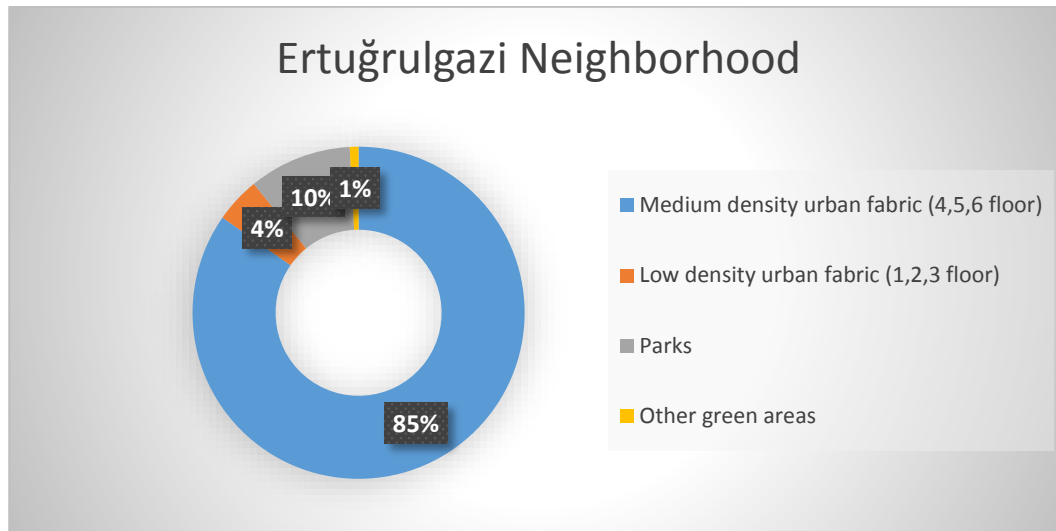


Figure 4. 10. Natural and built environment proportion in Ertuğrulgazi Neighborhood

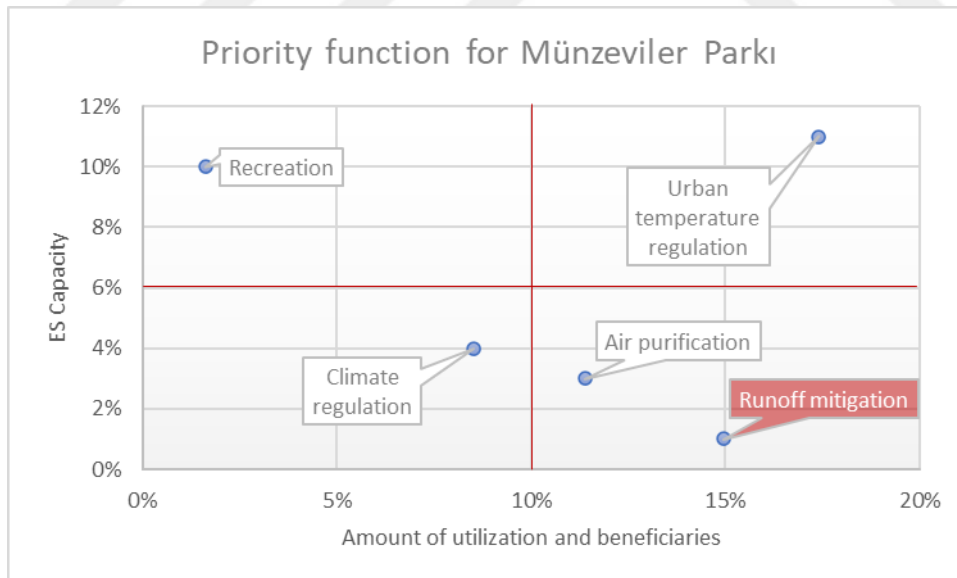
The total surface area of the park is 17.987 m² with covering 81% permeable surface. There are open-sport facilities, children playground, jogging tracks covers with non-permeable surface. There is a children playground in the park. The material of the toys is plastic.

There is mix type tree species with deciduous trees covers 13.528 m² and coniferous trees cover 3.398 m². There is no high irrigation needs-plants, the steppes cover 228 m².



Figure 4. 11. General overview of Münzeviler Parkı (Photograph: Elif Deniz Ülker)

Table 4. 5. Determination of priority ES function for Münzeviler Parkı



According to Table 4. 5, recreation service performance should be protected. Urban temperature regulation service and climate regulation services should be monitoring. Air purification and runoff mitigation service is the primary ES functions of the park.

Because the need of the service value is higher in runoff mitigation service, design inputs are given to enhance this service capacity in Table 4. 6. In urban scale, restoration in flood plains in the lower basin can help to mitigate runoff. In street and park scale, lawn replacement with native plants, bioretention areas, rain gardens, disconnection downspouts, water harvesting, permeable pavements, green roofs, green façades, green walls usage can help to increase the runoff mitigation performance. In park scale, plants with helophyte filters usage also enhance the capacity. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.

Table 4. 6. Design inputs to enhance runoff mitigation service performance.

	Urban	Street	Park
Runoff mitigation	restoration in flood plains in the lower basin	lawn replacement with native plants bioretention areas rain gardens disconnection downspouts water harvesting permeable pavements green roofs, green façades, green walls	lawn replacement with native plants plants with helophyte filters bioretention areas rain gardens disconnection downspouts water harvesting permeable pavements green roofs, green façades, green walls

4.3.4 Dikmen Vadisi

Dikmen Vadisi is the largest one with around 49.5 ha among the selected parks which located in three neighborhoods İlkadım, Ayrancı and Güzeltepe. In this case, all three neighborhoods will be evaluated when examine the park. The parks cover 25% of the neighborhoods. Medium density urban fabric covers 50% of three neighborhoods.

Dikmen Vadisi covers 96% of the parks located in these three neighborhoods. Dikmen Vadisi Project is among the first examples of large-scale urban regeneration projects in Turkey and implemented step by step in different years. The first step was established in 1994. As it is seen from the satellite image (Figure 4. 12), there are newly developed areas, and old one with squatter housing with fossil fuel use. The valley connects settlement areas with different socio-economic levels.

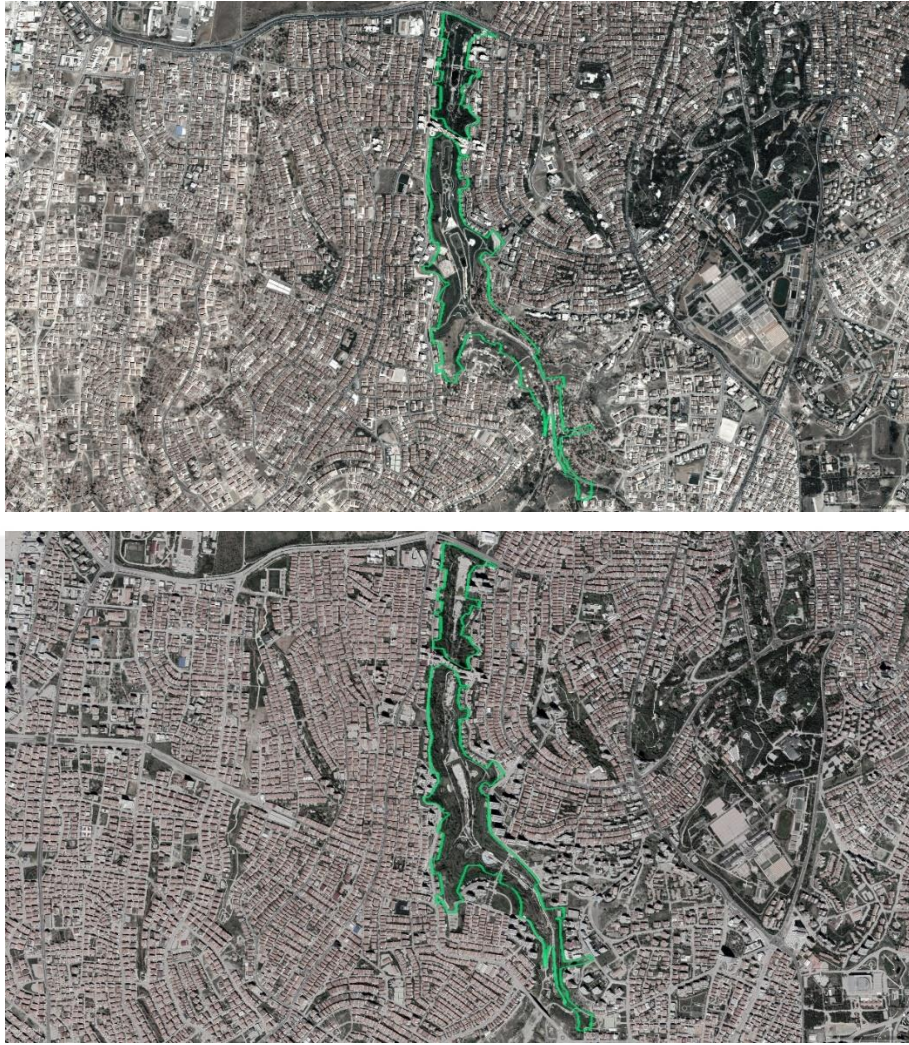


Figure 4. 12. Satellite images of Dikmen Vadisi took in 2004 and 2020 (Google Earth Pro)

Because the area of the park is large, there are many educational, technical and health service facilities in 300 m buffer. Hoşdere Street passes on the west side of the park. Commercial uses are concentrated on this street. There are 1 kindergarden, 9 primary school and 5 high school units in this buffer. 1 nursing home and elderly rehabilitation center, and 3 health facility areas are in the area. In addition, 7 technical infrastructure units, and 2 gas station is also located.

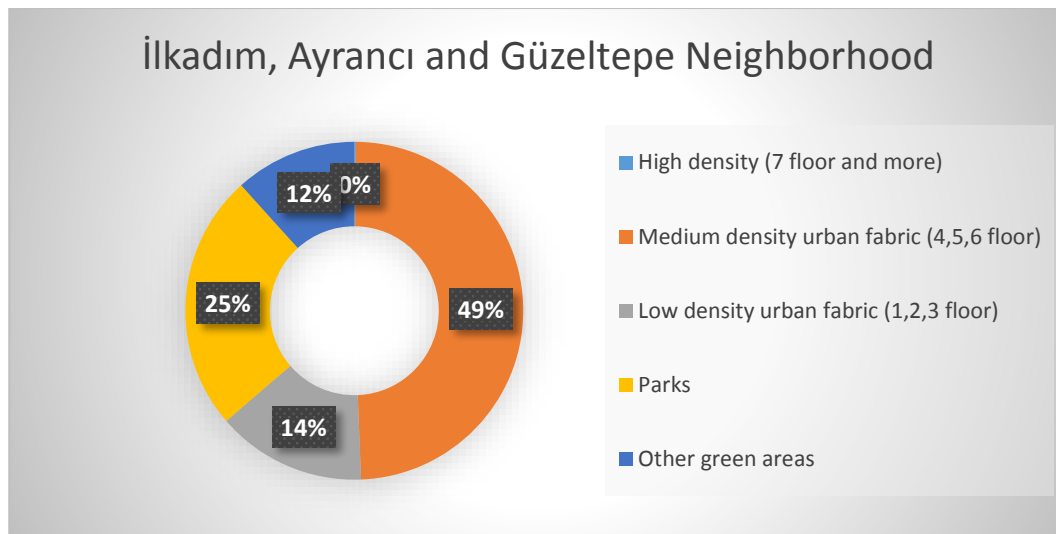


Figure 4. 13. Natural and built environment proportion in İlkadım, Ayrancı and Güzeltepe Neighborhood

The total surface area of the park is 49.4075 ha with covering 84% permeable surface. There is a commercial facility, concert hall, walking trail and jogging tracks with non-permeable surfaces in this area that visitors can benefit from. There is a children playground in the park. The material of the toys is plastic. There is an artificial pound in the park with around 2.926 m².

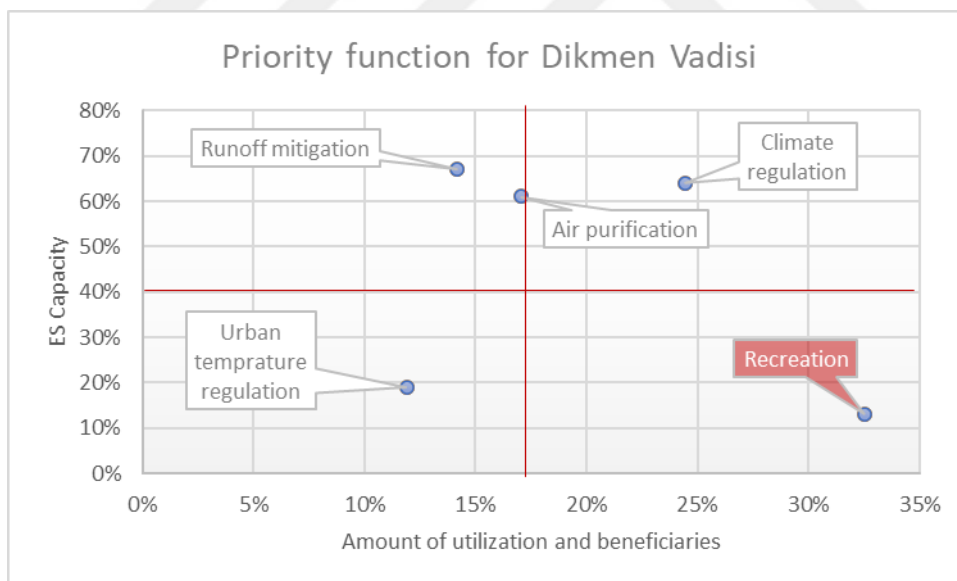
In the area the composition of vegetation and tree species various. Steppe vegetation covers 8.430 m² with 2% of the park. There is mix type tree species with deciduous trees covers 313.582 m² with 63% and coniferous trees cover 22. 512 m² with 5%.

There are high irrigation needs-planting areas, and grass surfaces cover around 67.512 m² with 16% of the park.



Figure 4. 14. General overview inside Dikmen Vadisi (Photograph: Elif Deniz Ülker)

Table 4. 7. Determination of priority ES function for Dikmen Vadisi



According to Table 4. 17 results, the prior ES function of the park is recreation services. To enhance this service capacity, designing areas that will allow recreational activities is important. Dikmen Vadisi have opportunity to walking, nature observation, and other recreational activities. The components that might

increase the usage of the park for recreational usage, such as creating platforms that can be performed dancing or other artistic or physical activities can be added.

4.3.5 Emin Sarıkaya Park

Emin Sarıkaya Parkı is in Koru neighborhood with covering only 26% of the total parks in the neighborhood. The streets around the park consist of high density with more than 7 floor. As it is seen in the satellite image (see Figure 4. 15) took in 2004 and 2020, It is obvious that the form of the near settings has been not changed.



Figure 4. 15. Satellite images of Emin Sarıkaya took in 2004 and 2020 (Google Earth Pro)

Residential areas are densely located in the neighborhood. In addition, 2 primary schools, and commercial areas are in 300 m buffer.

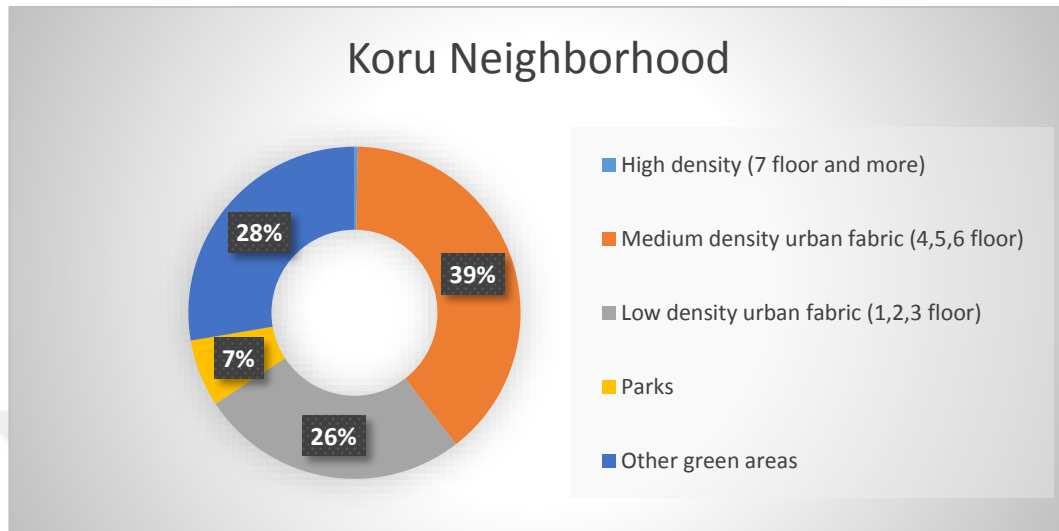
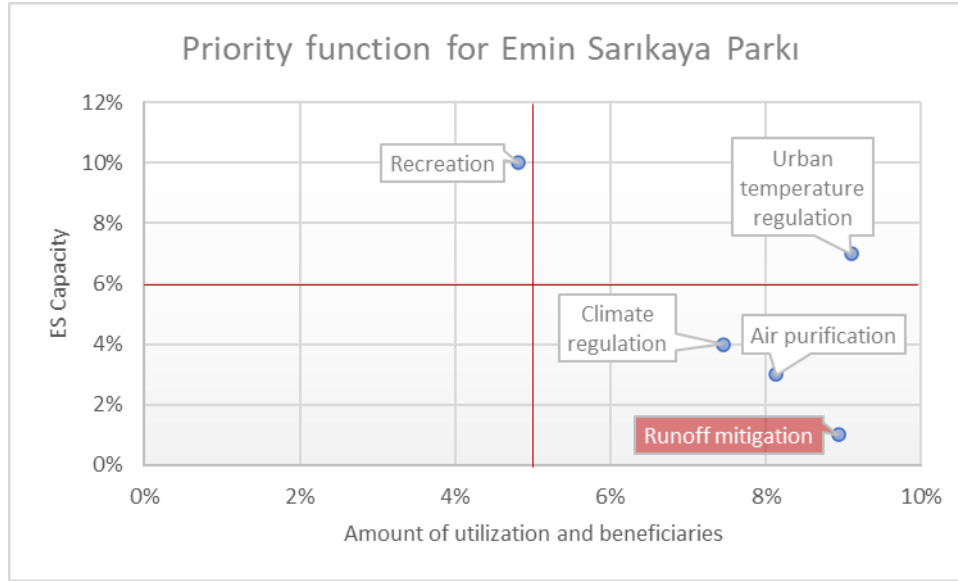


Figure 4. 16. Natural and built environment proportion in Koru Neighborhood.

The total surface area of the park is 29.521 m² with covering 37% impermeable surface. Most of the walking area covers with non-permeable surfaces, and the jogging tracks covers with artificial grass material. There is a children playground in the park. The material of the toys is plastic. There is a tennis court with an impermeable surface. There is mix type tree species with mostly deciduous trees covers 12.793 m² with 63% and coniferous trees cover 3.234 m² with 11%.

Table 4. 8. Determination of priority ES function for Emin Sarıkaya Parkı



According to Table 4. 8, recreation service performance should be protected. Urban temperature services should be monitoring. Climate regulation, air purification and runoff mitigation service is the primary ES functions of the park. Because amount of utilization and beneficiaries value is higher in runoff mitigation service, design inputs are given to enhance this service capacity. Design inputs were given in Table 4. 6 as mentioned in Münzeviler Parkı. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.

4.3.6 Portakal Çiçeği Parkı

The area of Portakal Çiçeği Parkı is 5.38 ha. The Park was established in 1991. Medium density urban fabric covers 77% of the neighborhood. As it is seen from the satellite image (Figure 4. 17), the park was maintained in 16 years.



Figure 4. 17. Satellite images of Portakal Çiçeği took in 2004 and 2020 (Google Earth Pro).

Residential areas are densely located in the neighborhood. There are two high-story buildings next to the park. In addition, 1 primary schools, 3 high schools, commercial areas, and two health service units are located in 300 m buffer.

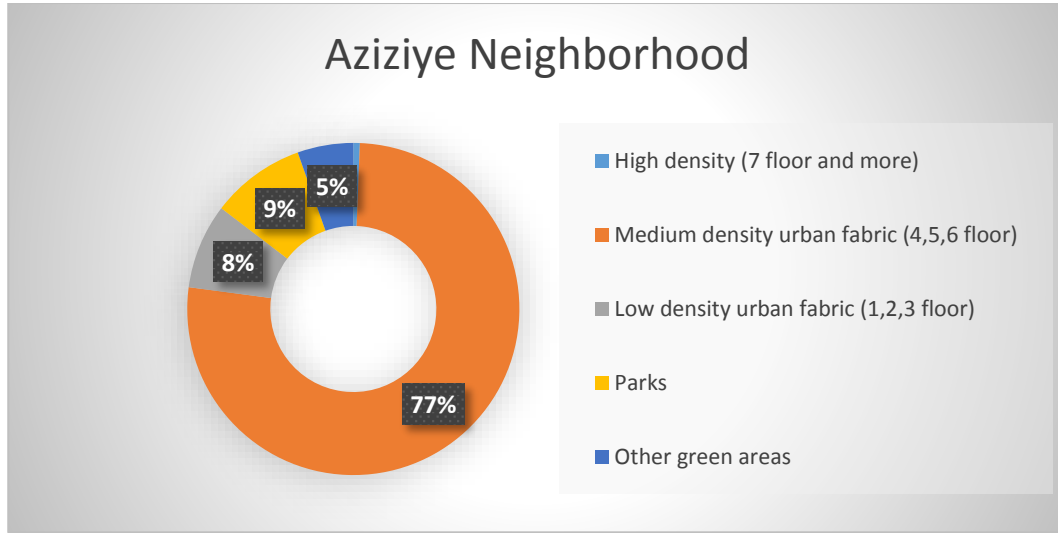


Figure 4. 18. Natural and built environment proportion in Aziziye Neighborhood.

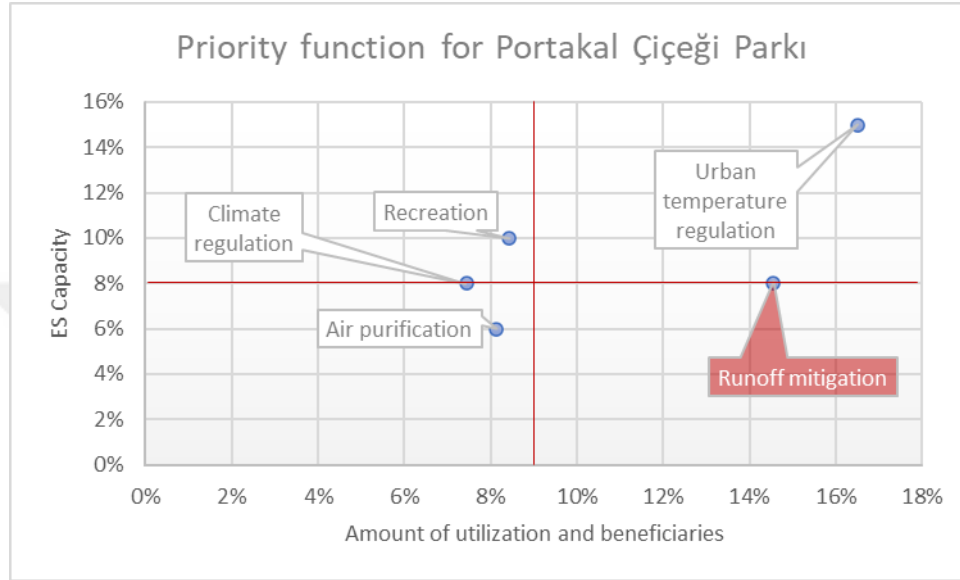


Figure 4. 19. General overview inside Portakal Çiçeği Parkı (Photograph: Elif Deniz Ülker)

The total surface area of the park is 53.863 m² with covering 9% impermeable surface. Most of the walking area covers with non-permeable surfaces with permeable. There is a children playground in the park.

There is mix type tree species with mostly deciduous trees covers 31.182 m² with 58% and coniferous trees cover 1.701 m² with 3%. There is an artificial pound in the park with around 12.000 m².

Table 4. 9. Determination of priority ES function for Portakal Çiçeği Parkı



According to Table 4. 9, recreation and climate regulation service performance should be protected. Urban temperature and air purification services should be monitoring. Runoff mitigation service is the primary ES function of the park. Design inputs were given in Table 4. 6 as mentioned in Münzeviler Parkı. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.

4.3.7 Ahmed Arif Parkı

Ahmed Arif Parkı is located in Öveçler Neighborhood with covering 30% of the total parks in the neighborhood. The park was established in 2000. The streets around the park consist of medium-rise (4,5,6 floor) residential units. Satellite image taken in 2004 shows the squatter housing area to the west of the park. In the image taken in

2020, it is seen that this area has been transformed into a short green area corridor (Figure 4. 20).



Figure 4. 20. Satellite images of Ahmed Arif Park took in 2004 and 2020 (Google Earth Pro)

Residential areas are densely located in the neighborhood. In addition, 1 high school, gas station, and technical infrastructure units are located in 300 m buffer.

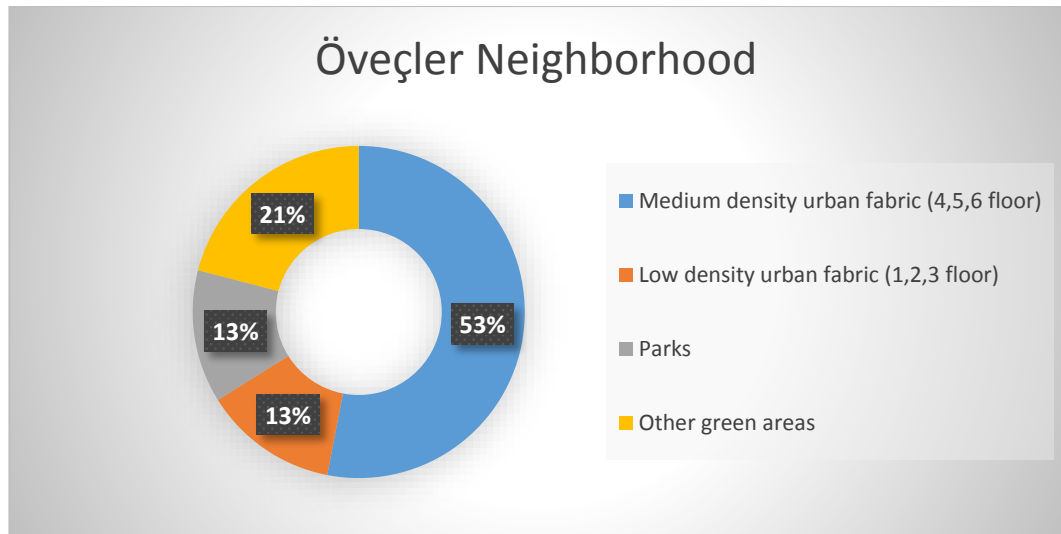


Figure 4. 21. Natural and built environment proportion in Öveçler Neighborhood

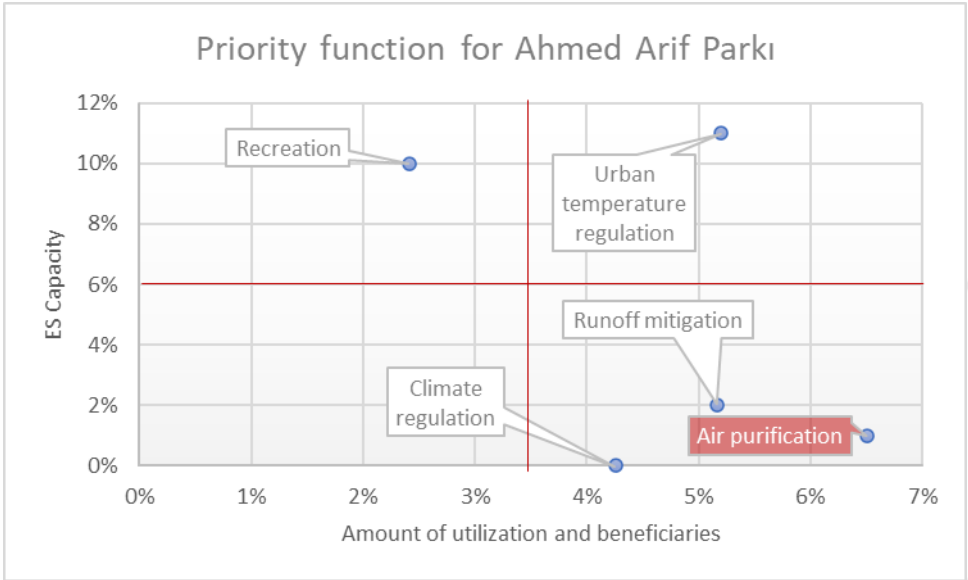


Figure 4. 22. General overview inside Ahmed Arif Parkı (Photograph: Elif Deniz Ülker)

The total surface area of the park is 14.900 m² with covering 12% impermeable surface. Most of the walking area covers with non-permeable surfaces. There is a children playground in the park.

There is mix type tree species with mostly deciduous trees covers 31.182 m² with 58% and coniferous trees cover 1.701 m² with 3%. There is an artificial pound in the park with around 412 m².

Table 4. 10. Determination of priority ES function for Ahmed Arif Parkı



According to Table 4. 10, recreation service performance should be protected. Urban temperature regulation service should be monitoring. Climate regulation service, Runoff mitigation and air purification services are the primary ES functions of the park. Because amount of utilization and beneficiaries value is higher in air purification service, design inputs are given to enhance this service capacity. Design inputs were given in Table 4. 11. In urban scale, green corridors can help to enhance air quality. In street and park scale, vegetation barriers, roadside vegetation, mix of deciduous and coniferous tree plantation, green façades, green walls, green roofs , shrubs and intense green roofs in limited space for trees can enhance the air purification service performance. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.

Table 4. 11. Design inputs to enhance air purification service performance.

	Urban	Street	Park
Air purification	green corridors	vegetation barriers roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees	vegetation barriers roadside vegetation mix of deciduous and coniferous tree plantation green façades, green walls, green roofs shrubs and intense green roofs in limited space for trees

4.3.8 Muharrem Kaleli Parkı

Muharrem Kaleli Parkı is located in Ata neighborhood. It was established in 2009. The total area of the park is around 0,89 ha with covering 17% of the total parks in the neighborhood. As it is seen in the satellite images took in 2004 and 2020 (see Figure 4. 23), most of the squatter houses seem to have been demolished. It can be inferred from the images; the area is newly developed. The streets around the park consist of buildings with 4 story heights.



Figure 4. 23. Satellite images of Muharrem Kaleli Park took in 2004 and 2020 (Google Earth Pro)

There are mostly residential areas in the neighborhood. In addition, there area also educational units with one kindergarden, one special education, two primary school and one high school units. There are also nursing home and elderly rehabilitation, and health facilities in the neighborhood. Also, technical infrastructure units and gas station are located. There is low density traffic around the park.

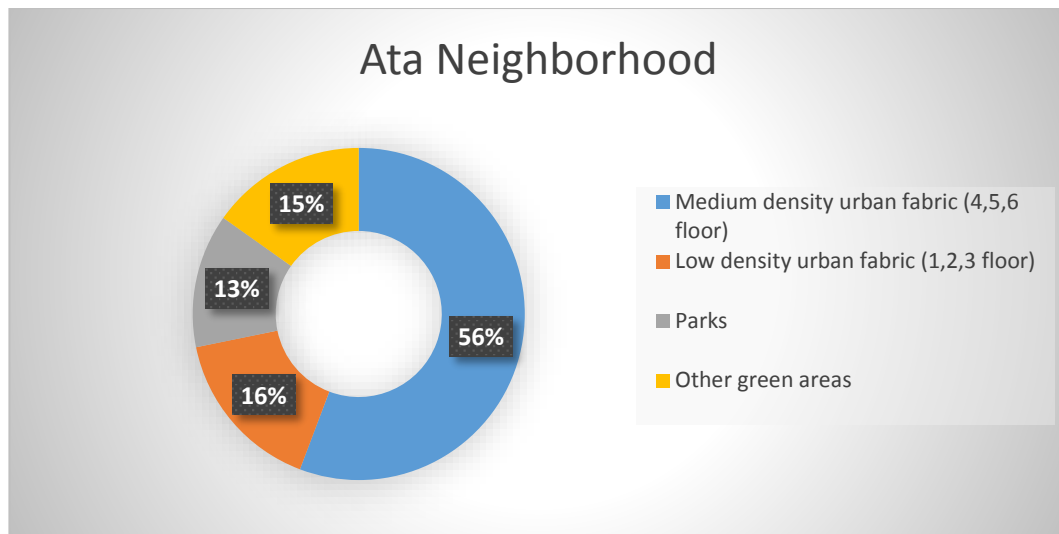


Figure 4. 24. Natural and built environment proportion in Öveçler Neighborhood

The Park has 8.972 m² area. 21% of the area covers with impermeable surface. Most of the walking area covers with non-permeable surfaces. There is a children playground in the park.

There is walking trail with permeable and impermeable surfaces, jogging tracks with artificial grass and sport facilities in the area. There is a children playground in the park. The material of the toys is plastic.

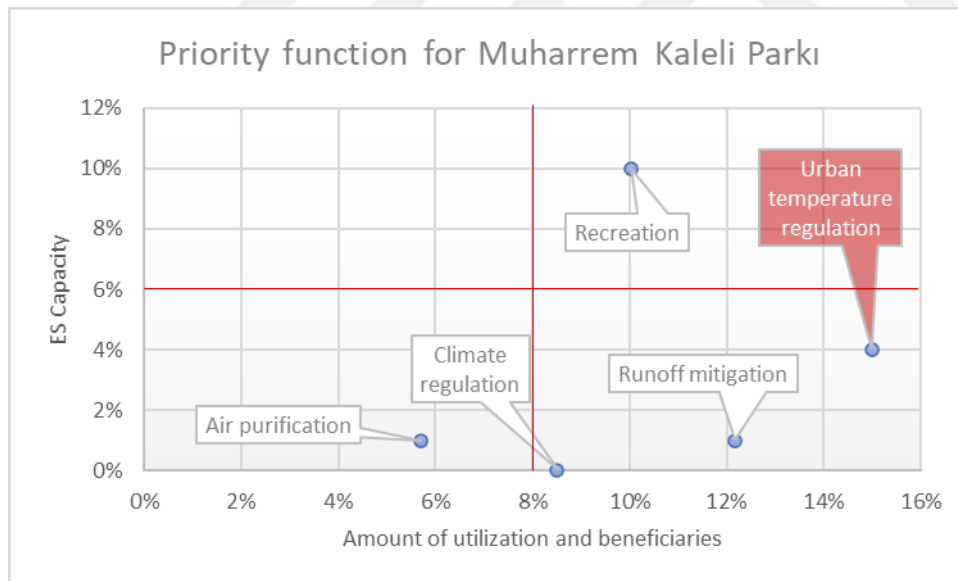
In the park the composition of vegetation and tree species various. Steppe vegetation covers 1.206 m² with 13% of the park. There is mix type tree species with deciduous trees covers 4.803 m² with 54% and coniferous trees cover 172 m² with 2%.

There are high irrigation needs-planting areas, and grass surfaces cover around 756 m² with 8% of the park.



Figure 4. 25. General overview inside Muharrem Kaleli Parkı (Photograph: Elif Deniz Ülker)

Table 4. 12. Determination of priority ES function for Muharrem Kaleli Parkı



According to Table 4. 12, recreation and air purification services should be monitoring. Climate regulation, runoff mitigation and urban temperature regulation services are the primary ES function of the park. Because amount of utilization and beneficiaries value is higher in urban temperature service, design inputs are

suggested to enhance this service capacity. Design inputs were given in Table 4. 13. In urban scale, UGI networks connection, avoiding to building blocks parallel to slopes, and increasing UGI along the waterways can help to enhance urban temperature regulation service performance. In street and park scale, permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles), using wood blocks or timber grids where porous concrete is preferred, rain gardens, swales, rain gardens, swales, planting large canopy trees in one or double side of the streets, lighter-colored buildings, greening façades-walls-roofs and water-based cooling (such as blue roofs) can contribute to enhance urban temperature regulation service performance. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.

Table 4. 13. Design inputs to enhance urban temperature service performance.

	Design input		
	Urban	Street	Park
Urban temperature regulation	UGI networks connection avoiding to building blocks parallel to slopes increasing UGI along the waterways	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred rain gardens swales planting large canopy trees in one or double side of the streets lighter-colored buildings, greening façades-walls-roofs, and water-based cooling (such as blue roofs)	permeable surfaces (such as shingle grids, gravel lawns, bark chippings, and pebbles) using wood blocks or timber grids where porous concrete is preferred collecting water in retention ponds, swales, and lakes infiltration ponds rain gardens planting large canopy trees Inside the park, buildings are suggested with lighter-colored, greening façades-walls-roofs and water-based cooling (such as blue roofs)

4.3.9 Muharrem Dalkılıç Parkı

Muharrem Dalkılıç Parkı is located in Ahmet Taner Kışlalı neighborhood. It was established in 2000. The total area of the park is around 0,89 ha with covering 17% of the total parks in the neighborhood. As can be seen from the satellite image, the park is located in a developing area. Around the park there are different urban forms with different heights.



Figure 4. 26. Satellite images of Muharrem Dalkılıç Parkı took in 2004 and 2020 (Google Earth Pro)

There are mostly residential areas in the neighborhood. In addition, there area also educational units with one kindergarten and one high school units. There are also nursing home and elderly rehabilitation in the neighborhood. Also, three technical infrastructure units and gas station are located. There is low density traffic around the park. There are also commercial uses in 300 m buffer.

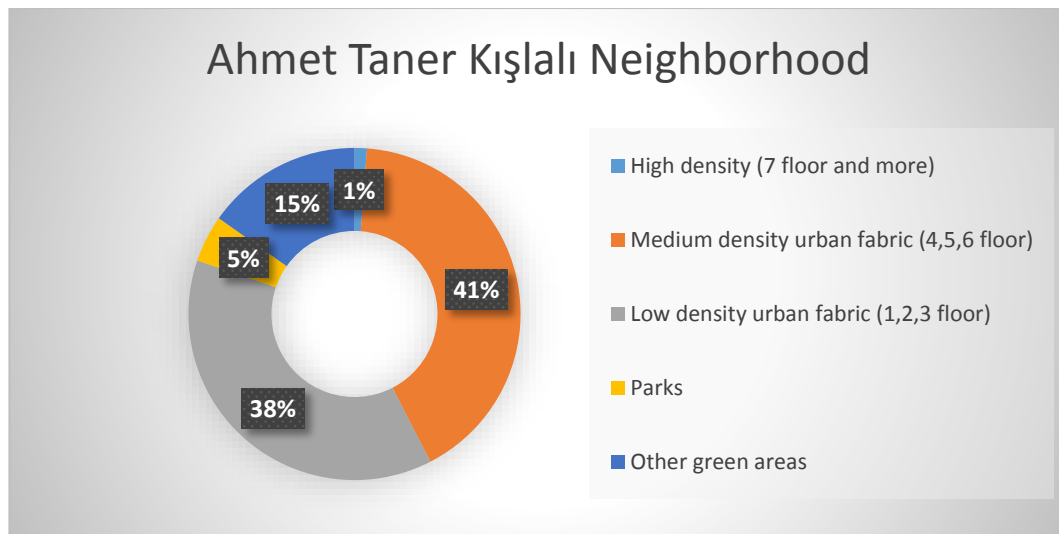
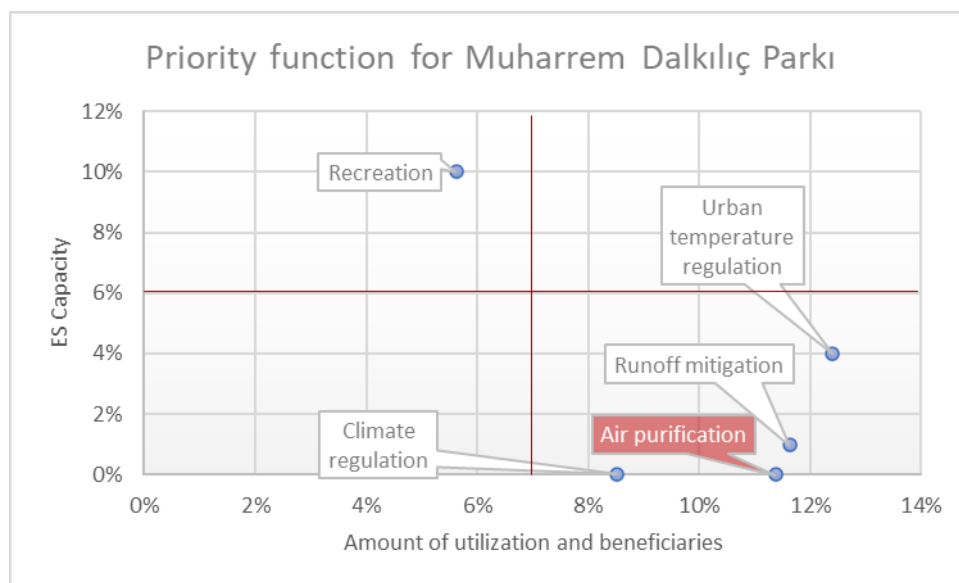


Figure 4. 27. Natural and built environment proportion in Ahmet Taner Kışlalı Neighborhood

There are sport facilities, children's playgrounds, and jogging tracks in the park. Most of the surfaces covers with grass with 83%. While coniferous trees cover only 1% of the area, broadleaf trees cover more than half of the park.

Table 4. 14. Determination of priority ES function for Muharrem Dalkılıç Parkı



According to Table 4. 14, recreation service should be monitoring. Climate regulation, runoff mitigation, air purification and urban temperature regulation

services are the primary ES function of the park. Because amount of utilization and beneficiaries value is higher in urban temperature service, design inputs are suggested to enhance this service capacity. Design inputs were given in Table 4. 13. Urban design inputs belonging habitat for biodiversity service performance should be applied for the park, as mentioned Chapter 2.



CHAPTER 5

CONCLUSION

The concept of ecosystem services has gained increasing prominence in academic circles. It provides a framework where the benefits of ecosystems are translated into actions that benefit humans.

This thesis focuses on design inputs of enhancing parks' urban ecosystem services capacity in accordance with developing analysis tool to test on selected 9 case areas in Çankaya, Ankara. These parks are 50. Yıl, Kurtuluş Parkı, Dikmen Vadisi, Münzeviler, Portakal Çiçeği, Emin Sarıkaya, Ahmed Arif, Muharrem Kaleli and Muharrem Dalkılıç Parkı. Flows of the study starts with literature, continues with analysis tool inputs preparation and its application. In the final step, analysis tool is tested in selected case areas. The findings and recommendations of these assessments can inform the decisions that are made regarding the management of ecosystems.

5.1 Research Findings

In literature, concept of ES, firstly introduced as “nature’s service” in late 1970s by Westman which is a vital services that people need to sustain their life in urban context. Moreover, ES provisioning in urban area deals with be threatened by rapid urbanization which causes series of social and enviromental challenges. Urban parks and natural areas are the main ES SPU that should be developed to increase the UES provisioning capacity. Within this context, this study inferred that existing literature and practices show the socio-ecological function of the urban parks are neglected. To that end, benefits of ES were searched in details, and identified by associating

them with the social groups and areas that most in need of the selected services. Furthermore, possible nature-based solutions that will increase the potential of this service were explained in three different scales.

The study has two main research questions: (1) “to what extent urban ecosystem services promote the life quality of citizens?” and (2) “how can be maximized the contribution of the green areas into urban environment via effective planning of the ES?”

And other sub-questions to support main questions are;

- what the relationship between ES and urban planning and design
- how to measure spatial distribution of ES and primary beneficiaries
- how to enhance the green spaces current ES provisioning capacity via design.

The first main question searches for theoretical knowledge to define benefits of ES and beneficiaries (please see Chapter 2, Table 2. 9). The qualitative data about how citizens are utilizing the UES was collected. Accordingly, benefits of UES, and urban design inputs are defined with deductive method (see Chapter 2, Table 2. 10).

Secondly, to answer second main question, current ES potential was presented via ES mapping study (mapping study -1). In this context, one of the input of this mapping study was creating land cover data which was produced with remote sensing images, and urban plans. As mentioned in Chapter 1. 3, this study develops design inputs in urban design field by using mapping work produced in the EU project called Nature and Cities. For a more holistic understanding of the current ES potential, the criteria, data and mapping technique used in the calculation were mentioned in details in Chapter 3. Then, selected UES primary beneficiaries’ spatial equivalents (see Appendix-B) were adapted from the land cover data (see Chapter 3, Table 3.14). The result of *mapping study-1* and *mapping study-2* converted into numerical values, and transferred into comparable values (see Chapter 3. 7). These values were adapted into analysis tool for each 9 urban parks to adapted to each park

to measure whether parks' current ES potential meet the needed. Site selection criterias were defined as park size, location of the park accordance with urban developments plans, establishment year of the park, height of sorrounding buildings and closeness to the natural areas (see Chapter 3.3).

The analysis tool provides guidance on how to manage selected ES (see Chapter 3.7). Moreover, 4 different parts were defined in the tool and the types of ES that need to be monitored, protected and developed were shown separately for each park. Since the main purpose of the study is to meet the needs by increasing the capacity of ES, urban design inputs were suggested only for “need to be developed” area which is “C part” of the tool. Results show that different spatial, natural and social settings differentiate the need of ES provision.

In Chapter 4, 9 selected cases tested with analysis tool. This case studies help to examine research questions' answer with testing current ES capacity and need of them with different variables. According to analysis tool results, Münzeviler, Emin Sarıkaya and Portakal Çiçeği Parkı's priority ES function, “need to be developed” in terms of provisioning capacity of ES, was “run-off mitigation”. While Ahmed Arif and Muharrem Dalkılıç Parkı's ES function was “air purification”, Muharrem Kaleli Parkı was “urban temperature regulation”. “Climate regulation” ES was 50.Yıl Parkı's, and “recreation” was Dikmen Vadisi's ES functions. Based on analysis tool results, there was no service that needs to be developed in Kurtuluş Parkı. However, there were services in this park that need to be protected and monitored. As mentioned in theoratical part, habitat for biodiversity service is the services that need to be developed in every park to sustain more livable and healthy ecosystems. In accordance with the results, design inputs were suggested (please see Chapter 4).

5.2 Discussions

There is still uncertainty regarding the number of ES types. Because this study is limited to selected of ES types, ES function of the park would be change if more ES types would add to the study.

Although park-based urban design inputs were presented, green areas must be planned more holistically for a healthy ecosystem and the welfare of the citizens. Although suggestions are also presented at urban scale in the study, it has not been studied in detail because it falls outside the focus of the study. There are no clear lines separating the urban design inputs that will increase the selected ES capacity. The proposed design inputs are therefore not very different from each other. Therefore, it is thought that addressing the city as a holistic rather than park scale will yield more comprehensive results. In this direction, policy-level practices or incentives will also be beneficial to support the continuity of more resilient and sustainable cities throughout the city. For example, spatial decisions of investments or arrangements can be made in the future by determining the needs based on the priority areas and ecosystem service benefits determined by ES mapping.

5.3 Limitations of the Study and Implications for Future Research

The analysis tool developed within the scope of the thesis which has two important inputs. The limitations of the study and suggestions for future studies were given through these two inputs. Also, analysis tool was criticized separately.

Mapping Study -1: Current ES Capacity in Selected Parks

- Since there are no boundaries in nature, ES offered by natural and urban green spaces was limited by detecting remote sensing data, urban plans, and metric data. This value can reach a more accurate result if citizen science projects take an inventory of the natural existence of the city, for example the number of trees and tree species, the age and health status.

- This research uses convergent parallel mixed method approach. Because the larger scales increase the accuracy rate in calculation of ES, the assessment of the current capacity of ES in Çankaya was calculated in province scale. However, the accuracy rate would be increased if the scale was in the city of Ankara. Since it is a plan produced for the purpose of urban management, it includes predictions and projections for the future as well as the current situation. Although a controlled classification was made using satellite images to determine the current situation, the actuality of the application images constitutes the margin of error.
- The *mapping study-1* was carried out in Çankaya scale. This gives the value of the service provided by urban parks in the whole district, instead of providing the ES directly offered by the park. Moreover, since the district border is a virtual border, the service provided by the parks and natural areas in the areas outside this border has been neglected. Neglecting this situation leads to the inability to analyze the ES need around the park correctly.

Mapping study – 2: Amount of Utilization and Beneficiaries

- 300 m buffer around the park covers walking distance for everyone. This value reflects the average. However, this distance can be recalculated by using impact distance of ecosystem services. Since the calculation of impact distance is not a subject of this study, an average standard (300 m walking distance) value was used for each service.
- The impact of different services, for example a tree's carbon sequestration service, may vary with factors such as the tree's developmental status, age, leaf width, trunk diameter. Accordingly, the impact area can be less or more than 300 m. The same is true for other services too. Setting a standard value

reduces the differentiation between services. This value should be considered for future studies.

- Units and areas in land cover map were used to analyze demand for ES. However, more reliable results can be obtained by using population data and units, such as bed capacity for hospitals or student capacity for schools.
- In order to increase the potential of providing specific ecosystem services, the use of broad-leaved trees has been presented as an urban design inputs. Although this natural component has the potential to increase service, the ecosystem is a whole and is different in every geography. For example, although coniferous trees can grow in the steppes, the natural vegetation of Ankara is steppe. It can damage the steppe and biodiversity, also affect other ecosystem components in short and long term.
- While determining the function of the selected parks, selected UES primary beneficiaries' spatial equivalents were adapted from land cover data. However, cities are dynamic. Plans and land use decisions are not permanent. Therefore, deciding according to units and areas around the selected park may not give the desired result in the long term. Therefore, it is important to constantly inspect these parks and to make changes to meet the needs of the citizens.
- Geographical conditions, especially water components should be considered in the implementation phase of urban design inputs. It also increase the habitat for biodiversity service which is a cross-cutting issue that ensure the healthy environment.
- Urban green areas and natural green areas is so important for public health. They provide essential services that are very crucial to sustaining healthy

ecosystems and health life. It is also an environmental justice issue. More maintained parks in Ankara especially are located in neighborhood where the socio-economic level is higher. Also, developing and enhancing the maintenance of the park may be result as a marketing tool which may leads to increase in housing and rental price. It may lead to increase inequality in the city in terms of segregating residential distribution. This paradoxical effect was termed eco-gentrification (Patrick, 2011) or environmental gentrification (Checker, 2011).

- Large datasets are often difficult to interpret. In case of adding more ES types in the analysis tool, Principal Component Analysis (PCA) method can be used to develop and get more reliable results for further studies.

All in all, this thesis draws attention to how to get maximum benefit from green areas in the city with more efficient use of ES with using design inputs. Thus, it provided a methodological framework for increasing the quality of life. In this context, like any research, there are limitations. It can be developed in terms of scope and scale in the later stages of the study.



REFERENCES

- Akbari, H., M. Pomerantz, & H. Taha. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas, *Solar Energy*, 70, pp. 295 – 310
- American Museum of Natural History. n.d. What is Biodiversity? Why Is It Important?: AMNH. Retrieved from: <https://www.amnh.org/research/center-for-biodiversity-conservation/what-is-biodiversity>
- Anguelovski, I. (2013). Beyond a livable and green neighborhood: asserting control, sovereignty, and transgression in the Casc Antic of Barcelona. *Int. J. Urban Reg. Res.* doi:<http://dx.doi.org/10.1111/1468-2427.12054>
- Aquarama (2011). Rietland bvba wil rietveldsysteem op een hoger plan tillen. Aquarama nummer 51, Dossier Waterzuivering & Hergebruik.
- Arslantaş, F., Sanalan, K. C., Çil, A. (Eds). (2020). Examples of Best Practices on Green Infrastructure and Nature Based Solutions in Cities. 120 pages.
- Aylor, D., Garner, J. H., & Johnson, D. (2003). Ecological effects of particulate matter. *Environment International*, 29 (2–3), 213–239.
- Barker, A., Clay, G., Rothwell, J., Gilchrist, A., Tantanasi, I., Morrison, R., & Payne, S. (2019). Understanding Green Infrastructure at Different Scales: a signposting guide. The University of Manchester. <https://doi.org/10.13140/RG.2.2.26366.95045>
- Baró F, Palomo I, Zulian G et al. (2016) Mapping ecosystem service capacity, flow and demand for landscape and urban planning: a case study in the Barcelona metropolitan region. *Land use policy* 57:405–417. <https://doi.org/10.1016/j.landusepol.2016.06.006>
- Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D. J., & Terradas, J. (2014). Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain. *AMBIO*, 43(4), 466–479. <https://doi.org/10.1007/s13280-014-0507-x>
- Barthel, Stephan & Isendahl, Christian. (2013). Urban gardens, Agriculture, And water management: Sources of resilience for long-term food security in cities. *Ecological Economics*. 86. 224–234. [10.1016/j.ecolecon.2012.06.018](https://doi.org/10.1016/j.ecolecon.2012.06.018).

- Belaire, J.A., Whelan, C.J., Minor, E.S. (2014). Having our yards and sharing them too: the collective effects of yards on native bird species in an urban landscape. *Ecological Applications* 24(8):2132–2143.
- Bellows, Anne & Brown, Katherine & Smit, Jac. (2008). Health Benefits of Urban Agriculture.
- Bendt, P., Barthel, S. and Colding, J. (2013). Civic greening and environmental learning in public access community gardens in Berlin, *Landscape and Urban Planning*, 109(1), pp. 18–30.
- Beninde, J., Veith, M., Hochkirch, A. (2015). Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters* 18(6):581– 592.
- Blaine TW, Grewal PS, Dawes A, Snider, D. (2010). Profiling community gardeners. *J Extension* 48 (6):1–12
- Bolund, P. and Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics* 29, 293–301.
- Bonan, G. B. (2002). *Ecological climatology: Concepts and applications*. Cambridge: Cambridge University Press.
- Brauman, K.A., Gretchen, C.D., Duarte, T.K., Mooney, H.A. (2007). The nature and value of ecosystem services: an overview highlighting hydrologic services. *Annu. Rev. Environ. Resour.* 32, 67–98
- Breuste, J., Artmann, M. (2014). Allotment gardens contribute to urban ecosystem service: case study Salzburg, Austria. *J. Urban Plann. Dev.* doi: [http://dx.doi.org/10.1061/\(ASCE\)UP.1943-5444.0000264](http://dx.doi.org/10.1061/(ASCE)UP.1943-5444.0000264).
- Brown, Katherine H and Anne Carter, et al. (2003). Urban Agriculture and Community Food Security in the United States: Farming from the City Center To the Urban Fringe. Urban Agriculture Committee of the Community Food Security Coalition (CFSC). CFSC Report.
- Burden of Disease from Ambient Air Pollution for 2012, Description of Method, Version 1.3 WHO, Geneva (2014) “The Global Health Observatory.” Retrieved 01.03.2014, 2014
- Chan, K.M.A., Satterfield, T., Goldstein, J. (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics* 74, 8–18.

- Checker, M. (2011). Wiped out by the “greenwave”: Environmental gentrification and the paradoxical politics of urban sustainability. *City & Society*, 23(2), 210-229.
- Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning* 68, 129–138.
- Copernicus Land Monitoring Service. Retrieved from: <https://land.copernicus.eu/user-corner/publications/clc-flyer/view>
- Corine Land Cover (CLC) 2012. Version 20
- Cortinovis, C., Geneletti, D. (2018) Mapping and assessing ecosystem services to support urban planning: A case study on brownfield regeneration in Trento, Italy. *One Ecosystem* 3: e25477. <https://doi.org/10.3897/oneeco.3.e25477>
- Currie, B.A., Bass, B. (2008). Estimates of air pollution mitigation with green plants and green roofs using the UFORE model. *Urban Ecosystems*. Doi 10.1007/s11252-008-0054-y
- Çağlayan, S.D., Balkız, Ö., Arslantaş, F., Sanalan, K.C., Lise, Y., Zeydanlı, U. (2020). Şehir Planlama Aracı Olarak Ekosistem Hizmetleri: Çankaya İlçesi Örneği. *Ankara, Doğa Koruma Merkezi*, 236 sayfa.
- Çankaya Belediyesi. Retrieved from: <https://www.cankaya.bel.tr/pages/14/RAKAMLARLA-CANKAYA/>
- Çevre ve Şehircilik Bakanlığı Ulusal Hava Kalitesi İzleme Ağı, (2019). https://sim.csb.gov.tr/STN/STN_Report/StationDataDownload Last visited on August 2019.
- Dahlgren, R.A., Horwath, W.R., Tate, K.W., Camping, T.J. (2003). Blue oak enhance soil quality in California oak woodlands. *California Agriculture* 57(2):42–47.
- Dahlgren, R.A., Singer, M.J. and Huang, X. (1997). Oak tree and grazing impacts on soil properties and nutrients in a California oak woodland. 39(1):20.
- Díaz, J.P. and Harris, P. (2005). “Urban Agriculture in Havana: Opportunities for the Future,” in CPULs: Continuous Productive Urban Landscapes. *Designing Urban Agriculture for Sustainable Cities*, ed. André Viljoen (London; New York: Routledge) 136.
- Dodman, D. (2009). Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories. *Environment and Urbanization*, 21(1), 185–201. <https://doi.org/10.1177/0956247809103016>

- Dzierzanowski, K., Popek, R., Gawrońska, H., et al. (2011). Deposition of particulate matter of different size fractions on leaf surfaces and in waxes of urban forest species. *International Journal of Phytoremediation*, 13 (10), 1037–1046.
- Edmonds, W. A., & Kennedy, T. D. (2016). *An applied guide to research designs: Quantitative, qualitative, and mixed methods*. Sage Publications.
- EEA, JRC and WHO, 2008, *Impacts of Europe's changing climate: 2008 indicator-based assessment*, EEA Report No 4/2008, European Environment Agency
- Ehrlich, P.R., Ehrlich, A.H., (1981). *Extinction: the causes and consequences of the disappearance of species*. Random House, New York
- Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., Wilkinson, C. (Eds.). (2013). *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities*. Springer Netherlands. (438, http://bieb.ruaf.org/ruaf_b/upload/3791.pdf)
- Gómez-Baggethun, E., Martín-López, B., Barton, D., Braat, L., Saarikoski, H., Kelemen, E., ... & Harrison, P. (2014). State-of-the-art report on integrated valuation of ecosystem services. EU FP7 OpenNESS project deliverable, 4, 1-33.
- European Commission (EC). (2013): *Communication from The Commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions on Green Infrastructure (GI) – Enhancing Europe’s Capital*, Brussels, 6.5.2013. SWD(2013) 15
- European Commission. (2012). Retrieved from: https://ec.europa.eu/environment/nature/ecosystems/docs/Green_Infrastructure.pdf
- European Commission. (2013). *Green Infrastructure (GI) — Enhancing Europe’s Natural Capital. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM(2013)249 final)*
- European Environment Agency. (2012). *Urban adaptation to climate change in Europe. Challenges and opportunities for cities together with supportive national and European policies*, Copenhagen
- European Environmental Agency. (2011). *Green infrastructure and territorial cohesion. The concept of green infrastructure and its integration into policies using monitoring systems*. Luxembourg: European Environment Agency.

- FAN, H. and SAILOR, D.J. (2005). Modelling the impacts of anthropogenic heating on the urban climate of Philadelphia: a comparison of implementations in two PBL schemes. *Atmospheric Environment* 39, 73–84.
- FAO. (2020). Urban food systems and COVID-19: the role of cities and local governments in responding to the emergency. Policy brief. Chicago
- Fick, S.E., Hijmans, R.J. (2017). Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*.
- Fisher, B., Costanza, R., Turner, R.K., Morling, P. (2007). Defining and classifying ecosystem services for decision making, CSERGE Working Paper EDM, No. 07-04, University of East Anglia, The Centre for Social and Economic Research on the Global Environment (CSERGE), Norwich
- Folke, C., Å. Jansson, J. Larsson, and R. Costanza. (1997). Ecosystem appropriation by cities. *Ambio* 26:3.
- Geneletti, D., Cortinovis, C., Zardo, L., & Adem Esmail, B. (2019). Developing Ecosystem Service Models for Urban Planning: A Focus on Micro-Climate Regulation. In *SpringerBriefs in Environmental Science* (pp. 31–42). Springer International Publishing. https://doi.org/10.1007/978-3-030-20024-4_4
- Geneletti, D., Cortinovis, C., Zardo, L., & Esmail, B. A. (2020). Planning for ecosystem services in cities (p. 87). Springer Nature.
- Geneletti, D., Cortinovis, C., Zardo, L., and Adem Esmail, B. (2019). Introduction. In *Springer Briefs in Environmental Science* (pp. 1–6). Springer International Publishing. https://doi.org/10.1007/978-3-030-20024-4_1
- Goddard, M.A., Dougill, A.J., Benton, T.G. (2010). Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology & Evolution* 25(2):90–98.
- Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245. <https://doi.org/10.1016/j.ecolecon.2012.08.019>
- Gómez-Baggethun, E., de Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics*, 69(6), 1209–1218. <https://doi.org/10.1016/j.ecolecon.2009.11.007>
- Gómez-Baggethun, E., Gren, Å., Barton, D. N., Langemeyer, J., McPhearson, T., O’Farrell, P., Andersson, E., Hamstead, Z., & Kremer, P. (2013). Urban Ecosystem Services. In *Urbanization, Biodiversity and Ecosystem Services*:

- Challenges and Opportunities (pp. 175–251). Springer Netherlands. https://doi.org/10.1007/978-94-007-7088-1_11
- Greater London Authority. (2019). Using Green Infrastructure to Protect People from Air Pollution. Retrieved from: https://www.london.gov.uk/sites/default/files/green_infrastruture_air_pollution_may_19.pdf
- Gronlund, C. J., Berrocal, V. J., White-Newsome, J. L., Conlon, K. C., & O'Neill, M. S. (2015). Vulnerability to extreme heat by socio-demographic characteristics and area green space among the elderly in Michigan, 1990–2007. *Environmental Research*, 136, 449–461. <https://doi.org/10.1016/j.envres.2014.08.042>
- Güner, Ş.T., Çömez, A. (2017). Biomass Equations And Changes In Carbon Stock In Afforested Black Pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) Stands In Turkey, *Fresenius Environmental Bulletin*, volume 26, No. 3, pages 2368-2379.
- Hand, K. L., Freeman, C., Seddon, P. J., Recio, M. R., Stein, A., & van Heezik, Y. (2016). The importance of urban gardens in supporting children's biophilia. *Proceedings of the National Academy of Sciences*, 114(2), 274–279. <https://doi.org/10.1073/pnas.1609588114>
- Hewitt, C. N., Ashworth, K., & MacKenzie, A. R. (2019). Using green infrastructure to improve urban air quality (GI4AQ). *Ambio*, 49(1), 62–73. <https://doi.org/10.1007/s13280-019-01164-3>
- Hilly, G., Vojinovic, Z., Weesakul, S., Sanchez, A., Hoang, D., Djordjevic, S., Chen, A., & Evans, B. (2018). Methodological Framework for Analysing Cascading Effects from Flood Events: The Case of Sukhumvit Area, Bangkok, Thailand. *Water*, 10(1), 81. <https://doi.org/10.3390/w10010081>
- Huang, H., Hailin, Y. A. N. G., Xin, D. E. N. G., Peng, Z. E. N. G., Yong, L. I., Zhang, L., Lei, Z. H. U. (2019). Influencing Mechanisms of Urban Heat Island on Respiratory Diseases. *Iranian Journal of Public Health*, 48(9), 1636-1646.
- IEA. (2008). Shares of residential energy consumption by end use in selected IEA countries. IEA, Paris <https://www.iea.org/data-and-statistics/charts/shares-of-residential-energy-consumption-by-end-use-in-selected-iea-countries-2018>
- Intergovernmental Panel on Climate Change (IPCC). (2006). Guidelines for National Greenhouse Gas Inventories, Cambridge University Press, Cambridge.

- Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Guèze, M., Agard, J., ... & Zayas, C. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
- Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). IPCC guidelines for national greenhouse gas inventories.
- Jenness, J. (2006). Topographic Position Index extension for ArcView 3.c,v.1.3a. Jenness Enterprises
- Kong, F., Sun, C., Liu, F., Yin, H., Jiang, F., Pu, Y., Cavan, G., Skelhorn, C., Middel, A., & Dronova, I. (2016). Energy saving potential of fragmented green spaces due to their temperature regulating ecosystem services in the summer. *Applied Energy*, 183, 1428-1440. <https://doi.org/10.1016/j.apenergy.2016.09.070>
- Landscape Institute. (2009). Green infrastructure: connected and multifunctional landscapes — position document (<https://landscapewpstorage01.blob.core.windows.net/www-landscapeinstitute-org/2016/03/GreenInfrastructurepositionstatement13May09.pdf>) accessed 8 March 2020.
- Lee, K., Kim, Y., Sung, H. C., Ryu, J., & Jeon, S. W. (2019). Trend Analysis of Urban Heat Island Intensity According to Urban Area Change in Asian Mega Cities. *Sustainability*, 12(1), 112. <https://doi.org/10.3390/su12010112>
- Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., & Dash, P. (2013). Ecosystem Services: Origins, Contributions, Pitfalls, and Alternatives. *Conservation and Society*, 11(4), 343. <https://doi.org/10.4103/0972-4923.125752>
- Lin, B. B., Philpott, S. M., Jha, S., & Liere, H. (2017). Urban Agriculture as a Productive Green Infrastructure for Environmental and Social Well-Being. In *Advances in 21st Century Human Settlements* (pp. 155–179). Springer Singapore. https://doi.org/10.1007/978-981-10-4113-6_8
- Lindén, L., Riikonen, A., Setälä, H., & Yli-Pelkonen, V. (2020). Quantifying carbon stocks in urban parks under cold climate conditions. *Urban Forestry & Urban Greening*, 49, 126633. <https://doi.org/10.1016/j.ufug.2020.126633>
- Lock, K., Zeeuw, H.D. (2001). Mitigating the health risks associated with urban and periurban agriculture: results of the E-conference 'Urban and Periurban

Agriculture on the Policy Agenda'. Urban agriculture magazine/Resource Centre for Urban Agriculture (RUAF)

- Lovasi, G. S., Quinn, J. W., Neckerman, K. M., Perzanowski, M. S., & Rundle, A. (2008). Children living in areas with more street trees have lower prevalence of asthma. *Journal of Epidemiology & Community Health*, 62(7), 647–649. <https://doi.org/10.1136/jech.2007.071894>
- Loyd, C. (2013). Putting Landsat 8's Bands to Work. NASA, USA. Retrieved from <https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands>
- Makri, A., & Stilianakis, N. I. (2008). Vulnerability to air pollution health effects. *International Journal of Hygiene and Environmental Health*, 211(3–4), 326–336. <https://doi.org/10.1016/j.ijheh.2007.06.005>
- Martínez-Harms, M. J., & Balvanera, P. (2012). Methods for mapping ecosystem service supply: a review. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 8(1–2), 17–25. <https://doi.org/10.1080/21513732.2012.663792>
- McGranahan, G., Marcotullio, P., Bai, X., et al. (2005). Urban systems. In R. Hassan, R. Scholes, & N. Ash (Eds.), *Ecosystems and human well-being: Current state and trends*. Washington, DC: Island Press.
- McPhearson, P. T. (2011). Toward a sustainable New York City: Greening through urban forest restoration. In *Sustainability in America's cities* (pp. 181–203). Island Press, Washington, DC.
- McPherson, E. G., & Simpson, J. R. (1999). Carbon dioxide reduction through urban forestry: Guidelines for professional and volunteer tree planters. USDA Forest Service Pacific Southwest Research Station General Technical Report PSW-GTR-171, Berkeley, CA.
- MGM. (2019). İlere Ait Mevsim Normalleri. Erişim: <https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceleristatistik.aspx>
- Milligan, C., Gatrell, A., & Bingley, A. (2004). 'Cultivating health': therapeutic landscapes and older people in northern England. *Social Science & Medicine*, 58(9), 1781–1793. [https://doi.org/10.1016/s0277-9536\(03\)00397-6](https://doi.org/10.1016/s0277-9536(03)00397-6)
- Milner, J., Davies, M., & Wilkinson, P. (2012). Urban energy, carbon management (low carbon cities) and co-benefits for human health. *Current Opinion in Environmental Sustainability*, 4(4), 398–404.
- Mougeot, L. (2006). Growing better cities: urban agriculture for sustainable development. Ottawa: IDRC

NASA Global Climate Change, Retrieved from:
<https://climate.nasa.gov/solutions/adaptation-mitigation/>

NIR Turkey, 2017. Turkey Greenhouse Gas Inventory Report, 1990 to 2015. Annual Report submission under the “United Nations Framework Convention on Climate Change”. Turkish Statistical Institute.

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K. K. Y., Rowe, B. (2007). Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. *BioScience*, 57(10), 823–833. <https://doi.org/10.1641/b571005>

OGM. (2017). Ekosistem Tabanlı Fonksiyonel Orman Amenajmanı Planlarının Düzenlenmesine Ait Usul ve Esaslar; 299 Nolu Tebliğ. Orman Genel Müdürlüğü. Ankara

Overview. (2019). Retrieved November 24, 2019, from <https://www.worldbank.org/en/topic/urbandevelopment/overview>.

Parker, J. H. (1981). "Use of landscaping for energy conservation," Department of Physical Sciences, Florida International University, Miami, Florida.

Pataki, D. E., Xu, T., Luo, Y. Q., & Ehleringer, J. R. (2007). Inferring biogenic and anthropogenic carbon dioxide sources across an urban to rural gradient. *Oecologia*, 2007 (152), 307–322.

Patel, Ishwarbhai C. (1996). “Rutgers urban gardening: A case study in urban agriculture.” *Journal of Agriculture and Food Information*. 3(3):35-46.

Patrick, D. J. (2011). The Politics of Urban Sustainability: Preservation, Redevelopment, and Landscape on the High Line. Central European University, Budapest (Master’s Thesis).

Peper, P. J., McPherson, E. G., Simpson, J. R., Gardner, S. L., Vargas, K. E., & Xiao, Q. (2007). New York city, New York municipal forest resource analysis. [Technical Report]. US Department of Agriculture Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research. 65 p.

Petrucci, G., Gromaire, M.C., Shorshani, M.F. and Chebbo, G. (2014). Nonpoint source pollution of urban stormwater runoff: a methodology for source analysis *Environ. Sci. Pollut. Res.*, 21 (17) (2014), pp. 10225-10242

Pigram, J. (1983). Outdoor recreation and resource management. Croom Helm Ltd.

Pochee, H., Johnston, I. (2017). Understanding design scales for a range of potential green infrastructure benefits in a London Garden City. *Building Services*

- Engineering Research and Technology, 38(6), 728–756. <https://doi.org/10.1177/0143624417734526>
- Porter, M. M., & Niksiar, P. (2018). Multidimensional mechanics: Performance mapping of natural biological systems using permuted radar charts. *PloS one*, 13(9), e0204309.
- Rogers, M. A. (2018). Urban Agriculture as a Tool for Horticultural Education and Youth Development. In *Sustainable Development and Biodiversity* (pp. 211–232). Springer International Publishing. https://doi.org/10.1007/978-3-319-67017-1_9
- Ryu, Y.-H., & Baik, J.-J. (2012). Quantitative Analysis of Factors Contributing to Urban Heat Island Intensity. *Journal of Applied Meteorology and Climatology*, 51(5), 842–854. <https://doi.org/10.1175/jamc-d-11-098.1>
- San Francisco Estuary Institute. (2019). Making Nature’s City: A science-based framework for building urban biodiversity. A product of the Healthy Watersheds, Resilient Baylands project. Funded by the San Francisco Bay Water Quality Improvement Fund, EPA Region IX. SFEI Publication #947, San Francisco Estuary Institute, Richmond, CA.
- Seto, K. C., & Shepherd, J. M. (2009). Global urban land-use trends and climate impacts. *Current Opinion in Environmental Sustainability*, 1 (1), 89–95.
- Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A meta-analysis of global urban land expansion. *PLoS ONE*, 6(8), e23777.
- Seto, K. C., Parnell, S., & Elmqvist, T. (2013). A Global Outlook on Urbanization. In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities* (pp. 1–12). https://doi.org/10.1007/978-94-007-7088-1_1
- Shava, S., Krasny, M.E., Tidball, K.G., Zazu, C., (2010). Agricultural knowledge in urban and resettled communities: applications to social–ecological resilience and environmental education. *Environ. Educ. Res.* 16 (5–6), 575–589. doi:<http://dx.doi.org/10.1080/13504622.2010.505436>.
- Shem, W., & Shepherd, M. (2009). On the impact of urbanization on summertime thunderstorms in Atlanta: Two numerical model case studies. *Atmospheric Research*, 92 , 172–189.
- Silvennoinen, S., Taka, M., Yli-Pelkonen, V., Koivusalo, H., Ollikainen, M., & Setälä, H. (2017). Monetary value of urban green space as an ecosystem service provider: A case study of urban runoff management in Finland. *Ecosystem Services*, 28, 17–27. <https://doi.org/10.1016/j.ecoser.2017.09.013>

- Smith, C., Lindley, S., & Levermore, G. (2009). Estimating spatial and temporal patterns of urban anthropogenic heat fluxes for UK cities: the case of Manchester. *Theoretical and Applied Climatology*, 98(1), 19-35.
- Soga, M., Yamaura, Y., Koike, S., Gaston, K.J. (2014). Woodland remnants as an urban wildlife refuge: a cross-taxonomic assessment. *Biodiversity and Conservation* 23(3):649–659.
- Sommers, P and Smit, J. (1994). Promoting Urban Agriculture: A Strategy for Planners in North America, Europe, and Asia. Cities Feeding People Report Series #9. Ottawa, International Development Research Centre (IDRC), www.idrc.ca/cfp
- Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., Thomaier, S., Henckel, D., Walk, H., & Dierich, A. (2013). Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. *Agriculture and Human Values*, 31(1), 33–51. <https://doi.org/10.1007/s10460-013-9448-4>
- Spellberg, I. F. (1994). Evaluation and assessment for conservation: ecological guidelines for determining priorities for nature conservation (Vol. 4). Springer Science & Business Media
- Stocker, L., & Barnett, K. (1998). The significance and praxis of community- based sustainability projects: community gardens in western Australia. *Local environment*, 3(2), 179-189.
- TEEB – The Economics of Ecosystems and Biodiversity. (2011). TEEB Manual for Cities: Ecosystem Services in Urban Management. www.teebweb.org
- TEEB. (2010). The economics of ecosystems and biodiversity. Ecological and Economic Foundations. Earthscan London and Washington.
- The U.S. Environmental Protection Agency. (2020). Saving the Rain. Green Stormwater Solutions for Congregations. Retrieved from: https://www.epa.gov/sites/default/files/2020-06/documents/stormwatersolutionscongregations_508.pdf
- Tolunay, D. (2013). Türkiye’de artım ve ağaç servetinden bitkisel kütle ve karbon miktarlarının hesaplamasında kullanılabilecek katsayılar. *Ormancılıkta Sektörel Planlamanın 50. Yılı Uluslararası Sempozyumu, Bildiriler Kitabı*, 240-251.
- U.S. Environmental Protection Agency. (2003). Protecting Water Quality from Urban Runoff (Brochure) Washington, DC https://www3.epa.gov/npdes/pubs/nps_urban-facts_final.pdf

- United Nations Environment Programme Finance Initiative (UNEP FI). (2008). Biodiversity and Ecosystem Services Bloom or Bust?
- United Nations. (2014). World urbanization prospects: The 2014 revision - highlights, Statistical Papers - United Nations (Ser. A), Population and Vital Statistics Report, UN, New York, <https://doi.org/10.18356/527e5125-en>.
- United States Environmental Protection Agency website, Heat Islands, Retrieved from: <https://www.epa.gov/heatislands/learn-about-heat-islands#heat-islands>
- USGS. Landsat 8 Data Users Handbook. (2019, April). Retrieved from <https://www.usgs.gov/media/files/landsat-8-data-users-handbook>. Access date: October 5, 2019.
- Van Dam RM, AJ Schuit, EJ Feskens, JC Seidell, D Kromhout. (2002). "Physical activity and glucose tolerance in elderly men: the Zutphen Elderly study." *Medicine & Science in Sports & Exercise*. 34(7):1132-6, Jul.
- Van den Berg, A.E., van Winsum-Westra, M., de Vries, S., van Dillen, S.M.E. (2010). Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment. *Environ. Health: Glob. Access Sci. Source* 9 (1), 74. doi:<http://dx.doi.org/10.1186/1476-069X-9-74>.
- Vandewalle, M., Sykes, M.T., Harrison, P.A., Luck, G.W., Berry, P., Bugter, R., Dawson, T. P., Feld, C.K., Harrington, R., Haslett, J.R., Hering, D., Jones, K.B., Jongman, R., Lavorel, S., Martins da Silva, P., Moora, M., Paterson, J., Rounsevell, M.D.A., Sandin, L., Settele, J., Sousa, J.P., Zobel, M., 2013. Review paper on concepts of dynamic ecosystems and their services 2014.
- Wells N.M., Lekies, K.S. (2006). Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. *Child Youth Environ* 16(1):1–24.
- Westman, W. (1977). How much are nature's services worth? *Science* 197, 960–964
- Wikipedia. Retrieved from: https://en.wikipedia.org/wiki/Google_Maps
- Yin, X. (2017). Design to Promote Urban Ecosystem Services: Examples of solutions with green - blue infrastructure in public spaces (Master Thesis, KTH Royal Institute of Technology)
- Zardo, L., Geneletti, D., Pérez-Soba, M., & Van Eupen, M. (2017). Estimating the cooling capacity of green infrastructures to support urban planning. *Ecosystem Services*, 26, 225–235. <https://doi.org/10.1016/j.ecoser.2017.06.016>

Zhao, L., Oppenheimer, M., Zhu, Q., Baldwin, J. W., Ebi, K. L., Bou-Zeid, E., Guan, K., & Liu, X. (2018). Interactions between urban heat islands and heat waves. *Environmental Research Letters*, 13(3), 034003. <https://doi.org/10.1088/1748-9326/aa9f73>

Zhu, J., Dai, Q., Deng, Y., Zhang, A., Zhang, Y., & Zhang, S. (2018). Indirect Damage of Urban Flooding: Investigation of Flood-Induced Traffic Congestion Using Dynamic Modeling. *Water*, 10(5), 622. <https://doi.org/10.3390/w10050622>





APPENDICES

APPENDIX A

Field observation survey



Yaşam ortamı sağlama hizmeti uzman görüşü kriterleri ve puanları

Doğal bitki örtüsünün zenginliği

- 5: Bitki örtüsü neredeyse tamamen doğal (%100-80) veya doğal bitki örtüsünde bulunan türlerden oluşuyor
- 4: Bitki örtüsünün büyük kısmı doğal (%80-60) veya doğal bitki örtüsünde bulunan türlerden oluşuyor
- 3: En az yarısı (%60-40) doğal veya doğal bitki örtüsünde bulunan türlerden oluşuyor
- 2: Küçük bir kısmı doğal (%40-20) veya doğa bitki örtüsünde bulunan türlerden oluşuyor
- 1: Neredeyse tamamı (%20-0) yabancı veya süs bitkilerinden oluşuyor

Bitki örtüsünün yapısal çeşitliliği:

- 5: Çok büyük ağaçlar (20 m'den büyük), orta boy ağaçlar (20 m'ye kadar), çalı ve ot katları var
- 4: Ağaç, çalı ve ot katları var
- 3: Ağaç ve çalı katları var
- 3: Ağaç ve ot katı var
- 2: Çalı ve ot katları var
- 1: Sadece ot katı var

Su varlığı: Su tüm canlılar için vazgeçilmez bir kaynaktır. Alandaki su varlığının doğrallığı üzerinden değerlendirme yapılmıştır.

- 5: Doğal göl, gölet
- 4: Akarsu
- 3: Mevsimsel akarsu, geçici göl
- 2: Yapay rezerv, gölet, havuz, su kanalı
- 1: Su yüzeyi yok

Çekirdek alan büyüklüğü: Hayvanlar, şehir gürültüsü, ışık kirliliği vb. rahatsız edici durumlara farklı tepkiler gösterebilir. Bu tip çekingenlikleri olan türler için parkın kenar bölümleri rahatsızlıklara karşı duyarlı oldukları bölge, parkın orta bölümü ise potansiyel habitat varsa bir vaha gibi olacaktır. Çekirdek alan büyüdükçe içerdiği tür sayısı da artacaktır.

Gelişme periyodu: Eşdeğer bir alanın başka bir yerde aynı şekilde oluşması için gereken zaman periyodu uzmanlar tarafından puanlanmıştır.

- 5: 50 yıldan fazla
- 4: 50-20 yıl
- 3: 20 -10 yıl
- 2: 10 – 5 yıl
- 1: 5 yıldan az

Nadirlik: Eşdeğerde bir biyotopun en fazla ne kadar yakında ve hangi sayıda olduğuna bakarak alanın nadirliği değerlendirilmiştir.

- 5: Eşdeğerde bir biyotop ilçe sınırı içerisinde yok
- 4: Eşdeğerde bir biyotop 2 km'den uzakta, ilçe sınırı içerisinde 5-10 tane
- 3: Eşdeğerde bir biyotop 12 km yakında, ilçe sınırı içerisinde bir kaç tane
- 2: Eşdeğerde bir biyotop 500 - 1000 m yakında, ilçe sınırı içerisinde bir kaç tane
- 1: Eşdeğerde bir biyotop 500 m yakında, ilçe sınırı içerisinde çok sayıda

APPENDIX B

ES benefits and their beneficiaries as units or areas

ES	ES Benefits																										
		Impervious areas (%) (neighborhood scale)	High density urban fabric (neighborhood) (%)	Medium density urban fabric (neighborhood) (%)	Low density urban fabric (neighborhood)	Newly developed residential area	Fossil fuel used area	Working area (commercial landuse)	Technopark	Small industrial area	Industrial area	Kindergarden (3-6 Age)	Special Education	Primary school (6-14 Age)	High school (14-18 Age)	University (18-30)	Dormitory (18-30)	Nursing Home and Elderly Rehabilitation Centers (over 60)	Health facility area	Sport facilities	Power distribution units	Urban storage area	Technical infrastructure	Heat center	Gas station	Fire station	Intensive transportation area
Food production	Nutrition and food security																										
Food production	Education opportunities																										
Food production	Health benefits																										
Food production	Social cohesion and integration																										
Urban temperature regulation	Decreasing energy consumption for heating&cooling																										
Urban temperature regulation	Health benefits																										
Air purification	Improving air quality																										
Air purification	Health benefits																										
Carbon sequestration	Carbon mitigation																										
Carbon sequestration	Health benefits																										
Runoff mitigation	Impact on water supply services																										
Runoff mitigation	Impact on transportation services																										
Runoff mitigation	Impact on power supply services																										
Recreation	Education opportunities																										
Recreation	Health benefits																										
Recreation	Social cohesion and integration																										
Recreation	Increase in workforce and productivity																										