# SIGNIFICANCE OF ECOSYSTEM SERVICES MAPPING FOR THE INTEGRATION OF SPATIAL PLANNING AND CLIMATE ADAPTATION*

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## Abstract

Recent global concerns are focusing on biodiversity loss (species and ecosystems) and global climate change especially in regard to sustainable urban development. Global warming, rapid urbanization and environmental degradation are closely related to the challenges of present urban settlements and mainly these are affecting the well-being of ecosystems and their services (Millennium Ecosystem Assessment-MEA, 2005). The need for better understanding of urban development and its impacts on ecosystems where these developments occur should be carefully assessed for the sustainability of the functions provided by natural systems. Meanwhile, the existing spatial information is concentrated on land cover and land use information. On the other hand, ecosystem services (ESs) may provide better understanding and more efficient spatial development in the process of spatial planning design and policy development (Daily 1997). Recent transnational organizations and EU institutions are also focused on the integration of ESs into spatial planning (EEA 2010).

As a result of the complexity of urban systems and ecosystem functions together with the limitations on the consistency of spatial information, the key ESs can be used to identify ecologically sensitive areas. In this approach, it is aimed that relevant mapping of ESs will be a key step to lead rational spatial development policies. Therefore, mapping of ESs and the socio-ecological drivers of space can be a relevant tool to achieve more sustainable development strategies by integrating ESs and urban socio-economic dynamics to the spatial decision making process. This


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approach can be a rational tool to implement climate change adaptive policy development as well.

This paper aims to integrate ecosystems and their services into spatial planning through relevant mapping of ESs to be utilized for climate adaptive spatial policy development process in the Istanbul case. Istanbul is an exceptional geography for the biological diversity with its location when compared with other settlements in the region. On the other hand, the urban development dynamics of the metropolitan area have a significant role for the well-being of ecological units, biological diversity in other words its life support systems such as drinking water sources, forests, coastal and riparian corridors, wetlands and heathlands which are the representatives of the major habitats of Istanbul Metropolitan Area (Ozhatay et.al. 2005, Tezer 2005, Tezer 2008).

## 1. Introduction: Climate Change and impact on cities

Global GHG emissions due to human activities have grown since pre-industrial times with an increase of 70% between 1970 and 2004 (IPCC, 2007). A projection of current trends as represented by a number of different scenarios, gives global surface temperature increases of about 1.8° to 4° C by the year 2100. Sea level is expected to rise between 18 and 59 centimeters. Climate change foreseen impacts are ocean warming, rise in sea level, increase in continental-average temperatures, extreme weather events like cyclones, tornados, change in precipitation, heat waves, natural threats such as drought, flood, spread of diseases (IPCC, 2007). Cities especially the developed ones, are major contributors to climate change by producing greenhouse gas emissions, mainly through energy generation, vehicles and industry (Pimm and Raven, 2000).

Climate change and urban dynamics-based impacts are expected to cause vulnerabilities in urban areas by decreasing accessibility to urban services and natural resources like water and food. Existing urban dynamics-based problems can be triggered by climate change impacts as well. The vulnerabilities of settlements with the results of these impacts should be re-assessed by mitigation and adaptation tools and strategies to achieve more resilient and sustainable urban areas. Defining vulnerabilities is a complex and uncertain issue as both urban dynamics and climate change and their future impacts are uncertain and based on projections and foresights. It is important to be able to foresee future climate change risks and identify main drivers of urban vulnerabilities (Hallegatte et al., 2011).

The dependency of vegetation on variations of rainfall and temperature are studied in many studies. Rise in temperature and change in precipitation are expected to change also the land cover especially the green cover (c). Thus key ESscan be also affected by these impacts. Desertification can be a good explanation for defining the land degradation in arid, semiarid, and dry sub-humid areas resulting from climatic variations and human activities. Change in main ESs components like forests, agricultural areas, pastures, scrubs, water bodies etc. can cause loss in their qualities. Existing species may be replaced by other species that have less economic importance and also this may cause a loss in the productive, regulative and supportive capacity of the earth (UN, 94). Millennium Ecosystem Assessment (MEA, 2005) claims that especially deforestation may cause a decrease in precipitation. As forest existence depends on precipitation level, its change can cause a change in forest cover as well.

Pollution (land, air and water) due to the impacts of urbanization increases greenhouse effect and accelerates climate change. Insufficient capacity of infrastructure and heat island effect of built up areas are also considerable outcomes of urbanization. As Cadenasso et al. (2007) indicates; land cover, density, used materials and the morphology of urban landscapes cause differences in local air temperatures. Climate change based vulnerabilities like change in temperature, precipitation, hydrological cycle, food chain and land cover/use (forest, agriculture etc.) are expected to have more severe impacts in urban areas as a result of their dynamics and needs. Therefore climate change impacts, unexpected natural risks may cause insufficiency in infrastructure, problems in food and water accessibilities. These impacts may threaten quality of life as well as environmental quality and future prosperity.

Millennium Ecosystem Assessment (MEA, 2005) put forward that climate change will have very sudden impacts on ESs in the following 50-100 years. According to the report, climate change is a direct driver that affects ESs and human well-being. But, at the same time it can complicate the management and assessment of ESs to be more complex in all scales. Beside that, as a result of human activities and climate change, the degradation on ESs cause a contribution to greenhouse gas emissions which has effects not only in local but also in global level.

## 2. Spatial Planning and Integration of Ecosystem Services (ESs)

Planning and urban design professionals have been always related with questioning and establishing better “nature” and “development” interactions since far back to post-industrialism with the severe and sudden impacts of rapid industrialization and urbanization. The first reaction of urban settlements to early problems of industrialization has been widely researched and well documented. “The City Beautiful Movement” and “The Garden City Movement” at the beginning of 1900’s were related movements of urban planning and nature interaction (Platt 2004). Later, Ian Mc Harg (1969) had significant influence of ecology and urban design interaction with his prominent work of “Design with Nature”. They were the relevant stepping stones of ecologically sensitive spatial planning practices in the last century. Ultimately, today, the need for having better interactions of urbanization, nature and community is beyond beautification efforts, but is an urgent necessity especially with the growing concern of climate change impacts.

The Millennium Ecosystem Assessment (MEA, 2005) brought new approaches to nature and human relations and the issue of ecosystem services (ESs) accelerated the efforts for the integration of planning processes. From 1990 to 2010 more than 2,000 scientific articles were published on this subject. The majority of these publications were related to ecology, environmental sciences and studies, economics and biological diversity conservation. In these publications, the integration of spatial planning with ESs is not very common and has a small figure with 47 counts (Tezer et al, 2011).

Although the ESs issue has become an increasingly important subject in scientific literature and at the global level policy making processes, the lack of inventory regarding to the services leads to disconnection between planning and policy-making domains. In addition, existing planning models for policy development are oriented by land use and sectoral information (Willemen et al., 2008). In this context, to be able to integrate the ecosystem approach to planning, the principles of ESs based planning approach will be relevant to review its content and characteristics. These features can be summarized under five main headings:

- ESs-based planning approach is holistic and interdisciplinary
- ESs-based planning approaches focus on relationships and processes of the ecosystems and society.
- ESs-based planning approaches include the appropriate purposes related to spatial and temporal scales.
- ESs-based planning approaches aim for the equitable sharing of benefits and resources for every segment of the society in order to foster participation in the planning process.
- ESs-based planning approaches use adaptive management activities.

On the other hand, the identification of relevant planning tools and the clarification of commonalities of the two approaches' principles will be beneficial for identifying a framework to integrate ESs into spatial planning process. In this context, the conceptual framework of MEA (2005) clarifies the links between ESs and human well-being while then again it presents a draft framework to be applied to the planning process from global to local level scales with an analytical approach. The key tasks are defined in this analytical process, such as (MEA, 2005):

- Definition of ecosystems and categorization of the services provided by them,
- Identification of ESs and the links with society,
- Identification of direct and indirect factors changing ESs,
- Identification of the indicators of factors changing ecosystems' services, structures and human well-being,
- Assessing past trends of ESs,
- Uncertainty analysis, projection of changes on ESs and human well-being under specific scenario analyses, and
- Definition of basic outcomes and development of future policies after comprehensive assessment process.

Conversely, the strategic spatial planning can be a relevant tool for sustainable planning of ESs with its multi-dimensional and multi-stakeholder nature. This approach may provide the development of land use decisions under resource protection, action-based multi-dimensional governance, sustainable investment decisions, coordinated and long-term spatial development policies (Gedikli, 2010).

ESs-based spatial planning can be developed in four phases (Albayrak, 2012). First phase is the definition stage where existing ecological, socio-economic and administrative characteristics are put forward. In this stage, ecosystems and their services, sensitive habitats, direct and indirect factors changing ecosystems are defined with local ecological knowledge. Additionally, existing planning policies and tools are identified in this stage with the support of ownership patterns, socio-cultural characteristics, public and private stakeholders who may have role in the planning process of ESs. Second stage, entitled as identification, is where key ESs and their trends are identified. The key ESs are the ones which have significance on the planning decisions. In this stage, their sustainability indicators and status are assessed together with previous trends to direct planning decisions. The third phase measuring, assessing and mapping is the stage where spatial, socio-cultural and economic analyses put forward; and scenarios analyzed under past/present trend analyses. The final phase is the decision making and modeling stage where spatial, institutional and legal frameworks of planning process is set under the outcomes of previous stages (Figure 1).

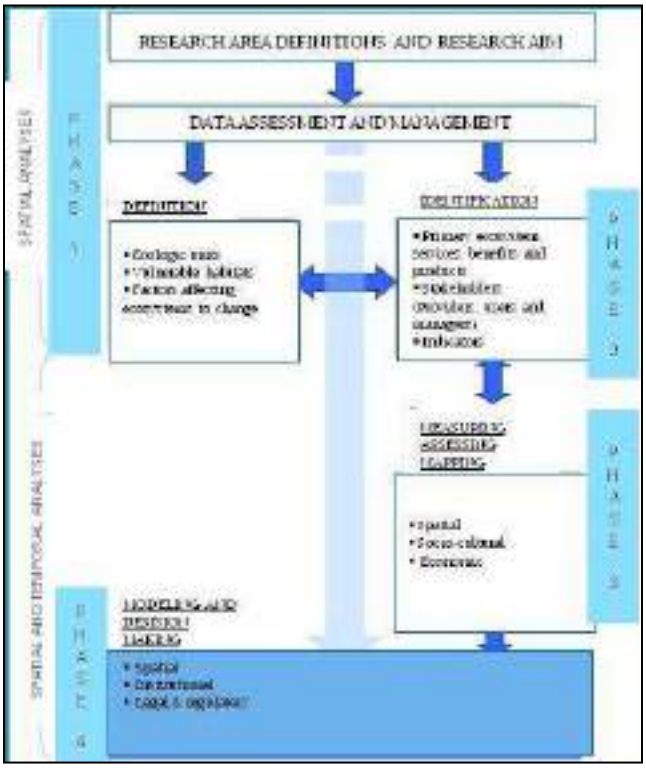


Figure 1. Stages of ESs integration with spatial planning (Albayrak, 2012)

### 2.1.Mapping of ESs

Geographically referenced data of GIS have to be defined at a selected common coordinate system for using the GIS capabilities effectively. On the other hand, maps, which are used for communication of the information obtained as a result of the analyses executed with decision makers and end users in GIS, add another dimension to this technology for being so popular (Ulugtekin et al., 2009). Because of the above mentioned characteristics, GIS is often used by several disciplines to find solutions to global problems through a systematic approach. Therefore, it is considered as a multi-disciplinary tool and is used for different variety of applications, such as transportation, disaster management, navigation, medicine, city planning, agriculture, and etc. In this research, GIS was effectively used to organize, manipulate, retrieve and present the spatially referenced data obtained from different sources related to ESs and land cover/use data. In this context, the vector data obtained, produced or derived from existing maps, remotely sensed images and GPS surveys were firstly imported into a GIS database as layers and then all vector data were reorganized by identifying them at a common coordinate system that is Universal Transverse Mercator (UTM) Projection. Additionally, European Datum 1950 (ED50) was also considered as the defined datum of the system in this case. A GIS database on which spatial analysis can be executed properly were obtained by the definition of the vector data at common coordinate system. As the following step of the study; relations between non-geometric and geometric data were provided based on the relational database principles. As a result GIS database is prepared for executing queries and analyses and also for mapping their results thematically. Positional, thematic, temporal analyses were used in the analyzing process of ESs of Istanbul case. In this context:

- Positional analyses were executed by comparing different parts of the study area at the same scale to introduce general characteristics of the study area.
- Thematic analyses were executed for investigating different themes in the same area at the same scale comparatively.
- Temporal analyses were executed for comparing the data of the same area collected at different dates of the study area were determined based on temporal analyses.

Finally, results of these analyses were visualized as thematic maps indicating the several characteristics of ESs in Istanbul.

## 3. Evaluation of the main ESs integrated with climate change in Istanbul

Istanbul, covering 5344 $km^2$ area with 12.915.158 people and the urbanization ratio of 90%, is located on a unique ecosystem location by combining two continents and the climatic regions of both Mediterranean and Black Sea climates with diverse flora and fauna characteristics. Bosporus and the Marmara Sea have also very significant role in the natural structure of the city. The existing pressure of increasing urbanization, growing population and rapidly emerging economical activities are expected to increase in the future. Unplanned urbanization, residential areas of the internal immigrants with infrastructure deficiencies, location choices and plans conflicting with the natural characteristics interfere sustainable urban development of Istanbul.

The pressure on this vulnerable natural environment is expected to continue by the impacts of climate change (Figure 2). Addressing the impacts of climate change on

ESs and urban area, determining the vulnerable areas and developing strategies to increase the resiliency can be a relevant policy development tool to achieve sustainability in Istanbul. Therefore in this research, terrestrial and climatic features of Istanbul are mapped to produce ESs based spatial knowledge for future spatial policy development.

Evaluating actual land cover and land use with projected changes in primary climate parameters (e.g., temperature and precipitation) can help understanding the vulnerabilities on urban functions and ESs. Other climate parameters such as evapotranspiration, runoff and wind should be also integrated to understand the possible impacts on ESs.

### 3.2. Mapping of ESs in Istanbul

In this research Istanbul Metropolitan Area Boarders' land cover and land use data is studied at regional scale. Main land cover and land use data are determined as artificial surfaces, urban green areas, urban unused areas, forest areas, agricultural areas, scrub and herbaceous vegetation. Beside these, beaches, dunes and rocks, wetlands as marshlands, water bodies and main transportation axes (TEM, E5 and railway) are included in the assessment of existing ecologic and built up area characteristics.

According to the Millenium Ecosystem Assessment (MEA) 2005 Report; ESs are classified as supporting (nutrient cycling, soil formation, primary production), provisioning (food, fresh water, wood and fiber, fuel), regulating (climate regulation, flood regulation, disease regulation, water purification) and cultural services (aesthetic, spritul, educational, recreational). In this study, ESs of Istanbul are intended to be classified according to MEA, 2005 classification as shown in Figure 3.

These services can be developed more in details especially to address the socio cultural characteristics of Istanbul.

### 3.3. Evaluation of the ESs in Istanbul

In this research, ESs addressed for Istanbul Metropolitan Area are tried to be evaluated for integrating with climate change scenarios. Increase in temperature and change in precipitation are expected to have impacts on existing ESs in Istanbul. In order to increase resilience of Istanbul and develop appropriate spatial planning policies and strategies; these impacts should be addressed. Above some of the estimated impacts of climate change are mentioned. Additionally the impacts of CC on the ESs should be clarified. Hence further assessments have to be evaluated with the integration of the two.

**Soil Formation:** Increase in precipitation should be taken into consideration especially for low drainage soil formations like hydromorphic and vertisol soils. The high quality soil can be protected and avoid from urbanization.

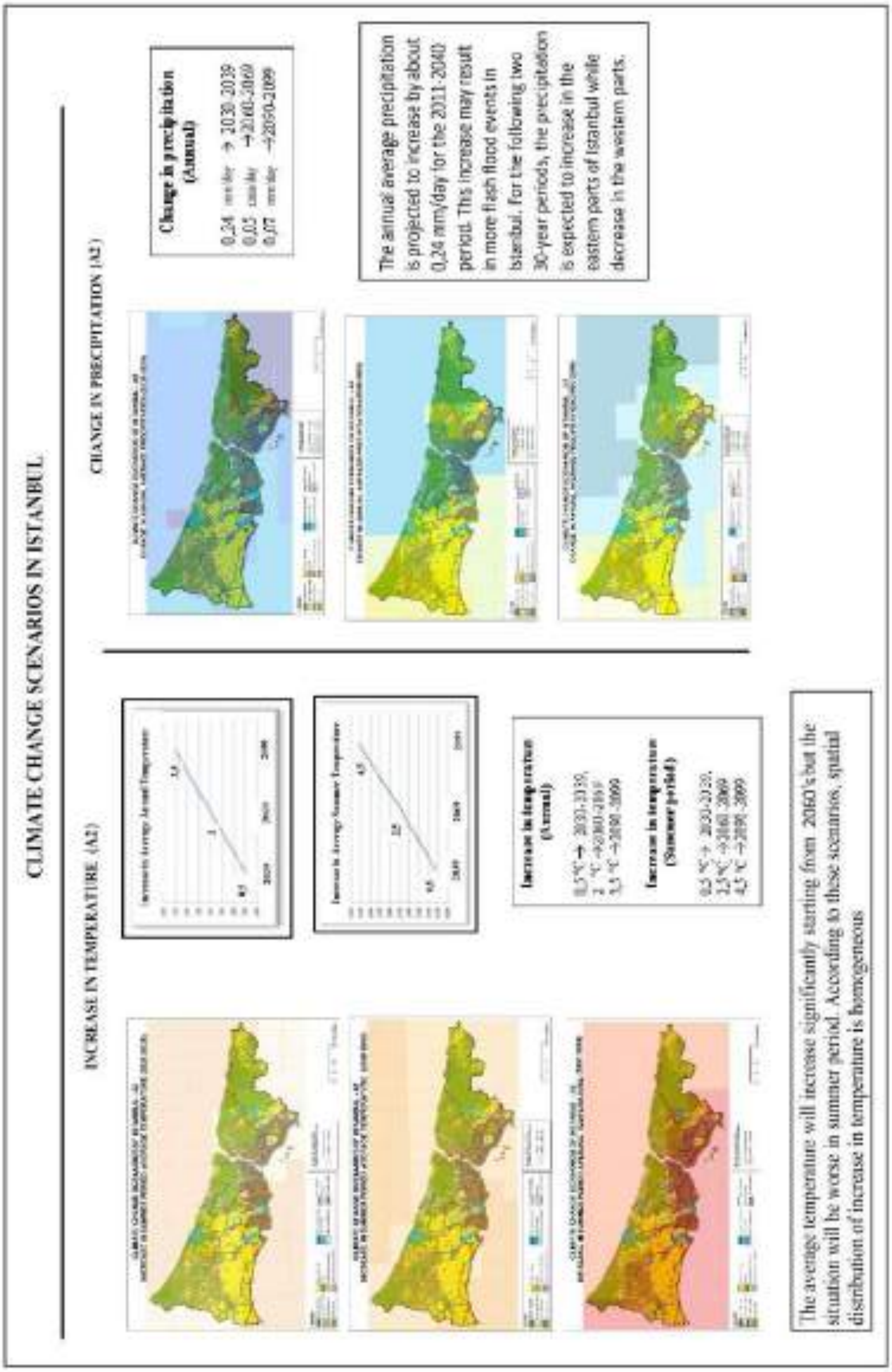


Figure 2. Projected changes in climate parameters in Istanbul (based on A2 scenario simulation of ECHAM5 Global Circulation Model)

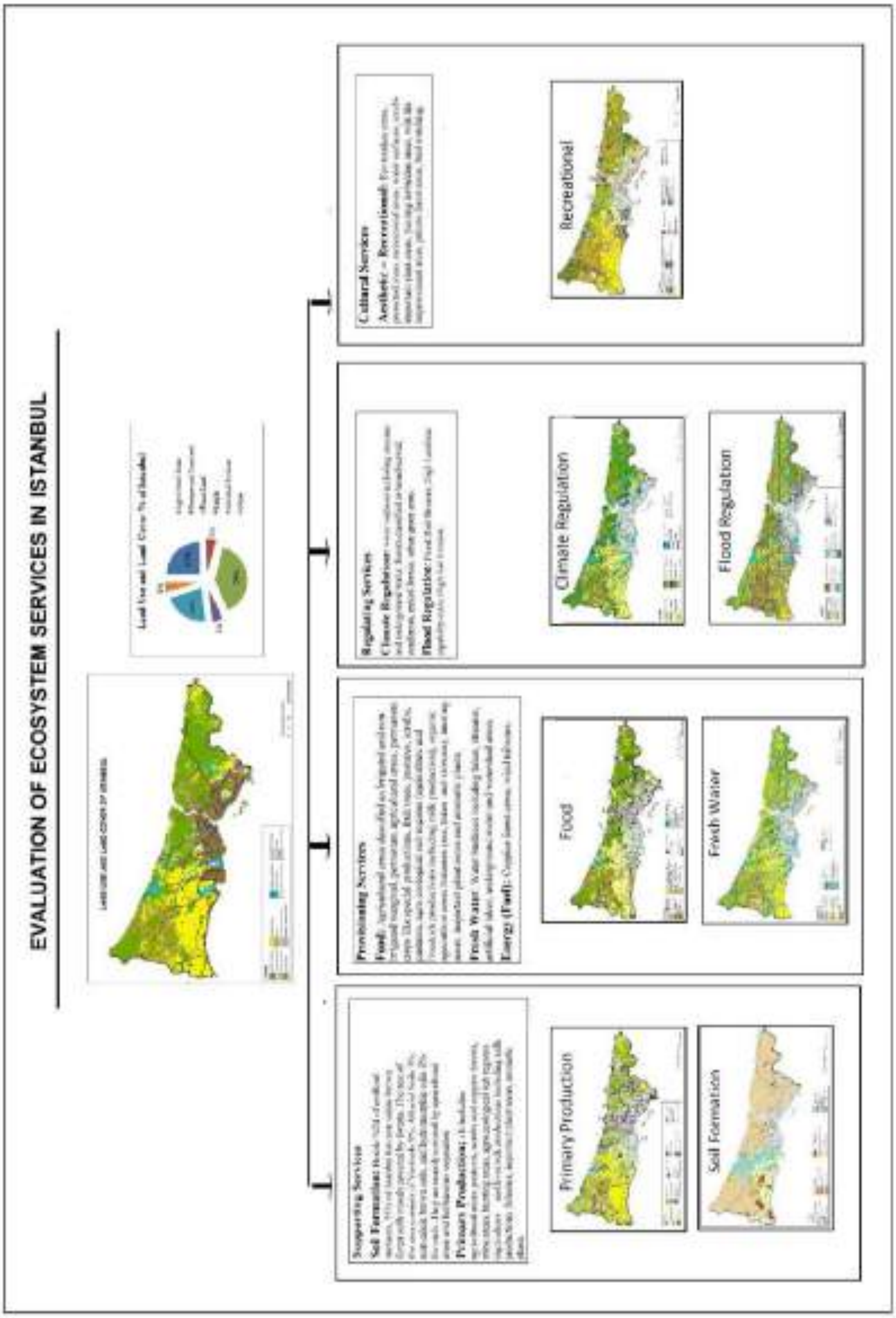


Figure 3. Evaluation of Ecosystem Services (ESs) in Istanbul

**Primary Production and Food:** Temperature rise can affect all agricultural areas, forests, agro ecological sub regions and their products, all plants, fisheries etc. Beside that decrease in precipitation in the west part of Istanbul after 2060’s, drought can be seen and primary productions like agriculture, forest, livestock etc. may be replaced with other land uses and land covers like from forest areas to agriculture areas, from permanent agricultural areas to marginal agricultural areas or built up areas etc. These changes may cause significant losses in ESs and on the economy which is strictly related to these ESs.

**Fresh Water**: One of the most affected services is expected to be fresh water services. It depends on atmospheric changes like precipitation and evaporation. Actually, the water demand of Istanbul urban areas is higher than the local water supply and there are new projects for supplying water demand from other locations. According to climate change scenarios, this situation can be worse especially in the European part.

**Fuel:** Coppice forest areas can be destroyed as a result of rising temperature and decrease in precipitation especially in the west part. Wind turbines can be good solution for decreasing the greenhouse gas effect and dependency on external energy sources like natural gas.

**Climate Regulation:** As a result of damages on forests, green areas and water surfaces, this service which is also very important for climate change mitigation may function very slow and inefficiently.

**Flood Regulation**: Flood risk can be very high especially in the east part and both urban areas and primary productions can be under risk. Due to previous experiences in Istanbul, this may cause an enormous pressure on economy and human well being.

**Aesthetic – Recreational:** Increasing temperatures and decreasing precipitation will enhance the stress on the flora and fauna in the recreational areas, and may result in the adoption of more resilient species

These impacts and more should be well addressed in order to determine the vulnerabilities. Most vulnerable services are determined as fresh water services, primary production and food services, climate regulation, flood regulation, aesthetic services and fuel services respectively. Strategies among these services in order to increase the resilience for economical growth and human well-being should be integrated with spatial planning tools.

## 4. Conclusion

This study tries to develop a new methodology for the integration of climate change and ESs. This approach may help to figure out with the uncertainties related to climate change and urbanization dynamics. For sustainable cities and ESs not only the existing situation but also the future vulnerabilities should be addressed. Therefore this study will be developed more in details and further research and analyses will be done. In this study only the main ESs are intended to be evaluated.

At the following stages, beside taking ESs into consideration, urban built areas' physical, socio-economical issues will also be evaluated. Scenario analysis is the tool preferred here to develop and to lead future urban development policies (Figure 4).

In order to achieve this, the land use scenarios should also be generated and integrated with climate change scenarios. Land use scenarios are necessary to be able to understand the change in land cover, the impact of land cover change on ESs, how the ESs will change due to land cover change. Then, integrating with climate change scenarios, climate change impacts on actual ESs and future ESs can be evaluated.

As it is shown in Figure 4, in the first stage of the research; main ESs are intended to be identified by mapping of the spatial distribution of these services. In second stage; climate change scenarios based on temperature and precipitation are developed and the spatial differentiation of these scenarios are indicated. As a result of these stages; climate vulnerable ESs are identified. These vulnerabilities may clarify the actual vulnerabilities under the view of climate change scenarios. As climate change scenarios are made for future, beside actual situation also future ESs should be addressed by developing land use scenarios. With this perspective; the future vulnerabilities of ESs can be determined and spatial planning decision making process can be supported according to these scenarios. As a result; in order to create climate resilient cities in the future, appropriate spatial planning strategies and policies can be created and main actors and their roles can be identified. Increasing the resilience of ESs can be the most feasible and rational mitigation tool for combating climate change.

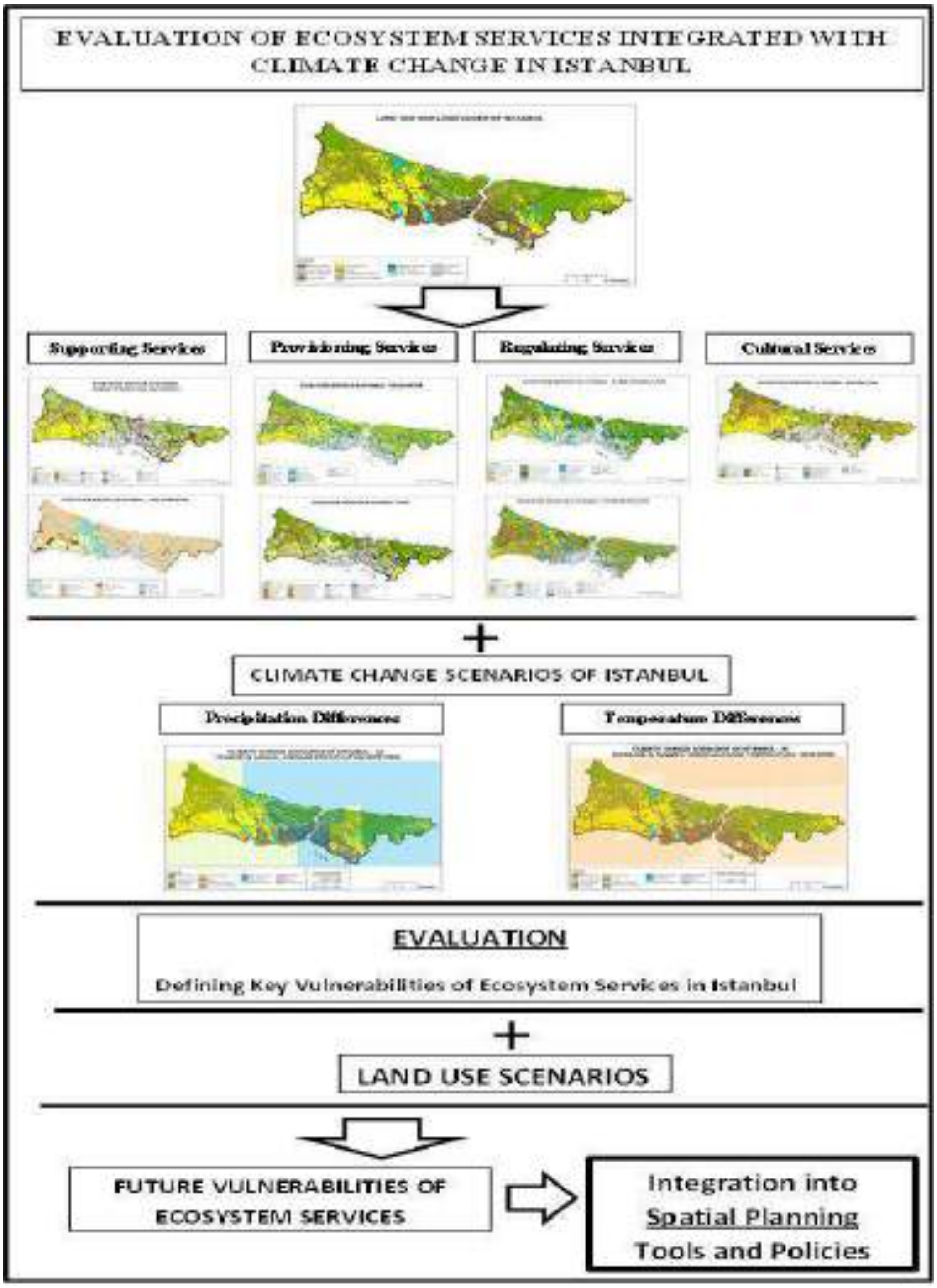


Figure 4. Evaluation Methodology of ESs Integrated with Climate Change in Istanbul

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