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A landscape scenario development to enhance ecological integrity in landscape planning

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Abstract

In urban areas, land-use changes and urban form are often influenced by the compulsory demands of immediate population changes. With rapidly growing populations, cities often experience negative impacts on urban landscapes, such as in slums and during the growth of urban sprawl. However, the sustainability of cities can be managed by paying attention to the ecological integrity of both the built and natural environments. The present study aims to present a landscape scenario development to enhance ecological integrity in landscape planning via the patch-corridor-matrix model. The research deals with the Sariyer district of Istanbul and its immediate surroundings.

A detailed investigation of landscape structure and the function of the fundamental landscape components were defined via GIS applications, while landscape metrics of these components were interpreted through the FRAGSTATS program. The method of the study relies on a combination of ecological principles, policies, regulations, and the approach of the actors involved in urban planning and development processes.

The study enabled structuring a cultural and ecological landscape planning strategy, and the results point out how to define the valuable landscape components that should be protected during urban growth development. Eventually, the research enriches the classical methods of understanding landscape patterns under urban pressure and presents a method to develop an ecological landscape planning strategy to be integrated with a variety of urban growth and land use – land cover change studies.

Keywords
Landscape ecology, Urban growth, Ecological integrity, Landscape change, Scenario development.

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1. Introduction

Maintaining ecological integrity in urban landscapes is an imperative goal for urban resilience and sustainability. When Aldo Leopold first mentioned integrity in his essay on land ethics, he described the notion as "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community." This description was further elaborated on by Kay et.al., (1999): "If a system can maintain its organization in the face of changing environmental conditions, it is then said to have integrity." Noss (2003) saw ecological integrity as an umbrella concept embracing all that is good and right in ecosystems, however, it should be recognized that establishing the near-natural levels of biodiversity, naturalness, and ecological resilience of pristine wilderness areas is challenging in urban areas. Noss suggested developing gradients spanning from the standard landscape condition in the wilderness to the most degraded urban condition. Reducing fragmentation, maintaining naturalness, and improving adjacent land use compatibility with open space patches enhances the ecological integrity of urban open space patches (Noss, 2003; Esbah et al., 2009). The existence of ecological processes and minimum human influence ensures high integrity (Angermeier & Karr, 1994; Parrish et al., 2003). Generally, as human disturbance increases, ecological integrity decreases. Thus, ecological patterns, processes, and human impacts can be used as parameters to measure ecological integrity in urban landscapes.

Ecological integrity and sustainability is a challenging but imperative goal to improve the health of the built and natural environments for urban areas. Urban sustainability is a place-specific, evolutionary process, which seeks to provide a high quality of life that is democratic, socially equitable, sound and comprehensive, economically vibrant, biologically rich, ecologically functional, and aesthetically pleasing. As Ibes (2013) stated: "these concerns are related to the ecological concepts of carrying capacity (the ability to meet the needs of citizens and the environment), fitness (the suitability of the built environment to both human and nonhuman inhabitants), resilience (the ability of the urban ecosystem to resist or recover from disturbances), diversity (including the harmonious co-existence of human and nonhuman inhabitants in cities), and balance (between the various needs and preferences of urban inhabitants and the natural environment)."

Environmentalism, and landscape planning are highly influenced by Ian McHarg's studies and practices. His Potomac River Basin Study was a clear example of the reciprocal relation between planning and natural landscape determinants. He devoted one chapter of "Design with Nature" (McHarg, 1969) to investigate the natural, sustainable environment in Barrier Island and revealed a holistic approach to elaborate multiple parameters in the landscape. Within his studies, he underlined the importance of conducting an "ecological inventory" to be able to read the biological, physical, and cultural landscapes and bridged the gap between decision-makers and scientists. Along with Ian McHarg, Phill Lewis is credited for the development of the natural resource inventory. Lewis's "environmental corridor" and "map overlay" approach promoted the landscape design process and guided planning efforts (Lewis, 1996).

With the lessons learned from these fundamental studies, this paper elaborates on the environmental parameters of the landscape and presents, by using the patch-corridor-matrix model, a landscape scenario development to guide the planning decisions to enhance ecological integrity.

The landscape planning, often referred to as environmentally responsive land use planning, is not new paradigm. Julius Fabos, one of the early advocates of this notion, proposed in his book published in 1979 illuminative strategies for planning the total landscape. He studied landscape planning in the metropolitan landscape and presented emerging system models (Fabos, 1979). Following his studies, the concept of landscape integration into planning has become a powerful strategy for increasing the quality of urban life and urban sustainability. In the last few decades, some new theories and practices have also emerged, such as Green Urbanism, Ecological Urbanism, New Urbanism, Integral Urbanism, Critical Regionalism, Bioregionalism, Biophilic Urbanism, Smart Growth, and Landscape Urbanism. These are some of the theories and practices that have emerged to tackle contemporary urban problems in more inclusive ways by understanding the landscape with all of its dimensions (Erdem & Yildirim, 2014; Adhya et al., 2010).

It is the utmost responsibility of landscape architects to design urban environments that restore, maintain, and improve urban ecological integrity. A variety of methods are beign used to detect the changes in landscape patterns and inform possible environmental risks. Here, we elaborate on how landscape dynamics can be captured to understand the possible effects of land use scenarios on urban ecological integrity. In this study, we demonstrate the implementation of a landscape ecology-based approach, combined with the development strategies of policymakers and actors by utilizing the Patch-Corridor-Matrix model, in the town of Sariyer in Istanbul, Turkey. This model proposes a framework to understand the reciprocal relationships between the structure and functioning of this complex mosaic.

To analyze the landscape structure, one should observe the landscape as a whole and examine its composition, configuration, and change by looking at the shapes, sizes, numbers, locations of its components, and their role in the landscape function. These analyses guide the development of future landscape scenarios. In his *Upper San Pedro River Basin Project* (Steinitz et al., 2003), Carl Steinitz emphasized the role of developing alternative scenarios and concepts for the future and revealed the effects of various development policies on the landscape. His studies contributed significantly to the research field by developing a collaborative approach to landscape planning.

A well-structured scenario development involves four necessary steps: 1- Definition of scope and question to be addressed. 2- Perception analysis: Identifying primary actors and the perception, binding policies, actions, and decision-making power of primary actors. This step can be conducted in a workshop setting with relevant organizations or during interviews with the key administrators in the organization. Also, it should be supported by scrutinizing the policies and determining the degree of decision-making power. 3- Trend analysis: Explaining the underlying trends, critical driving forces, and their ranking based on their importance and potential impact, hence identifying a baseline condition. This step can involve analyzing master plans and future visions. 4- The "scenario building step" is an expert-led approach describing different future states of the world. The final step involves generating narratives. These narratives reflect different assumptions about various land-use policies and decisions as well as economic and regulatory conditions.

All these growth scenarios describe how the future may unfold, and they encourage users to think "beyond the conventional wisdom" (Bohunovsky et al., 2011; Jäger et al., 2008; Houet et al., 2016). Scenario development may rely on different aspects and intents. Scenario-based planning is neither for predicting the future nor developing a set of land-use recommendations; rather, it is for describing what is possible in the future (Xiang & Clarke, 2003). Exploring these alternative future scenarios can be a puzzling task while dealing with complex global challenges when working on geographic scales. Fisher et al. (2020) revealed a planning and design approach to bring a variety of disciplines together for collaboration and provided methods to explore alternative future scenarios around the world.

Scenarios can combine multiple disciplines and decision-makers while exploring the potential future consequences of land-use choices and policies. Therefore, the urban growth strategies of this study include not only the physical environmental components but also the socio-cultural actors, such as decision-makers, governmental institutions, and organizations.

2. Study area

The pilot model was developed for Sariyer, a rapidly growing town in Istanbul, Turkey. Sariyer is located at the entrance point to the northeastern areas of the European part of Istanbul at the Black Sea end on the Bosporus strait (Figure 1). The town, covering an area of 151 km², is unique with its cultural landscapes, historical monuments, and fishing villages (Aksoy et al., 2017). Also, the town includes some high-quality natural landscapes. Sariyer contains the majority of the northern forests of Istanbul and hosts important historical water resources in the city (Kaptanoğlu & Bilgi, 2019; Ayaslıgil, 2011).

The topography of the area determines microclimatic conditions and vegetation typologies in the landscape, which also results in ecologically rich valleys and plains. The town consists of many water reservoirs, dams, streams, wetlands, and riparian landscapes (Sarıyer Rehberi, 1998). The northern parts of the forest lands are under protection, and some parts are under natural park status.

Accessibility makes the town an attractive destination for both locals and visitors. In recent years, Sariyer has experienced dynamic urbanization and landscape changes. Especially after the establishment of the "Bosporus Bridge" in 1973 and the "Fatih Sultan Mehmet Bridge" in 1988, rapid transportation developments have pushed urban growth to the northern part of Istanbul, towards Sariyer. Yet, a third bridge was constructed in 2014. The increasing demand for land resources and urban development has put the town under pressure for urban growth and land-use change. Specifically, new projects such as the third bridge on Bosporus and a major northern highway connecting Anatolia and the Middle East with Europe will possibly affect a variety of ecosystem services in the town.

This new infrastructure will most likely act as a magnet for real estate development in the northern part of the city. Therefore, the promotion of sustainable land-use decisions over the next few years is vitally important to preserve Sariyer's, and eventually Istanbul's, ecological integrity under the increased urban pressure. Hence, the method applied here is representative not only of the whole city but also of many other fast-developing metropolitan areas around the world.

Figure 1. *Study Area (ArcGIS base map, 2020).*

3. Methodology

Materials of the study include satellite images, aerial photos, environmental plans, and development plans retrieved from Istanbul Metropolitan Municipality, Sariyer Municipality, and Space Research Center of Istanbul Technical University. Satellite images (2013 dated, SPOT 5) were used to produce a land-use classification map. 1/100,000 scaled Environmental Plan (2009) and 1/5,000 scaled Development Plan were used for the interpretation of regulations and execution of their spatial reflections on the urban landscape matrix.

As the first step of the study, a detailed literature review of relevant publications provided the theoretical background of the research (Figure 2). The rest of the study relies on the case study applied to Sariyer. Geographic Information Systems (GIS) and Remote Sensing Technology (ArcGIS 10.2, and ENVI) enabled landscape assessments, spatial analysis, and image processing to understand the landscape structure and function. The supervised classification method was used for the production and elaboration of the land-use classification map (2013) that made it possible to understand the spatial patterns of the landscape structure. Five classes from CORINE, namely, (1) artificial surfaces, (2) forest and semi-natural areas, (3) agricultural areas, (4) wetlands, and (5) water bodies constitute the land-use classes of the case study. Areas of each class were calculated by multiplying the pixel area of the main image and the pixel number of each class in the attribute table of

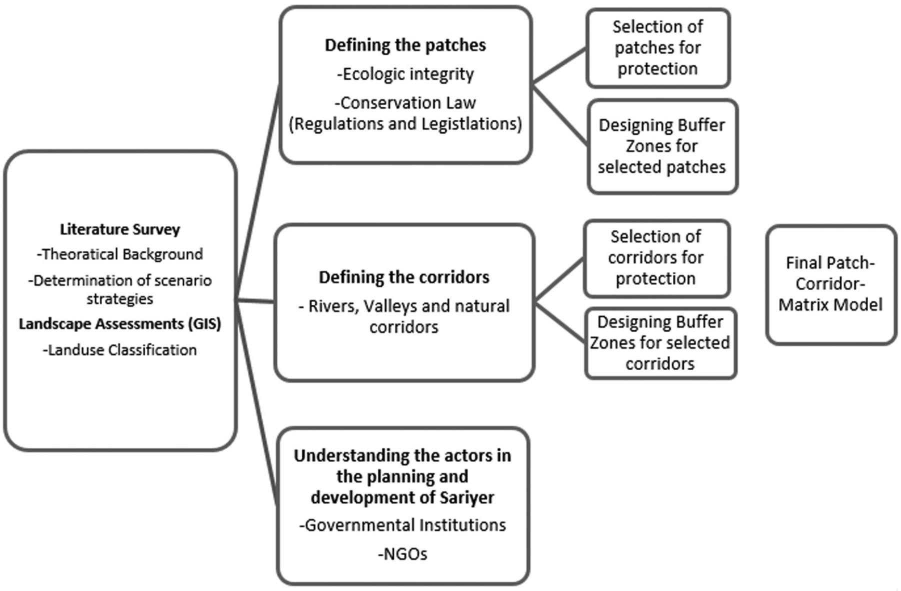

Figure 2. *Ecological Landscape Planning Scenario Development method.*

classification data. An area of 48,404.48 hectares was calculated in total, and Sariyer District covers 15,421.5 hectares of the study area.

In the second step of the methodology, landscape patches and corridors were revealed to understand the current condition of the landscape structure. Landscape ecology principles constitute the basis of this elaboration; therefore, the study adopted the following strategies to protect the landscape structure and function (Forman, 1995; Dramstat, 2006):

- Preservation of ecologically sensitive habitat patches.
- Protecting the corridors that provide opportunities for habitat and energy flow while strengthening the landscape connectivity.
- Providing the habitat with stepping stones to support wildlife in cities and contribute to connectivity.
- Proposing buffer areas around valuable patches and corridors to make these areas more efficient.

3.1. Determination of patches, corridors, and matrix of the landscape

Ecologic integrity and current regulations and legislation guided the determination of patches in the landscape mosaic while spatial analysis defined the rivers, valleys, and natural corridors. This process also guided the development of the ecological structure that is essential to maintain in the site. Landscape configuration and composition metrics decoded the patches and corridors in the landscape pattern.

Landscape patches are classified under five main classes (Dramstad, 1996). These are environmental patches, remnant patches, introduced patches, regenerated patches, and disturbance patches.

Linear landscape components that are isolated from their environments in the landscape matrix are classified as corridors. These corridors mostly contain ecologically rich valleys, stream beds, hedgerows, while roads and highways are also considered artificial corridors. The function of these corridors in the landscape matrix varies according to their location in the landscape composition. Similar to Dramstad's classification of corridor functions (2006), the corridor pattern revealed different functions in Sariyer. Ecological corridors are classified as habitats, canals, resources, and filters, while some roads function as a barrier or a swamp. This study categorized the corridors, based on their role in land-use patterns, as remnant corridors, regenerated corridors, vegetated corridors, disturbance corridors, and natural corridors (Odum & Barrett, 2008).

This study categorized the continuous vegetations (preferably native plants), especially between a natural system component and changing land use, as a buffer area. The primary objective of these buffers is to protect valuable landscapes from their changing environment. Eventually, proposals are developed for buffers in the landscape structure of Sariyer.

3.2. Actors involved in the planning and development of Sariyer

The study employed environmental plans and strategic plans retrieved from Istanbul Metropolitan Municipality, and the statistical information and demographic data were provided by the Statistics Institution of Turkey (TUIK) to understand different actors involved in urban planning and their actions.

Two major groups of actors are involved in the planning process of Sariyer: local administrations (municipalities) and non-governmental organizations (NGOs). Each group was investigated considering relevant laws, regulations, and organizational structures. Also, current plans, reports of the Town council or executive committee meetings, and relevant media coverages were examined.

3.3. Utilizing landscape metrics to determine patches and corridors in the landscape

The composition and configuration are interpreted via the FRAGSTATS program (McGarigal & Marks, 1994). The program provided an opportunity to analyze the landscape components through metrics (Leitao, 2006). Class Area (CA) and Class Area Proportion (CAP) metrics were used to analyze landscape composition, and Patch Number (PN), Patch Area (PA), and SHAPE metrics were used to analyze the configuration of the landscape matrix.

Class Area Proportion

The Class Area Proportion (CAP) metric is the area proportion of a land-use class to the entire landscape. CAP is a composition metric that analyzes the class distribution and changes in their sizes instead of their locational distributions. This metric is capable of comparing different landscapes and revealing similarities and differences.

$$CAP_{\text{i}} = \frac{\sum_{j=1}^{n} a_{ij}}{A}$$

CAPi= i land-use class proportion to the total study area
aij=the area of j patch in i land-use class (m²).
A: Total landscape area (m²).
Value Range: 0<CAP≤ 1

Patch Number

The patch number (PN) metric represents the total number of patches in the whole landscape or in a specified land-use class. It solely deals with the spatial fragmentation of the landscape. When used in a historical data set, this metric can give information about fragmentation in the configuration of the landscape mosaic. Since this metric is related to the entire landscape, there is no value range limitation. The larger the landscape, the more likely it is that it has a higher number of patches. Therefore, applying this metric in different landscape sizes may be misleading.

Patch Area (PA)

Mean patch size is useful in understanding the landscape structure. The change in the mean patch size of each class represents the fragmentation through the years.

$$\text{MPS} = \frac{\sum_{j=1}^{n} a_{ij}}{ni}$$

MPS= Mean Patch Size

Patch Shape (SHAPE)

The shape metric measures the geometric complexity of a patch while revealing the spatial character of the patch and helping to understand the configuration of the landscape. This index is related to the maximum area and minimum perimeter. Therefore, it is related to compactness. If the value is 1.0, the patch reveals a more compact statue, which means it is resistant to fragmentation. On the other hand, complex,

$$\text{Patch Shape (SHAPE)} = \frac{Pij}{minPij}$$

$$\text{SHAPE\_MN(mean)} = \frac{\sum_{j=1}^{n} \frac{P\,ji}{min_{pji}}}{n_i}$$

Pij = ij Perimeter of Patch ij
MinPij = Minimum perimeter of patch ij according to the cell number at the edges
ni= number of patches in the i land-use class
Range Value: 1, unlimited

geometric shapes reveal values greater than 1.0. The shape metric is highly affected by adjacent land-use classes.

4. Results

4.1. Landscape assessments

Urban growth is inevitable in fast-growing cities like Istanbul. The land-use classification map (2013) shows that landscape resources are surrounded by urban areas, and new extensions of the transportation network divide critical landscape resources (forests and wetlands), which cause fragmentation in the future (Figure 3). Considering their role in landscape ecology, wetlands provide living spaces for birds and many other animals in and around the city. Therefore the pressure on wetlands may lead to a retrogressing landscape structure. Planning a tampon zone around these water resources and wetlands emerges as a landscape strategy in the study area.

Yet, urban landscapes are dynamic and complex organisms, and they should be analyzed in terms of not only configuration but also composition. Rapid urban growth such as breeding new centers or diffusive growth, as in Istanbul's case, may result in fragmentation or disturbance in the landscape structure in the future.

Subsequently, the land-use classification map shows that the forest area is more compact and not fragmented by urban development yet, the environmental patch size is larger, and the natural connections between the patches are viable (Table 1).

The existence of large natural areas and corridors favors recreation opportunities, indicates livability, and ensures urban ecological integrity. Moreover, wetlands provide great habitat for wildlife in the urban context, yet they should be protected from agricultural expansion.

The on-screen digitizing technique provided an accurate determination of rivers, water dams, lakes, and other water bodies.

4.1.1. Hydrology

The study area presents a valuable hydrology potential with its lakes, streams, and dams, which supports not only the vegetation cover and soil structure but also the wildlife in the surrounding landscape. The area hosts seven water dams, with an area of 36-38 ha (Avg.) and a height of 13.5-17 m (Avg.) (Ayaşlıgil, 2011; MHT, 2001). The hydrology analysis shows all water bodies and their relationship with surrounding land uses (Figure 4).

Alibey and Elmalı Dam are important water resources that provide clean water to the city. Also, a wide network of stream and river corridors (Alibeyköy Stream, Kağıthane Stream, and Göksu Streams) surrounds the

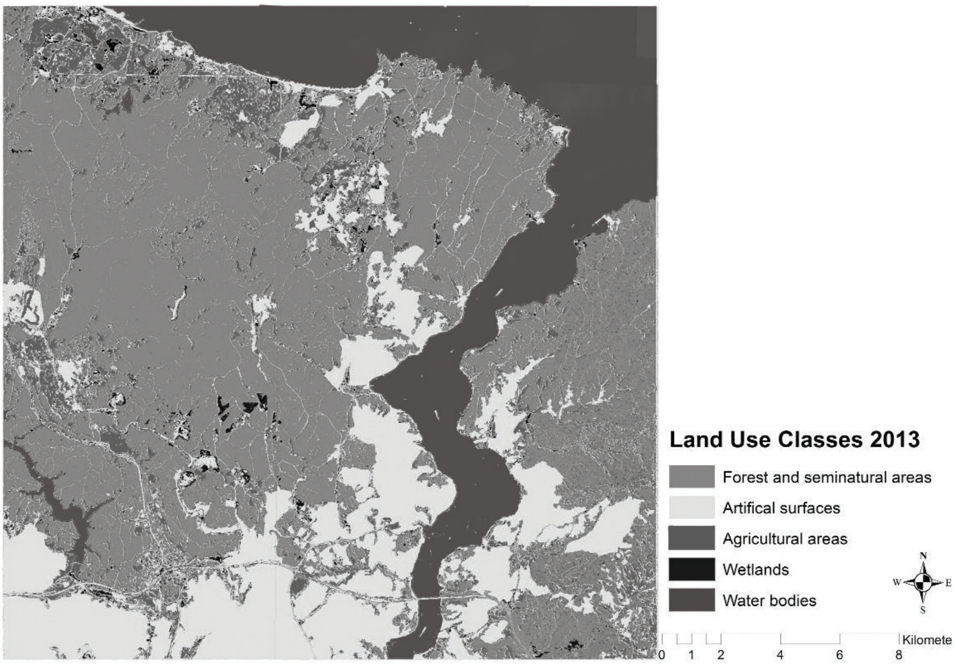

Figure 3. *Land Use Classification of Sariyer, Istanbul-2013 (Akyol, 2016).*

entire urban landscape (Figure 4). Considering its role in the landscape mosaic, this hydrological infrastructure creates habitat and constitutes ecological corridors, providing many interests for living environments.

Water bodies contribute significantly to urban biodiversity. They provide living spaces for shelter, nutrition, etc. for many species. Therefore, understanding the potentials and problems of landscape hydrology has a vital role in landscape function.

The hydrology network provides suitable habitat for the native flora and supports the wetland ecosystems in the surrounding landscape. This reciprocal relationship between water and biotic components is an indicator of a functioning landscape structure, which should be preserved against urban pressure.

4.1.2. Flora and fauna assessments and mapping

The topographic character of the study area is influential on climatic conditions and vegetation cover, and forest, maqui, and pseudo-maqui are three dominant plant formations in the area (Ayaşlıgil, 2011). Mixed forests generally host Castanea sp, Quercus sp, Ulmus sp., Carpinus sp., Tilia sp., Acacia sp., and Fraxinus sp. species (Çolak, 2013). Plant diversity in the area is a result of the existence of large water dams and forests. Belgrad Forest is the largest vegetation patch of the entire landscape. Quercus sp. covers 75% of all species in these mixed forests, while 25% of the plants include Fagus orientalis, Carpinus betulus, Castanea sativa, Alnus glutinosa, Populus tremula, Tilia tomentosa, Acer campestre, Acer pseudoplatanus, and Ulmus campestre (Yaltırık,1963).

These mixed forests provide opportunities for sequent vegetation, especially in the peri-urban parts of the landscape where the urban pressure is less obvious. *Hedera helix*, *Daphne pontica, Hypericum calycinum, Primula acualis, Latyrus hirsutus, Campanula percicifolia, Viola adorata,* and *Salvia forskahlei* are common plant species in these forests. *Hedera helix, Ruscus hirsus, Festuca arundinaceae, Carex sylvatica, Euphorbia amygdaloides, Geum urbanum,* and *Ajuga reptans* species generally spread themselves near damp and humid soils near *Acer campestre, Corylus avellana,* and *Ligustrum vulgare* trees or bushes (Tokuş, 2012).

Table 1. *Landuse classifications for 2013 and landscape metrics.*

Land use classes	CA (ha)	CAP	PN	PS (Mean)	SHAPE
Forest and Semi-natural Areas Forests, meadows, grasslands, and open green spaces in the urban and peri-urban	10.097	49%	101041	18.26	1.3189
Urban Area Settlements, commercial areas, quarries, roads, ports, and	23.760,5	21%	237499	4.32	1.1592
Agricultural Lands Vegetative production fields and	4.227,4	3%	42323	0.90	1.1552
Wetlands Marsh and wetlands	1.489,5	9%	15045	0.45	1.1779
Water Surfaces Bosporus strait, lakes, dams,	8.825,4	18%	88089	10.25	1.0396
Total Area	48.404,48				

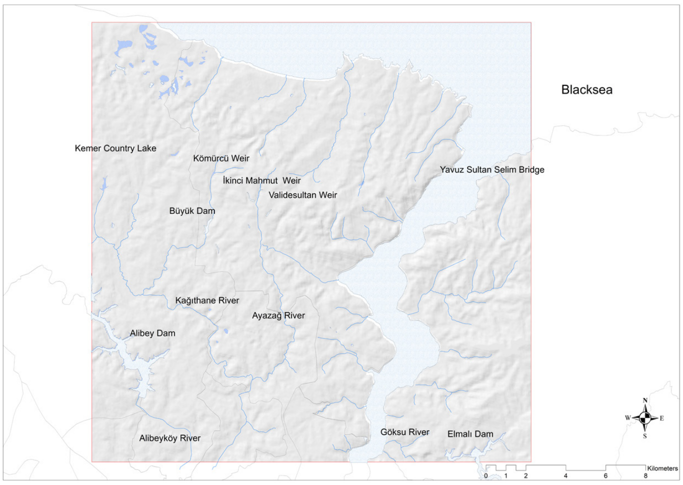

Figure 4. *Hydrology network of the study area.*

The vegetation of the study area has an interconnected relationship with the fauna diversity. The study area provides living spaces for a very diverse fauna community including 14 mammal species, 16 bird species, 12 reptile species, and many butterfly species (OAP, 2002).

The landscape model in this study adopts not only the physical factors but also the social indicators of urban growth. Therefore, as a major decision-maker, Istanbul Metropolitan Municipality is considered an actor involved in urban growth. The study uses

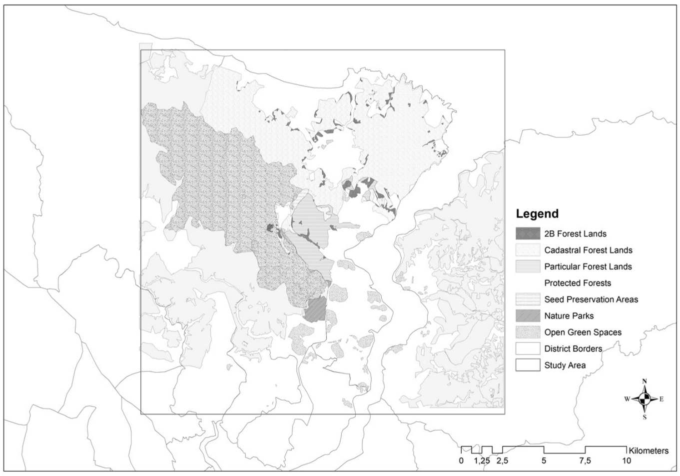

Figure 5. *Vegetation classes in the study area.*

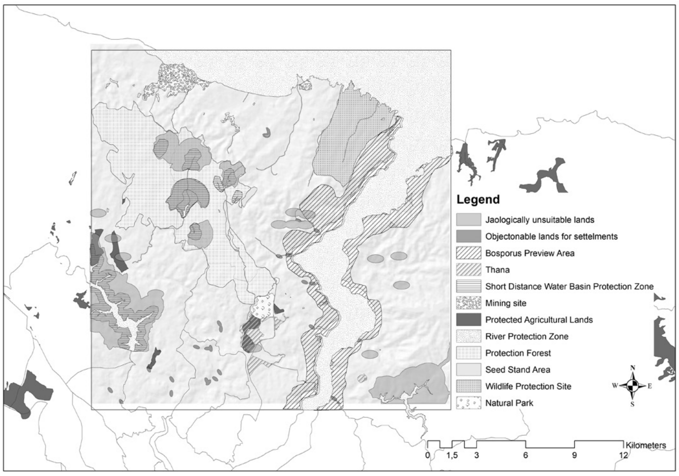

Figure 6. *The development restrictions by law.*

current legislation, regulations, and development plans as a base to develop a protection strategy.

4.2. Interconnected policies and regulations

The urban growth limitations and preservation decisions are made based on the following regulations and laws (Figure 6).

- ISKI-Drinking Water Basins Control and Protection Regulations, 1981 (water basin protection bends distances),
- 6831 numbered, Forest Law, 1956 (protected forests, wildlife improvement sites, seed stand sites, natural parks),
- TKB, Regulation related to Protection and Function of Agricultural Lands, 1991 (protected agricultural lands),
- 1983 dated, 2863 numbered, Protection of Cultural and Natural Assets Law (natural protected areas),
- 6301 numbered Bosporus Law (1/5000 scale Bosporus land use plan,1983)

Istanbul Metropolitan Municipality revised the land use plan with a preservation approach in 2004, and the Environmental Plan (1/100,000) issued in 2010 has put urban pressure over valuable water resources and forests in Sariyer.

Throughout history, the urban pattern on Bosporus Strait has been changed by different civilizations and cultures. Urbanization policies have been shaped by the urgent needs of citizens. Recent major projects, such as Yavuz Sultan Selim Bridge, Northern Highway, and Istanbul Airport have been discussed by a variety of NGOs and governmental agencies (Union of Chambers of Turkish Engineers and Architects Report) in Sariyer. Landscape resources have been trying to find value through economic priorities and demographic needs. This study aims to provide a holistic approach that values both nature and human requirements. Evaluation of landscape structure, function, and connectivity is critical to interpreting all these aspects with a holistic approach.

4.2.1. Actors involved in the development and planning of Sariyer

Municipality: Istanbul Metropolitan Municipality is the main institution that manages the collaboration between all municipalities in Istanbul at the metropolitan scale. The Municipality of Sariyer is a member of the Metropolitan Council and is the main planner agent making land-use decisions in the town. The Municipality of Sariyer is in charge of making 1/10,000, 1/5,000, and 1/1,000 scaled urban master plans, based on the 1/25,000 Environmental Plan, which was developed and approved by the Ministry of Environment and Urbanization. The Municipality has adopted Agenda 21, and thus, supports increasing quality of life and ecosystem services. Also, the municipality has re-established a new participatory management system (instead of the traditional hierarchical system). Therefore, a Town Council was established in 2007. The council consists of the mayor and the mayor's representatives, representatives of the Metropolitan Council, provincial assembly members, public institutions, universities, neighborhood leaders, and representatives of political parties, professional associations, trade unions, associations, foundations, as well as women, retirees, youth, and neighborhood council representatives. Including all these shareholders, land-use decisions are taken through a participatory process. The Municipality of Sariyer is aware of the urban pressure on natural resources (forests, wetlands, water bodies, etc.); yet, the municipality encourages residential and commercial development close to these important ecological features to boost land values and hence maximize tax revenues. In the 1/25,000 Environmental Plan, most forests in Sariyer were dedicated as areas of absolute protection, as the northern forests were providing many ecosystem services to the larger city system. As these ecologically vital features are subject to in-situ protection, the larger landscape context is, most of the time, overlooked. Moreover, the decisions of the Metropolitan Council (with regards to planning the third bridge and a major transportation route passing through the northern forests) did not comply with the land-use strategies in the Environmental Plans, making the plans obsolete.

Non-Governmental Organizations: NGOs are voluntary, non-profit groups organized at a local, national, or international level. These groups mostly consist of voluntary citizens and individuals with similar intents and interests. Funding comes from membership fees, donations, and also from local municipalities based on the type of their projects. In the case of Sariyer, active non-profit organizations aim to protect the environmental quality of the northern forests, raise awareness, and organize various outdoor education activities to raise a voice against any irregular use of forests and natural resources. They value sustainability more in an ecological sense while opposing residential and commercial development trends taking place close to ecological features.

The physical constraints and the actions and attitudes of the main planning actors constructed a development approach for the future growth scenario. Considering all their actions, the patch–corridor–matrix model proposes protection of valuable landscape areas that are under threat.

4.3. Developing the Patch-Corridor-Matrix model

4.3.1. Determination and selection of patches via landscape metrics

The results of landscape assessments and analyses revealed four classifications of patches in the study area landscape mosaic. Environmental patches include forests, lakes, dams, and large water resources while remnant patches cover green spaces surrounded by urban areas, small urban parks, and open green spaces. Introduced patches include agricultural lands, plant nurseries, and fields in operation. Finally, disturbance patches include mining fields, vacant lots, and worksites in the landscape (Figure 7).

The assessments revealed 2,173 patches in the whole landscape mosaic (PN=2,173). Metrics provided minimum, maximum, mean, and standard deviation values. The patches that are larger than the mean size are selected for protection (Table 2). Also, previous cultural and demographic assessments shaped the preservation decisions.

Water bodies, vegetation clusters, or wetlands in the study area provide resources for many ecosystem services. Therefore, the ecological land-

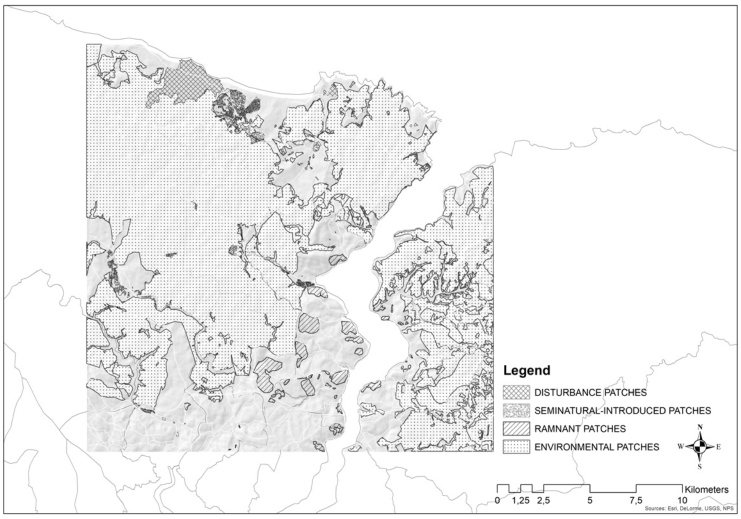

Figure 7. Patches in the study area.

scape scenario proposed 30m buffer zones surrounding these patches. These buffers avoid any threat from surrounding land uses while forbidding any urbanization in these zones.

There are 59 water patches in the landscape mosaic (Water PN=59), while Alibeyköy Dam, in the southeastern part of the area, is the largest one with an area of 284.2 ha (PA=284.2).

Results and interpretations revealed that agricultural lands, as introduced patches, also constitute an important component for the landscape function and structure in the study area. Especially the changes in the regulations (2B forest lands law) have enabled urbanization on these valuable productive landscapes, which also work as transition landscapes.

The PN metric revealed 1,754 agricultural land patches in the total landscape (Table 2). These agricultural lands cover 432.5 ha in total, with a mean area of 2,466.2 ha. The largest of these patches is located on the extensions of Alibeyköy Dam in the east. These agricultural patches are relatively distributed towards the coastal areas in the north and in the inner lands in the east. The lack of any productive land through the Bosporus Strait and in the urban context is apparent in the resulting maps. Due to the urban pressure on these sensitive ecological patches, 15m buffer zones are proposed (Fischer & Fischenich, 2000).

The results of landscape assessments and the land-use map show that the environmental patches (forest lands) constitute the dominant patch class, with 370 patches in the whole landscape mosaic. These environmental patches are intensely visible in the peripheries of urban areas, and they mostly host landscape resources such as lakes or rivers inside and create valuable habitats for many wildlife species and ecosystem services.

Only 14 of the patches are larger than the mean patch size (17.2 ha), and Belgrad Forest is the largest one with an area of 15,065 ha. The proposed landscape scenario protects these valuable environmental patches with a 100m buffer zone (Council, 2004), avoiding the neighboring urban pressure.

4.3.2. Ecological corridors

Landscape assessments and the land-use classification map show that valleys, rivers, and vegetated corridors, even under protection by law (300m protection band), are disturbed especially in the southern parts of the study area, where a fast urban growth occurs (Figure 8). However, valleys, rivers, and streams create wide corridors connecting major landscape resources and provide opportunities for energy, nutrition, and habitat flow in the landscape structure. Therefore, these landscape elements are considered the major ecological corridors in the landscape mosaic.

Table 2. *The metrics for landscape patches and corridors.*

METRICS	Environmental Patches	Introduced patches	Remnant Patches	Disturbance Patches	Rivers	Valleys	Stepping Stones
Min.AREA (ha)	83,9	0, 09	0,3	30	0,5	377	0,003
Max. Alan (ha)	15065	42,5	154	511	3,5	1322, 9	58
Total Area (ha)	25690	432,5	721	573	16, 5	2444, 7	236,8
Mean Area (ha)	17,42	0,2	15,6	191	0,3	814,9	2,4
Standard Deviation	3833	0,3	27	266	0,5	389,3	6,3

The mapping also reveals that in the suburbs, a natural vegetation cover surrounds the water bodies and creates a riparian corridor reaching up to urban areas. While entering the urban fabric, the natural riverbank transforms into a concrete canal, and it is rare to see vegetation around the water bodies.

The average length of the water network in the study area is 4,713 meters. The width and length of the rivers are larger and longer in the peripheries of the urban fabric. Therefore, the rivers in the northern part and the rivers that meet the Alibey Dam in the south are the longest and the most consistent corridors of the landscape structure, with the three largest valleys in the landscape. Therefore 30m buffer zones (Council, 2004) are proposed to protect these critical landscape corridors in the study area.

Small urban parks and green spaces in the urban areas can work as stepping stones that can bound habitat centers and create ecological corridors. In this context, 16 habitat corridors larger than the mean size (2.4 ha) are selected within 99 patches. The protection of these stepping stones with buffer zones is a critical strategy to avoid surrounding urban pressure.

The ecological landscape scenario proposes 100m buffer zones for natural, 15m buffer zones for semi-natural patches, and 30m buffer zones for rivers and valleys. The width of these zones is determined with a relevant literature survey (Bennett, 1994; Council, 2004).

Results of landscape assessments underlined the urgent restoration and protection needs of the urban green network. The land-use classification analysis shows the urban pressure over core environmental patches, while the current patch-corridor-matrix of the landscape presented a vulnerable mosaic due to the lack of connecting or conserving landscape components. The absence of any transitional land use between forests and intense residential areas may result in shrinkage and attrition, causing habitat loss and isolation (Forman, 2008; Forman, 1995). Yet, the construction of new transportation arteries and the introduction of new residential and commercial projects to the city are the initiators of a potential fragmentation in the landscape. In the case of Sariyer, the vulnerability of forest lands, wetlands, productive landscapes, and the habitats of many wildlife species constitutes a possible threat to the urban ecological integrity. Therefore, the ecological landscape planning scenario aims at developing a landscape structure that is resilient against urban growth.

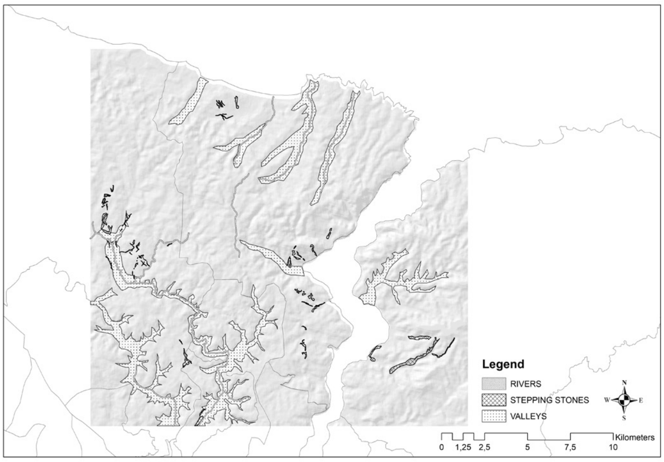

Figure 8. *Ecological corridors in the study area.*

5. Discussion and conclusions

Fast urban growth, due to the development of industrial and residential areas, results in the fragmentation of vulnerable habitats and a decline in biodiversity (Volker et al., 2010). Thus, a site-specific ecological landscape planning scenario is essential to understand the threats and potentials in the landscape mosaic and can enable urban growth policies to support the ecological integrity of the fast-changing urban context.

The sustainability of urban green spaces and their contribution to overall urban ecological integrity relies on geographic, built, social, and historical contexts (Byrne & Wolch, 2009; Harnik & Welle, 2009), and how complex socioecological systems communicate with this context. Urban landscapes are highly complex, dynamic, and multifunctional. Therefore, there is a need for improved methods of measurement and assessments of the effects of urban land-use change on urban ecological integrity. In landscape architecture research, quantifying the cost of highly incompatible land-use problems can be a puzzling task. Thus, landscape architecture research faces the challenge of describing landscape composition, configuration, and connectivity before and after the land-use change, whilst explaining the underlying social, economic, and environmental issues and mechanisms that affect the ecological integrity of the landscape.

Landscape metrics, used for the determination of patches and corridors, provided an opportunity to develop a landscape planning scenario to see the possible compositional and configurational alternatives. Since landscape ecology uses a variety of parameters, there are many approaches to tracking the changes in complex urban systems (Yin et al., 2016). This study enriches this existing research by including actors' strategies and visions in urban development, policies, and regulations into landscape ecology principles. With the collaborative method presented in this study, landscape ecologists and urban planners can be integrated into the urban growth development process with a landscape conservative approach.

The study shows the effective power of actors involved in planning and how they influence the social pattern and encourage urbanization while ignoring the vulnerability of valuable landscapes. The ecological landscape planning scenario can be a clear framework to explore the potential collaborations and to design solutions, and it should be considered an important tool for spatial policy and design implementations. Future studies, regarding the integration of landscape scenario development, CA-based urban growth models, and Agent-Based Modeling, can create great opportunities to predict future challenges and advantages.

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