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Integrated planning for the resilience of urban riverine ecosystems: the Istanbul-Omerli Watershed case

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Abstract

Since urban areas display nonlinear and dynamic interactions within their growth patterns, a crucial question is how complex systems can be integrated into urban planning practices in relation to urban ecosystems. Natural threats and extreme weather conditions resulting from climate change will threaten social, environmental and economic assets in urban riverine ecosystems due to their cumulative vulnerabilities, especially in less developed regions. This paper will discuss an "ecosystem services based watershed management framework" to increase the resilience capacity of urban riverine systems using the case of the Omerli Watershed (Turkey), which is located in a metropolitan area characterized by rapid population growth and ecosystem change. Three research domains, i.e. ecosystem services (ESs), spatial planning and climate change (CC) mitigation, will be integrated in order to propose an analytical methodology for spatial planning of urban riverine systems. The adaptive mitigation approach is used to accommodate both mitigation and adaptation policies in its structure. The methodology used here is a part of an ongoing research effort. However, this assessment is aimed at clarifying the integration of the three research domains for use in policy development.

Key words: Climate change, ecosystem services, spatial planning, adaptive mitigation, Omerli Watershed, Istanbul.

1. Introduction

Civilizations are restricted by the quality and quantity of available safe drinking water and by climatic conditions affecting the production of food, energy, transportation and industry. Therefore, expectedly, the location of the earliest civilizations was identified mainly by the availability of water. As well-known examples, the fertile crescent of Tigris-Euphrates, and the valleys of the Jordan, Nile, Indus and the Yellow Rivers accommodated the early civilizations who had a very strong relationship with these riverine corridors (Fig. 1) (Biswas *et al.* 2008; Girardet 2008).

From the point of water quality, at the time of these early civilizations, the clusters of human populations were small, and the range of human activities were very limited (Biswas *et al.* 2008). But, as the human populations steadily increased over centuries, communities became more vulnerable to water and climate based problems. From 1900 to 2000, the global human population increased fourfold, from 1.5 to 6.2 billion, and the global urban population increased from 225 million to 2.9 billion (Girardet 2008). In this period, especially after the industrial revolution, expansion of human activities and rapid urbanization have started to affect negatively natural resources in terms of quantity and quality. Therefore, starting from water related stresses, all natural resources came under increasing stress in many parts of the world, more than ever before. Future projections show that this stress will increase gradually. According to the 2003 World Population Report of United Nations (UN), by 2030, 60% of the world population, and, by 2050, 6.3 billion of the 8 billion projected world population (78%), is expected to live in urban areas (UN 2004).

The rapid growth of urban populations has been of interest to the scientific community for many years, especially with regard to aspects of the sustainability of urban ecosystems. For instance, urban areas are influenced by diverse ecosystems, creating a complex system of interactions characterized by multidirectional flows of water, matter, pollutants and energy (Zalewski, Wagner 2005). Climate change and population increases in urban areas are two important concerns relating to sustainable development policies. Beside the impacts of rapid urbanization and agglomeration of population in urban areas, the impact of climate change has been increasing the vulnerabilities of cities and their ecosystems that will exacerbate the deteriorations in the fresh air, water and food cycles of future populations (WaterAid 2007). In this context, riverine corridors and watersheds seem to be the most vulnerable ecosystems to the effects of climate change, being the most important sources of freshwater to urban areas, agriculture, industry and energy production. Hence, the interaction between water sources and climate change has been a growing concern of the scientific community (Fig. 2).

An analysis of the keywords "climate change (CC) and planning" appearing in international scientific journals indicate that these research subjects are mainly based on energy, water or agriculture-related sectorial contents. As can be seen in figure 2, climate change (CC) and either spatial planning or urbanization related topics are the least mentioned subjects relating to these resources. Therefore, an integrative methodology is needed for formulating effective development policies, urban design guidelines and implementation measures for spatial

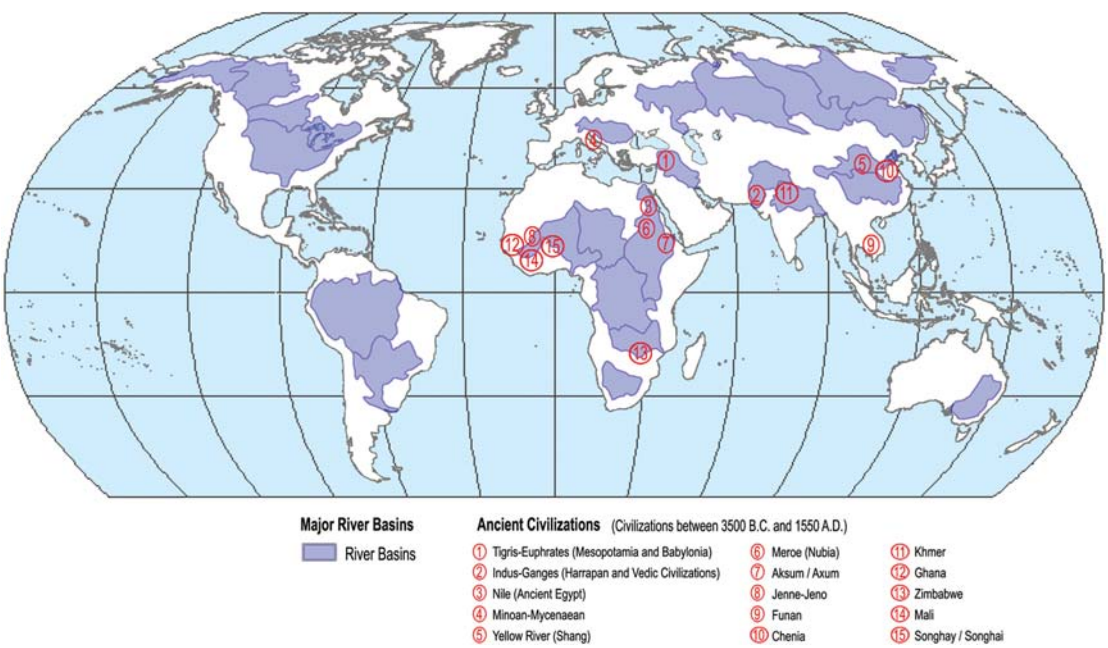

Fig. 1. Locations of the early civilizations and major river basins in the world (Source: Produced with the information from Allen, Shalinsky 2003; UNEP-WCMC 2001).

planning policies (Blakely 2007). In Turkey, the research results have similar characteristics as the international ones and the majority of climate change related research focuses on CC scenarios and environmental consequences of CC, especially water availability and agricultural development. However, the impacts of CC on urban spatial development, policies for mitigation and adaptation to these impacts are open to new research aimed at enhancing the resilience of urban ecosystems and developing an integrated planning strategy for today's planning practices (Tezer *et al.* 2011a).

According to the scientific literature, a holistic approach consisting of multidisciplinary perspectives based on social, environmental and economic aspects has not been integrated into these sectorial evaluations (Lindley *et al.* 2006; Parker, Rowlands 2007; Kirshen *et al.* 2008; Hope 2009; Jo *et al.* 2009). As a result of our literature review, there are limited studies on urban planning which combine scientific knowledge about climate change and its likely effects on planning and design issues in urban areas (Hamin, Gurran 2009; Hope 2009). Over the last decades, the contents of the publications have been focused on extreme weather conditions and events, sea level rise, natural hazards, urban heat island effects and their impacts on the health of urban settlements. However, in recent years, scientific consensus has been moving in the direction of adaptive policies for urban settlements to achieve urban sustainability and resilience. Therefore, an integrative methodology is needed for formulating effective development policies, urban design guidelines and implementation measures for spatial planning policies (Blakely 2007).

1.1. Climate change estimations in the region

According to the summary of the IPCC (Intergovernmental Panel on Climate Change) assessments, there are two major estimations related to the effects of climate change on society and ecosystems. The first one is the extreme and severe changes in weather events such as heat waves, droughts, extreme precipitations, severe tropical cyclones and the exceptional precipitation levels causing extreme floods. The second one is related to the availability of water supplies in respect to water scarcity and abundance (Hare 2009). From this perspective, by 2050, the annual rainfall ratio for the rivers in the dry lands of the middle latitudes and tropical regions is expected to decrease (IPCC 2007).

In Europe and the Mediterranean region; the annual mean temperature levels are likely to increase more than the global mean and be linked with changing seasonal characteristics. For instance the warming in the Northern Europe is likely to be greatest in winter while in the Mediterranean area warming is expected to occur in the summer. The lowest winter temperatures are likely to increase more than the average in the Northern Europe, and the highest summer temperatures are likely to increase more than the average in the Southern and Central Europe (IPCC 2007). Moreover, annual precipitation is very likely to increase in most of Northern Europe and decrease in most of the Mediterranean area. Therefore the risk of summer drought is likely to increase in Central Europe and in the Mediterranean area. In addition to this, climate studies project that a 3.6°C increase in mean temperatures will cause more than 50% of the flora in the Northern Mediterranean Region and highlands to vanish (IPCC 2007). The transition process associated with these estimates show that ecosystems (especially water related ones, and their flora and fauna, etc.) are at risk of extinction. Under these assumptions, the transition to sustainable ecosystem management seems to be an urgent need for climate adaptation policies.

1.2. The Omerli Watershed: a biodiversity hotspot of Istanbul

The Omerli Watershed (Turkey) is the most important drinking water source among the seven watersheds, supplying almost 1/3 of Istanbul's drinking water demand. It also is one of the most vulnerable, being under pressure from extensive urban development (Fig. 3) (ISKI 2010). If the development process in the Omerli Watershed is

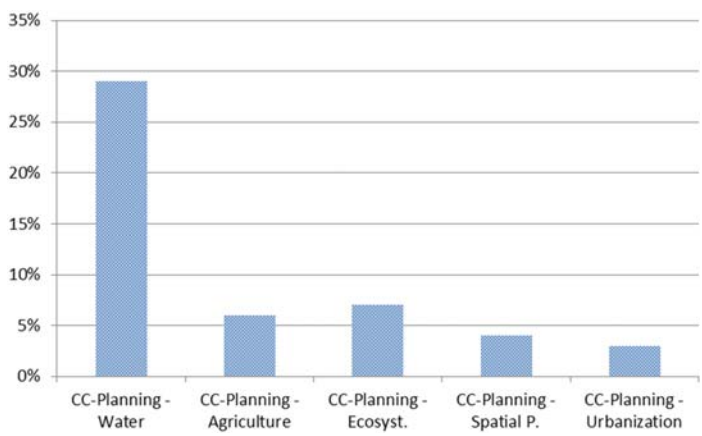

Fig. 2. Publication subjects in regard to "climate change and planning" keywords between 1990 and 2011, in %) (Source: Web of Science).

analyzed, it can be seen that the watershed had a rural character until the 1970s and starting from 1980s it was exposed to a rapid increase in population as a result of internal migration. The watershed's population was 23 561 in 1980 and increased at a rate of 64% to 33 402 in 1985. In 1990, the population increased at a rate of 359% to 153 558. Between 1990 and 1997, the watershed's population continued to increase at the rate of 101%, and, in 2000, the population reached 371 400 people. According to address-based population projections, the watershed's population in 2010 will have increased to 650 481 people, with an increase of 75% in just one decade. This population includes the population of the districts located either completely or partially in the Omerli Watershed and gives an overall idea of the current population level (TUIK 2010).

The Omerli Watershed has a rich biodiversity due to a flora and fauna that consists of an extensive mosaic of heath, coppice forest, and a wide range of associated habitats such as grasslands, seepage mires on peat, and seasonally flooded pools. In 2005, the Turkish Society for the Protection of Nature (DHKD) identified the area as one of the "Important Plant Areas (IPA) of Turkey" (Ozhatay *et al.* 2005; Tezer 2005; Tezer *et al.* 2008). The most significant land uses in the watershed are heathlands and oak-coppice forests. The watershed has the most widespread heathlands of all the countries of South-Eastern Europe and the Eastern Mediterranean region. Heathlands, being rare habitats that occur under certain circumstances in humid and temperate regions in areas with acidic soils; are known as one of the rarest habitats and are under threat. They provide a valuable biological diversity of rare birds and plant species, insects, reptiles and amphibians (Ozhatay *et al.* 2005).

The Omerli Watershed's land uses have changed substantially during the last two decades. While natural areas covered by heathlands, forests and other types of green areas constituted 46 227 ha in 1987, these areas have decreased to 41 133 ha in 2006. During this period, agricultural areas also declined at a rate of 82% while built-up areas climbed at a rate of 169%. These changes are the most critical for the sustainability of the Omerli Watershed's ecological assets and for drinking water quality/quantity drawn from the watershed (Tezer *et al.* 2011b; 2011c).

In light of urban land cover/use change in a watershed, climate scenarios become a significant issue to be integrated into ESs and the spatial decision making process in order to adapt into the impacts of climate change. According to climate change scenarios, a significant change in the precipitation level is expected in Turkey and in the vicinity of Istanbul. Although, in the Aegean and Mediterranean regions, precipitation is expected to decrease, precipitation in the Black Sea Region is expected to increase in the coming years (Ministry of Environment and Forestry 2007). Due to the location of Istanbul and the Omerli Watershed, the precipitation projections may be some combination of these two regional forecasts and the Omerli Watershed may

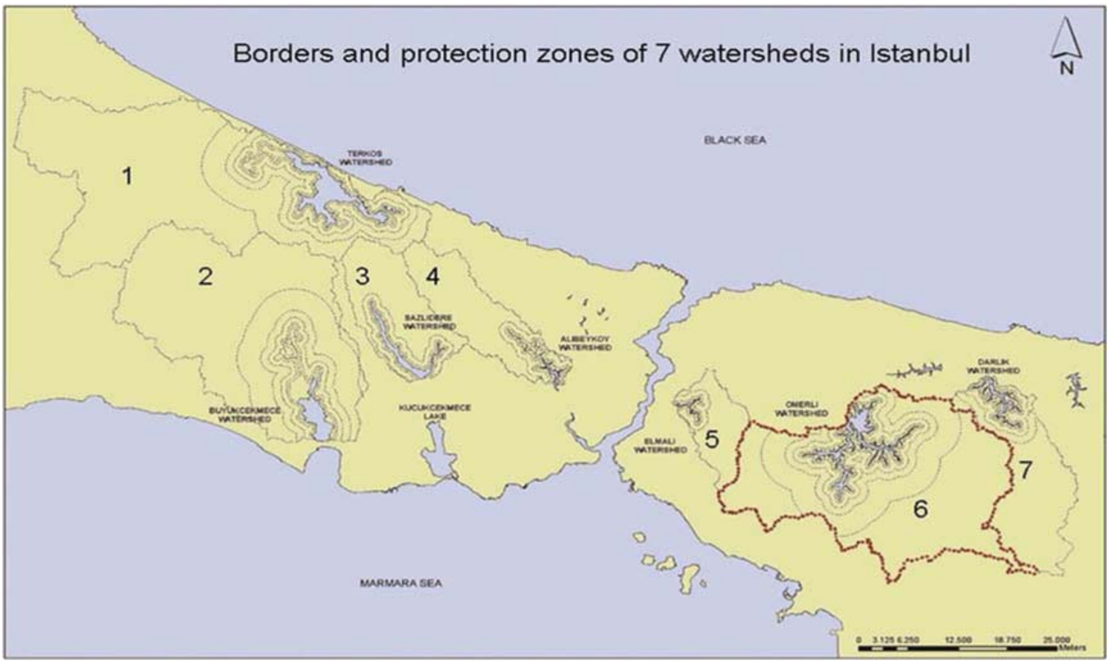

Fig. 3. Location of the Omerli Watershed in Istanbul (Source: IMM 2007; Tezer *et al.* 2011c).

experience increased precipitation. Along with the riparian corridors of streams flowing into the Omerli Reservoir, there may be more and severe flooding due to increased levels of precipitation and the expansion of impervious surfaces in urban areas. On the other hand, uncontrolled urbanization and increased levels of temperature and precipitation may cause habitat and ESs degradation which will further exacerbate the runoff within this watershed.

In this paper, urban riverine systems and climate change impacts will be assessed by integrating ecosystem services (ESs) with climate change scenarios in order to be used in the spatial planning decision making process. An ESs based spatial management approach will be proposed to achieve resilient and adaptive management of space, by integrating the forecasts of the climate change impact on urbanization. The case of the Omerli Watershed, Istanbul, will be presented. The methodology of the approach is explained below.

2. The method and results

The process of integrating ESs into spatial planning requires understanding of urban land use dynamics (Alberti, Marzluff 2004; Colding 2006). Land use dynamics include important elements for ecological functioning as urbanization expands through natural resource areas such as forests, wetlands and agricultural lands that have been replaced by land uses with more impervious surfaces that may significantly affect ecosystem functioning. Therefore, integrated information relating to urban/population growth rates and urban development patterns is essential for spatial planning policy development in terms of understanding the current and future impacts of such land use changes on ESs in view of climate change. The Omerli Watershed may face factors triggering degradation resulting from uncontrolled urbanization and climate change. The prediction of future environmental impacts requires

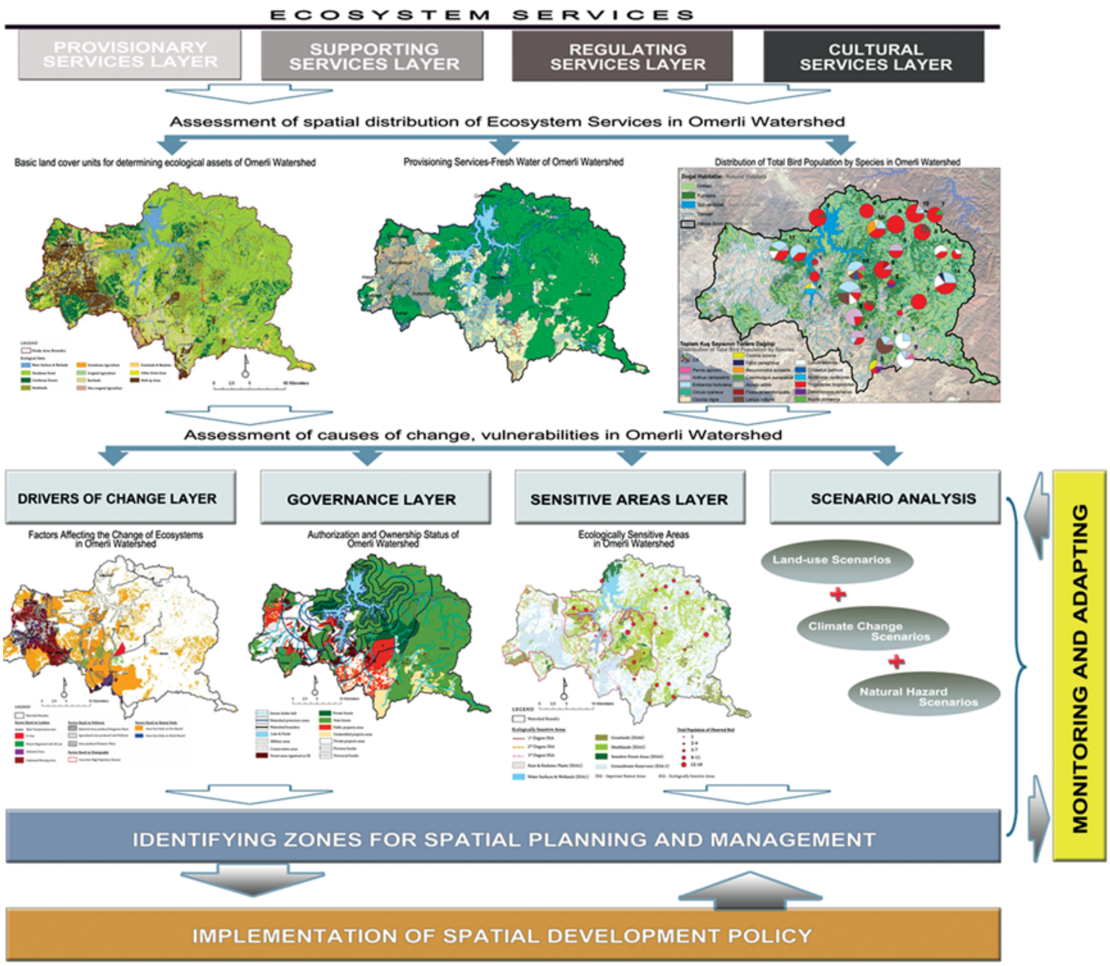

Fig. 4. Adaptive mitigation analytical process by integrating ESs into spatial planning (Source: Adopted from Tezer *et al.* 2011a, 2011b and 2011c).

the ability to estimate these land use changes and their effects on ecosystems which might be utilized to implement adaptive development and mitigation policies. In this process, the identification of ecologically sensitive areas and key ESs will be critical to sustain the ecological functioning of the area. Today, distance based watershed management regulation is used in the Omerli Watershed. Although the implementation of distance based buffer zones (absolute, short distance, medium distance and long distance protection zones) is practical for application anywhere, it has a weak relationship to the sustainability of ecological functioning or, in other words, to the ESs provided by the watershed area (Fig. 3). The identification of ecologically sensitive areas will better reflect their adaptive capacity to develop a watershed management model for the sustainable management of urban aquatic systems (Day *et al.* 2008).

The proposed approach is based on analytical assessments of spatial information with regard to land cover/use, ESs and climate change scenarios. Figure 4 indicates the methodological approach to identifying ESs based zoning in the Omerli Watershed in order to integrate adaptive mitigation perspectives into watershed management processes through ESs, spatial development and use of climate change related information. The identification of ecologically sensitive spatial management zones using this methodology is aimed at addressing the socio-ecological dynamics .

In the first stage of this methodology, ESs based information together with land cover/use is developed. Provisioning, regulating, supporting and cultural ESs are extracted based upon land cover/use characteristics which may provide diverse ESs in the watershed area (Fig. 4) (MEA 2005; Tezer 2011b). This information is transferred into the identification of ecologically sensitive areas to be used in the spatial management process. Detailed urban aquatic habitat information is developed for the better integration of ecological processes into the spatial decision making process during these evaluations.

In the second stage of the analytical method, climate and spatial development scenarios as well as their cumulative impacts on natural hazards are taken into account. Superposing ESs based information with climate related scenarios (either using existing information or future projections) is part of this stage to be assessed with other factors such as the drivers of change, ecologically sensitive areas and related authorities and governance affecting ESs' resilience and sustainability. This analytical process facilitates the identification of policies for spatial management, planning and implementation as well as providing a basis for the continuous monitoring of these characteristics (Fig. 4, Fig. 5, Fig. 6). Clarification of interrelatedness of Fig. 4, Fig. 5 and Fig. 6 will be relevant at this stage. Figure 4 aims to represent the integrated analytical process developed in this paper. On the other hand, Fig. 5 indicates the stage of zoning identification of Fig. 4 which will be used for spatial planning and management. Zones identified here are developed through ESs based assessments and regarding to their significance. Finally, Fig. 6 is representing an overview assessment to policy development for planning and implementation stage in the process. In figure 6, key ESs to climate change are integrated with land cover/use characteristics of the Omerli Watershed. A detailed representation of ESs provided by six land cover/uses is illustrated in this figure. Mapping all these factors facilitates spatial decision making process for the area to be integrated with scenario analyses on land use, climate change and natural hazards. The integration of key ESs driven by land cover/use into climate change impacts is assessed to identify future spatial development policies (Fig. 6). These assessments are used to assist in the identification of spatial reflections of the initial land cover/use information for future planning and management decisions.

In regard to uncertainties and unexpected developments in any prior stages, the methodology employs an adaptive mitigation approach by iterative functioning and inclusion of flexibility in the policy develop-

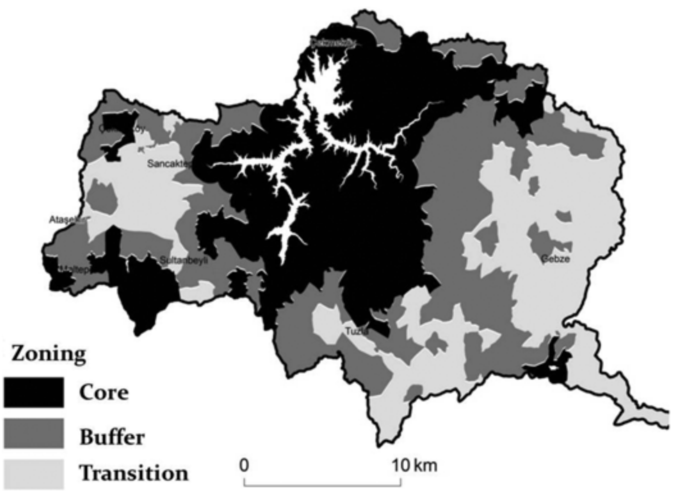

Fig. 5. ESs based three management zones for the Omerli Watershed (Albayrak 2012).

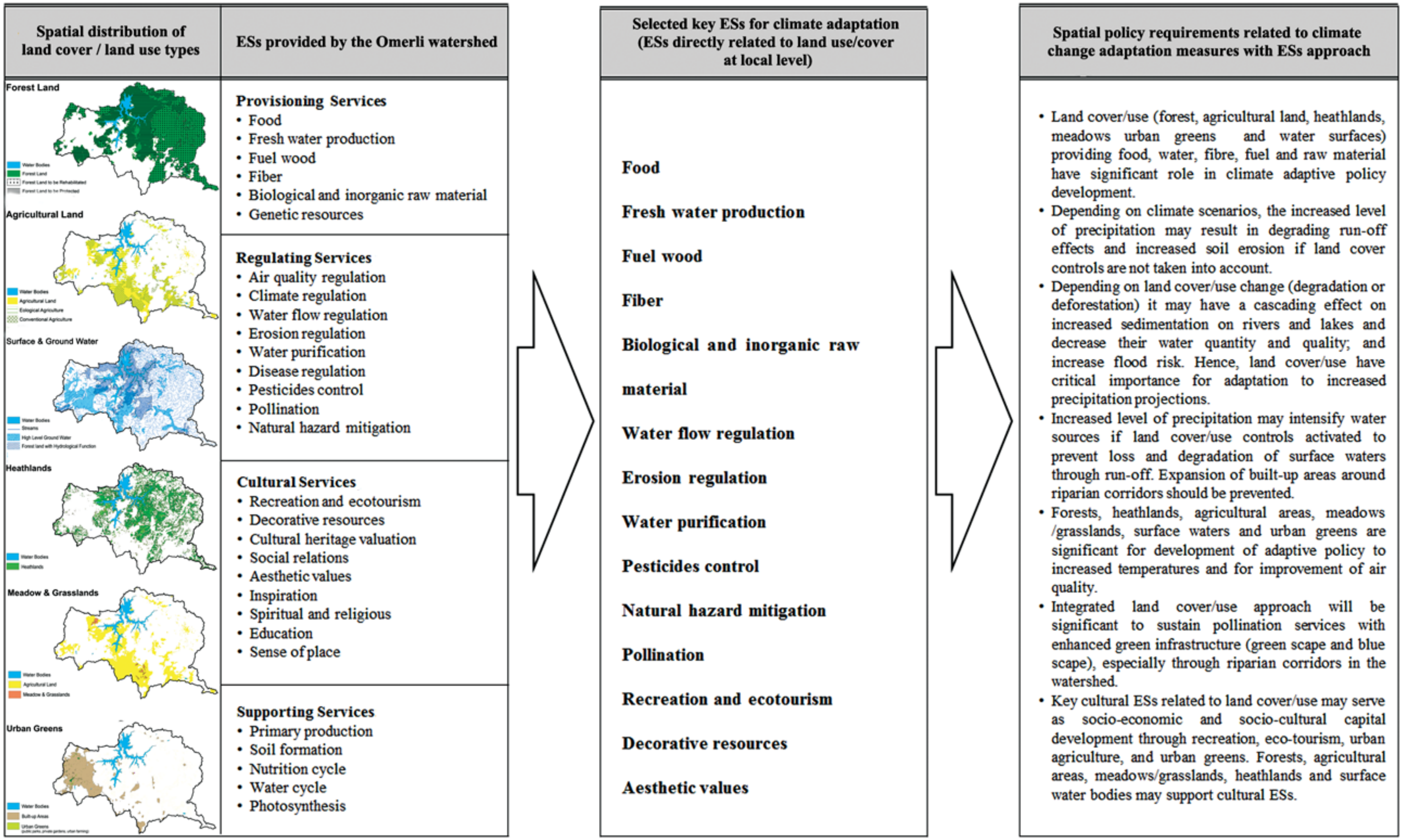

Fig. 6. Assessment of spatial policy development based on ESs approach for mitigation and adaptation to climate change in the Omerli Watershed.

ment process, to be followed by an implementation stage (Fig. 4).

In integrated ESs based spatial management, the interactions between social and ecological dynamics can be anticipated better and the potential impacts can be transferred to adaptive processes to achieve long term resilience and sustainability. In the Omerli Watershed case, the adaptive mitigation approach is investigated using the arguments discussed above as well as analyzed to clarify ecologically sensitive spatial management principles.

The hierarchical zoning approach used in the watershed is developed with the information based on ESs, and the spatial characteristics and expected climate change impacts using both existing and projected information. The zoning approach is similar to that applied in the biosphere reserve management program of the UNESCO-MAB Program, to control carrying capacity and sustain ESs provided by the watershed (Tezer 2005). In the zoning approach, the core is the most restricted area, having the greatest significance for preserving ecological functions and ESs provided to society. The buffer is the zone for the rehabilitation of ecological functions and ESs and the transition zone represents an area within which precautions should be taken to control the interactions at the threshold of the watershed (Albayrak 2012). The hierarchical zoning approach will be better integrated with the policies developed in ESs and climate change sensitive assessment process which are given in Figure 6. As a result of the difficulty for indicating all ESs provided by the Omerli Watershed in Figure 4, a detailed assessment of ESs in general and key ESs in regard to climate change are given in Figure 6 to interrelate with policy development stage of the adaptive mitigation analytical process (Fig. 4, Fig. 5 and Fig. 6).

3. Discussion: adaptive mitigation for climate change

In the face of global climate change scenarios, this paper proposes a sustainable ecosystem management approach. It assesses the impacts of climate change on urban riverine systems based on their ecosystem services (ESs) and integrates these into the decision making process for spatial planning. This approach can be defined as adaptive mitigation, designed to resolve and mitigate diverse impacts and threats originating from climate change and urbanization (Holling 1978; Walters 1986; NEPA 2003). Although traditional environmental management models include prediction, mitigation and implementation stages; the adaptive mitigation approach may provide better procedural reactions especially to climate adaptation policies by continuous monitoring and ongoing adaptation (NEPA 2003). The discussions on mitigation in the literature are generally anticipated as proactive policies, and they concentrate on the bottlenecks in contemporary responsive disaster management implementations (Burby 1999; Mileti 1999; Godschalk 2003). Although mitigation efforts are assumed to be proactive policies, they focus on reducing the impacts of potential risks, and therefore they are responsive in a way by their very nature. However the ESs based spatial management can be anticipated to be adaptive and resilient to climate adaptation in the longer term (Table I).

Policies such as de-carbonization, water demand and quality control, and decreasing heat-island effects by urban design are significant mitigation and adaptation strategies to moderate climate change. On the other hand, mitigation policies, as responsive actions to climate change, by their nature and/or the bilateral dynamics among multi-scales of space might not be adequate because of their incapability to overcome uncertainty in the impacts resulting from climate change (Handley, Carter 2006). Therefore an adaptive mitigation approach should be used to integrate ESs based spatial management of riverine ecosystems into the mitigation of climate change and urban development pressures. This approach can better react and adapt to the dynamic circumstances within watershed. Hence, the utilization of ESs based urban riverine ecosystem management policy can be accepted as an adaptive mitigation policy within the spatial planning process.

Table I. Distinction of mitigation and adaptive mitigation.

	Mitigation	Adaptive mitigation
Aim	- reducing, - eliminating, and/or - controlling future’s negative impacts	mitigating future’s impacts or uncertainties by monitoring and adaptation
Procedure attribute	Pro-active to potential impacts	Pro-active to uncertainties and potential impacts
Stages	- Prediction - Mitigation - Implementation	Continuous monitoring for: - Prediction and mitigation - Uncertainties and adaptation - Implementation

Conclusion

The approach utilized in this research is based on adaptive mitigation which is supported by the integrated information on ecologically sensitive areas (ESAs) that are identified by analysis of ecosystem services based information, using the Omerli Watershed of Turkey as a case study. This method is assumed to be crucial in enhancing the resilience and sustainability of the Omerli Watershed against uncertainties and potential degradation associated with socio-ecological and climate related dynamics. The first step in this process is to identify spatial data representing the four different ecosystem services, which are defined in Millennium Ecosystem Assessment (MEA 2005) (Fig. 4, Fig. 6).

The ecological character of the Omerli Watershed and the spatial representation of the main factors that cause changes in ESs are evaluated using these integrated data. The direct and indirect factors that cause changes in ecosystem functions are assessed in accordance with the Millennium Ecosystem Assessment Report (MEA 2005). In this context, these factors relate to demographic, economic, socio-political, and cultural values together with land use, pollution and eutrophication, natural hazard risks and climate change impacts, which are becoming significant. Although some of this information was not part of the assessment process, the information on land cover/use generating ESs will be beneficial to the spatial decision making process. In addition to the ecosystem functions and services (ESs), drivers of change in ecosystems are determined to be land uses (roads, unplanned housing, etc.), pollution sources (domestic, industrial, agricultural areas), demographic factors (the areas with high density of population) and the risks that may result from natural hazards or human-related activities (Tezer *et al.* 2011b).

ESs provide outputs or outcomes that directly and indirectly affect human well-being and ESs should be linked to socio-economic dynamics as well as to ecological processes (MEA 2005). At this point, the resilience concept, which aims to define drivers, interactions and interdependence between human and ecological systems, can be a relevant tool for the evaluating the continuity of ESs that support all aspects of human life (Adger 2000; Folke *et al.* 2002; Carpenter, Folke 2006). Therefore, there is a need to focus on socio-ecological resilience in cities (Folke *et al.* 2002; Pickett *et al.* 2004) related to ecosystem stability and diversity of ecosystem functions. In other words, the determination of ecological units, ecosystem services and ecosystem quality are necessary to sustain stability and functional diversity of ecosystems, especially in urban riverine ecosystems.

The attempt to integrate ecosystem services based spatial planning in urban riverine ecosystems aims to identify the important ecological characteristics of a spatial area. This integration provides guidance for urban spatial planning to organize future development in a manner consistent with ecologically responsive human activities. In general terms, the integration of ecosystem services into urban planning can easily be accomplished due to the similar nature of ecosystem services and spatial planning which share common goals. Both need multi-purpose land use information, have multi-level land management thresholds, and require multi-sector coordination, cooperation and governance based on information production and sharing, improving sustainable activities, and developing adaptive governance systems.

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