THE IMPORTANCE OF COASTAL CITY MORPHOLOGY IN TERMS OF ECOSYSTEM AND NATURAL ENVIRONMENT

MERVE YILMAZ, FATIH TERZI

Merve Yılmaz, Research Assistant

Istanbul Technical University, Urban and Regional Planning

yilmaz.merve@itu.edu.tr

Fatih Terzi, Associate Professor Dr.

Istanbul Technical University, Urban and Regional Planning

terzifati@itu.edu.tr

Received: October 2017 – Acceptance: September 2018

ABSTRACT

Ecosystems have a vital importance for all living since they are providers of life support systems. Degradation of the ecosystems resulted in destruction of biodiversity, excessive consumption of resources, contaminating water resources, rising up sea level, and climate change. In the last decades, degradation of ecosystem has been received growing interest and have become increasingly focused on attention. If urban development is not implemented in harmony with natural environment, urbanization will continue to threaten the functioning of ecosystems. Demands for different urban land use, cause to deteriorate surface water drainage lines, increase the amount of impermeable surfaces, and break the connection of ecological corridors unless sustainable planning principles are not applied in a city.

This study is an attempt to address the current issue of sustainable urban development patterns in coastal cities. It is known that both the pattern of urban spatial growth and the features of natural areas are widely considered to be important in terms of sustainable development. This study has been argued that urban development should be in harmony with the topography, ensure to sustain the hydrological cycle, promote pervious areas and establish ecological corridors. Otherwise, the coastal cities will be inevitably faced with natural risks, such as flooding, heavy storms, loss of biodiversity and sea level rise. Therefore, sustainable planning principles had to be implemented in the coastal cities to diminish the effects of the natural risks.

Keywords: Ecosystem, sustainable planning, hydrological cycle, urban pattern, coastal city.

Word Count: 3798

1. INTRODUCTION

Coastal zones are the most populated urban regions in the world. The richness in natural environment, economic activities, strategic location of coasts increase the attractiveness of the coastal regions. Therefore, urbanization pressure on coastal regions has been increased in the course of time. Coastal regions that have dense population and leading world trade centre thanks to economic attractiveness have been provided to many economic, natural and social resources (Burke et al. , 2001; Martínez et al., 2007, p. 255; McGranahan et al., 2005). Urban spatial development pattern on coastal areas has been chanced by leading economic activities such as industrial activities, port activities, tourism activities, second housing activities in the time.

The rate of the population lived within the 100-kilometer zone of the coastal region were respectively 30% and 40% in the 1990s and 2000s. It is estimated that this ratio will increase up to 75% in the 2025s. The coastal regions in the world have largely been built-up due to increasing population. Therefore, the increased built-up areas have been damaged to the coastal ecosystems (Hinrichsen and Olsen, 1998, UN-HABITAT, 2008). This increasing impact on the coastal areas has resulted in transformation of natural environment.

Ecologically coastal regions are an important interface between marine ecosystems and terrestrial ecosystems. The interface represents the sharpest change in habitat of the living organism. For this reason, coasts produce a unique flora and fauna adapting and challenging with environmental conditions (DoE 2011, p.849).

It is difficult to define the boundary of the coastal regions. Coastal regions can be characterized by their physical, biological and cultural characteristics. Therefore the natural thresholds such as topography, land cover types may be determined it specific boundaries changing by location of each region (Carter 1988, p.1, Hinrichsen and Olsen 1998, Small 2003, McGranahan et al. 2005, Balk et al. 2008, DoE 2011).

The interactions between coast and land use have positive or negative causes and consequences. For example, urban spatial development on physical geography causes not only land consumption but also destruction of natural environment, contaminating water resources, air pollution, disappearance of flora and fauna. At the same time, the interaction provides coastal ecosystem services such as hydrological resources, fisheries, building materials, flora-fauna, nutrient cycling, erosion prevention, tourism activities, recreational areas. The unbalance use of these limited natural resources such as water, flora-fauna has adversely affected the ecosystems. While changing climate conditions as a result of the degraded ecosystem, the global risks such as increase in sea level, temperature, flooding, strong storm and coastal erosion are rising (McGranahan et al., 2005).

One of the main reasons of the degradation of the coastal ecological systems is uncontrolled urban spatial development. In this study, the sustainable development of urban settlements in the coastal regions and its harmony with natural environment are attempted to measure with a method. The measurement method supports a system which can be jointly evaluated urban morphology and natural areas.

2. COASTAL ECOSYSTEM AND NATURAL ENVIRONMENT

An ecosystem may be defined at different scales. The ecosystem is the "interacting with the environment as a dynamic, complex and functional unit of plant, animal and microorganism communities" (McGranahan et al. 2005, p.vii). Ecosystems such as forest ecosystem, marine ecosystem, and coastal ecosystem are evaluated within this definition. Among these ecosystems, coastal and marine ecosystems are the most productive ecosystems. While coastal areas cover 6% of the world, they contribute to 38% of ecosystem services (Costanza et al. 1998, Agardy et al. 2005). There may be lost their sustainability in urban ecosystems when these ecosystems have been together with the urbanized area.

From a conservative perspective, the wildlife corridors help promote movement plants and animals, which are for ecosystems vitally and environmentally important. The continuity of these movement connections has important roles within the ecosystems. Biological diversity, water resources, agricultural activities, recreation, climate diversity are the roles in the ecosystem. The connections are provided by landscape areas such as forest areas, roadside planting areas, riparian regions, and vegetation at farmland boundaries (Forman 1991, Bennett 2003).

Coastal regions are a totality of natural systems effecting to and interacting with each other (Figure 1) (Forman 2014). The regions have an interface which is marked interaction between existing marine and terrestrial ecosystems thanks to their cycle, which has shelter for many species and genetic diversity. This variety has important tasks as providing water, nutrient cycling and protecting coastal areas from erosion and storms. One of the important ecological functions in the coastal ecosystems is the hydrological cycle. The cycle provides water, nutrient, and energy conversion. Moreover, water is important for economic activities such as agriculture, fisheries, industry, and energy (Alberti, 2008). It is based on the size of the area covered by the vegetation and the size of the permeable surfaces (Barling and Moore, 1994; Binford and Buchenau, 1993; Clinnick, 1985; Forman and Godron, 1981; Ward and Stanford, 1995).

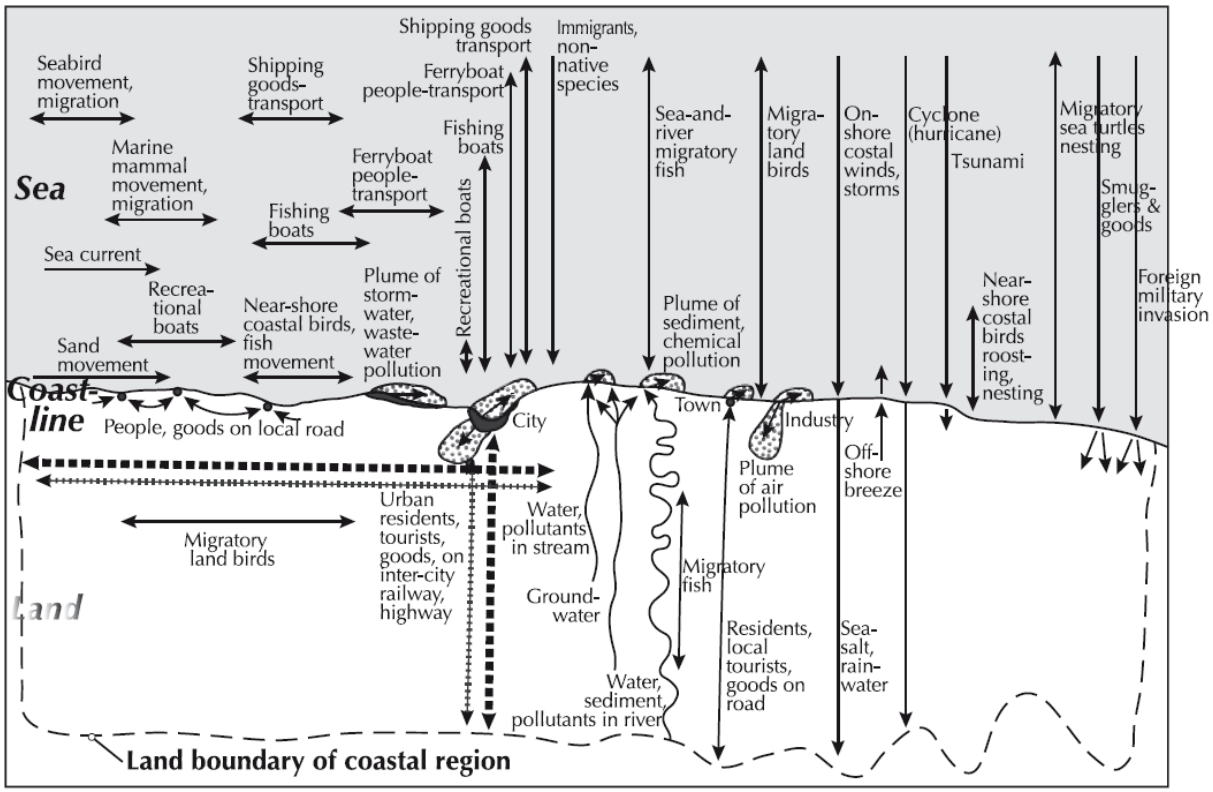

Figure 1 Characteristic flows and movements in a coastal region

The coastal ecosystem and the natural environment are adversely affected by the global warming. Unless the sustainable urban spatial development is achieved in coastal cities, the natural environment of coasts will be increasing threatened, which the coast provides many services in point of social, economic, environment activities (Agardy et al., 2005; Burke et al., 2001; Kennedy, Cuddihy, and Engel-Yan, 2007; Peterson and Lubchenco, 1997; Wolman, 1965). In additional, as coastal areas are been converted to built-up area, increasing pressure on hydrologic systems will critically destroy coastal ecosystem services (Agardy et al., 2005; Erol, 1993).

Areas associated with ecosystem that are consist of permeable surfaces such as forests, agriculture areas, riparian areas, are transformed into shrunk areas or disconnected green connectivity by being changed their size and form

(Batty and Longley, 1988). Housing areas, transportation, urban infrastructure, human safety and bio-diversity in the coastal regions have been exposed to natural disasters such as coastal erosion, flooding, storms, tsunami, climate change that caused the transformed natural areas. Furthermore, increased of the impervious surfaces leads to increase in heat island effects and decrease in surface water absorption (Pelling 2003, Agardy et al. 2005, Dilley et al. 2005, Vitousek et al. 2008).

The destruction natural environment and its consequences are reflected on both natural life and the urbanized area as adversely conditions. It is emphasized that millions of people will be displaced because of the sea level rise in the future (Burke et al. 2001, Dasgupta et al. 2009). Sustainable planning principles must be implemented to decrease the negative effects of built-up areas and to preserve the natural environment in the future. These planning principles mean harmony between the urbanized area and the natural environment.

3. COASTAL CITY MORPHOLOGY

The natural morphological formations of the coasts are differently formed. Coastal geography may be classified as flat coasts, peninsulas, estuaries, deltas, straits, coastal-oval, rivers, gulfs, coastal-lakes. These geographic forms are determining thresholds in forming of coastal city patterns. There are topography, rivers, soil classification, land cover types (e.g. forests, agriculture areas etc.), sensitive ecological regions in addition to geographic forms of coasts. It is also important determining planning policies such as transportation, industrial investment.

Spatial growth of coastal cities should be carried out by geographic features harmonized with natural environment. Otherwise, conversion natural area into built-up areas has been directly or indirectly changed ecological cycles (e.g. hydrological cycles, nutrient cycle etc.). The changes in the land use lead to the conversion of landscape areas that have ecological areas connected with green corridors to each other (Alberti 2005, Alberti 2008, Paul and Meyer 2008).

The sea which has an essential role in hydrological cycle, is water collection region having the highest degree in coastal settlements. Green corridors (riparian regions, linearly vegetation regions), natural areas (forests, agriculture areas), water surfaces support the hydrological cycle, which are significant for the surface water flows and absorption. (Figure 2). Otherwise, the cycle cannot maintain its continuity. Valleys (surface water drainage lines) that have an important role in hydrological cycle, are adversely affected occurring built-up areas within them. As a result of the destruction, the urban form will also cause to fragmentation green areas and green connectivity. The fragmentations are related with the changes of green areas such as shape, size and disconnected connectivity. It is pointed out that in the evaluation of these forms, there are landscape metrics that have been developed by researchers in landscape discipline since the 1980s. The metrics can be used to assess both forms of landscape areas and impacts on the ecosystem (McGarigal and Marks 1995, Reis et al. 2015).

As it is indicated in Figure 2, connectivity between water surface and terrestrial area are emphasized as corridors of surface water drainage lines, green corridors, river corridor (e.g. riparian areas). Coastal green corridors that provide to increase the resistance of coastal cities against disasters, green corridors having important roles in connecting different ecosystems (forest ecosystem, hydrological ecosystem, coastal ecosystem) and the surface water drainage lines have essentially important for urban spatial development in coastal areas and coastal ecosystems.

Weak ecological systems and natural thresholds in coastal regions have been exposed to adverse environmental conditions which is because of their limits are have been exceeded. The coastal cities at or very close to sea level are have directly affected by flooding, strong storms, tidal events and sea level rise due to the weakness and the

destructions. Also, increasing impervious surfaces is one of the most important factors of these negative consequences (Alberti 2005).

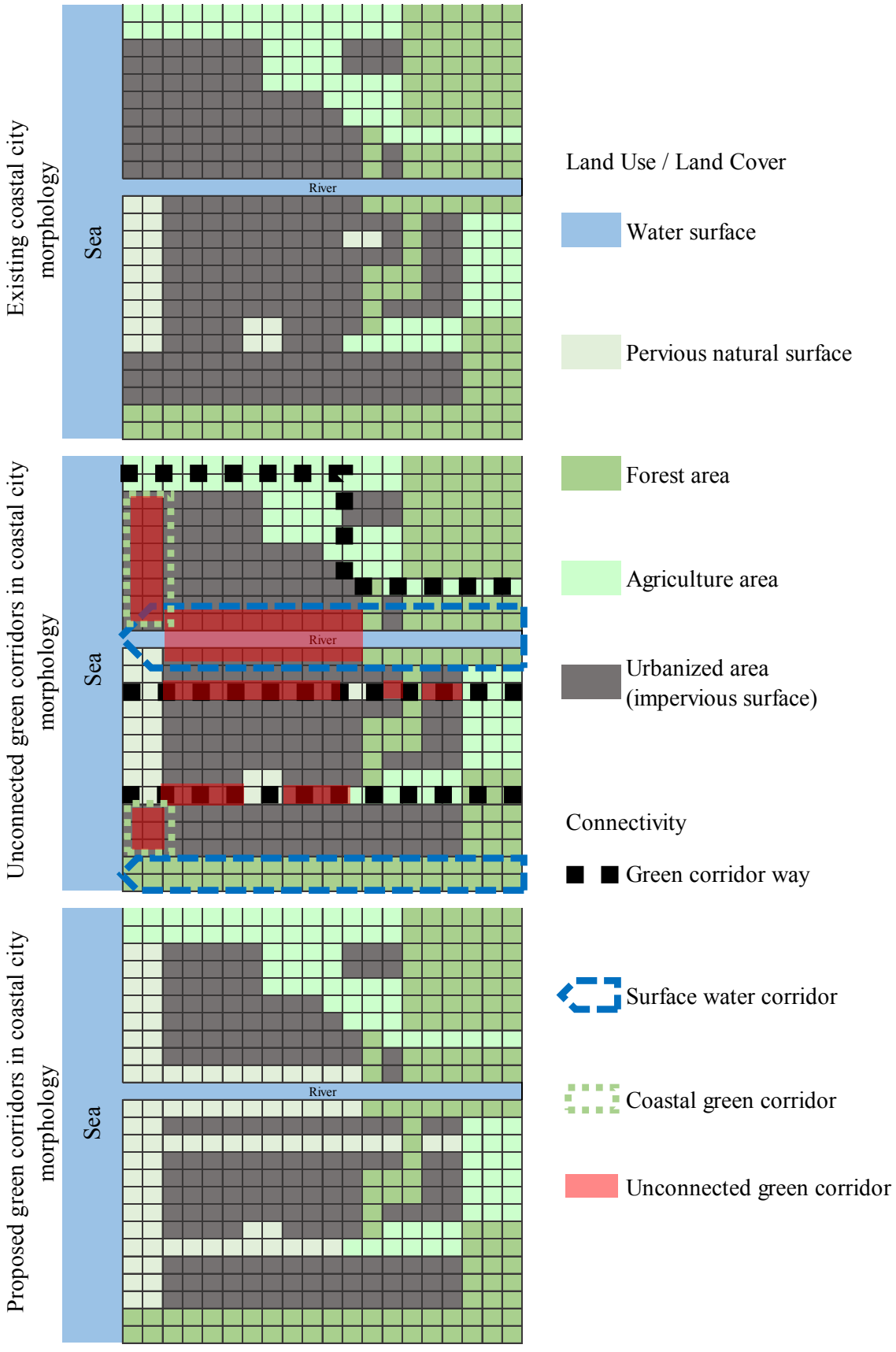

Figure 2 The concept of coastal city morphology

4. CASE STUDY: KOCAELI

Kocaeli province is located in the east of the Marmara Region in Turkey. It is a coast settlement where spatial development is kept along coast of the Marmara Sea. The city has been developed under the impact of the national industrial policies in the 1960s. The northern part of the city has been growth as industry-based areas under impact of industrial relations and transport movement in Istanbul. Kocaeli has become one of the most growth city in production, investment, and employment in Turkey during about the last 30 years. The settlement areas in the south are rural-based settlements which have the resources of agricultural production, also (Figure 3). Another challenging period of Kocaeli as well as its industrial changes has had many experiences in point of social, economic, built-up areas and planning policies following the earthquake of 1999. In the result of that, there was occurred an increase in the number of houses in the southern part of the city after the earthquake (Öztekin et al. 2012).

It is observed that urban spatial development in Kocaeli has been growing along coast since the 1980s (Figure 3). After the year 1999, this growth was ongoing towards north, north-east, and south. The 1980s to 2015s, the rate of urbanized area was increased about 400 percent (Figure 3). Industrial investment areas (spot I in Figure 3), transportation in the direction of Istanbul and Sakarya provinces (spot T in Figure 3), and ports (spot P in Figure 3) have been triggered to the spatial development. Urban spatial development has been gradually occurred to hinterland of ports, industrial areas which are expanded inside and along coast (spot I and P in Figure 3). There are natural limiting factors that are forests, protected agriculture areas, and topography in addition to triggered factors.

On the other hand, natural environment in Kocaeli has been converted into built-up areas. As results of the conversion, sensitive ecological areas such as agriculture areas, riparian areas, and surface water drainage lines decreased in the time. For example, Sarı River and Kullar River (east of Marmara Sea) that were declared as Izmit Gulf Wetland Protection Area in 2008, is one of the most sensitive coastal cities among the coastal cities of Turkey (Öztekin et al. 2012, Sılaydın and Kahraman 2016). The sensitive areas have been increasing destruction due to built-up areas in the course of time (region in spot I_4, I_5, T_2 in Figure 3).

The continuity of surface water drainage lines is one of the most important criteria in coastal city morphology in green corridor connections. In addition, coastal areas which are the interface between land and water is also an important connection in green corridors. These connections of Kocaeli have been analysed surface water drainage corridors and coastal green corridor in Figure 4. The green connections have been decreased and occurred fragmentation green corridors because of built-up within these corridors. In the 1980s, these disconnected corridors were started to increase in industrial areas, hinterland of ports, along the main road, and along the coast. The phenomenon has been continued by increasing up to 2015s (Figure 4).

Conversion of natural areas into built-up areas increases to impermeable surfaces. Increasing impervious surfaces causes deteriorating the hydrological cycle and water absorption of soil. Disconnected surface water drainage lines densely observed in and around industrial and port areas (spot I_1, I_2, I_3, I_4, P_1 in Figure 4). The main factor of more spatially development than the south region of Kocaeli is the direction of the main road (between spot T_1 and T_2 in Figure 3) in the north. Therefore, we observed more unconnected surface water drainage lines in these regions (Figure 4). The other affecting factors are leapfrogging spatial development and sprawling development along coast; therefore, the corridors have been fragmented.

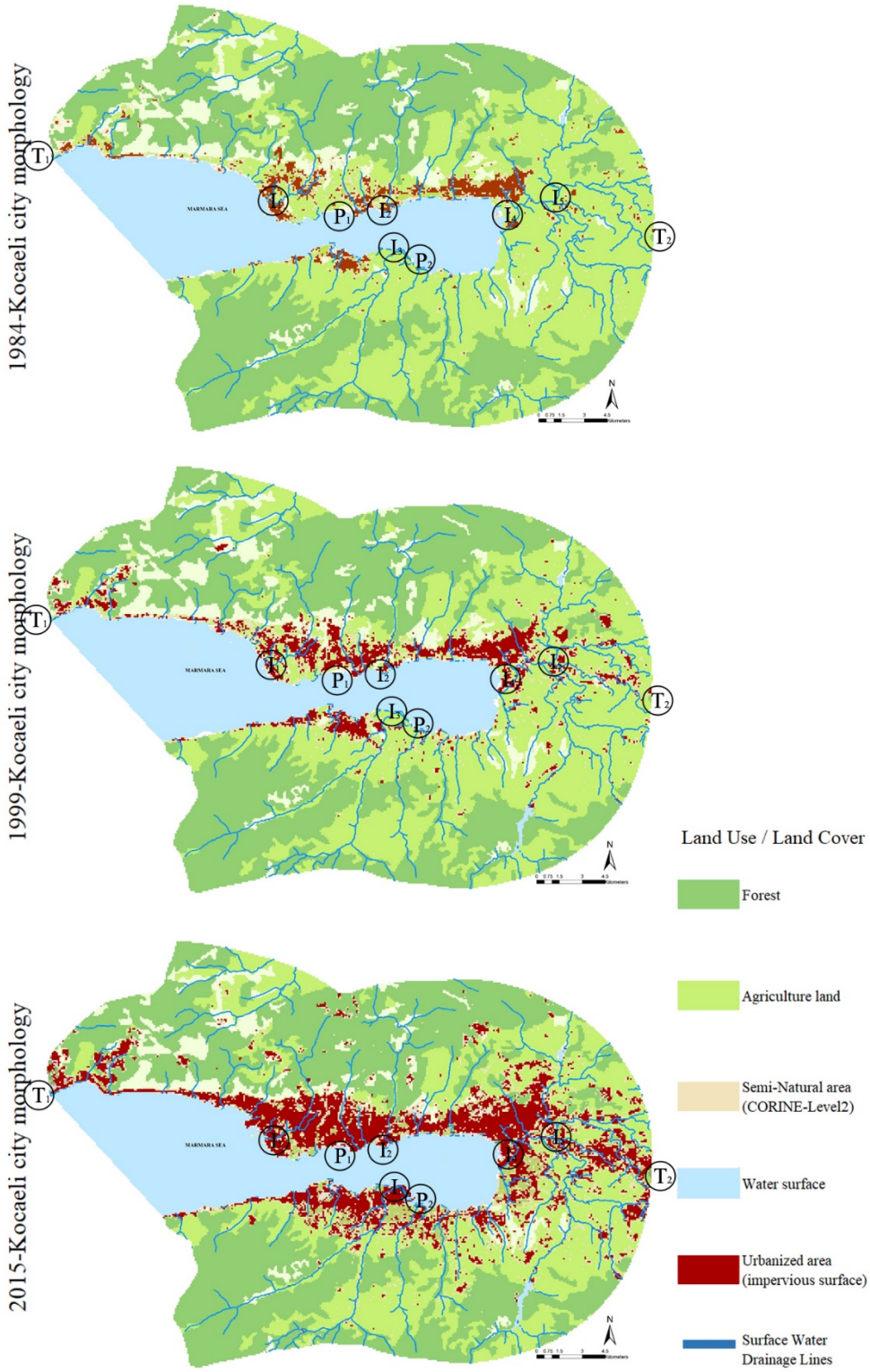

Figure 3 Kocaeli city morphology by years (T: main road direction, P: Port, I: Industrial area)

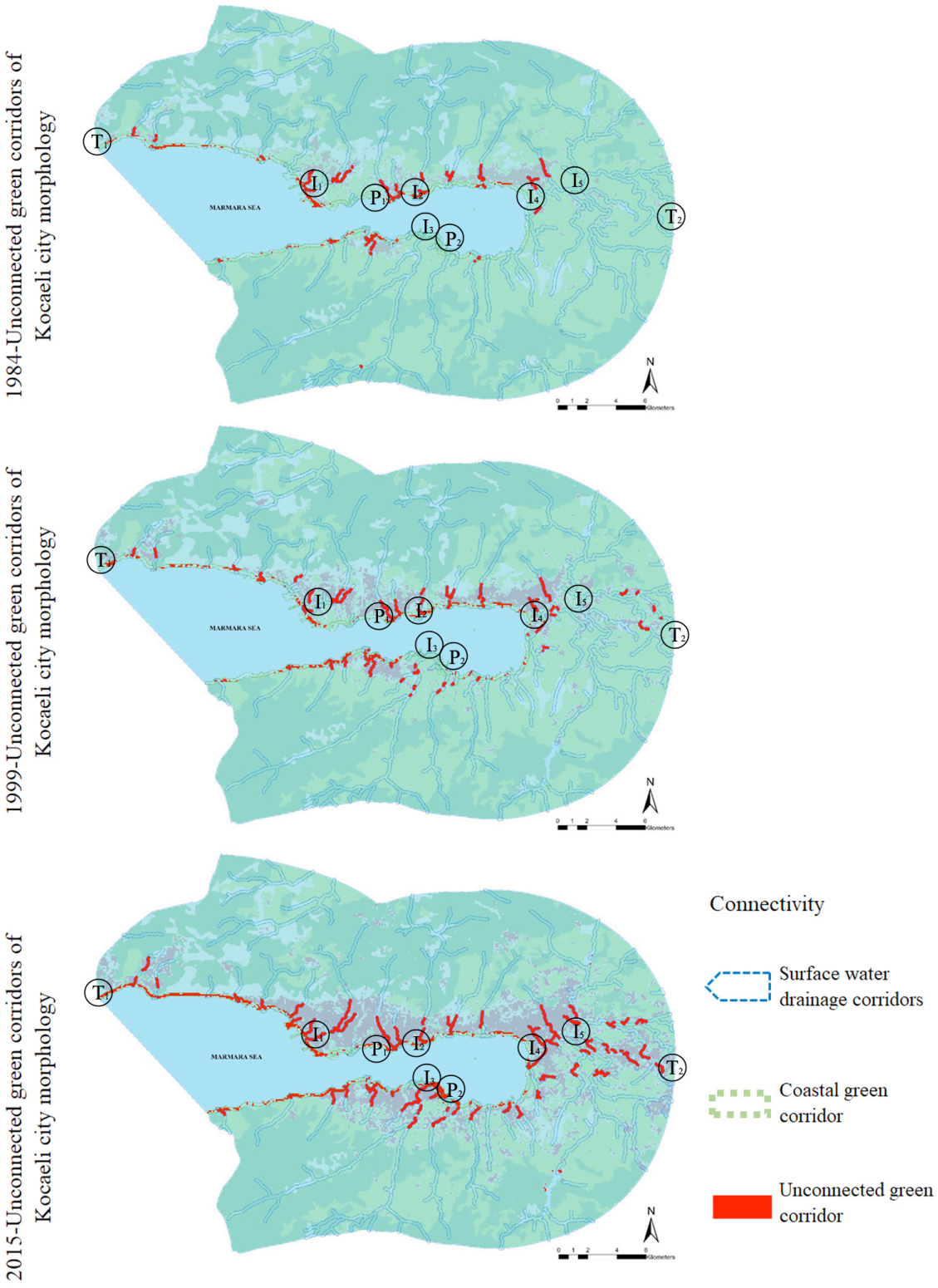

Figure 4 Green corridor connectivity of Kocaeli city morphology by years (T: main road direction, P: Port, I: Industrial area)

6. DISCUSSION AND CONCLUSION

The geomorphological differences of the coasts have primary roles in forming the coastal cities. The issue of "how coastal city morphology affects the coastal ecosystem and the natural environment?" needs to be considered within sustainable planning principles. Land uses of coastal city affect natural environment and ecological characteristics of the coast. Built-up areas that consist of different the land uses, lead to degradation of the coastal ecological systems such as hydrological cycle and nutrient cycling. One of the most effective factors of this deterioration is increased impervious surfaces. As a result of that surfaces, coastal cities are adversely affected by climatic change (e.g. sea level rise, increasing heat-island effects, sea surface temperature rise, deteriorating micro-climate stabilization, etc.) and natural disasters (e.g. flooding, storms, etc.).

While it is difficult to draw universal conclusions from a specific case study due to unique natural thresholds differing by location, we try to suggest that can be determined coastal city morphology in the extent of ecological connections. Therefore, the assessment may be varied from city to city and from scale to scale. The purpose of the study is to address the current issue of sustainable urban development patterns in coastal cities. This study is an attempt to identify protected green corridors in a coastal city as sustainable planning principles. Firstly, it was determined disconnected green corridor evaluation in Kocaeli. Secondly, it was evaluated to effects on natural area of built-up areas using the data of surface water drainage lines that are important for hydrology cycle, coastal green area and land cover. The research is also an attempt to how coastal city morphology is proposed based on the result of evaluation the interface between sea and land (Figure 2). On the one hand, the ecological connections are important because of mitigation during or after disaster such as flooding, tsunami; providing ecological cycles (e.g. hydrological, nutrient, energy); protecting ecological interaction between sea and land. The results will provide a support to protect the sensitive ecological connections in coastal regions. It is necessary to carry out the control, protection of green corridors and areas with planning policies.

Determinative thresholds forming urban pattern in Kocaeli are the Coast of Marmara Sea, forests in the north of area, topography, and direction of the main road. Built-up areas around the road and along the coast have been caused disconnected almost all surface water drainage lines between land and sea. This coastal city pattern should be considered together with the green connections in sustainable planning principles. As the settlement is located at very close to sea level, it may be directly affected by flooding and sea level rise. Sustainable urban spatial development must, therefore, be based on prevention of deteriorating conditions. Coastal settlements should be more resistant to these conditions. Kocaeli city morphology in the time has figured to get away being a sustainable urban form.

The conclusions give clues about how to design of urban form and to use sustainable planning principles by locations and its natural environment. With respect to the results, the study achieves to emphasize deteriorate of the interface between sea and land, and disconnecting surface water drainage lines.

How to implement sustainable planning principles in coastal morphology primary base on planning policies and decisions. To reduce the deteriorating conditions, planning policies should be developed to increase the proportion of green corridor in coastal and terrestrial ecosystem. It is important for sustainable planning to ensure future development pattern of coastal cities in harmony with natural systems that makes the cities more resistant to possible climatic conditions and supportive to functional ecological systems.

REFERENCES

Agardy, T., Alder, J., Dayton, P., Curran, S., Kitchingman, A., Wilson, M., Catenazzi, A., Restrepo, J., Birkeland, C., Blaber, S., Saifullah, S., Branch, G., Boersma, D., Nixon, S., Dugan, P., Davidson, N. and Vörösmarty, C.

(2005). 'Coastal systems' in Eades, J. and Ezcurra, E., eds., *Ecosystems and Human Well-Being: Current State and Trends : Findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment*, Washington DC: Island Press, 513-549.

Alberti, M. (2005) 'The Effects of Urban Patterns on Ecosystem Function', *International Regional Science Review*, 28(2), 168-192.

Alberti, M. (2008). *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems*, New York: Springer.

Balk, D., McGranahan, G. and Anderson, B. (2008). 'Risks of Climate Change for Urban Settlements in Low Elevation Coastal Zones' in *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century* London • Sterling, VA: Earthscan, 165-182.

Bennett, A. F. (2003). *Linkages in the Landscape; The Role of Corridors and Connectivity in Wildlife Conservation*, Australia: IUCN - The World Conservation Union.

Burke, L., Kura, Y., Kassem, K., Revenga, C., Spalding, M. and McAllıster, D. (2001). *Pilot Analysis of Global Ecosystems: Coastal Ecosystems*, Washington, DC.: World Resources Institute.

Carter, B. (1988). *Coastal environments: an introduction to the physical, ecological and cultural systems of coastlines*, London, England: Academic Press.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P. and van den Belt, M. (1998) 'The value of the world's ecosystem services and natural capital', *Ecological Economics*, 25(1), 3-15.

Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D. and Yan, J. (2009) 'The impact of sea level rise on developing countries: a comparative analysis', *Climatic Change*, 93(3), 379-388.

Dilley, M., Chen, R. S., Deichmann, U., Lerner-Lam, A. L. and Arnold, M. (2005). *Natural Disaster Hotspots : A Global Risk Analysis*, Washington: World Bank Publications.

DoE (2011). *Coasts*, Canberra: Australian Government, Department of the Environment.

Forman, R. T. T. (1991) 'Landscape corridors: from theoretical foundations to public policy', *Nature conservation*, 2, 71-84.

Forman, R. T. T. (2014). *Urban ecology: science of cities*, New York: Cambridge University Press.

Hinrichsen, D. and Olsen, S. (1998). *Coastal Waters of the World*, Washington DC, UNITED STATES: Island Press.

McGarigal, K. and Marks, B. J. (1995) 'FRAGSTATS: spatial pattern analysis program for quantifying landscape structure', *General Technical Report - US Department of Agriculture, Forest Service*, (351).

McGranahan, G., Marcotullio, P., Bai, X., Balk, D., Braga, T., Douglas, I., Elmqvist, T., Rees, W., Satterthwaite, D., Songsore, J. and Zlotnik, H. (2005). 'Urban Systems' in Hassan, R. M., Scholes, R. and Ash, N., eds., *Ecosystems and human well-being: current state and trends : findings of the Condition and Trends Working Group of the Millennium Ecosystem Assessment*, Washington DC: Island Press, 795-825.

Öztekin, D., Mengüç, G., Yiğit, A., Kutluata, Ö., Temelli, T., Simavlı, A. S., Postalcıoğlu, O. and Erdi, F. (2012). 'Kocaeli yeni kent merkezi kentsel dönüşüm projesi yaklaşımı' in *Mekansal Değişim ve Dönüşüm*, Ankara: 351-365.

Paul, M. J. and Meyer, J. L. (2008). 'Streams in the Urban Landscape' in Marzluff, J. M., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., Simon, U. and ZumBrunnen, C., eds., *Urban Ecology:*

An International Perspective on the Interaction between Humans and Nature, Boston, MA: Springer US, 207-231.

Pelling, M. (2003). *The vulnerability of cities: natural disasters and social resilience*, Sterling, VA;London;: Earthscan Publications.

Reis, J. P., Silva, E. A. and Pinho, P. (2015) 'Spatial metrics to study urban patterns in growing and shrinking cities', *Urban Geography*, 37(2), 246-271.

Sılaydın , M. B. and Kahraman, E. D. (2016) 'Determining the Spatial Vulnerability Levels and Typologies of Coastal Cities to Climate Change: Case of Turkey', *International Science Index, Geological and Environmental Engineering*, 10(11), 1058-1062.

Small, C. N., Robert J. (2003) 'A Global Analysis of Human Settlement in Coastal Zones', *Journal of Coastal Research*, 19(3), 584-599.

Vitousek, P. M., Mooney, H. A., Lubchenco, J. and Melillo, J. M. (2008). 'Human Domination of Earth's Ecosystems' in Marzluff, J. M., Shulenberger, E., Endlicher, W., Alberti, M., Bradley, G., Ryan, C., Simon, U. and ZumBrunnen, C., eds., *Urban Ecology: An International Perspective on the Interaction Between Humans and Nature*, Boston, MA: Springer US, 3-13.