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Green corridors and fragmentation in South Eastern Black Sea coastal landscape

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ABSTRACT

Green corridors are inevitable part of land cover and land use planning activities as they affect climate, hydrology and ecology of the urbanized regions. Detection and monitoring of green corridors and their relative functions are very important in terms of landscape management. They also carry information on changing speed from "green to grey" and fragmentation level of the urbanized regions. Analyzing the fragmentation level of the landscape formation reflects the management strategy and overall success of decision makers. This paper aims to assessment landscape fragmentation in relation to green corridor planning for the first time on coastal section of Trabzon and Rize city centers from South Eastern part of the Black Sea. The study area is densely populated coastal region with linear-littoral formation. Remote Sensing (RS), Geographical Information System (GIS) and *in-situ* techniques were used to detect pattern and role of green corridors in the study area. Green coverage was extracted by using Support Vector Machine (SVM) classification algorithm. SVM classifier performed better on digital aerial images when compared to multispectral satellite data. After the classification, five land use/cover (LULC) classes were obtained: urban green areas, asphalt ways, water, other urban objects and shades with 94.64 and 96.53 overall accuracies for Trabzon and Rize cities, respectively. Shape related landscape metrics were computed to show the level of fragmented green covers in study area. Larger patches were observed in Rize with higher Largest Patch Index (LPI) values. Computed Area Weighted Mean Shape Index (AWMSI) and Area Weighted Mean Patch Fractal Dimension (AWMPFD) values indicated higher urbanization rates in Trabzon city. Green corridor networks were proposed for each city by considering the fragmentation level and landscape design rules. Finally, some implications were done towards creating ecologic cities in the context of sustainable landscape and ecological conservation.

1. Introduction

Green infrastructure of big cities is continuously decreasing due to rapid increase in population and urbanization. Loss of green coverage triggers air, visual and noise pollution as well as climatic and ecologic changes in the environment. Moreover, recreational and open green spaces of urban inhabitants are getting limited. Therefore, in order to establish a continuous green space and connect the major landscape elements in urbanized regions, green infrastructure should be improved and linked together. Linkage of green areas is important in terms of direction and formation of city development (Kurtaslan, 2010). From that point of view, green corridors are the main connection elements of landscape and a critical tool to apply landscape ecology in landscape planning.

The term "Green Corridor" can be defined as linear open green spaces used for recreational, ecological and cultural purposes (Jongman et al., 2004). Wildlife corridors, green belts, coasts, valleys, historical paths and alleys are examples for green corridors and they are generally used for recreational purposes (Arslan, 2004). These are scenic routes for various outdoor activities such as jogging, trekking and cycling along the riverbanks or lanes (Conine et al., 2004). Beside their ecological function, green corridors can be used to link different land use classes such as industrial areas and settlement sites. They are also an integral part of other recreational areas and uses in landscape design concept.

Main thematic approach of green corridors is to keep the linear landscape structure green and connect different routes like rivers, valleys and streets to establish an integrated landscape infrastructure (Salici and Altunkasa., 2010).

There are many successfully applied examples of green corridors from European and western countries in order to create inhabitable environments and protect ecological equilibrium. In Turkey, green

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corridors are mostly ignored or just remained as a part of landscape design projects without applications in real terms. Remote sensing (RS) and Geographic Information System (GIS) techniques are technological tools for simulating and analyzing the landscape design elements including green corridors. There are many applications of RS and GIS in landscape design for monitoring, identification and analyzing landscape structures (Duran et al., 2006). These techniques are also used for characterization of patches and fragmentation of green cover. They become ideal and consistent tools in environmental applications as they offer extendable and updateable database (Doygun et al., 2003). Green-way design of developing cities, green infrastructure evaluation based on morphological image processing and improving green webs in ecological cities are some examples of RS and GIS in landscape architecture (Wickham et al., 2010; Kong et al., 2010; Teng et al., 2011).

The cities "Trabzon and Rize" are two of the most developed cities in North Eastern part of Turkey. Due to harsh and steep environmental conditions of the region, settlement can be characterized as "littoral-linear" along the Black Sea coastal zone. The coastal zone of the region has been mostly accreted to complete international Black Sea highway and extended seaward to gain new recreational areas and protect the highway from negative wave effects (Karsli et al., 2011). Even though, newly created public areas have great potential, there is no effort to plan and use those areas as green corridors. Furthermore, fragmented and inappropriate green cover usage of city centers is now dominating on coastal areas.

Fragmentation can be defined as splitting the natural landscape in to smaller parcels by means of artificial or natural causes without considering the habitat loss itself (Collinge, 2009). Landscape fragmentation is widely considered as a negative effect of unplanned urbanization. Furthermore, this anthropogenic phenomenon has some unpredictable potential impacts on global climate change, biogeochemical cycles and land use/cover (LULC) processes (Batistella et al., 2000).

The aim of this study is to evaluate green infrastructure of two coastal cities "Rize and Trabzon" from South Eastern Black Sea region, examine the fragmentation level and delineate the potential green corridors within current landscape usage plan by using landscape design rules, RS and GIS. Therefore, it carries a potential as an integral component for terrestrial part of coastal zone management and reports for the first time the current status of typical coastal formation of North Eastern Anatolian Coast.

2. Study area

The South Eastern Black Sea or North Eastern part of Anatolia is an important cultural, historical and ecologic site of Turkey. The region consists of five coastal and two landward cities: Ordu, Giresun, Trabzon, Rize and Artvin are located in coastal zone whereas Gumushane and Bayburt are away from the sea and located on mountains. The region suffers from migration, unemployment and pollution. Trabzon and Rize are the most developed cities of the region. Therefore this study was carried out in Trabzon and Rize cities (Fig. 1). The mountains are situated along the coastal zone and create very immediate steep hinterland of the coast. The geomorphology of the region pushes the cities to be developed as linear settlements along the coast so as very vulnerable to negative effects of marine environment. The economy of the cities mostly relies on fishing and agricultural products such as tea and hazelnut. Tea gardens show linear scenic coastal beauties as an agricultural landscape element and connect coastal ecosystem components to upper areas.

3. Material and methods

Green corridors are integral part of landscape design projects therefore together with landscape design methodology and principals, RS and GIS were utilized in the study. Digital aerial images, satellite data and city plans were processed to map current situation and delineate linear structures in the area. Employed methodology is explicitly shown in flow diagram (Fig. 2).

The contribution of green corridors to overall landscape structure was also investigated. Multispectral digital aerial images from General Command of Mapping of Turkey and satellite data provided by Ikonos and Quickbird were used in this study. For the aerial images after ortho-rectification based on Digital Elevation Model (DEM), image rectification was implemented. Available satellite images were projected to same datum and coordinate system after geometric and radiometric correction. Ground sampling

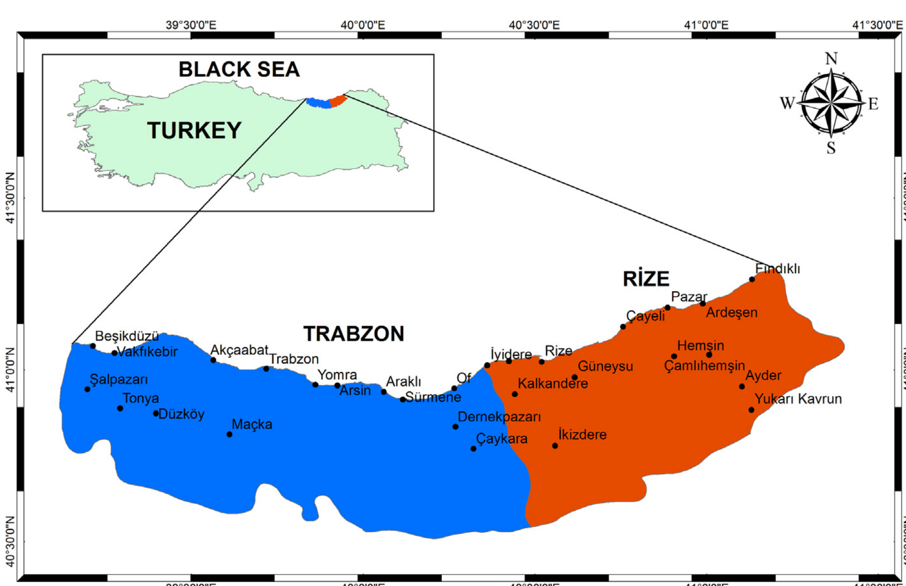

Fig. 1. Location of study area (Guneroglu and Acar, 2010).

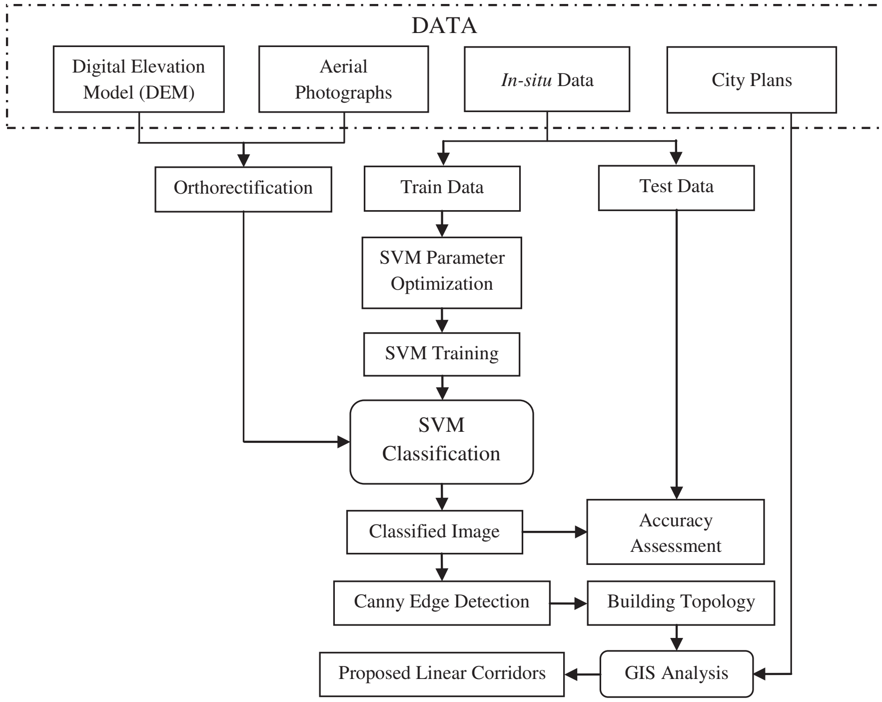

Fig. 2. Flow diagram of proposed methodology.

distance of the available aerial images is 46 cm whereas 2.4 m for Quickbird and 4 m for Ikonos multispectral images. Supervised image classification techniques were used to obtain different land use classes including green cover in the study area. Non-parametric Support Vector Machine (SVM) classifier that is widely accepted methodology in analyzing multi-dimensional datasets was applied (Duro et al., 2012). In order to obtain training dataset and test the overall accuracy of the SVM classifier, previously collected *in-situ* data was allocated as field data. Stratified random sampling technique was implemented at this stage for dividing the data set to two blocks, first 60% and second 40% as train and test data, respectively. The first field data block was used to train SVM and classify the multispectral images. In order to explain SVM classifier robustness on high spatial resolution data, a comparison was carried out between satellite and aerial images. Consequently, Quickbird and Ikonos multispectral satellite images were utilized for Trabzon and Rize cities, respectively (Table 1). After the classification, five LULC classes were obtained: urban green areas, asphalt ways, water, other urban objects and shades with 94.64 and 96.53 overall accuracies for Trabzon and Rize cities, respectively. As a next step, except green cover all other classes were masked to delineate green infrastructure of the study area. Before edge detection process very small pixel groups which are not belong to vegetation class and available noise on classified images were eliminated by using post processing morphological image operations. Therefore an image cleaning operation based on 8-connected neighborhood was applied by selecting 2-pixel threshold value. Resultant image was converted to binary form for further processing.

Table 1
Classification accuracies for digital aerial images and satellite data.

Data	Satellite image (Quickbird + Ikonos)	Aerial image
Cities		
Trabzon	87.52%	94.64%
Rize	81.12%	96.53%

As a final step, Canny Edge detector was applied to obtain the edges of polygons in classified image and later on the data was vectorized, topologically cleaned and transferred to GIS environment. In this study image classification procedure was performed by using ENVI software. Edge detection and post image processing operations were carried out in MATLAB environment. Finally, ArcGIS 10.1 by ESRI was used for planning and GIS analysis. Analytical GIS operations were pursued to evaluate and show potential green corridors on final GIS coverages.

In order to quantitatively obtain the level of green cover fragmentation, Patch Analyst, an ArcGIS extension of Fragstats software, (McGarigal and Marks, 1995; McGarigal et al., 2002; Rempel et al., 2012) was used. Landscape metrics are important in terms of landscape configuration as they determine the spatial or physical distribution of patches. In this study, eight shape-related landscape metrics were considered to examine the fragmentation level of the study area. These metrics are Class Area (CA), Class Percent of Landscape (PL), Number of Patch (NumP), Largest Patch Index (LPI), Mean Patch Size (MPS), Area Weighted Mean Shape Index (AWMSI), Area Weighted Mean Patch Fractal Dimension (AWMPFD) and Patch Density (PD). These metrics carry information on structural composition of landscape formation. For example, MPS can give information about the average size of the patches in the landscapes well as providing a tendency for a patch characteristic, which is very important for the suitability and connectivity of the landscape elements. AWMSI metric is important as it reflects circularity level of patch shape. If the patch shape can be described by basic geometric features then AWMSI tends to approaching “1” but increases with increasing patch shape irregularity. Similarly, independent of patch size, AWMPFD value was also used to decide about the shape complexity it takes quantitative values between “1” and “2” and approaches “2” when the patch becomes more complex. Some other metrics such as CA and LPI are giving information on areal extension of landscape patches. Extension of patch area sometimes can be even more important than the size of the area per se within context of landscape ecology and connectivity (McGarigal and Marks, 1995; Rempel et al., 2012). In order to express patch density per area in each city, index of PD metrics were calculated. PD index is a good reference to understand the degree of the fragmentation in the landscape structure. Therefore higher PD values per area suggest more fragmentation. Detailed information and interpretations on landscape metrics are provided by McGarigal et al., 2002.

4. Results

The study area consists of two cities, which are very urbanized therefore one of the fundamental landscape element "connectivity" is highly diminished. Landscape metrics were computed to define spatial configuration of two cities as well as to make some comparisons in terms of linear connection of the fragmented patches and the level of fragmentation in urban fringes. The study revealed that the green infrastructure of urbanized regions in Trabzon and Rize cities were highly fragmented and diminished in spite of well-known and nationally accepted green character of the region. It is also clear from the images (Figs. 3 and 4), green cover of the cities is considerably low and there is no clear sign of linear connection of green landscape elements so called "Green Corridors". According to findings in this study green cover and fragmentation level of Trabzon and Rize cities could be evaluated separately.

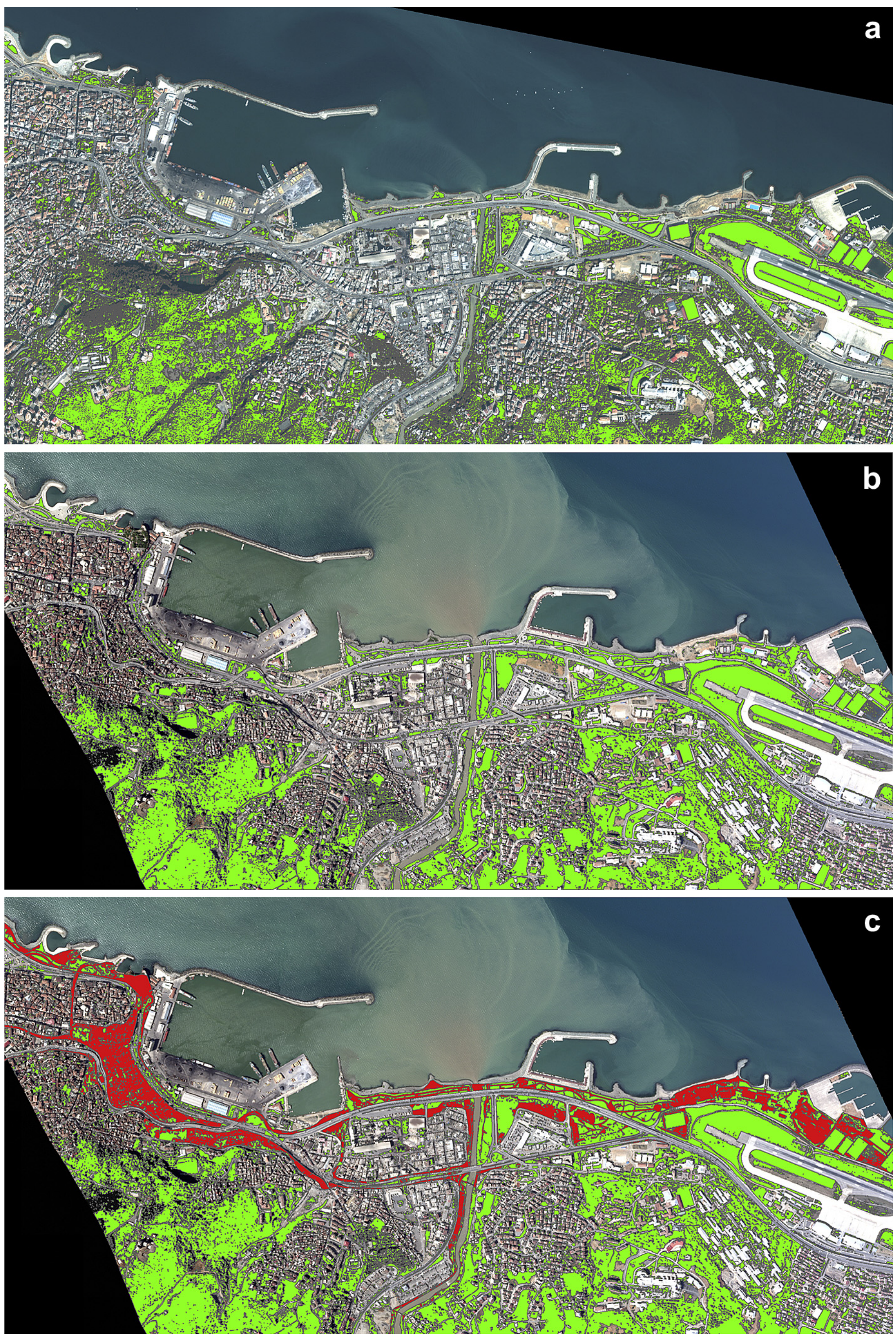

Fig. 3. Green cover of Trabzon; a) fragmented patches (Quickbird image), b) fragmented patches (digital aerial image), c) proposed linear green corridors. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 4. Green cover of Rize; a) fragmented patches (Ikonos image), b) fragmented patches (digital aerial image), c) proposed linear green corridors. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Trabzon city is highly developed and urbanized in unplanned manner therefore green corridor design is generally omitted from city development plans, rehabilitation and transportation projects. Classification results of remotely sensed images revealed the green coverage in high accuracy for Trabzon city. High-resolution multispectral digital aerial images and Quickbird multispectral satellite image were classified and compared to each other for Trabzon. SVM classifier produced higher accuracies for aerial images when compared to Quickbird satellite data, overall accuracies were 94.64% and 87.52%, respectively. Computed landscape metrics were shown the degree of urban sprawl and fragmentation in Trabzon. The landscape patches were incompatible with each other and generally with compact shape, resulting relatively low "1.36"AWMPFD value which is an indication of high fragmentation. Similarly, some other shape related metrics values for Trabzon city were "13.61" for AWMSI, "30.17" for LPI and "0.16" for MPS and they also confirmed the high urbanization related fragmentation of Trabzon city. Steep geomorphology of the Trabzon city is appropriate to create the broken ecological networks as many valleys between mountains can be rehabilitated to link coastal linear structures to upper ecosystem components. There are limited efforts by governmental organizations and decision makers to use those valleys as green corridors. Degirmendere stream is a good example that can serve for this purpose but today is mostly used for agriculture, housing, industrial and stone crushing activities (Fig. 5). An immediate action is needed to connect this valuable natural green corridor to the city landscape as Degirmendere is just geographically dividing the city center into two parts.

The situation in Rize city is not very different than Trabzon city with an exception of law protected agricultural areas availability. Rize is responsible for more than 65% of tea production in Turkey and tea cultivation lands are under protection by recent announcements of amendments in land management and zoning law. Therefore, severe effects of urbanization in the city are explicit but relatively with moderate fragmentations figures. Likewise in Trabzon city classification results of remotely sensed data showed better classification accuracies when multispectral aerial images were used. Ikonos image with relatively coarse spatial resolution produced 81.12% in Rize whereas aerial image with the same processing schema revealed 96.53% overall accuracy for the study area. It is clear from the results that shape irregularity, shape size and largest patch index and patch density values were quantitatively described the fragmentation level in the city of Rize (Table 2).

To evaluate the current situation in two coastal cities of North Eastern part of Anatolia some landscape spatial configuration metrics were computed based on maps produced following the procedure in Fig. 2.

According to results from patch analysis, Trabzon city urban landscape showed very high total patch numbers comparing to Rize city landscape structure. Fractal dimension was calculated as 1.40 in Rize city and it was slightly (3%) higher than Trabzon city. Patch density value was around 6.32 in Trabzon and 5.80 in Rize according to urbanization and fragmentation character of the cities. Calculated LPI values proved that larger patches exist in Rize city center with approximately 23% exceeding limits of Trabzon city. Mean patch size was approximately equal in both cities with values 0.16 ha and 0.17 ha for Trabzon and Rize, respectively. AWMSI value for Rize was 17.77 and greater when compared to relatively urbanized city of Trabzon.

Due to high population density depended urbanization, the situation in Trabzon city was worse than Rize in terms of total green cover percentage and fragmentation (Figs. 3 and 4). To establish a linear connectivity in a landscape domain proposed linear connectivity design plans were depicted in red color on Fig. 3(c) and Fig. 4(c) for Trabzon and Rize coastal area. Proposed realistic landscape rehabilitation plan can be further differentiated to finer scales and placed in official city plans registered by the local authorities. Accordingly, built-up areas and traffic network projects can be designed by taking into account green cover concept and habitat connectivity. It should be also stressed that recently completed North Eastern highway is an artificially established linear corridor that can be potentially converted to "green

Fig. 5. Degirmendere stream and its surroundings in Trabzon.

corridor". There are some limited recreational coastal areas such as trekking lanes and parks that can be regarded as green corridors in guidance of landscape design principles. But there are no pronounced links created by those elements. They were just used as green zones to meet recreational demands of urban inhabitants. Those green areas were created after the accretion projects aimed to serve for recently completed Black Sea coastal highway construction. Therefore, trees were intentionally not used instead; shrubs and some ground cover species were preferred.

In the city center of Rize tea cultivation areas are protected bylaw. Therefore total green cover percentage was higher than Trabzon City. Fragmentation percentage was also lower due to artificial and natural effects of green infrastructure (Fig. 6).

Under current circumstances it is almost impossible to create green corridors as houses and other artificial constructions strictly limit such an action for both cities. Lately, there are some efforts to transform ugly grey cover to green cover in city centers by carrying out urban transformation projects which are very demanding, time consuming and expensive. There is a successfully implemented example from Trabzon City "the Zagnos Valley Project". Some other efforts such as Ayasofya, Ortahisar, Tabakhane and Comlekci are infeasibility stage in Trabzon.

Green areas in city centers were also fragmented and not linked to create ecologically and systematically accepted landscapes (Fig. 7). Green corridor infrastructure was hardly seen in recent conditions of both city centers.

Table 2
Calculated structural landscape metrics for Trabzon and Rize city centers.

Landscape metrics	CA (ha)	NumP	MPS (ha)	PL (%)	LPI (%)	AWMSI	AWMPFD	PD
Cities								
Trabzon	255.35	1614	0.16	100.00	30.17	13.61	1.36	6.32
Rize	170.76	991	0.17	100.00	53.65	17.77	1.40	5.80

CA (Class Area), PL (Class Percent of Landscape), NumP (Number of Patch), LPI (Largest Patch Index), MPS (Mean Patch Size), AWMSI (Area Weighted Mean Shape Index), AWMPFD (Area Weighted Mean Patch Fractal Dimension) and PD (Patch Density).

5. Discussion

Due to continuous and sharp increase in population density and rapid urbanization, a systematic landscape design approach should be pursued and implemented in Trabzon and Rize cities. Green corridors are inevitable part of open and green cover of city landscape system. They have potential to physically balance the ugly grey cover with green linear spaces. Such areas can not only be used for aesthetic purposes but also for ecologic continuity, climate regulation, recreation and pollution.

Effect of urbanization and its adverse impacts on connectivity of landscape elements should be strictly stressed both in Trabzon and Rize. Even though the current study did not specifically aim to analyze temporal urbanization, negative results of urbanization in long-term was very well documented by Reis (2008); Karsli et al. (2009); Sancar et al. (2009) and Reis et al. (2012). Therefore urbanization related landscape fragmentation is widely acceptable in the study area without doubt.

The level of fragmentation was computed by using landscape metrics provided by Patch Analyst. Total number of patches was higher in Trabzon city due to high urbanization ratio when compared to Rize city. Lower mean patch size is a good proxy for habitat fragmentation that is the case for Trabzon city. Relatively

Fig. 6. Tea cultivation areas (red color) under protection bylaw in Rize. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

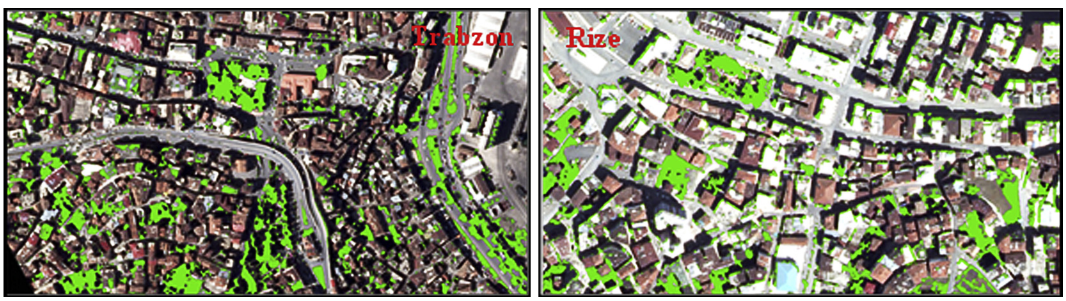

Fig. 7. Enlarged view of green infrastructures for Trabzon and Rize city centers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

larger green cover patches (mainly tea gardens) are protected by law in Rize city. Similarly, landscape spatial structure is also supported by higher patch density per area in Trabzon city. These are all acceptable quantities showing urbanization rates. Moreover due to peculiarities of Rize city fractal dimension was higher than Trabzon, which is an expected result of spatial heterogeneity and landscape morphology. This can be explained as Rize city has very steep hilly terrain starting adjacent to coastline in most areas whereas Trabzon city has relatively gentle slopes toward the mountains, thus natural texture and heterogeneity is better preserved in Rize than Trabzon city (Guner et al., 2001; Reis et al., 2012).

It was proved that applied methodology to process remotely sensed data revealed very high classification accuracies. Reis and Yomralioglu (2006) and Sancar et al. (2009) reported similar results for the study area by using supervised classification techniques on Landsat satellite images. Kahya et al. (2010) used an expert system and maximum likelihood classification to determine LULC of Trabzon city and obtained high accuracies for each class of land cover. Even though, cited literature ended with high classification accuracies, they were considerably limited by spatial resolution of satellite images, which is very important in terms of landscape fragmentation in urbanized regions. Therefore spatial resolution (0.46×0.46 m) in this study is very high enough to capture the sub-pixel signatures that are not available by coarse spatial resolution of satellite images. Evaluating satellite and aerial images separately for each city also proved that aerial images with very high spatial resolution revealed better classification accuracies. For the Rize city similar results with high classification accuracies were reported by Reis (2008). Strength of SVM classifier over conventional classification methods was also reported by different authors (Chova et al., 2008; Wang and Ma, 2008; Pouteau et al., 2010; Thai et al., 2010).

6. Conclusion

This study showed that contrary to contemporary landscape concept, green corridors are mostly omitted and even not considered in landscape design projects of Trabzon and Rize coastal cities in North Eastern part of Turkey. Therefore, an urgent need arises to put in to effect such landscape design action in order to establish connected nodes and corridors in fragmented city landscapes. There are some areas that can be potentially used to create such links in both Trabzon and Rize. The climate of the region is also very tolerable in this context. Rehabilitation projects are also needed for available limited green corridors that mostly attributed to highway barriers and pedestrian lanes. Additionally private house and roof gardens should be encouraged where possible to establish an ecosystem connection.

In coastal areas some sea water tolerable natural species should be considered instead of aesthetic exotic species. In order to build perennial landscape structure, areas with shrubs and ground covers should be altered toward trees and evergreen species.

Topographically available valleys should be used to create natural green corridors. Projects aiming to transform those areas to connection links should be supported by governing bodies. Somehow a connection between coast line and mountain ridges should be established. City transformation and rehabilitation projects are necessary to rebuild historical, cultural and ecologic linear connections in the area.

Finally, current landscape design situation in both cities is an acute and explicit failure of decision makers. An opportunity of recent public awareness regarding environmental issues can be exploited to create green linear spaces beginning from a single house scale to city plan. There is also a need to temporal evaluation of fragmentation and application the methodology in some other areas to monitor the situation of densely urbanized regions.

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