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Assessment of Basic Green Infrastructure Components as Part of Landscape Structure for Siirt

Peyzaj Yapısının Bir Parçası Olarak Temel Yeşil Altyapı Bileşenlerinin Siirt için Değerlendirilmesi

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Abstract

The study aims to create an upper-scaled green infrastructure plan for the Siirt, using ecological planning principles. In order to create this plan, the cores, corridors and sites, which are green infrastructure components, were determined using 1/100.000 scaled Environmental Plan. Landscape core areas have been analysed using landscape structure metrics, and evaluated in terms of fragmentation, connectivity, and isolation. The areas that are of high importance in terms of the landscape structure that will form the basis of the Siirt green infrastructure plan were determined. For landscape connectivity, links have been established between areas whose function is important in the landscape by using least-cost-path and Euclidean distance methods. As a result, the ecological roles and importance of the components in the landscape structure was determined the green infrastructure plan framework for the Siirt. Considering these evaluations, a biodiversity network, arable network and green access network were created, and a green infrastructure plan was designed in Siirt. In this study, while planning a green infrastructure on the upper scale, the fragmentation of the components, which ones can be protected or recovered, and how the strategies formed according to the results of the analysis can be included and applied in other plans were evaluated with a holistic approach. The results of this study and the method used will contribute to other studies in terms of applicability.

Keywords: Green infrastructure, Landscape structure, Landscape connectivity, Ecological planning, Siirt

Özet

Bu çalışmanın amacı, ekolojik planlama ilkeleri kullanılarak Siirt için üst ölçekte bir yeşil altyapı planı oluşturmaktır. Bu planı oluşturmak için 1/100.000 ölçekli Çevre Düzeni Planı kullanılarak yeşil altyapı bileşenleri olan çekirdekler, bağlantılar ve bçlgeler belirlenmiştir. Peyzaj çekirdek alanları peyzaj yapısı metrikleri kullanılarak analiz edilmiş ve parçalanma, bağlantılılık, izolasyon açısından değerlendirilmiştir. Böylelikle, Siirt yeşil altyapı planına temel oluşturan peyzaj yapısı açısından önemli alanlar belirlenmiştir. En az masraflı yol ve Öklid uzaklık yöntemleri kullanılarak peyzajda işlevsel açıdan önemli olan alanlar arasındaki peyzaj bağlantılılığı analiz edilmiştir. Sonuç olarak, yeşil altyapı bileşenlerinin peyzajdaki ekolojik roller ve önem dereceleri Siirt için oluşturulan yeşil altyapı planının çerçevesini belirlemiştir. Tüm analizler yeşil altyapı kapsamında değerlendirildiğinde, biyolojik çeşitlilik ağı, ekilebilir ağ ve yeşil geçiş ağı oluşturularak Siirt için bir yeşil altyapı planı tasarlanmıştır. Bu çalışmada üst ölçekte yeşil bir altyapı planlanırkenö bileşenlerin parçalanma durumları, hangilerinin korunabileceği veya kurtarılabileceği ve analiz sonuçlarına göre oluşturulan stratejilerin diğer planlara nasıl dahil edilip uygulanabileceği bütüncül bir yaklaşımla değerlendirilmiştir. Bu öalışmanın sonuçları ve kullanılan yöntem yeşil altyapı çalışmalarının uygulanabilirliği açısından diğer çalışmalara katkı sağlayacaktır.

Anahtar Kelimeler: Yeşil altyapı, Peyzaj yapısı, Peyzaj bağlantılılığı, Ekolojik planlama, Siirt

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1. Introduction

Green infrastructure approach is one of the most useful applications in order to reduce the effect of impermeable surfaces that occur due to the urbanisation texture that is concentrated around the world, to facilitate the penetration of rainwater into the underground along with the runoff, to support biodiversity and to manage natural resources in a holistic way by linking fragmented blue-green areas, ensuring continuity of landscape connectivity (Benedict & McMahon, 2006; Yiğit Avdan et al., 2015; Eaton, 2018; Staddon, et al., 2018; Ünal & Akyüz, 2018; Filazzola et al., 2019; Zuniga-Teran, et al., 2020). Undoubtedly, the basic principle of successful green infrastructure planning is to analyse and evaluate the components within the scope of the approach in terms of the structure and functions of the landscape. When looking at the studies in the literature, (Ahern, 2007; Chang et al., 2012; Coşkun Hepcan & Hepcan, 2018; Demir & Baylan, 2019) it is seen that the spatial dimension of the green infrastructure issue is frequently examined. However, the green infrastructure approach is a multi-disciplinary planning tool and the studies should be interpreted by different professional disciplines. For this reason, due to the increase of urbanisation dynamism and human interventions in recent years and the negative reflections of this increase on the structure of the landscape, it became necessary to create a green infrastructure plan for Siirt by using ecological planning principles. With this study, it was aimed to determine the green infrastructure components (cores, connections and sites) of Siirt province at the upper scale (1/100.000) and to analyse, map and evaluate these components within the scope of the landscape structure and to eliminate the deficiency in this matter. For this purpose, fragmented and unfragmented natural habitats in the Siirt landscape were determined, the isolation of these habitats was analysed, their interconnectedness was evaluated, and a green infrastructure planning was designed to support the connection of the green infrastructure system of the Siirt landscape with other ecosystems.

2. Material and Method

2.1. Material

Siirt is located in Turkey’s South-eastern Anatolia 37.9293° north latitude and east longitude 41.9413° (Figure 1).

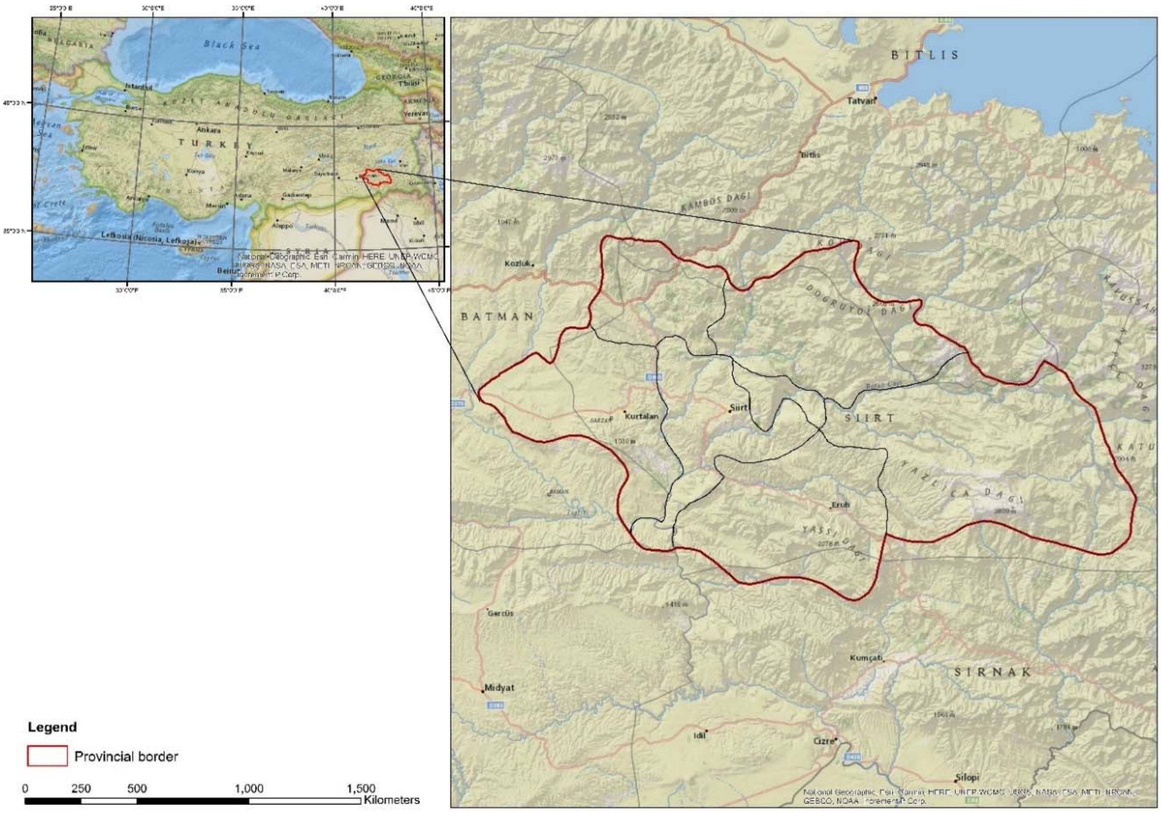

Figure 1. Geo-location of Siirt.

With the increasing population in recent years, urbanisation activities have caused the connection with the landscape to be broken. In Siirt, where the rural population is intense, a green infrastructure system was designed in order to reconnect the landscape with other systems. In the first stage of the method, the basic components (cores, connections and sites) of this plan were determined and mapped. In the second stage, fragmented and unfragmented natural habitats were determined. In the third stage, the interconnectedness and isolation of habitats were analysed. In the fourth stage, the unfragmented habitats connected with each other were defined regionally. In the last stage, a green infrastructure plan was created for the province of Siirt. Environmental Plan (EP) scaled at 1/100.000 was used to plan the green infrastructure system in Siirt province. All the land cover/land use features on the plan were digitised using Geographical Information Systems (GIS) techniques (Figure 2).

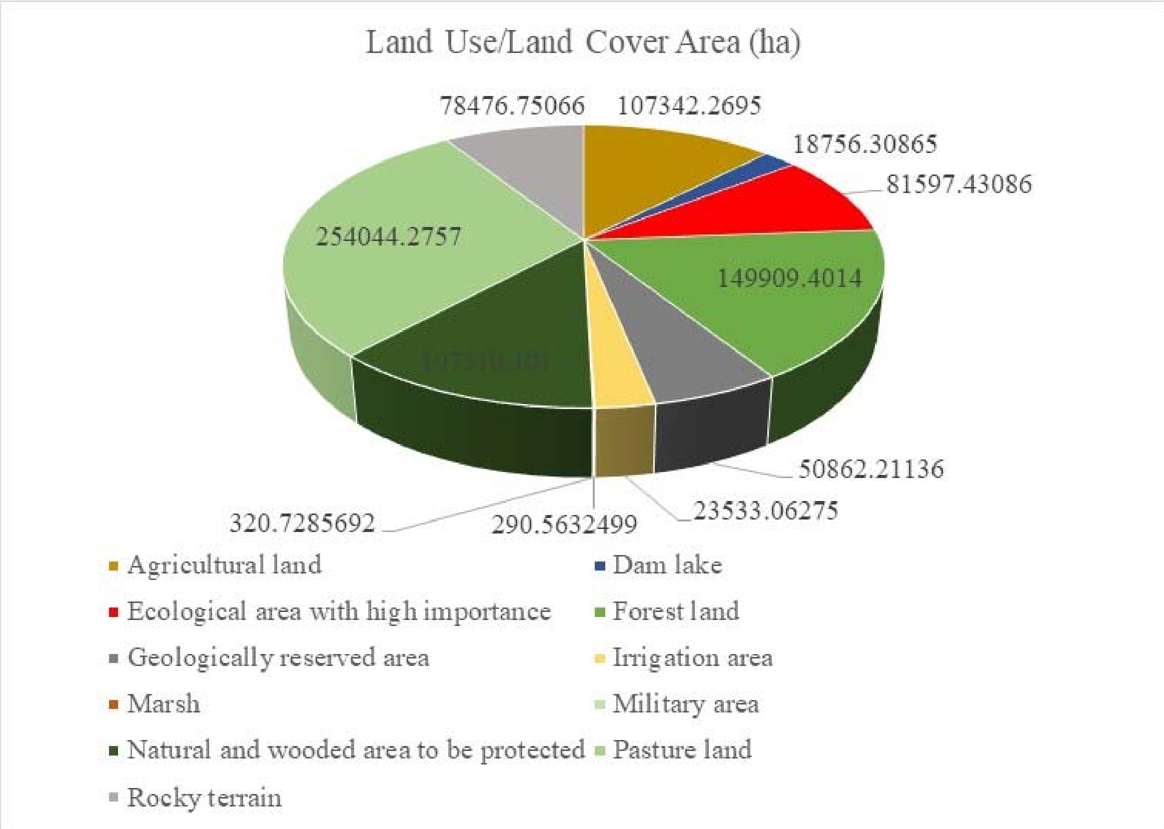

Figure 2. Land use/land cover types in Siirt with regard to EP.

2.2. Methods

2.2.1. Landscape Core Areas

Land cover/land use data were digitised through ArcGIS (ESRI, 2016) programme by using 1/100.000 EP to determine core areas. Patch classes were created for this vector dataset and the core areas at vector level were determined using Patch Analyst programme (Rempel, 2015). In the next step, the dataset was converted to raster format and Fragstats interface of the same programme (McGarigal et al., 2012) was used and core area metrics/indices were computed. For core areas, Total Core Area (TCA), Core Area Density (CAD), Mean Core Area (MCA), Core Area Standard Deviation (CASD), Core Area Coefficient of Variation (CACV) and Total Core Area Index (TCAI) were calculated (Table 1). The buffer zone width used for the determination of core areas was determined based on the literature (Semlitsch & Bodie, 2003; Blackwell et al., 2009; Hamer et al., 2012; Firehock, 2015; Filazzola et al., 2019).

Table 1. Core area metrics and statistical formula used in this study (Forman, 1995; McGarigal, Cushman, & Ene, 2012).

Metrics/Indices	Formula
TCA	$TCA = \sum_{j=1}^{n} a_{ij}^{c} \left(\frac{1}{10{,}000} \right)$
CAD	$DCAD = \frac{\sum_{j=1}^{n} n_{ij}^{c}}{A} (10{,}000)(100)$
MCA	$MN = \frac{\sum_{j=1}^{n} x_{ij}}{n_i}$
CASD	$SD = \sqrt{\frac{\sum_{j=1}^{n} \left[x_{ij} - \left(\frac{\sum_{j=1}^{n} x_{ij}}{n_i} \right) \right]^2}{n_i}}$
CACV	$CV = \frac{SD}{MN} (100)$
CAI	$CAI = \frac{a_{ij}^{c}}{a_{ij}} (100)$

2.2.2. Landscape Connectivity Corridors

Corridors in the study area were determined through the Linkage Mapper (McRae & Kavanagh, 2011) programme. The programme includes a toolbox that works compatible with GIS based programmes. Thus, landscape connectivity corridors that support wildlife are mapped more easily. Least-cost-path and Euclidean distance methods were used as a method in corridor mapping (Cohen & Amit-Cohen, 2009; Gonçalves, 2010; Castillo et al., 2015; Wei et al., 2018; Balbi, et al., 2019; Lee & Oh, 2019). This analysis shows the relative value of each grid cell in providing focus areas (link between tightly protected areas or between protected areas mosaic) and identifies software guidelines for ways to facilitate or prevent species movement between focus areas (McRae & Kavanagh, 2017). The distance between core areas is determined by the Euclidean distance method. Connection units and potential corridors are calculated using distance values.

2.2.3. Landscape Sites

In this study, urban settlements, urban development areas, industrial areas, military areas, regional parks/green areas, non-residential areas of use and university campuses were determined as landscape sites from green infrastructure components. The buffer zone determined for these regions is 500 metres.

2.2.4. Fragmentation, Connectivity and Isolation

In order to determine the core areas that unfragmented/least fragmented before the creation of the green infrastructure of Siirt city and in the next stage, to define the connections of these core areas with each other and their isolation status, the PatchGrid extension, which is included in the Patch Analyst programme (Rempel, 2015) and works with the Fragstats (McGarigal et al., 2012) interface was used. 7 metrics shown in Table 2 were used to calculate the fragmentation, connectivity and isolation degree of the core areas.

Table 2. Landscape metrics used for fragmentation, connectivity and isolation analysis

Patch size and density metrics	Shape metrics	Edge metrics	Diversity metrics
Mean patch size (MPS)	Average weighted mean shape index (AWMSI)	Edge density (ED)	Interspersion juxtaposition index (IJI)
Number of patches (NumP)			Mean proximity index (MPI)
Class area (CA)			

CA is the areal definition of each patch class. NumP is the number of patches within the class. CA and NumP are used to reveal the landscape change. MPS is the average patch size and the most important indicator of biodiversity in a landscape. AWMSI weights patches according to their size. In particular, large patches are weighted more than small patches in calculating the average patch shape within the landscape or class. In addition, AWMSI is used to measure patch sensitivity in fragmentation. ED is the density of the patch edges in the landscape. ED was chosen to make sense of interrelated ecological effects. IJI measures the proximity of the patches to each other. The IJI value approaches 0 (zero) when distribution of the adjacency state of unique patches is unequal, and approaches 100 when all patch types are equally adjacent each other. MPI measures the degree of fragmentation and isolation of a patch. When performing this measurement, the nearest neighbour statistics is used.

2.2.5. Buffer Zones

Creating buffer zones in green infrastructure studies makes the protected area/areas to be protected ecologically more flexible. The purpose of the buffer zone is to protect ecological zones from negative effects of adjacent land uses (Boitani et al., 2007). According to Firehock (2015), it is appropriate to use 100 metres buffer zone for core areas, corridors, and zones to both support wildlife and protect water quality in a green infrastructure planning. While creating the Siirt green infrastructure plan, taking into account the topographic features and urbanisation tendency, the buffer zone has been determined as 100 metres for core areas and landscape corridors 500 metres for landscape sites.

3. Results and Discussion

3.1. Analyses

TCAI and MCA values show that the patch with the largest core area on a percentage basis (94.70%) and on hectare basis (6962.33 ha) is the irrigation area in the landscape of Siirt (Figure 3).

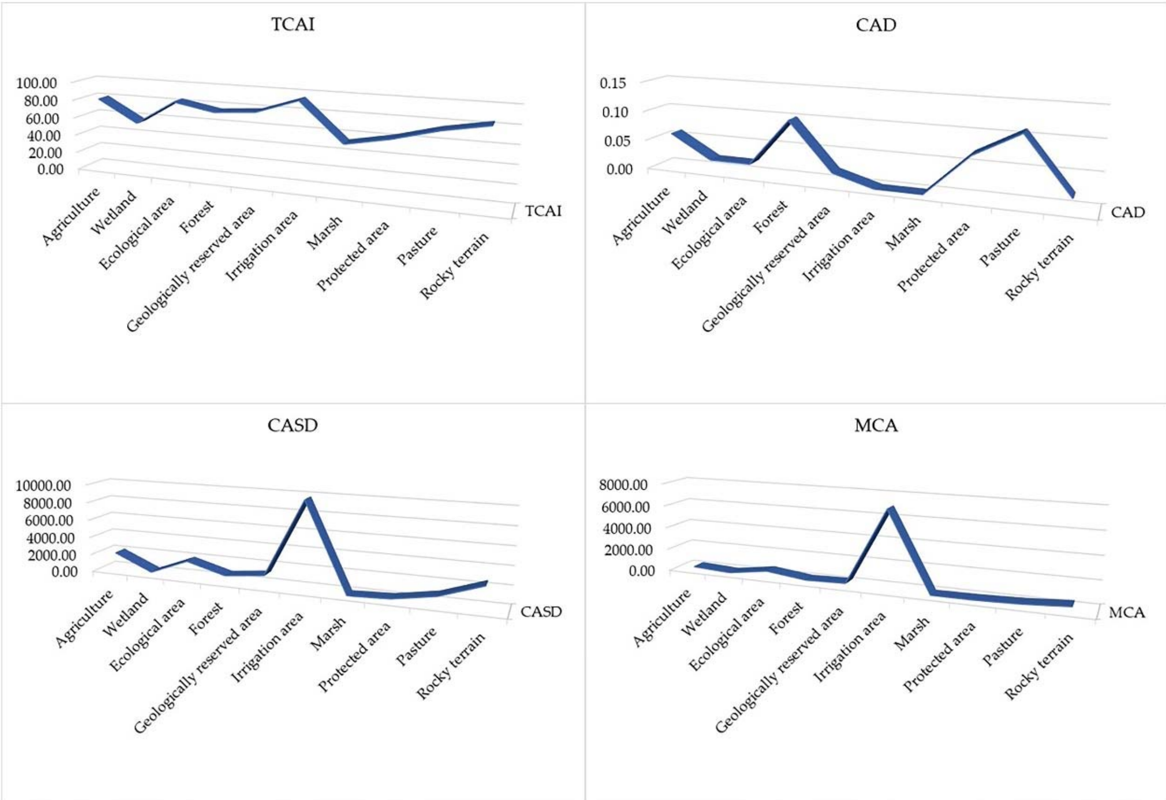

Figure 3. Land use/land cover types in Siirt with regard to EP.

It can be interpreted that the species in the patch with a large core index can continue their lives without being affected by the environment (Forman, 1995). Ecological units which are in core areas with a high index value, are in a more protected and balanced environment than others. Irrigation area, respectively, is followed by rocky terrain (84.06%), ecological area (83.51%), agricultural land (80.55%), geologically reserved area (79.21%), forest land (75.58%), pasture (75/31%), protected area (62.82%), wetland (56.38) and marshes (53.53%). Considering the MCA values, the irrigation area (6962.33 ha) is the patch with the largest average core area. Both TCAI and MCA values calculate between patches within the total class.

CAD values indicate the density of core areas in the total landscape area in hectares. According to this explanation, it is seen that the core area density in the Siirt landscape shows a different trend. It is pasture with the highest core area density in the total landscape area (0.11). This value is followed by forest (0.10), protected area (0.07), agriculture land (0.06), respectively. Ecological area, wetland, geologically reserved area and rocky terrain meet the same values (0.02). Irrigation area and marshes value are 0 (zero). CASD calculates the variability in core area size per hectare. The CASD value of the irrigation area in Siirt landscape is the highest (9745.29 ha). This means how differently the patch belonging to the irrigation area differs from other patches. The patch with a high core standard deviation has a greater core area distribution. Patches with low standard deviations also have a low core area distribution. In summary, the wetland in the landscape of Siirt appears to be more resistant and superior to interventions due to the high self-area values of the patch class. This class is followed by rocky terrain (2608.48 ha), agricultural land (2073.84 ha) and ecological area (1937.26 ha). In addition, the higher this value indicates that the patch class is less fragmented. Patch classes with low values are weak and the sensitivity of the core areas to various interventions is high. It has been concluded that the classes listed above should be evaluated with priority while creating the Siirt green infrastructure of core areas. Habitat, channel and source functions, which are among the features of corridors, vary in parallel with high connectivity that enable species to move easily along the corridor (Forman & Godron, 1986). The less spaces there is per unit length along the corridor, the connectedness is so high. In addition to the number of gaps, the degree of aggregation and the length of each cavity are ecologically important. Clustered spaces serve as a series of stepping stones within the corridor system (Forman, 1983; Forman & Godron, 1986; Baum et al., 2004; Kramer-Schadt et al., 2011). Landscape connectivity corridors connecting the core areas in Siirt landscape are shown in Figure 4. The core areas with the highest index value are coloured red, while the lowest ones are green. According to the map, the corridor feature of the rocky terrain (core area density, 2nd after the wetland/84%), which is expressed in red, came to the fore more than the irrigation area with the highest core area density (index value 94%). Another striking result is that all of the red areas in the map, which have a high corridor feature and relatively separate from the western irrigation area, are all rocky terrain.

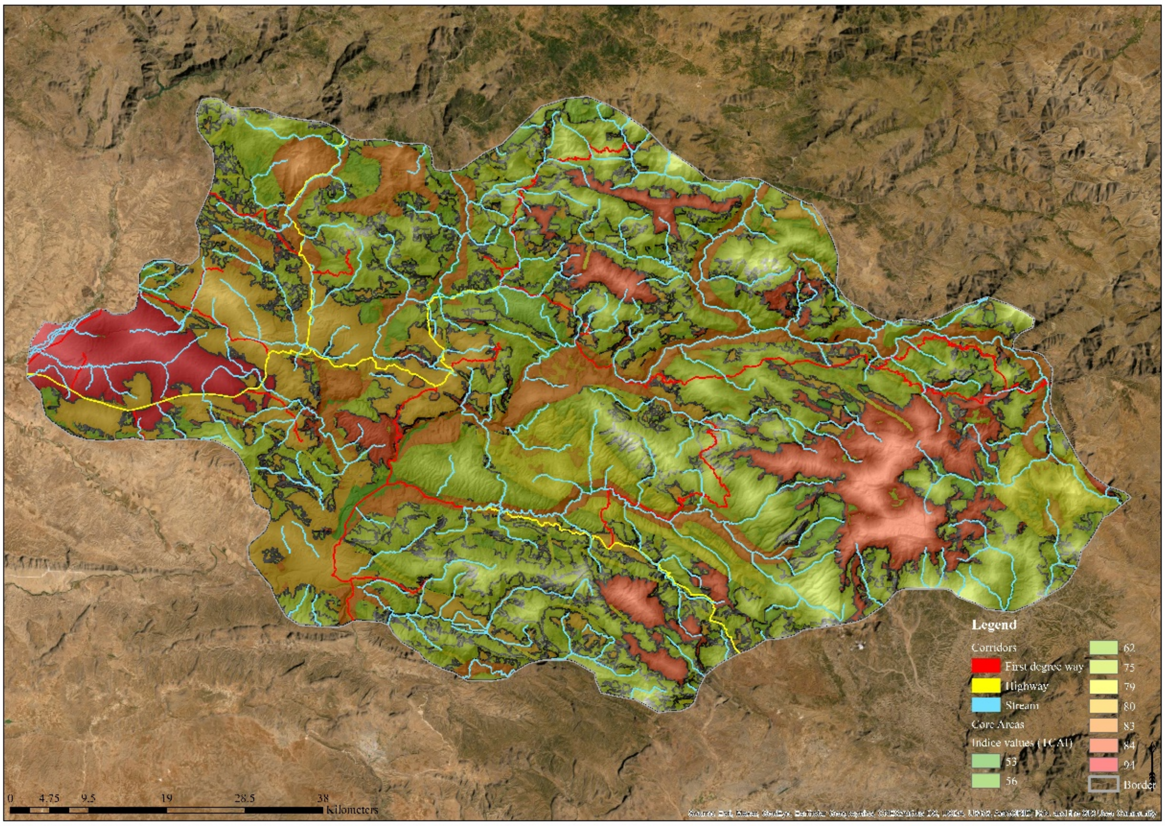

Figure 4. Landscape connectivity corridors.

Other areas with high corridor feature show forest/pasture feature that match with green colour. CA is a measure of landscape composition (McGarigal & Marks, 1995) (McGarigal & Cushman, 2003). In particular, it shows how much of the landscape consists of a certain type of patch. According to the results, the core area with the highest CA in Siirt landscape is forest/pasture with 215.700 ha. This figure corresponds to 43.74% of all core areas. Agricultural land comes 2nd with 16.26%. The patch number of a particular patch type is a simple measure of the subdivision of the patch type or the size of the breakdown. Although the number of patches in class can be fundamentally important for a number of ecological processes, it usually has limited interpretative value on its own, as it carries no information about the area distribution or density of patches (Forman, 1995; McGarigal & Marks, 1995; Gustafson, 1998; Fahrig, 2003). Of course, if the Total Landscape Area (TLA) and CA are kept constant, NumP conveys the same information as the patch density (PD) or average patch size MPS and can be a useful index to interpret. As the basis for calculating other interpretable metrics, the NumP may be more acceptable (McGarigal et al., 2012). The point to be considered is that NumP alone cannot provide enough information about fragmentation.

When other metrics are kept constant and NumP is evaluated alone, comments can be made that the lower the number of patches, the less the fragmentation may be, or the greater number of patches, the greater the fragmentation, but these comments will be misleading. Therefore, NumP must be interpreted together with other metrics (CA and MPS). Forest/pasture (215.700 ha) with the highest CA value among the core areas in Siirt landscape, also appears as the most fragmented core area. In addition, the irrigation area is the least fragmented and has shown itself as the most diverse core area in the Siirt landscape. Edges and inner surroundings exhibit different structure. For example, the vertical and horizontal structure, thickness, species composition and abundance, patch edge and conditions within are different and together they form the edge effect (Zheng & Chen, 2000; Dramstad, et al., 2001; Zurita et al., 2012; Wang et al., 2014). The patch edge is an important feature for the management of ecological transition zones between different habitats and the ecological functions of the landscape. This is because the edges of the patch contain areas where the transition zones are adjacent to where the mutual relations between different living things are most intense. Therefore, the lower the edge density (ED) in this region, the more comfortable the flow of matter, energy, etc. between the inner species in the core area. Among the core areas in the Siirt landscape, the densest edge value (15.62 m) stands out in the forest/pasture core area. Therefore, forest/pasture has the feature of the core area which is under the most pressure due to both the most fragmented and high edge density. (Forman, 1995) stated that circular patches have more ecological advantages in optimum conditions. Increasing the AWMSI value indicates that the patch shapes are more irregular. On the contrary, a decrease in AWMSI value indicates a more regular patch shape (Paudel & Yuan, 2012). In other words, high AWMSI value means high degree of fragmentation and non-circular patch shape. In Siirt landscape, the AWMSI values of all core areas are greater than 1 and therefore the patch shapes are not circular. The core area (4.74) where the patch shape is most irregular is the rocky terrain. Marshes (1.4) were the core area, which showed the most uniform distribution in shape compared to other core areas. MPI measures the isolation and fragmentation of a patch (Gustafson & Parker, 1992). If all other situations are equal, a patch that contains more than another patch of the respective patch type and is in an environment defined by the scan radius has a higher index value. Similarly, if all other conditions are equal, a patch in an environment where the corresponding patch type is distributed by larger, more adjacent, and/or closer than another patch has a higher index value. Irrigation area (4126.87) may be interpreted as adjacent, closer together, or larger than other core areas. The core area that is the most separate and isolated (0.26) from each other is the marshes.

This core area occupies a smaller area in the Siirt landscape than other core areas. The IJI index measures the extent to which patch types are well distributed (equally adjacent to each other), while low values characterize landscapes where the patch types are poorly distributed. As with the MPI index, the IJI value (0%) of the marshes core area is smaller. This can be assumed as proof that this core area is poorly distributed in the Siirt landscape. On the other hand, it is seen that forest/pasture (71.82%) core area has a better distribution. According to the results of other indices, although the forest/pasture core area is the most fragmented patch in the results, the reason it shows the best distribution is that the edge type of the core areas takes into account the total perimeter when calculating the IJI. While calculating other indices, calculations are made per hectare. While the most fragmented core areas in the Siirt landscape are forest/pasture, the least fragmented core area is irrigation area. According to Firehock (2015), the most important step recommended to be followed in a green infrastructure planning is the mapping of the highest value natural assets that contribute to a healthy ecology and also support cultural/economic values. Therefore, the core area, which s defined as irrigation area, supports ecological/cultural/economic values in the Siirt landscape and also plays an active role in connecting other core areas with each other due to the least fragmentation. The interconnections of the core areas in the Siirt landscape were determined according to their distance (Euclidean distance, least-cost-path and cost weighted distance) based on the core area indices and their proximity to each other. Potential connections of core areas that are close to each other are shown in Figure 5. The core areas that established the strongest connection in the Siirt landscape were forest/pasture, protected area and wetland. When the IJI indices of these three core areas are examined, their closeness to each other is striking (71.82%, 48.43%, 36.86%). When the fragmentation indices are evaluated together, these patches showed a relatively more regular distribution than the rocky terrain, ecological area, and agricultural area. In the second place is the geologically reserved area and marshes, the third is agriculture, and the fourth is the ecological area and rocky terrain. In terms of edge density, forest/pasture has a denser structure than wetland and protected areas. The areas where the core areas preferred to establish a matrix among themselves were the rocky terrain and irrigation area. Ecological area is in the 2nd place, and agricultural land is in the 3rd place. Due to the structural functionality it has maintained for many years, the irrigation area has contributed both ecologically and economically in terms of ensuring the continuity of the agricultural areas in the region and preventing the fragmentation of the landscape with this continuity.

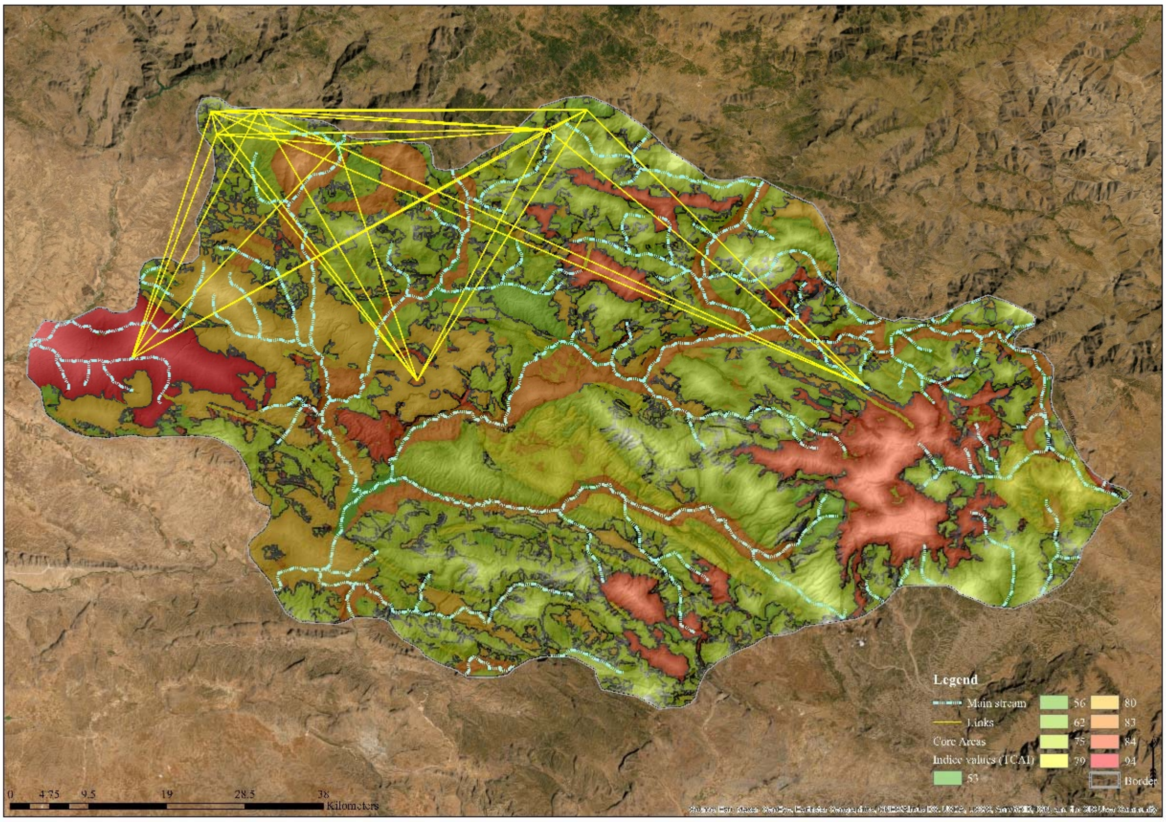

Figure 5. Potential links between core areas.

The rocky terrain, on the other hand, has ensured its continuity without being fragmented due to its structural unsuitability to human interventions (agriculture, settlement, etc.) and contributed ecologically to maintaining its connection with other landscape elements. On the other hand, due to dynamic changes in the salt content of the soil and the water regime, marshes create a different mosaic pattern even at a small scale. This natural mosaic contributes to the conservation of biodiversity at the landscape scale and also provides suitable habitats for a variety of plant and animal taxa, especially for animal breeding and migrating birds. These wetlands also play important roles as green corridors and stepping stones in fragmented farmland (Balázs et al., 2014). The marshy areas in the landscape of Siirt play an important role in terms of establishing connections between other core areas and serving as a stepping stone, as they shown an extremely isolated and monolithic structure. When Figure 6 is examined, it is seen that the connection between ecological areas identified in red colour occurs naturally through river corridors. This system consists of streams and tributaries feeding the Tigris River.

However, considering that the system is a whole, it should be believed that not only streams and streams connecting ecological areas, but also parts of the system that feed other core areas should be included in the plan, and conserving use of this natural system in the creation of Siirt green infrastructure plan will also mean continuing the connection between habitats.

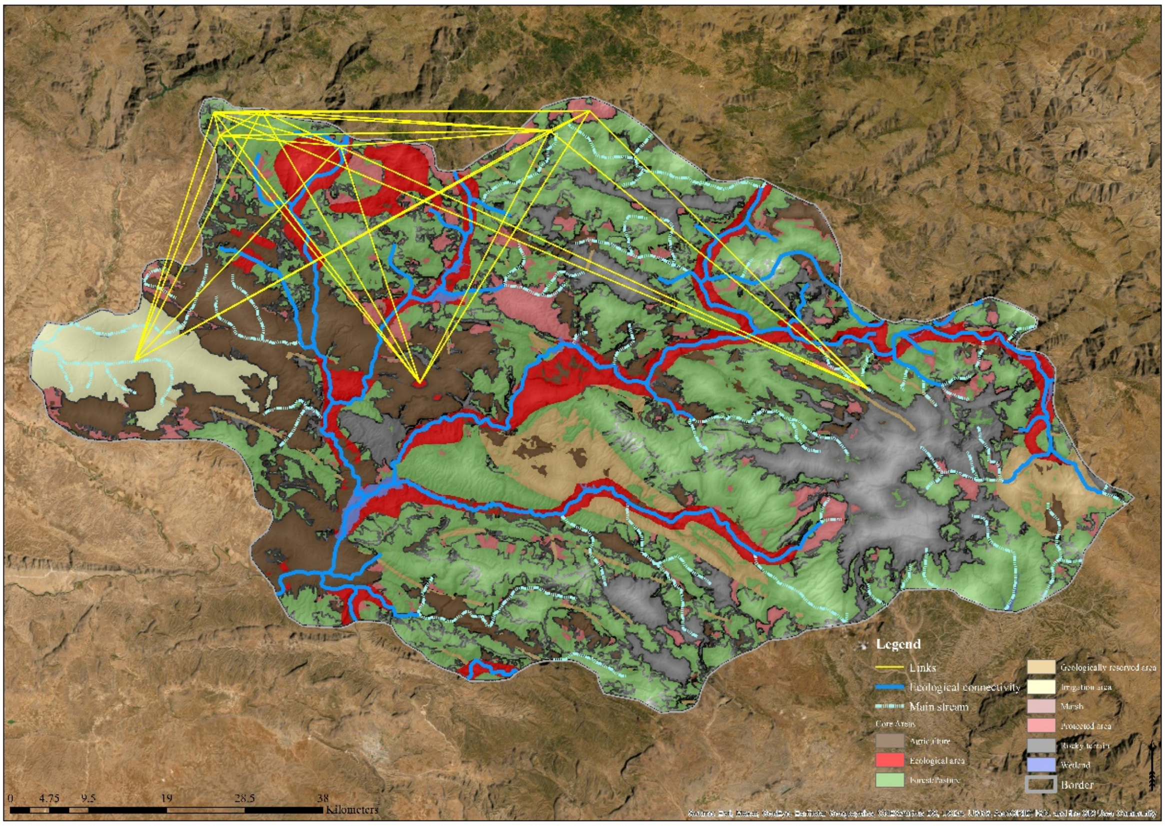

Figure 6. Connectivity between ecological areas, main streams and tributaries.

3.2. Green Infrastructure Plan for Siirt

After conducting fragmentation and isolation analyses fore core areas, connections and sites, the units that will form the green infrastructure plan of Siirt province should be protected and the corridors that provide connections between these units were determined. In addition, taking into account the city centre and the urban development areas of the districts, zoning was made and strategies that will contribute to green infrastructure were created. In this context, it was concluded that the ecological structure formed by the irrigation area, which has a high core area density and almost no fragmentation degree, and the streams feeding it, should be protected by taking into account its economic and social benefits as a whole. A 500 metres buffer zone was applied for the landscape sites in order to protect the landscape structure and fulfil its functions.

On the other hand, the fact that the rocky area is far from human intervention prevented fragmentation and created a support mechanism for the plant and animal habitats that survive in the rocky terrain. Marshes, which are few in the number in the province, play an important role for the entire system that forms the landscape. Marshes act as stepping stones as part of green infrastructure plans due to their biodiversity. For this reason, it has shown its feature as the most isolated structure. The core area with the highest fragmentation has emerged as forest/pasture. Although this core area also has the densest edge, the material exchange of the habitat, which is formed depending on the internal environment of the core area, with other patches in the external environment is at the lowest level. Agricultural land, irrigation area, rocky terrain and ecological areas are placed in the 3rd in the matrix formed between the core areas due to the support of ecological connectivity. In addition to these and importantly, the most important result from the analysis is that the ecological areas around the tributaries that feed the Tigris River naturally form a connection with each other. For this reason, a 1000 metres buffer zone was applied to streams in order to maintain a healthy connection with the landscape. Therefore, the green infrastructure plan of Siirt province was designed by creating a biodiversity network, arable network, and green access network, taking into account the ecological roles of the core areas mentioned above in the landscape structure and function of the green infrastructure plan (Figure 7).

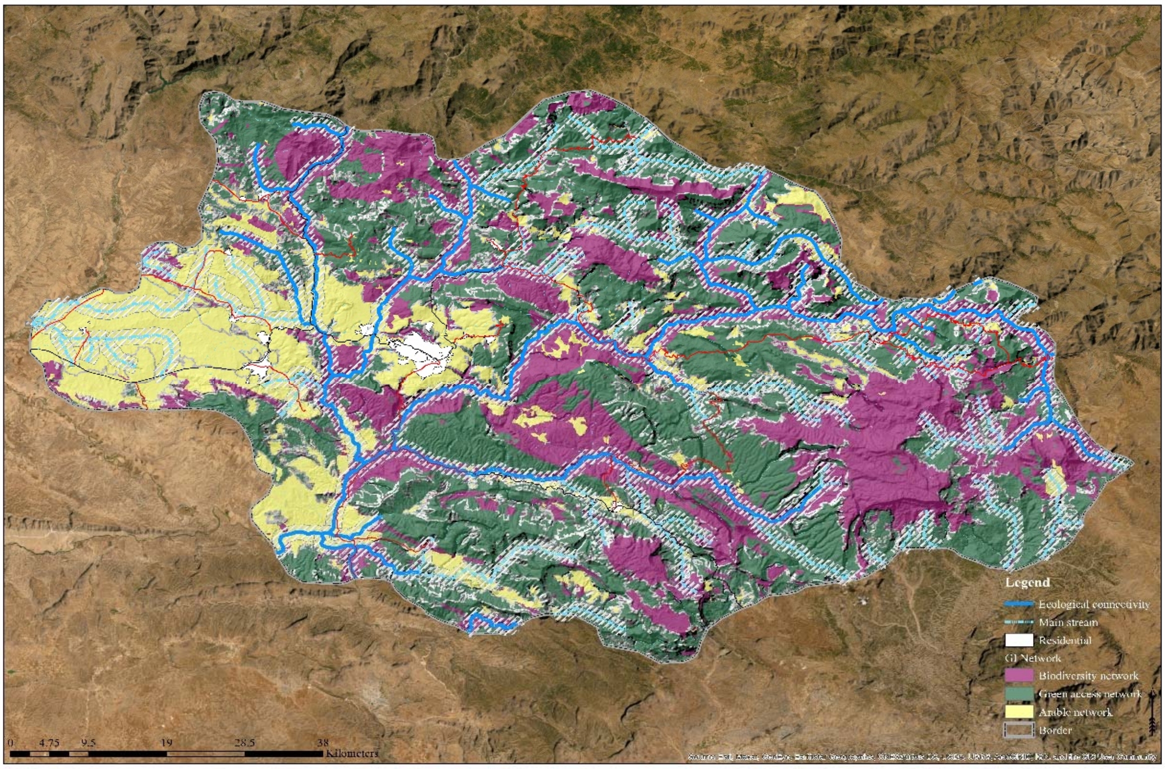

Figure 7. The green infrastructure plan for Siirt.

4. Results

In this study, it is aimed to establish an upper-scaled green infrastructure for Siirt, located in the South-eastern Anatolia Region, and create a basis for the studies to be implemented at the regional scale. Previous studies at different scales have completed an important part of green infrastructure planning studies by focusing on one or more parts of landscape structure and function analyses, which are emphasized to be the basis of green infrastructure planning. However, when considered from a broad perspective, it will be easier to implement these studies by supporting them with different approaches and evaluations. The steps that form the basis of this study and allow the establishment of green infrastructure at the upper-scale are suggested below:

- Determination of objectives: Deciding which natural assets and functions are important,
- Data analysis: Examination of the data required to map the assets in the 1st stage,
- Asset mapping: Mapping natural assets of the highest value based on stage 1 goals and stage 2 data that contribute to a healthy ecology and also support cultural/economic values,
- Assessing risks: Which assets are more at risk and what can be lost if no action is taken?
- Determining opportunities: Determining which ones can be recovered or improved based on the defined assets and risks, and deciding which ones should be intervened as soon as possible,
- Fulfilment of opportunities: Incorporation of natural asset maps into daily and long term planning such as park planning, comprehensive planning, transportation planning, tourism development and economic planning.

Based on the structure and function of the landscape, developing new methods and approaches with a holistic perspective, creating a sustainable green infrastructure plan that can be understood not only by a specific professional discipline but also by different professional disciplines will be the key to making the plans more involved in practise, not just theory.

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