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Optimization of Landscape Structure Based on Ecological Network Analysis and Graph Theory

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Mahdis Sadat[1], Esmail Salehi [1*], Mohammad Javad Amiri[1], Amir Houshang Ehsani[2]

1 Department of Environmental Planning, Management and Education, School of Environment, College of Engineering, University of Tehran, Tehran, Iran.
2 Department of Environmental Design, School of Environment, College of Engineering, University of Tehran, Tehran, Iran.

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Abstract

Over the last few years, extreme land degradation in the Northern provinces of Iran has led to extensive destruction to ecological systems in these areas. However, the connection of green spots and animal habitats is one of their most important features that allows the shift of animals and gene transfer among habitats. By applying landscape Ecology, the concepts in graph theory and ecological network, can simulate and analyze ecological and habitat networks and provide a decent plan to improve the structure, performance and conservation of biodiversity. The framework for setting up and improving ecological network structure in this study is based on morphological spatial pattern analysis model, graph theory (using Conefor 2.6 software) and path analysis with the least cost considering the amount of resistance and distance threshold for Phasianus colchicus species. In the ecological network, the small and limited natural corridors beside multitude core, illustrates the need of this network to devise corridors by experts and draftsmen. In addition, the small number of holes inside the cores confirms the optimal state of the network in terms of internal cohesion of the cores. Thus, in this research, a pattern of identification and planning is explicated, which will definitely be helpful in modeling the landscape and spatial planning of ecological networks.

Keywords: Ecological network, Graph theory, Habitat, Corridor, Phasianus colchicus.

* Corresponding author Email: tehransaleh@ut.ac.ir

Extended abstract

Introduction

Landscape fragmentation reduces the patch area of internal habitat, hinders the operating and regulating ability of normal landscape ecological processes, and damages ecological corridors. Therefore, connecting isolated broken ecological patches and stepping stones through potential corridors within the borders can improve the impact of fragmented landscapes on biodiversity and the connectivity of landscape and promote the exchanges of genetic material and species between patches, which would effectively improve the service functions of natural ecosystems and have an important ecological significance. Basically correct landscape pattern requires ecological network and ecological system. Ecological network helps planners to increase the landscape connectivity between habitat patches. Network optimization is mainly based on the improvement in network connectivity, including the optimization of corridors and nodes. The optimization of corridors mainly refers to the increase in the number of corridors and the repair of ecological breakpoints in the corridors based on the degree of connectivity. Corridor connectivity should be increased in areas with low landscape connectivity. In recent years, the morphological spatial pattern analysis (MSPA) approach, which mainly focuses on structural connectivity, has been increasingly applied in ecological network analysis. This model is mainly used for the analysis of structural connectivity and can be used to accurately distinguish between landscape types and structures. The MSPA method applies four parameters, namely “connectivity”, “edge width”, “transition” and “intext” to classify landscape. Landscape connectivity can be used as a quantitative indicator of how facilitating a source landscape patch is for species migration, as a high degree of connectivity facilitates biodiversity protection and the maintenance of landscape ecological functions. The connectivity of the landscape and the importance of the various landscape patches to landscape connectivity can be reflected under graph.In northern Iranian provinces like Gilan province, cities have experienced irregular and horizontal urban sprawls during recent decades due to the existence of Hyrcanian Forests, special climatic setting, presence of green areas and adjacency to Caspian Sea, high population density, and the development of economic activities across the region. As a result of land-use change, urban growth and land degradation, the distributions of some terrestrial species have changed in recent years. Phasianus colchicus is one of the focal species in this region. The maximal dispersal distance of the Phasianus colchicus 3.2. The species prefers forests with canopy cover of 5–25% because these forests are largely covered by shrubs and bushes, which common pheasant use as a refuge. Pheasants live out their lives within a home range of about one square mile (640 acres), requiring all habitat components (nesting cover, brood habitat, winter cover and food plots) to be in close proximity. Ideally, a minimum of 30-60 acres (about 5-10 percent) of this range should be nesting cover. In this study, seeking to make a more comprehensive assessment of landscape connectivity, the core habitats and corridors will be identified according to the habitat type and dispersal distance of the focal species.

Material and Methods

The study area in this study is located in the two watersheds of Lahijan Chabaksar (49° 12′ to 50°05′ E, 37° 07′ to 37° 25′ N) and Astaneh- Kuchesfahan (50°21′ to 50° 26′ E, 37° 02′ to 37° 06′ N), in the east and center of Gilan province, respectively.

In the first step to classify the land cover in this study, the total Landsat 8 images in the period 01/01/2019 to 31/12/2019, which had a cloud cover below 10%, were used. Then, using Google Earth Engine and the products and instructions of vegetation index (NDVI) which related to the four seasons in 2019, urban lands, tree canopy cover to identify forest areas with trees height above 30 meters and finally the data removed from the ground and entered into the system by the user Land cover was classified into eight categories: forest land, rangeland, farmland, water, built up area, and tea farmland, garden and open space. According to the classified map of NDVI and land cover index and finally the identification of rangelands, gardens, forest lands with canopy cover less than 30%, agricultural lands and tea cultivation on the one hand and on the other hand considering the minimum area, elevation (Less than 1200 m above sea level) and slope (low to medium) required for the habitat of this species, the habitats of pheasant species in the region were identified. Then, MSPA analysis was used to form the ecological network and obtain core area. So forest land is extracted to be the foreground, and other land as the background, a series of image processing methods are used to divide the foreground into seven non-overlapping categories (namely, core, bridge, edge, branch, loop, islet and preformation), and then categories that are important for maintaining connectivity are identified, which increases the scientific nature of the ecological source and ecological corridor selection. The level of landscape connectivity in a region can quantitatively characterize whether a certain landscape type is suitable for species exchange and migration, which is of great significance for biodiversity protection and ecosystem balance. In this study, in the aspect of landscape connectivity evaluation, the integral index of connectivity (IIC), the probability of connectivity (PC), the delta of PC (dPC) and the delta of IIC (dIIC) are commonly used as the important indicators of landscape pattern and function, which can reflect well the degree of connection between core patches in the regional level and are calculated by Conefor 2.6 software. As the dispersal ability of different species varies, we assigned the dispersal distance 3.2 km and ring-necked pheasant, respectively. Finally, the top 8 patches with value of dPC above 4 were chosen as the most important habitats. The using least-cost path the corridors between them were determined. The least-cost path is often used to optimize a grid module. The resistance value of a grid describes its facilitating or impeding influences on dispersal processes of species. The resistance value is attached to each land cover unit to calculate the connectivity between two habitats (Table 1). The least-cost path model makes it possible to calculate the minimum cumulative link (corridors) between the target patch and the nearest source patch (habitat). We calculated the path of least resistance for the organism to migrate along and obtained the potential corridors between source patches using the "cost path" analysis in ArcGIS. The different resistance values of each land cover class were the key factors affecting the result.

Table 1. Landscape resistance value

Land Cover Class	Resistance Value	Land Cover Class	Resistance Value
Forest	1	farmland	5
Open space	30	tea farmland	10
rangeland	10	Built up area	1000
garden	20	water	100

Discussion of Results

According to the output of the classified map by Google Earth Engine, the largest area of the studied district is Hyrcanian forests and agricultural lands. In the studied area, pheasant habitat has been identified in areas that have appropriate slope and canopy cover percentage as well as the capability to provide a safe space for nesting and the potential to provide food for this species. It should be noted that due to land use changes over the past years and the forest spots destruction, pastures and agricultural lands, the habitat has been scattered irregularly. The ecological network modeling results of these habitats display that 6347.32 square kilometers of the studied area comprise pheasant habitat. The main areas, known as the habitat core, are concentrated in the central part of the region and north of the Hyrcanian forests with an almost connected spatial pattern. The number of main cores is relatively unequally distributed and accounts for 51.17% of the total network area. in this ecological network, bridges which act as connecting corridors and facilitate species migration among habitats, occupied 29.38812 hectares of the total habitat network. Of course, this type of structure is more visible in the western half of the region than the eastern one because of the core disintegration. Also, the holes inside the core of the habitats, accounting for 2.77% of the total network, demonstrate the relatively interconnected conditions of the core. The presence of islands as isolated spots that have no relation to other habitats in this area is very low and overall occupies 888.63 hectares of total area.In the next step, the results of Conefore 2.6 model, which is used to evaluate the connection of pheasant habitat core, shows the sum dPC and dIIC in the studied area is above 0.002, which indicates the existence of isolated and insignificant habitats in the area. As mentioned previously, the top 8 patches with a dPC value above 4 were selected as the most important habitats in this study as a field for further analysis. Cores 5100, 5224, 4657, 536 and 1314 have been selected as the most important habitat cores. Finally, the optimal corridors between the two habitats have been determined using the analysis method of minimum cost with considering a maximum distance of 3500 meters. Regarding to the resistance of land cover, these corridors with a length of 35.9 km, mainly forest lands or tea farms, are mixed with the pastures that have the ability to improve the desired ecological network (Figure1).

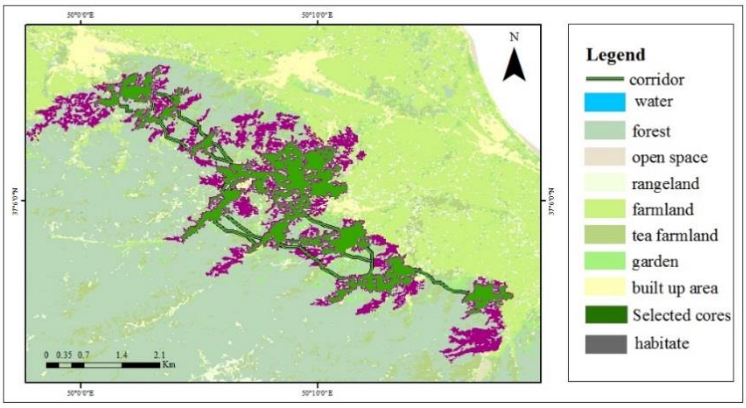

Figure 1. The most importance *Phasianus colchicus* habitats and potential corridors

Conclusion

In recent years, how to create ecological networks and plan to improve their structure has become a solution for habitat protection. Among the ecological network structure, corridors are one of the main components that facilitate species migration by increasing the structural continuity of habitats. In this study, a method based on constructing an ecological network rest on MSPA and graph theory (using Conefor 2.6 software) and analyzing the minimum cost to identify the ecological network, its coherence and improving its structure, is elucidated. The results of this study represent that a large part of the pheasant habitat is concentrated in a relatively good condition in point of continuity view, in the central part of the study area and north of the Hyrcanian forests. However, the existence of few bridges as corridors connecting habitats in this ecological network, along with the large number of cores, indicates the need of this network to scheme corridors by planners. In this research, after determining 8 habitat cores with high priority in the region that play a more significant and strategic role for network connectivity, important and optimal corridors were obtained to establish a connection between them. According to the findings, the method used in this work can be used in studies with different scales to identify potential corridors. This method is also efficient for habitats management according to the needs and sensitivity of the species, the resistance of each user and the ability of the species to move among habitats. In conclusion, it is suggested that besides preserving the bridges and loops in the ecological network, the proposed corridors as the best pheasant migration routes among habitat cores should be thoroughly examined and protected against cover changes. In addition, raising awareness of indigenous communities about aggress this species makes marginal and inter-habitat agricultural lands effective as stepping stones for pheasant migration.