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Connectivity Analysis for Green Infrastructure Restoration Planning on National Level

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Introduction

The green infrastructure idea has getting more and more importance in the last years research papers and planning guidelines (Rouse & Bunster-Ossa, 2013) (EEA, 2011). According to one of the first definition green infrastructure (GI) is an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas, greenways, parks and other conservation lands, farms, ranches and forests, wilderness areas and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life (Benedict & McMahon, 2000). According to the European Union's approach green infrastructure is not just a network, but on broader scale it is a theory addressing, the connectivity of ecosystems, their protection and the provision of ecosystem services, while also addressing mitigation and adaptation to climate change (EEA, 2011). It also emphasize that GI is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services, which incorporates green spaces and other physical features in terrestrial areas. (European Commission, 2013). Strategical studies (European Commission, 2014b) draw attention to the importance of restoration and connectivity planning.

Goals and objectives

According to EU Biodiversity Strategy under the Target 2, for year 2020, ecosystems and their services should be maintained and enhanced by establishing green infrastructure network and restoring at least 15 % of degraded ecosystems (European Commission, 2014a). This goal provides good possibilities for planners to help to reduce the fragmentation by connecting the most valuable ecosystems with green corridors (European Commission, 2014b). But where are these degraded ecosystems, missing connectivity gaps and areas need to be restored? Is there a way to model this connectivity planning on national level? The main question was in our research how can we help to locate these restoration areas and what kind of automatic GIS tool can be utilized on national level for connectivity analysis. The proposed methodology would help practitioners define a landscape GI network to identify areas where key habitats can be reconnected and the overall ecological quality of the area can be improved (European Commission, 2014b).

Method(s)

The national level GI restoration efforts would cover the whole country area totally 93000 km2 which is already quite large in size not to use GIS methods as first step in the analysation process. As a starting point we used the convenient and popular patch-corridor-matrix landscape ecological model (Forman & Godron, 1986), (Forman, 1995) which has provided good methodological background to analyse categorical map patterns. For planners and designers of green infrastructure systems this model was translated to "hub" or "node" model (Rouse & Bunster-Ossa, 2013). Hubs anchor green infrastructure networks and provide an origin or destination for wildlife and ecological processes moving to or through it. Links are the connections (corridors) that tie the system. This concept was used on regional level in the Maryland Green Infrastructure Assessment plan (Weber, 2003). Based on this examples we tested on national level this hub and link model. Technically the analysis were performed by Linkage Mapper (McRae, Shah, & Mohapatra, n.d.) which is an ArcGIS extension tool designed to support regional wildlife habitat connectivity analyses. Linkage Mapper uses GIS maps of core habitat areas (hubs) and resistances to identify and map linkages between hubs. Analysation requires a resistance map where each cell is attributed with a value reflecting the energetic cost, difficulty, or mortality risk of moving across that cell. Resistance values are determined by cell characteristic such as Corine land cover (Büttner et. al., 2006). As animals move away from specific core areas, cost-weighted distance analyses produce maps of total movement resistance accumulated (McRae et al., n.d.). Although different individual species have special distinct requirements on the permeability of the landscape, we accepted the idea to model this permeability with one global character value (terrestrial resistance). In Table 1. lower resistance value means higher permeability of the land uses. The resistances estimation was based on different expert studies (Weber, 2003),(Spear et. al., 2010) and our experiences.

Table 1. Land use resistances

Corine land use codes	Land use type groups	Resistance
3112, 3211, 3212, 4122	Broad-leaved forest, natural grasslands, peat bogs	5
3111, 3113, 3114, 3121, 3131, 3243,	Broad-leaved forest coniferous forests with continuous canopy, mixed forest, bushy woodlands, fresh-water, saline marshes,	10

4113, 5111, 5112, 3313	rivers, channels, river banks, natural regeneration areas	
3115, 3135, 3241	Plantations of broad-leaved forests, young stands and clear-cuts, mixed forests	15
2312	Intensive pastures, degraded grassland with trees and shrubs	20
2433, 2434, 3125, 3139	Agricultural areas with significant share of natural vegetation, ponds and with prevalence of scattered natural vegetation	20
2432, 3244, 3245	Agricultural areas with significant share of natural vegetation and with prevalence of grasslands, forest nurseries, damaged forests	25
2311, 2431, 2435	Intensive pastures, degraded grassland without trees and shrubs, agricultural areas with presence of scattered natural vegetation	30
2112, 222, 2222, 222, 2226, 2211, 2421, 51211, 51212, 5122, 51222	Arable land with small fields, orchards, berry fruit plantations, hop plantations, wild willow plantations, vineyards complex cultivation patterns, natural water bodies natural, temporary, salt affected water bodies, artificial lakes, reservoirs, fish ponds	40
211, 2121	Arable land with large fields, irrigated arable land	50
1411, 1412, 1421, 1422, 3332, 3333	Parks, cemeteries, sport facilities, leisure areas, sparse vegetation on sands	70
1242, 4121, 1423, 12112	Airports with grass surfaces of runways, explored peat bogs, recreation settlements, agro-industry	80
1232, 2131, 12113, 24221	River and lake ports, rice fields, education and health facilities, complex cultivation patterns	90
1122, 1123, 1212, 1221, 1222, 3321, 24222	Discontinuous built-op areas with family houses with gardens, road network, rail network, bare rocks, farmsteads	95
1111, 1112, 1121, 3341, 1233, 1234, 1241 1311, 1312, 1321, 1322, 1331, 12111, 2113	Areas of urban centres, ancient cores discountinuous built-up areas with multiflat houses, burnt areas, shipyards, sport and recreation ports, airports with artifical surfaces of runways open cast mines, quarries, solid, liquid waste dump sites, construction sites, industrial and commenrcial units greenhouses	100

The resistance map was made from CORINE land use map (FÖMI, 2006) on the scale 1:50.000 with 4 ha minimum mapping unit (Büttner et. al., 2006).

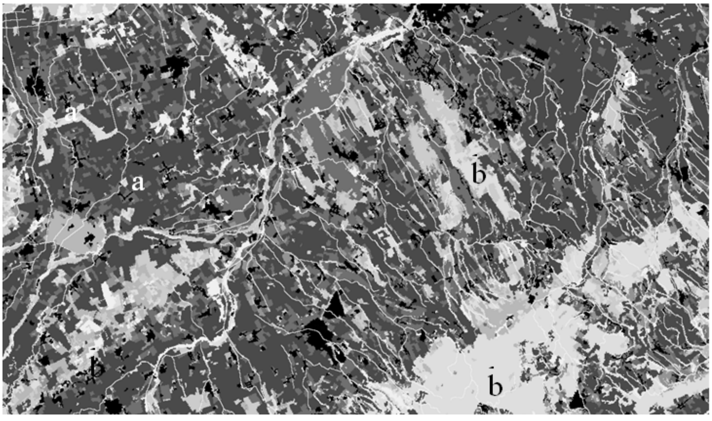

Figure 1. The resistance map

Analysis were performed on this raster data sets with 100-m spatial resolution. On Figure 1. darker shades means higher resistance (a), lighter shades smaller resistance (b) areas. Generally, each connectivity research starts with delineation of core areas, hubs from aerial imagery or remote sensing data. In our pilot study this first step were neglected, we used the existing boundaries of core areas of the national ecological map from National Structural Plan (OTrT, 2013). The main aim was the project to test the applicability of LinkageMapper automated corridor selection capabilities. Running the calculation process the software tried to find the least-cost-path (LCP) between two point (hubs). In the next phase, the results of the automatic corridor delineation was compared and checked by (1) the coincidence of existing ecological corridors (2), the actual land uses and (3), the landuse changes between years 2006 and 2012. The main aim of the comparison was to check the applicability of the methodology on regional, national level.

Results

The main result of corridor selection was the 6100 potential ecological corridor lines delineated on national level (Figure 2.). These corridors highlighted all the rough potential physical possibilities of a future network system, but lacked the detailed local surveys, assessments and restoration possibilities.

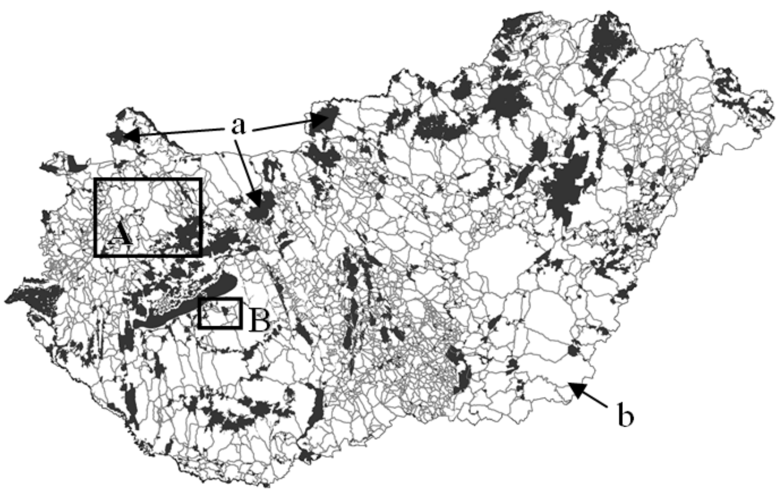

Figure 2. Core areas (a) with corridors (b)

On the next level the corridor lines was compared with existing land uses (Figure 3.). Black patches (a) are the fragmented core habitats, generally forested lands or pastures. (The forest rate is 21% in Hungary.) Gaps are agricultural, mined, or cleared lands within the green infrastructure network that could be targeted for restoration. Black lines (b) represent the potential corridor network. This level was also perfect for evaluate and eliminate the multiple connections (c) and simplify the networks system.

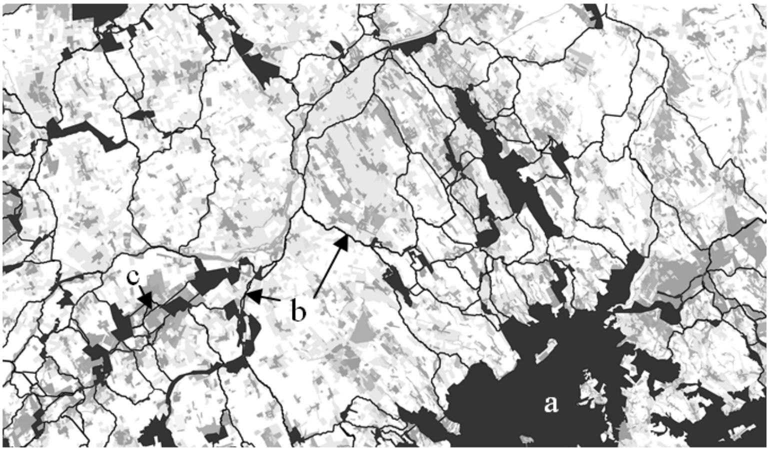

Figure 3. Core areas (a) with corridors (b)

In Figure 3. easily it can be recognised the large agricultural land and the fact the Hungary is one of the most tillaged land in Europe with its 46% cropland rate. This national scale research has provided good base in the delineation and restoration process for defining the main axis or channels of corridors on local level also (Figure 4.). In this detailed phase the rough corridor lines could be fine tuned to identify missing element, gaps of network on a parcel level (a).

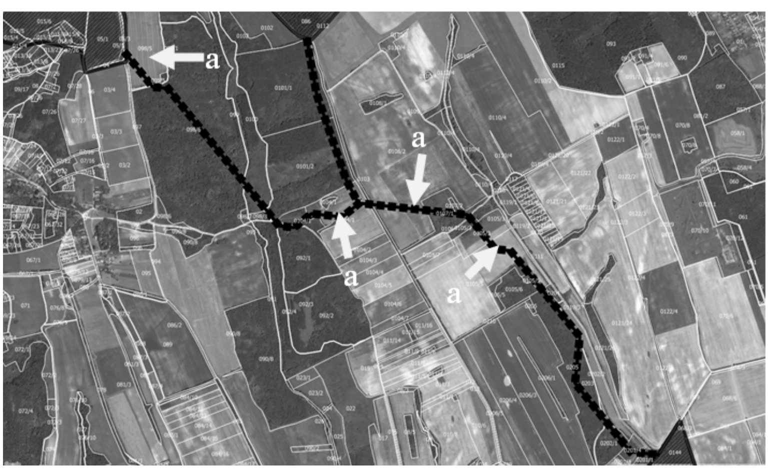

Figure 4. Core areas (hubs) with corridors and landuses

The missing connections of corridors elements (forested parcels, pastures) and intensive agricultural parcels can be easily recognised on the large scale maps. Because of the least-cost-path calculation can only locate slight centerline of the planned corridor, in the next step a 200 m wide buffer was generated around the line, where land uses and land use changes (2006-2012) were surveyed. Surveys of the present lands use shows that 33,8 % of the total lengths of the corridor is in agricultural usage which can be the target area of future corridor development. In the next step a comparison was made with CORINE land use change maps to identify/locate areas which has changed in the last couple years indicating the dynamic processes and stability of land uses along corridor lines. In this research more than 2800 location, in totally 130 km2 size of land use change was detected on this examined period (Figure 5. (a). Mostly these places are the least stable and dangerous areas where nature conservation would have priorities.

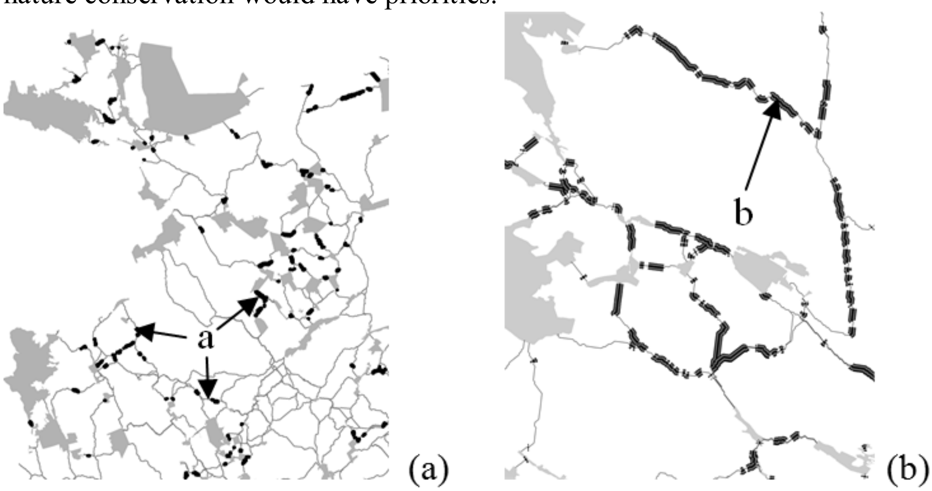

Figure 5. Detected land use changes along corridor between 2006-2012 (a) and corridor crossing agricultural land uses (b)

One of the most interesting analysation was to compare/validate the result of automated corridor selection with the manually defined corridors. On Figure 6. one can see that there is a good rate of overlapping between areas of existing corridors (grey) and the planned routes. The LCP modelled links not just followed the existing corridor areas, but was able to create new connections/links where core areas weren't previously existed. In the National Structural Plan the corridors were delineated only on the base of existing land uses without consideration of possible connections. In this way sometimes the important potential corridor linkages were missed from the network.

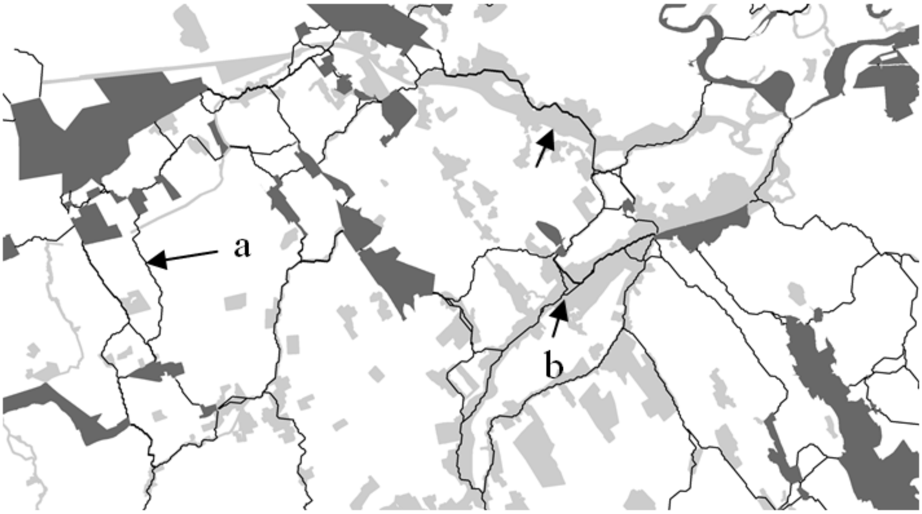

Figure 6. Comparison of planned (a) and existing corridors (b)

Discussion, conclusion

All of the three different comparison and validity checking ensured the usability of LCP method in the practice. On EU level Common Agricultural Policy and rural development provide instruments and measures to encourage GI and to enhance areas with a high nature value in the countryside. This applies to large-scale direct support for farmers, preventing land abandonment and fragmentation, and to smaller-scale measures supported through rural development programmes including agro-environmental measures (e.g. farmed landscape conservation measures, maintaining and enhancing hedgerows, buffer strips, terraces, dry walls, sylvo-pastoral measures etc.), (European Commission, 2013). In our research this new automated method helped to identify this potential ecological links on large scale and could provide tools for local level planning also. The ArcGIS LinkageMapper tool with combination of Corine land use map has demonstrated its capability and proved a good combination and solution in connectivity analysis.

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