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Multi-Functional Landscape Networks Identification by Impedance based Mapping Method: Two Case Studies at State Level Scale

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MULTIFUNCTIONALLANDSCAPENETWORKSIDENTIFICATIONBYIMPEDANCEBASEDMAPPINGMETHODTWOCASESTUDIESATSTATELEVELSCALE

Strictly as per the compliance and regulations of:

Multi-Functional Landscape Networks Identification by Impedance based Mapping Method: Two Case Studies at State Level Scale

Sawsan Mohamed [α] & Dr. Rer. Nat. hans-georg schwarz-V. raumer [σ]

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I. Introduction

a) Background and Objectives

To understand and to develop landscapes at a regional scale it is not enough to consider landscape as a mosaic of different land-cover, land-use or ecosystems. Landscape ecology but also regional geography emphasize, that we have to think about landscape in terms of spatial relationship, linkages and exchange. The conceptual framework for landscape cognition and thus for landscape development must - besides a spatio-dynamic view - include a perspective of network thinking. This kind of thinking reflects universal principles of spatial organization, and recently culminates in the debate and promotion of Green Infrastructure (GI) as a target for comprehensive spatial planning and as an appropriate idea for sustainable and resilient spatial structures. Landscape network thinking breaks with a choropleth model of landscape units when addressing and describing landscapes, and suggests a spatial model separating nodes or hubs from linkages or corridors, both delineated from a background on which the network is drawn as a figure (see fig. 1).

As implied, the intention of introducing the idea of landscape networks is a constructive lay down of a planning vision, and there are several reasons to prefer landscape network delineation. In general a first reason is to enable exchange between hubs. A second - related to the first – is to support function and preservation of hubs. In our study the following backgrounds are identified in particular:

This two contrasting types of intentions to think about landscape networks, provokes by presenting two different examples for what the meaning of landscape network thinking can be. However, the aim is to sketch the universality of a proposed methodological framework, and try to present the comparison of two geographically completely different regions brings up a wider range of methodological particularities inherent to the suggested approach of landscape network thinking.

So the target of this article is to discuss a unified methodology for multifunctional landscape network modelling and to demonstrate with different case studies its successful application. The method developed called, Impedance Based Network Mapping and apply it in two different research studies at the same spatial scale. The first research, applied the method for developing multi-functional green corridors that enhance preservation of biodiversity and geodiversity as well as conservation of landscape heritage and historic environment in Kurdistan Region (Mohamed 2011). The second research investigates the degree of dissection of landscape corridors at state level in Baden-Württemberg (Mohamed 2011). The different case studies can't be highlighted as an elaborated geographical comparative study but rather as an evidence of visibility and applicability of the method at supra-regional scale regardless to the distinctive and different natural and cultural resources and characteristics of each research area.

b) Kurdistan Region (KR)

One of the fundamental consequences of urbanization can be found in the loss of permeability of open space due to the development of settlement networks and urban growth. Ecological (e.g. bio-

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connectivity, remoteness, air exchange and uncontaminated soils and water) as well as other landscape qualities and services like suitability for recreation, cultural and agricultural functions or visual integrity, are affected by the landscape being dissected with roads, settlements and other infrastructure facilities. At a national scale, there was no legislation on biodiversity preservation areas till 2013. None the less the protection of natural preservation areas called Protected Areas (as isolated island) was a common practice without regulatory background in some areas in Kurdistan since the 1960s. At both national and regional scale managing manmade landscape (forest, agricultural habitat, fishery and etc.) was regulated by urban development restriction and limitation laws since the 1970s and by environmental laws since 1997. At a national scale a new institutional framework is developed for managing Natural Protected Areas in 2009 by the Ministry of Environment. At a regional scale since 2008 the Law of Environmental Protection and Improvement is issued and the protection of natural biodiversity areas is included. This was a natural outcome of the rapid economical and touristic development, due to high landscape qualities and recreation services in the heart of those rich biodiversity areas, since 1998 in KR. The rules - also as an adaption response to climate change and migratory policy for preventing desertification - include the construction policy of developing gardens, natural protective areas and general parks, and maintain natural sites which have an extensive heritage. Up to now there is no clear planning practice or regulation, neither at the national nor at the regional scale, covering ecological exchange or ecological network coherence. Moreover the Natural Protected Areas are identified but preservation and protection measures are rarely implemented.

c) Baden-Württemberg (BW)

Urban growth and and particularly transportation infrastructure development are the main cause of dissection, loss of permeability and visual integrity in landscape network. So in large parts of BW responding to urbanization and densification of the settlement network an appropriate counter-structure must be defined. For decades it was enough to think in patterns of scattered islands for preservation of valuable landscapes and for preserving big areas sufficient in size and lack of disturbance. In Germany e.g. areas of 100 km² which are nearly undisturbed by traffic had and still have an important role in national policy and planning guidelines. These areas nowadays got the role of hubs in migration networks for rare mammals.

d) Relevant Approaches

Since Wilson and Willis (1975) theories of equilibrium island biogeography, meta population, the ecological coherence and its integrity are under investigation. It has been proven that isolated reserves as self-contained independent entities are not enough for biodiversity and population conservation regardless to the intensity of management and protection measures (Bennett and Mulongoy 2006). Since then streams of research investigating and examining the connections among patches at landscape scale were developed: starting with the traditional ecological practice in late 1970s (Wilson and Willis 1975), continued by approaches which combine landscape structure, function, and dynamic pattern and in which ecological flow systems are highlighted in the 1980s and early 1990s (Forman 1983, Harms and Forman, 1989, Holland et al. 1991, Wiens 1992, Dramstad et al. 1996, Puth and Wilson 2001), and then being proceeded up to recent years by suggesting supra-regional and supra-national ecological networks following the idea of a patch-corridor structure within a broader landscape matrix (Bennett 1991, Smith and Maltby 2003, Bennett 2004, Böttcher et al. 2005, IUCN 2005, Bennett and Mulongoy 2006, (Schwarz-v.Raumer and Esswein 2010). sometimes extended by the classification of buffers and links (Fig. 1).

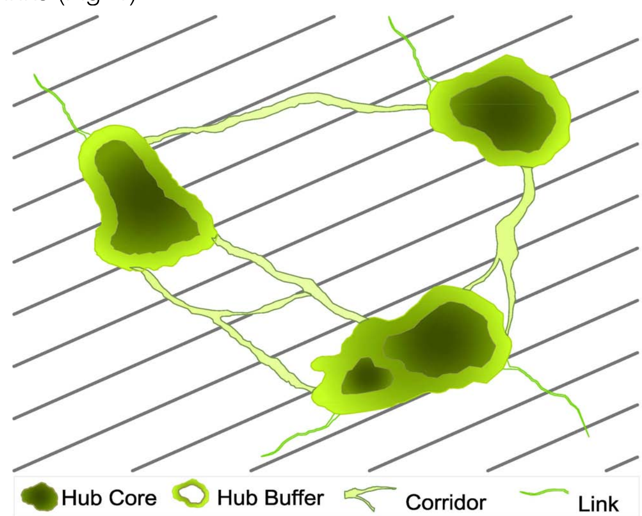


Fig. 1: General structure of ecological networks

In parallel to the growing idea of ecological networks, fragmentation and connectivity got a focus of landscape related ecology. The anthropogenic alteration of the landscape mosaic by urban development, transportation and other infrastructures as well as large scale agriculture practiced on big and intensively used plots or homogeneous afforestation using non-native species, landscapes and corridors have been fragmented, dissected, lost and/or modified (Loney and Hobbs 1991, Forman 1995). Ecological connectivity, defined by Taylor et al. (1993) as the degree to which the landscape facilitates or impedes movement among resource patches, is - besides eco-integrity – identified as the most significant feature for biodiversity preservation that enhances resiliency, population, community, and ecosystem processes (Noss and Coperrider 1994, Gilbert-Norton et al. 2010, Pino and Marull 2012).

Three basic concepts indicate eco-connectivity and its effectivity at regional and supra-regional scale: (1) GIS based mapping, (2) considerations about permeability depending on dissection and fragmentation and (3) approaches that take the perspective of moving individuals and evaluate landscapes based on specific preferences.

e) GIS based Mapping

The utilization and application of GIS in environmental planning and natural resource management has proved successful application since early 1990s (Lathrop and Bognar 1998). The classical application of GIS leads to Green Infrastructure (GI) or ecosystem mapping and traditional ecological practice for biodiversity conservation (e.g. site selection process for habitats) often supported by overlaying and buffering of different thematic layers (Lathrop and Bognar 1998, Hoctor et al. 2000, Wickham et al. 2011).

f) Permeability Indication

Within the field of permeability concepts which evaluate quantitatively landscape fragmentation and the degree of permeability, the measurement ´effective mesh size´ developed by Jaeger (2000) and applied for different case study areas at supra-regional scale (Jaeger 2000, Esswein and et al. 2002, Roedenbeck et al. 2005, Moser et al. 2007, Girvetz and et al. 2008) got prominent. The fragmentation geometry is identified by the specification of the landscape elements that cause dissection. Another method to identify permeability comes from approaches like Morphological Spatial Pattern Analysis (MSPA), the morphological analysis by geometrical analysis of morphological pattern that incorporate land-cover change information. It identifies hubs and links by - based on mathematical equations - creating related structural classes and creates the spatial relationship within the features of the single land-cover (Wickham et al. 2011).

g) Movement based Approaches

Beside individual-based simulations (DeAngelis and Grimm 2014) the application of least cost path technique for landscape fragmentation studies, structural and/or functional connectivity analyses, corridor delineation, scenario building and land management decision support is widely used (Walker et al. 1997, Tischendorf et al. 2000, Adriaensen et al. 2002, Schadt et al. 2002, Nikolakaki 2003, Mikel et al. 2010, Pino and Marull 2012, Rudnik et al. 2012). Here hub or habitat patch connectivity within a landscape matrix is evaluated by the calculation of cost function assigned to moving organisms as an effective or functional distance e.g. between the hubs within the network (Moilanen and Hanski 2001 and Adriaensen et al. 2002).

h) Methodology for the Case Studies

To delineate a multifunctional landscape network, using a method which allows considerations on movement and exchange is suggested. As a conceptual framework the widely accepted network structure of hubs and corridors is taken. But to ensure patency (low degree of dissection or obstruction) of the corridors connecting the hubs, least cost path method is adopted. To emphasize this, the approach indicated by Impedance Based Network Mapping, and as a master approach for the identification of a multifunctional landscape network, five step methodology is developed:

lay down of a multifunctionality concept

- hub identification
- impedance definition
- corridor delineation
- mapping and analysing

The result of the Impedance Based Network Mapping method is to create visibility of a spatial network structure which is able to support migratory but also resilience purposes. The resulting network map reflects multifunctional ecosystem benefits from hubs and linkages and can serve as a spatial guide for decisions on biodiversity, landscape and/or heritage conservation as well as on adaption measures.

II. Case Study I: Kurdistan Region

a) Case Study Area

The case study area “Kurdistan Region” (KR) is located between 32°57′N and 37°22′N and 41°17′E and 46°20′ E and contains all the administrative territory of “Kurdistan Region in Iraq” broaden by an extension. KR comprises an area of 48,435 km2 and its population is estimated by 6,657,277 inhabitants. The region is geographically diverse. Following the geological formations three major morphologic units - mountainous ranges (Zagros Mountain chain), foothill pediments and agricultural plains - can be identified. The topography of KR varies between 250 m and 3600 m above sea level. Topographically KR is divided into three main zones – plain, semi-mountainous and mountainous zone – in which climate varies from hot and dry plains to cooler mountainous areas.

One of the severe ecosystem changes as a human footprint consists in the fragmentation and destruction of natural forests. Human overexploitations of the natural forests, as well as shifting cultivation and uncontrolled grazing have denuded large areas of the natural forests. According to Chapman (1959) in 1957 the forest covered 60% of the mountainous region, decreasing to only 18% in 2009 (Mohamed 2011). This contributed significantly to the general decline of original forest cover in Iraq from 13% down to 2% in 2003 (Earth Trend 2010a).

Moreover there is loss of heterogeneity in agricultural landscapes. Earth Trend (2010b) reported 22,59 % decline of “Agricultural Lands Experiencing Greenness” in the period 1980 to 2003. In general the natural and managed land covers of KR have been shifted dramatically within half of a century as Fig. 2 illustrates.

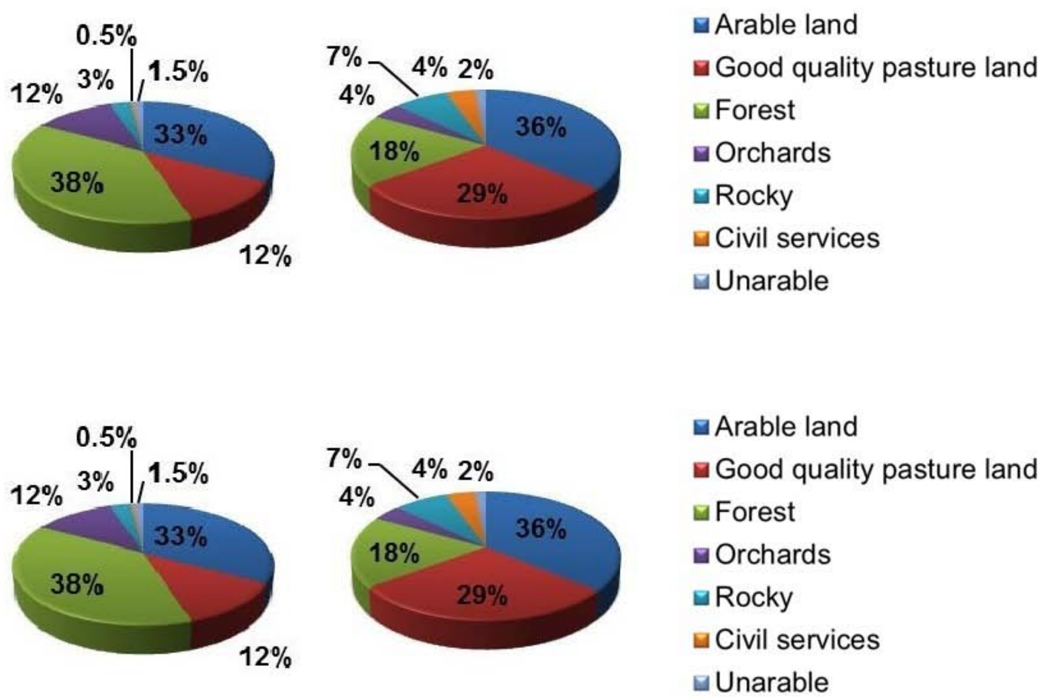


Fig. 2: Land use by type in KR for years 1947 (Chapman 1959) and 2000 (FAO 2003) Addopted from (Mohamed 2011)

The counter effect of war and political conflicts, and due to the fact that significant parts of KR is located in the mountainous area, urban development - the common expected cause of fragmentation of the biotic natural resources - was limited. However the destruction of rural landscape and natural landscape mosaic due to deliberate political decision caused fragmentation per se and due to infrastructural network development (Fig. 3).

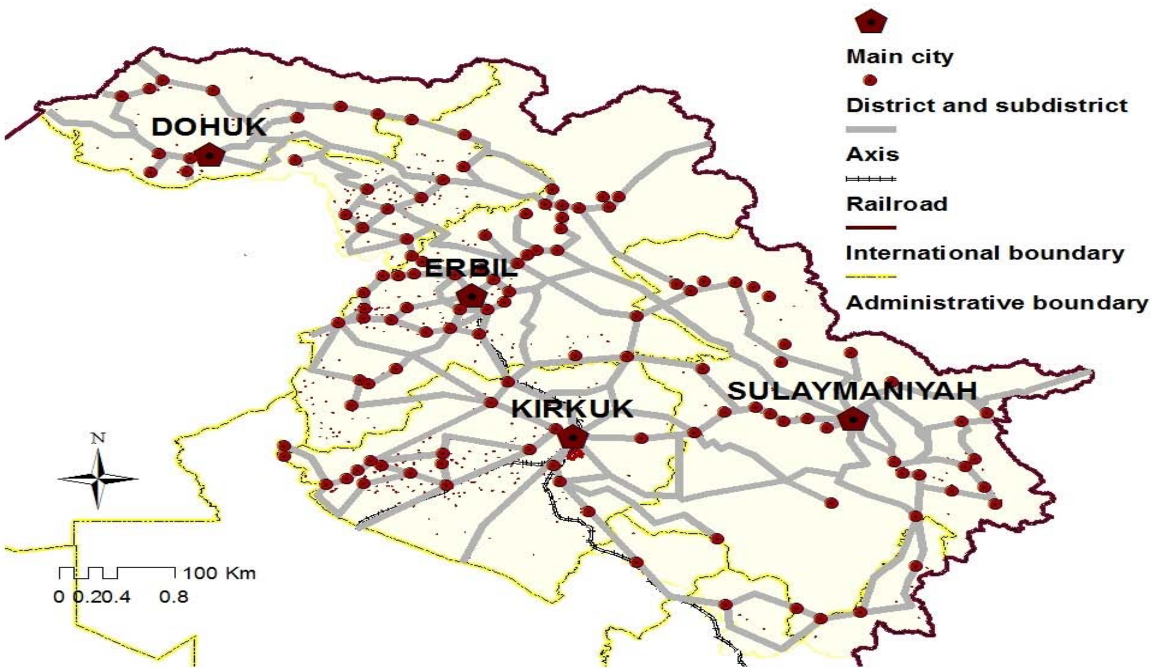


Fig. 3: Settlements, road and railroad infrastructures in the case study area KR

Compared to the whole Iraq KR is characterized rather as a rich region concerning the natural environment and in terms of the share of ecosystem services and biodiversity resources. In addition the KR is characterized as having a significant importance from the scenic landscape perspective which is intensified by a rich historic environment and cultural heritage. The historical sites are from a wide span of time starting from Middle Paleolithic period (the era of Neanderthals and cave dwelling, e.g. Shanader cave) and followed by early agricultural civilization in the plain region (e.g. 6750 BC at Jarmo) or by formal settlements (e.g. Erbil Citadel 7000 ago). This unique combination of human legacy and civilization of humankind is one of upmost important in terms of cultural heritage. Here preservation targets have to respect not only a local legacy, KR is belonging to the historic heritage of humankind as a whole being a vivid museum of civilization. The intention of the identification of landscape network for the KR is to combine this extraordinary cultural and historic importance of the region with its natural landscape potentials concerning biodiversity and scenic value.

b) Multifunctionality Concept

The development of a landscape network plan using Impedance Based Network Mapping method is highly dependent on the concept of emphasis of different ecosystem functions in addition to targets concerning biodiversity conservation. The significantly important ecosystem services, i.e. provisioning services, regulating services and cultural services, are to be maintained by a developed landscape network plan consequently. For KR biodiversity preservation, landscape heritage and historic environment conservation, scenic landscape quality and managing hydrology are identified as ecosystem services to be addressed. The developed plan aimed to identify the regional resources, by creating ecological infrastructure base map, then developing a concept for integrating and connecting these ecosystem resources spatially. It is to preserve and restore the ecological and cultural landscape diversity and its values within natural semi-natural and agricultural landscape.

The ecological network concept for maintaining biodiversity can be achieved by connecting and integration of conservation areas or areas with significant biodiversity through landscape corridors and links. Naveh (1995) demonstrates in the “green book” the importance of conservation of landscapes and environmental features, in parallel to traditional natural conservation and the species red list. Mander and et al. (2007) recommends establishing a link between biodiversity and cultural diversity to achieve ecological heterogeneity, in multi-functional landscape. Both concepts had been followed in defining corridors. Explicit spatial allocation by using the Impedance Based Mapping Method for the cores and corridors are applied at regional scale.

c) Hub Identification and Hub Buffer Zones

Benedict and McMahon (2003) define hub patches as “anchor green infrastructure networks and provide an origin or destination for wildlife and ecological processes moving to or through it”. That is why, the areas of high value of biodiversity and ecological process has been taken as targeted category for hub identification. Sensitive wildlife habitat areas can be identified mainly from Key Biodiversity Survey of Kurdistan provided by Nature Iraq (Ararat and et al. 2008). The Key Biodiversity Areas (KBAs) are defined as "sites that are large enough, or sufficiently interconnected, to support viable populations of the species to which they are important". The KBAs selection process (done by expert Richard Porter together with Bird Life International, an NGO association for nature conservation in the Middle East) uses a set of four criteria based on the presence of four categories of species for which site-scale conservation is appropriate. The criteria are (1) globally threatened species, (2) assemblages of restricted-range species, (3) congregations of species that concentrate in large numbers at particular sites during some stage in their life cycle and (4) assemblages of biome-restricted assemblages (Ararat and et al. 2008 and Ararat 2009).

In addition to the KBA Kurdistan-list, additional areas of biodiversity richness (from the KBA Marshland-list) together with concentrations of important areas for water and aquifer management are considered as a hub core (e.g. Hawija marsh which is identified by Bird Life International as a significant habitat for birds) (Mohamed 2011).

Hub buffer zones were defined around the core areas as a mitigation zone against fragmenting effects of developments on the edges of the core areas and enhancing the ecosystem services provided by the cores. Although buffer zones and its width should be designed on a case-by-case and site-by-site basis (Brown and et al. 1990 and Martino 2001) following the requirements of specific functionalities and spatial intensities, but a constant buffer zone of 1 km is suggested as an appropriate all requirements overarching neighborhood.

d) Impedance Definition

To develop a network of corridors between the hubs and to maximize the benefit in respect to multi-functionality including eco-connectivity and eco-integrity an impedance layer as a result of GIS-overlay procedures was generated. Based on a GI typology as well as mapping and analysing ecosystem resources, cultural and natural resources and landscape elements and components a set of nine indicators have been used to develop an impedance surface value covering the KR (impedance raster layer). The indicators that are identified to give input to the surface value for delaminating the corridors are considered as planning decision indicators and separated in two groups.

The ArcGIS-Toolbox utilities 'cost distance', 'least cost path' and 'corridor' are used for corridor delineation using a final impedance layer. The least cost algorithm is used as the cumulative cost calculation to reach destination cells and the location of paths and corridors having minimum cost when balancing cost for each cell crossed from the source cell to destination cell. In the application of least cost technique two main raster based layers are needed, the source layer (in which the hubs are identified) and the friction/resistance/impedance layer which is used for cost calculation. In other research applications the value of resistance grid cell layer is mostly derived from the land cover type (e.g. Adriaensen and et al. 2002) or from altitude and flow rate (Michels and et al. 2001). In the course this research the cost layers used are called "impedance layer" to emphasize that landscape connectivity is addressed as a degree to which the landscape facilitates movement. Also the impedance layer redefined to include not only land cover but also natural and cultural heritage, water and other ecosystem resources.

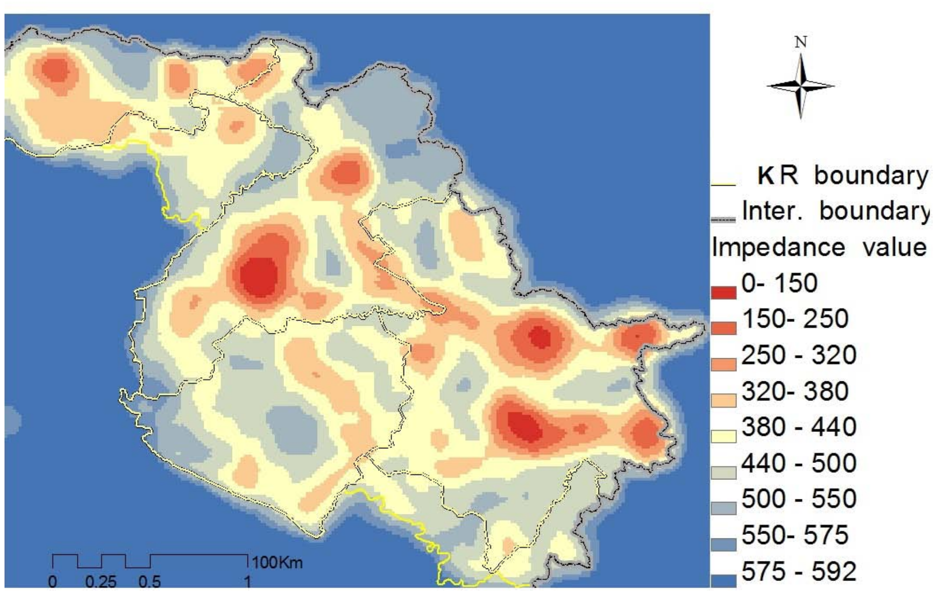
The first set A consists of six attraction-by-density indicators (Table 1). Density of these elements is considered as inversely proportional to impedance and the corridors are designed in the aim to pass through the more dense area. The second set B of attraction/avoidance-by-distance indicators has been used with the same basic principal with the difference in defining impedance by Euclidean distance. This gives surface value to the identified set of parameters based on closest proximity from the sources.

Table 1: Landscape elements leading to impedance definition

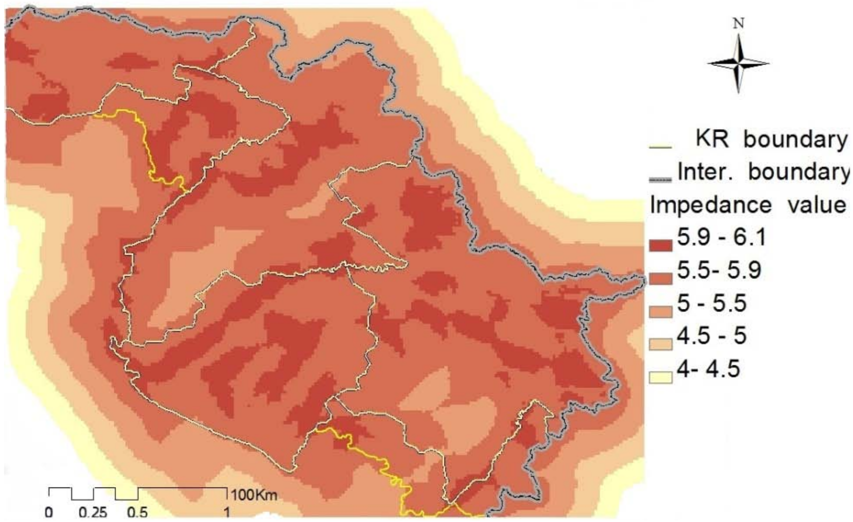
Set	Landscape Element	Effect for impedance [a]
A	Mound site [b]	Cultural heritage (–)
	Historical site	Cultural heritage (–)
	Landscape of high value	Attraction for tourism and as an ecological infrastructure (–)
	Karez [c]	Water supply and cultural heritage (–)
	Streams	Water resource management at watershed level and as an ecological infrastructure (–)
	Flood zone	Water resource management at watershed level (–)
B	River	Water resource management at watershed level and as an ecological infrastructure (–)
	Road	Anthropogenic dissection (+)
	Buildup area	Anthropogenic dissection (+)

[a] increase (+) or decrease (–), [b] artificial hill for human settlement, [c] subterranean aqueduct

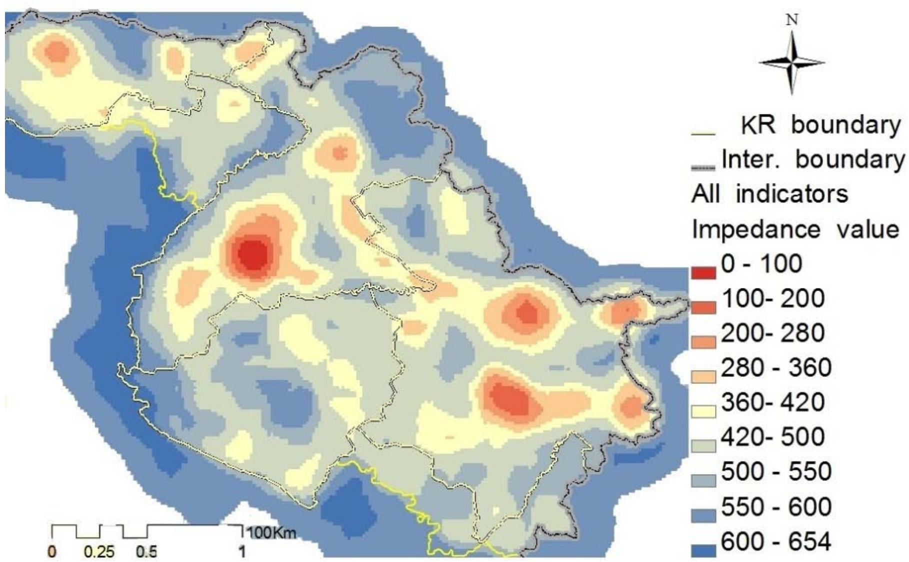
Following Tomlin (1990) a cell-by-cell aggregation has been applied. Instead of using local maximum method - in which the most constraining value at a raster cell is assigned to develop the attraction/resistance surface - a compensation accepting method in which all indicators contribute to the impedance values by equal weight is applied. So for each set of identified indicators the indicators have been equally weighted summed up by using an appropriate raster algebra function in GIS (Fig. 4a,b). To combine both sets of parameters (resulting from different analytical functions and processing steps) a normalization of scales have been applied before finally overlaying the aggregations of the two sets for the impedance map shown in Fig. 4c.



(a)



(b)



(c)

Fig. 4: Impedance map a) from set A, b) from set B and c) from overlay. Adapted from (Mohamed 2011).

e) Corridor Delineation

Different GI elements with high potential of conversation, preservation and cultural/historic/ recreational values exist in the KR and are used for a multifunctional definition of ecosystem network which respects economic feasibility and ethical responsibility. Thus corridor identification will not be exclusively bounded to wildlife movement and biodiversity conservation. To achieve a multifunctional network the corridor concept in the context here is designed to achieve the aim of conservation, preservation protection and restoration of ecosystem resources in comprehensive meaning including biodiversity and management of cultural, historic, recreational and water resources.

To identify the corridors path the impedance layer has been used as a cost raster to give weighted value for the identification between pairwise different sets of patches as source and destination (start/target). Then a threshold is set, and the accumulation of cells less than the threshold are identified as area for delineating the corridors.

f) Result and Discussion

After identifying hubs and corridors between the different hub patches multifunctional network that consist of hub, core and corridor have been developed. Fig. 5 shows the network. The corridor is identified from both the ecological infrastructure and the landscape perspective to deliver different ecosystem services, including landscape linkages (linear and non-linear), recreational routes (so called greenways) and entire ecological networks (Bennett 2006).

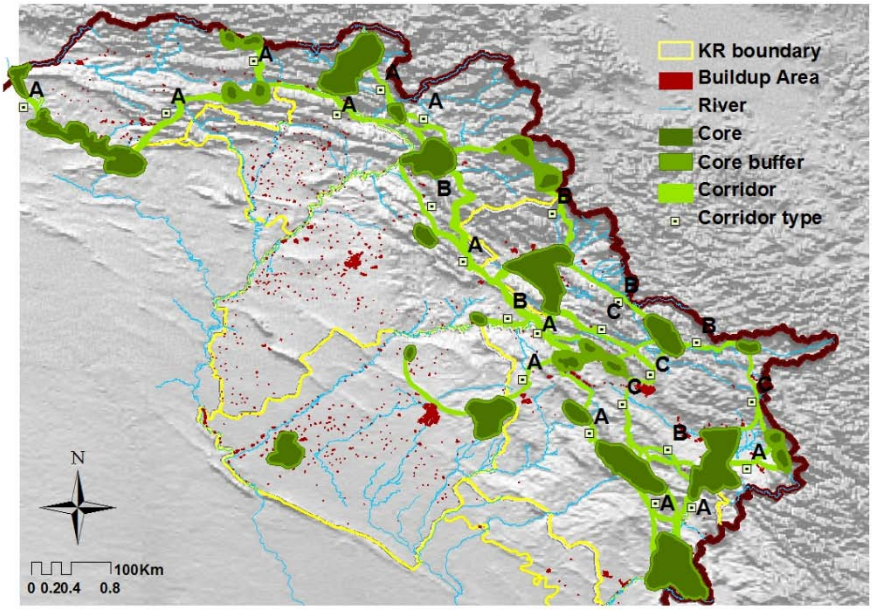


Fig. 5: Landscape network for the KR case study area that consist of hub cores and buffers, corridors and links. Adapted from (Mohamed 2011).

Although each corridor may have one or more functionalities, but the dominant function which is important to perform is identified and assigned to the corridor. For example some designed corridors are acting as a riparian buffer for the existing surface water (rivers). In Fig. 7 three main categories are identified: (A) wild life movement function, (B) Conservation function and (C) landscape function. When connecting hubs like KBA Maidan and Barzan - which have been identified as a hot spot in gap analysis for connectivity and integration (Mohamed 2011). the corridor is designed as category (A). Here wild life movement as mitigation and adaptation for climate change - particularly increase in temperature - can take place.

To validate the applicability of the Impedance Based Mapping Method and the effectiveness of identified parameters for corridor delineation and proposed network, the coincidence analysis is carried out by overlaying plan on the natural resources, land cover and natural ecosystem. A set of five main layers namely Land cover, Watershed, Karst, Soil type and Land limitation have been developed with further detailed Sub-classification. The proposed network set against each layer for analyzing the visibility. The identified corridor and core are located on areas 72% and 61% correspondently within areas presently vegetated. Also they have located on areas with soil type 82% and 71% is suitable for forestry area. The finding also suggested that the proposed plan have no salinity or low rainfall or rocky area. While watershed and Karst layer is covered with a high intensity. The delineated corridors and core hubs are covering 94% to 81 % of formally forest, agroforest or vegetated mosaics.

III. Case Study II: Baden-Württemberg

a) Case Study Area

Baden-Württemberg (BW) is a federal state of the Federal Republic of Germany situated in the southwest of Germany. The territory of BW covers 35.751 km² and is populated by 10,8 millions of inhabitants (BW 2015). In Baden-Württemberg we find 4 main types of landscapes. Beside the urban and suburban fabric and broad deciduous, coniferous and mixed forests, hilly and mountainous areas are covered by a more or less diverse pattern of small woods, grassland and arable land endowed with more or less densely dispersed structuring biotopes. In addition, river floodplains provide other specialized habitat.

There is a big urbanized/suburbanized area in the center and the northwestern sector of the state territory (Mannheim/ Karlsruhe/ Stuttgart/ Heilbronn) supplemented by existing and upcoming urban centers (Fig. 6). Physical planning tries to organize urban development and urban growth following a network structure of development centers and axes (Fig. 6) which also indicates the main network of dissection and fragmentation pressure for open space areas left.

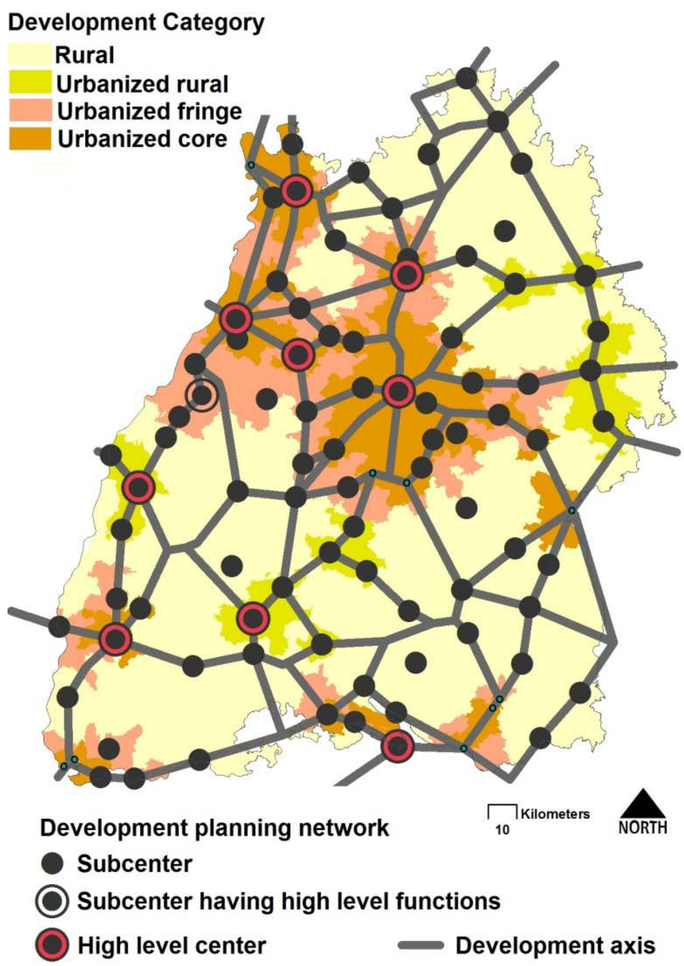


Fig. 6: Urbanized areas and development centers and axes in the state of Baden-Württemberg. Map generated from GIS data provided by State Agency LUBW according to WMBW (2002)

Jaeger et al (2007) have analyzed the temporal development of landscape dissection using the indicator Effective Meshsize. A decline of this indicator from 29 km² in the 1930s down to 13 km² in 2004 indicates a massive loss in permeability of landscapes in Baden-Württemberg. There is a concentration of this loss in the areas of high urbanization and we must state that the remaining permeable islands solely consist of the mountainous areas of the Black Forest and in the Sweabean Alb.

b) *Multifunctionality Concept*

As stated in the introduction, from a comprehensive landscape perspective there is a need to preserve natural landscape networks e.g. to establish a web of resilience against disturbance from transformations in the urbanized and urbanizing areas. Landscape networks often are defined from a single mostly bio-connectivity driven intention. But when arguing that the network should be ready to provide resilience services on a wide range of transformation impacts the definition of a landscape network must follow comprehensive principles. At the moment two of such principles are worth to follow: (1) either we have a complete survey of ecosystem services relevant for the task of the network and we then take that survey as a guiding background, or (2) we find one or a small number of universal indicators supporting the delineation of the network. For the case study of Baden-Württemberg we tried to take landscape dissection as a leading indicator, assuming that areas of low dissection by settlement and transportation infrastructures have a low anthropogenic disturbance, a high permeability and thus are universally predestined for preservation and resilience in regard to a lot of landscape functions (which has to be shown and proved).

c) *Hub Identification*

Hub identification goes back to the category of UZVR (as explained in the introduction) which is a well-established policy to preserve undisturbed open space being bigger than 100 km² in size. The borders of these units are generated by the combination of roads having a traffic volume of more than 1000 vehicles/day, railways, settlement and other anthropogenic structures. Considered as big un-dissected areas they should be preserved from further urban and transportation development. The State agency of environment (LUBW) as well as nature conservation NGOs are aware of the importance of those relicts and emphasize their contribution to biodiversity, recreation and clean air production. Fig. 7 shows the location and the spatial distribution of the units which here are considered as hubs. From the historic and recent suitabilities for settlement development their existence is linked to mountainous areas, but also to former and recent military use. Whereas in the area of the black forest woodland covers more or less completely the hubs, in the region of the Swaebean Alb they consist of hilly open landscapes mixed with forest.

d) Impedance Definition

Impedance was defined in the case study by a GIS procedure which uses the method of Effective Meshsize (meff) calculation (Jaeger 2000). Effective Meshsize measures the degree of landscape dissection by analysing a network which consists of meshes built up from settlement edges, roads and other anthropogenic linear elements which must be considered as reducing permeability and connectivity of extra-urban land. The bigger the meshes the higher meff is calculated by Eq. 1, in which the choice to calculate the square of mesh-area results from probabilistic considerations on the chance of a meeting of two individuals or the chance that a randomly fixed pathway crosses a border of a mesh.

Eq. 1

$$\boldsymbol{meff} = \left(\sum_{j=1}^{n} \boldsymbol{Aj}^2 \right) / \boldsymbol{Ar}$$

Region r divided into n meshes,

- A_j denotes area of mesh j $\in \{1,\ldots,n\}$,
- A_r denotes the area of the region

To get an impedance surface indicating the local permeability in terms of the meff-concept a regular lattice of points was generated and for each point the dissection of a radial 3km-neighborhood was calculated using Eq. 1. In a second step the result of the calculation at the points in the lattice was interpolated to get a continuous surface of local permeability. This meff-surface (Fig. 7) then can be interpreted as a spatially continuous impedance layer and can be used as an input for corridor delineation.

e) Corridor Delineation

Each corridor analysis needs a couple of start/target patches. A direct solution is (1) to take each hub of the set of hubs, (2) to extent this set of start/target locations with external locations to allow that the procedure delineates corridors to touch the borders of the area of interest and then (3) to connect each hub location with the other hubs. Practice shows, that not all hubs must be included in the analysis due to some hubs being automatically included. Fig. 7 shows the selected start/target locations used in the analysis.

The delineation of corridors between the start/target locations then was done using the ArcToolbox utilities 'cost distance' and 'corridor' and by the help of an ArcMap-Extension (Lang et al. 2008). The impedance surface generated as described above was used as cost layer for the corridor definition.

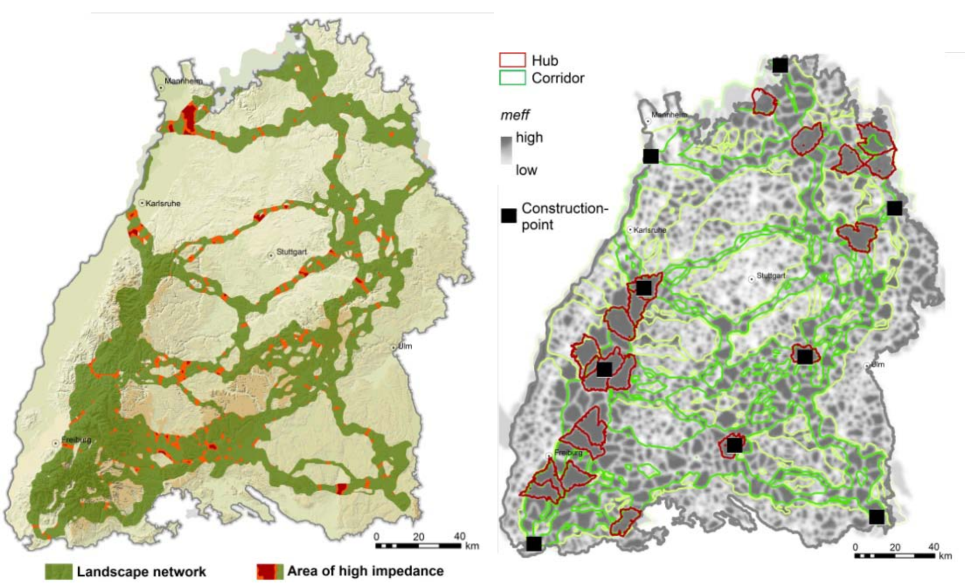


Fig. 7: Impedance surface, hubs and corridor generation points for the BW case study (left), and hot spots of obstruction (highly dissected areas / very low Effective Meshsize meff) (right) (adapted from XXX)

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f) Result and Discussion

Combining all corridor calculations and the start/target-meshes we get a system of corridors built up from relatively low dissected area connecting big un-dissected areas. We call this system of hubs and corridors "resilience network". The network indicates the location of undisturbed hubs and it gives an orientation for preserving areas which have the function of linking the hubs and being recommended to keep free from further reduction of permeability. Fig. 7 shows the result.

Fig. 7 also indicates hot spots of fragmentation inside the network, where the permeability is extremely low or blocked. These hotspots should be of high preference in the set-up of measures for rehabilitation of permeability e.g. by green bridges, traffic regulation or enhancing green infrastructures in settlements.

To qualify the landscape network we did some coincidence analysis by overlays with existing nation-wide corridor systems. The so called " Wild Cat Corridors" suggested by the NGO Friends Of The Earth (www.bund.de/wildcat) are covered very well by our corridor network (Schwarz-v.Raumer & Esswein 2010) and shows a good accordance in the Black Forest and the Swabian Alb. The habitat corridors ("Lebensraumkorridore") propagated by the German Federal Agency for Nature Conservation (Böttcher and Reck 2005) suggest three types of habitat corridors which can be compared to the network designed here: (1) The habitat network for species of forests and partly open landscapes is widely covered by the suggested network due to the coverage of big meshes by forests. (2) The habitat network for species of river valleys with humid and dry habitats cannot be considered from a conceptual point of view. (3) The habitat network for species of dry landscapes which covers the Swabian Alb is nearly congruent with our network. However in other regions (e.g. along the rivers "Murr" and "Rems") the network not existing there indicates the habitat network "Lebensraumkorridore" being highly fragmented.

A second analysis (Schwarz-v.Raumer & Esswein 2010) shows that (a) high value habitat structures can be found concentrated inside the network as well as (b) biotopes predestined for being included in a local biotope network and (c) Special Protection Areas (SPA) which are identical to bird protection areas as a part of the EU-wide natura2000 protection areas.

IV. Overall Discussion

Within rich and diverse landscape mosaics mutlifunctional resource management can be enhanced by developing multifunctional network. Up to now (even with the freshly established environmental regulations in Iraq) the connectivity is not a mentioned aspect although the fragmented landscape and isolated entities approach is proved to not be sufficient in dealing with natural and cultural ecosystem in a sustainable and resilient way. The landscape mosaics of cultural and natural resources are subject to opposing interests of economic development and nature conservation on the one hand and suffer from political conflicts on the other hand. At legislation and decision-making level, implementation of a connectivity and permeability approach is a must at both planning legislation and planning practice. A multifunctional network plan, by introducing the corridors to connect KBA and maximizing the benefit outcome by preserving the existing cultural and natural resources, is developed.

In Baden-Württemberg a revision of a significant number of ideas, proposals, guidelines and instructions concerning landscape networks must be initiated. Actually a revision of state wide development and environment plans is overdue. Besides the integration of network concepts this revision has to respect the developments in transformation research as well as the requirements of resilience in a comprehensive approach of spatial organization.

Network oriented organization is an obvious and a kind of 'natural' principle for the development of settlement and transportation infrastructure. The settlement systems spatial organization looks quite similar to nature borne phenomena (e.g. neural neuronal networks or growth patterns of fungi). Due to the advantage of settlements being concentrated and due to transportation following travel time and cost optimization a network system is a self-evident spatial organization. The question for an adequate organization of landscape arises if settlement networks get narrow or other pressures reduce spatial coherence of natural landscape. Then landscape networks as a "dual network structure" complementary to the settlement network structure has to be organized and established as a general principle in landscape preservation, as illustrated in Fig. 8. Following a methodological framework our case studies show, how - depending on the given geographical and societal framework - different construction rules can lead to such landscape networks. When following this idea different situations of interrelationship between urban hubs / landscape hubs and urban corridors / landscape corridors can be discussed based on a topological classification. Conflicting zones between corridors and transportation axes can be highlighted (Schwarz-v.Raumer & Esswein 2010) as well as distance thresholds for resilience and further development can be discussed.

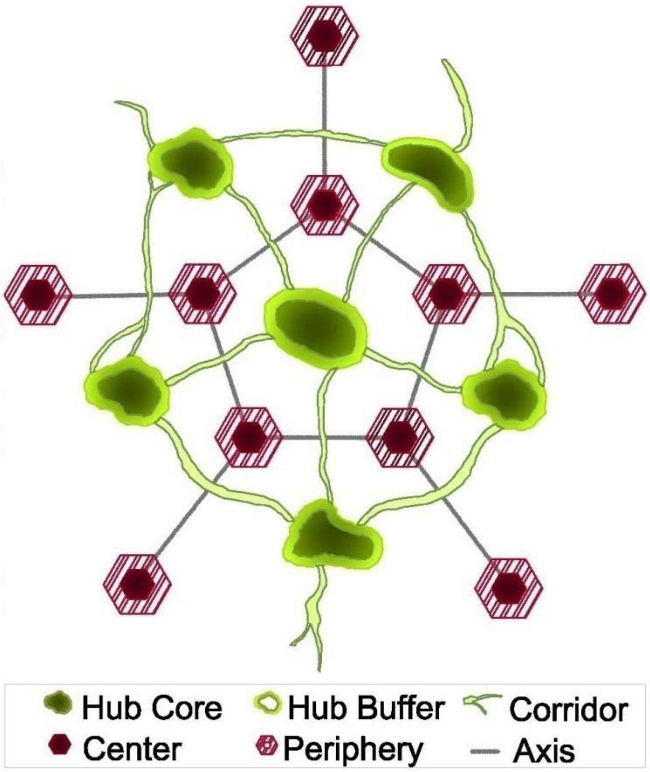

Fig. 8: A graphical diagram for thinking landscapes as dual networks

V. Conclusion

The Impedance Based Mapping Method applied is proved as very helpful method to draw a multi-functional landscape concept of ecological infrastructure and green infrastructure. It has proved to be an effective mapping method for investigating connectivity loss within ecological infrastructure in the case of BW and in developing a multifunctional network with high degree of connectivity and integrity in KR. It has been demonstrated that GIS is a very helpful tool to design multifunctional network and proposed method suggests a universal idea for integrated spatial development planning.

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Highlights

- Resilient landscape network planning by using impedance based network mapping method.
- Impedance layer includes land cover, natural and cultural heritage, water and other ecosystem resources.
- Corridor delineation contributes to achieve the aim of conservation, preservation protection and restoration of ecosystem.
- Resilience network indicates the location of undisturbed hubs and areas with linking functionality to be preserved and kept from dissection effects.
- Landscape networks as a "dual network structure" complementary to the settlement network structure.