Landscape Fragmentation Assessment Utilizing the Matrix Green Toolbox and CORINE Land Cover Data

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Abstract: While Land Cover data are usually used for visualizing and quantifying the surface coverage properties of a territory, in this study, they are utilized to graphically and numerically assess the landscape fragmentation and/or connect-ability. The main goal of the proposal is to visualize and quantify landscape fragmentation based on CORINE Land Cover (CLC), utilizing the Matrix Green (MG) toolbox in combination with Density Analyst tool of ArcGIS package. MG toolbox is tested here as a responsive technology in assessing landscape fragmentation. Open source CLC data provided via EIONET, of Albanian territory, is used as the main input for this experiment. The specimen target of the study is the broad-leaved forested lands encoded as 311 under CLC classification. The workflow of the process consists of ten steps which are applied to data of three different years: 2000, 2006, and 2012. As a result, two types of outputs are produced. First, a set of maps is generated which visually represents the spatial distribution of patches, links, and indirectly the fragmentation of a specific land cover class. Second, a series of statistical data measuring patch is produced, and edge to edge links quantity in three respective years. Interpretation of the results have led to remarkable conclusions about the proposed methodology and the context analyzed, in the scope of landscape fragmentation assessment.

Keywords: Landscape fragmentation, CORINE land cover, matrix green toolbox, ArcGIS, Albania.

1 Introduction

Landscape fragmentation is accepted as an adverse phenomenon majorly caused by human interaction with the natural environment (BOGAERT, FARINA, & CEULEMANS 2005). Settlement development, alteration of forested lands to agricultural use (FAHRIG, 2001) and transportation infrastructure expansions (GENELETTI 2004) are accepted as the major human activities causing fragmented landscapes. Recently, there has been an increase in consciousness about the importance of landscape fragmentation analysis. Furthermore, it is highlighted and advocated to be integrated in decision and policy making practices such as transportation and regional planning (EEA 2011). Thus, fragmentation assessment in a territory is essential.

The success of measuring landscape fragmentation is dependent upon the objectives of the study being performed (TAYLOR 2002). In the scope of this study, the landscape is analysed by its structural instead of functional properties (JONGMAN, KÜLVIK & KRISTIANSEN 2004, HESS & FISCHER 2001), as conceptualized in a matrix-patch-corridor paradigm pioneered by Forman and Gordon (FORMAN 1991). In this work, the matrix-patch-corridor concept is practiced by constructing the landscape network (matrix) of CORINE Land Cover (CLC) feature classes (patches) and connecting links (corridors). Consequently, landscape fragmentation is analysed through the reversed process of connect-ability, enabled via an edge to edge linking method as provided by Matrix Green (MG) toolbox (BODIN & ZETTERBERG 2010). MG is tested here as a responsive technology (CANTRELL & HOLZMAN 2016) in the process of landscape fragmentation assessment (LFA) by measuring the responsiveness of fragmentation behaviours in reference to land cover alterations.

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Furthermore, the study extends to a comparative analysis in terms of time-dependent variances. Open source data via EIONET, provides sufficient CLC records of three sequential periods covering an interval of twelve years in-between: respectively 2000, 2006, and 2012.

The target case of this experiment is the broad-leaved forested lands (CLC-311) of Albanian territory. The main selection criteria is the lack of relevant studies for this geography. Furthermore, Albania is a developing country facing high rates of unsupervised conflicts between development pressures and conservation goals. This results in a dynamic and fragile structure of natural lands, making the area of great interest for assessment. The broad-leaved forested surfaces were selected as the specimen of this study due to their dominant biodiversity and ecological values among other land cover classes (HILLI & KUITUNEN 2005).

2 Methodology

2.1 Workflow of the Experiment

The process of landscape fragmentation assessment in this study consists of 10 work packages. The workflow steps can be clustered into three main groups; ArcGIS modifying tools (1, 5, 6, 7, 8, 9), MG operations (2, 3, 4), ArcGIS Spatial Analyst (10). All steps have to be performed for each data clc-2000, clc-2006 and clc-2012.

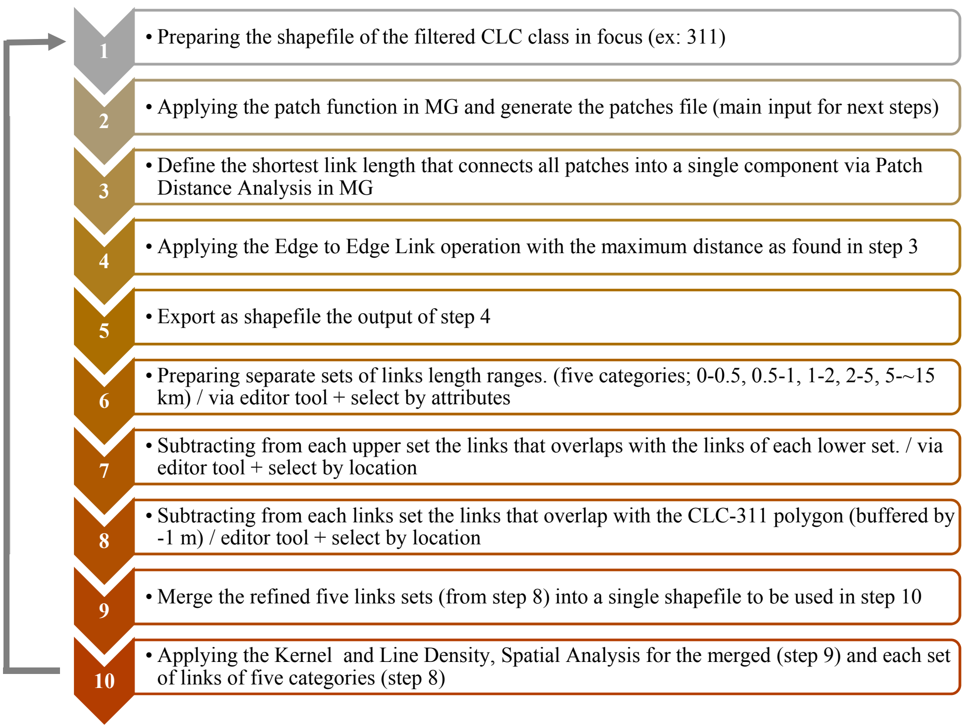


Fig. 1: Workflow of Landscape Fragmentation Visual Assessment – Matrix Green Toolbox

2.2 Utilizing CORINE Land Cover

Usually, CORINE land cover data are used to visualise and measure the land surface properties of a territory and for monitoring the change in landscape through time. In this study, they are utilized as landscape fragmentation assessment means. The connection capacities between patches of land cover classes through the closest edge to edge links indirectly highlight the prevailing fragmentation among them.

CLC uses 25 ha as the minimum mapping unit, and 100 m for linear features (JRC-EEA 2005), providing information on a much coarser scale when compared to other land cover monitoring methods such as LUCAS (GALLEGO & BAMPS 2008). At first look, there exists a conflict between the scale of information provided via CLC and the landscape fragmentation assessment goals- as a phenomenon occuring in a gradient of spatial scales. Still, due to availability limits of information on Albanian territory, the decision was made to proceed using CLC data. Yet, the work presented in this paper is conceptualized and should be considered as the first step of a multi-scale Landscape fragmentation assessment.

2.3 Utilizing Matrix Green Toolbox

Matrix Green is an ArcGIS extension tool developed by Bodin and Zetterberg at Stockholm Resilience Centre- KTH, which supports network based analysis of fragmented landscapes (BODIN & ZETTERBERG 2010). The toolbox generates patches and three types of links. Utilizing them, it can perform certain analyses. A specific analysis performed via MG is Patch Distance Analysis (PDA) as shown in figure 2. The tool generates information about the total area of the patches, the area of the largest component, the ratio between both in percentage, and the number of components generated at each interval distance applied. PDA assists primarily in understanding the threshold edge to edge distances between fragmented landscape patches that enables abrupt boost in landscape patches connectivity, thus, the component size.

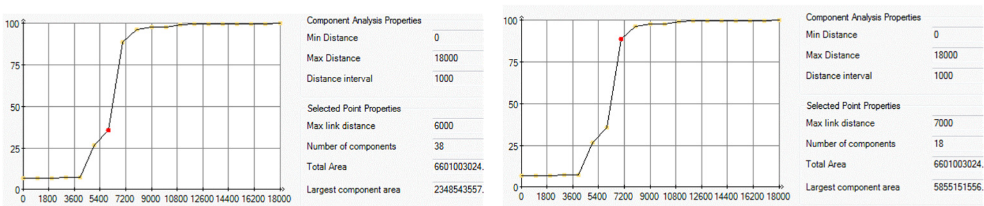


Fig. 2: PDA charts highlighting two thresholds up to 6 km (left) and up to 7 km (right); links between broad leaved surfaces (311) in 2012

2.4 Refining the Output Data of Matrix Green Toolbox

In step 4, a polyline features set is erected consisting of linkages between the closest points of each peer of fragmented landscape patches up to a certain defined distance. As a result, functionally meaning, a redundancy of links are generated. In other words, any link that intersects with any other link or overlapping any fragmented landscape patch, should be subtracted from the set of compulsory links. The refining process of MG generated links is performed in three stages as shown in table 1.

Table 1: The refining process of the EE links as generated by MG

	Aim	Example	Output
1	preparing the sets of ranges of link distances between patches	L_{EE}(0-5000) – L_{EE}(0-2000) = L_{EE} (2000-5000)	L_{EE}(0-500), L_{EE}(500-1000), L_{EE}(1000-2000), L_{EE}(2000-5000)
2	Subtracting links of each upper set that intersects with links of each lower set	L_{EE}(2000-5000) – Intersect(L_{EE} (2000-5000) and L_{EE}(0-2000)) = $L_{EE}(2000\text{-}5000)_{SUB}$	$L_{EE}(0\text{-}500)_{SUB}$, $L_{EE}(500\text{-}1000)_{SUB}$, L_{EE} $(1000\text{-}2000)_{SUB}$, $L_{EE}(2000\text{-}5000)_{SUB}$
3	Subtracting links of each set that intersects with the main landscape patch	$L_{EE}(2000\text{-}5000)_{SUB}$ – Intersect ($L_{EE}(2000\text{-}5000)_{SUB}$ and Landscape Patch) = $L_{EE}(2000\text{-}5000)_{SUB/BUFF}$	$L_{EE}(0\text{-}500)_{SUB/BUFF}$, $L_{EE}(500\text{-}1000)_{SUB/BUFF}$, $L_{EE}(1000\text{-}2000)_{SUB/BUFF}$, $L_{EE}(2000\text{-}5000)_{SUB/BUFF}$

LEE = Edge to Edge link, SUB = Subtracted, BUFF = Buffered

2.5 Utilizing the Density Spatial Analyst as Visual LFA Tool

In the final step, the refined data of landscape links are tested through the Kernel and Line Density tool utilising ArcMap 10.2.2. The toolbox generates rough graphics highlighting the most dominant zones urging for links, subsequently emphasizing the present fragmentation. The red to green gradient of 20 classes is selected to highlight the most fragmented landscape. Whereas, the greyscale gradient of 10 classes is used to visually represent and compare five sets of links produced in step 8. The darkest parts of the map imply the concentration of connecting links thus, the most fragmented landscape areas.

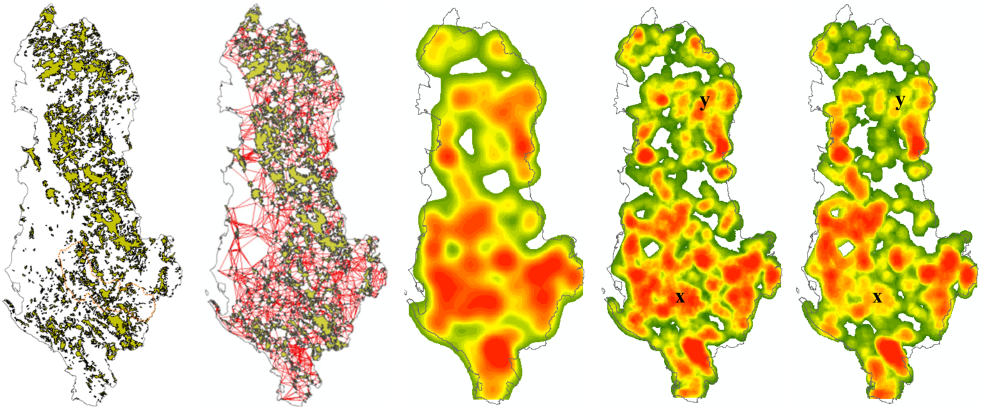
3 Results and Discussion

The results of this work can be categorized as visual and numerical information. The first group consists of a series of maps generated via MG operation as well as ArcGIS Spatial Analysts, density analysis tool. Illustrations of these graphics are included in Figures 3 and 4. The second set consists of statistical data from two main sources; PDA (MG) and feature classes statistics of both network elements; links and patches.

3.1 Visualizing the Fragmentation of Albanian Broad Leaved Forests

The main contribution of landscape fragmentation mapping is the spatial distribution of landscape fragmentation in the territory. For example, it is hard to derive the dispersal information from the map of land cover patches and links in Fig. 3 (a-b). However, the spatial concentration of the links-fragmentation becomes evident enough in Fig. 3 (c-d-e).

Referring to Fig. 3 (c), one sees that the highest level of landscape fragmentation among Albanian broad-leaved forested surfaces exists in the southern part. In Fig. 3 (d), via line density spatial analyst tool by population field set as “none”, finer graphical information is produced, compared with the kernel density (c). Whereas if the population field is tested as “line length”, the map highlights the links densification by their length properties, as shown in Fig. 3 (e). Consequently, it can be stated that the longest landscape links concentrate in the central west of Albania. Comparing Fig. 3 (d) and (e), there are certain zones becoming paler (ex; zone “x” and “y”). This change can be justified by the high quantity of short links close to the zone x and y.



a) b) c) d) e)

Fig. 3: clc-311 2012 (a); 5 km links via MG (b); Visually Weighted Fragmentation; kernel density (c); line density with population field; none (d), line length (e)

Further on in Fig.4, the kernel density mapping of five links classes as defined in step 6 of the workflow are presented, highlighting the spatial distribution density of links classified by their length. Responsively, it can be concluded that the fragmented landscape patches that are the closest to each other (0.5-1 km), are concentrated in northern Albania. Whereas fragmented surfaces that are no closer than 5 km to each other are mostly in the central part of the territory.

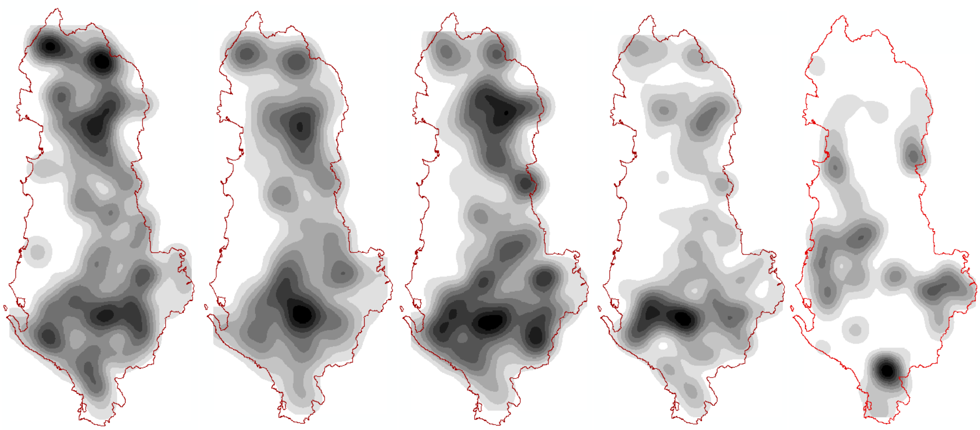


Fig. 4: Kernel Density maps of links of five length groups. Respectively left to right; 0-0.5 km, 0.5-1 km, 1-2 km, 2-5 km, 5-18 km. CLC-311, 2012, Albania

The visual assessment could expand by comparing between the density mappings of each year. But, due to the scale of the study the difference among three periods is visually imperceptible. Instead, the comparative assessment based on time-dependent variances is performed via the numerical assessment of landscape fragmentation.

3.2 Quantifying the Fragmentation of Albanian Broad-Leaved Forests

Statistical data on landscape patches and links are crucial in the process of comparison between the cases of three years; 2000, 2006, 2012. The numerical data is analysed under three main themes; feature-patch statistics, links measurements, and PDA indicators.

First, table 2 represents numerical data regarding the dynamics of feature and patch classes during three periods. According to records, there is an increase of 23 features and 20 patches of broad-leaved forested surfaces from 2000 to 2006, indicating the rise of the fragmentation amount of this specific land cover type. Referring to sum areas of features and patches it can be concluded that there exists a continuous decrease of the area of broad-leaved surfaces by 5760 ha between 2000-2006 and 2928 ha in 2006-2012. Another fact to be highlighted from table 2, is the decrease of the mean area of features and patches. The average surface area of clc311 has decreased with 18 ha from 2000 to 2012, implying the shrink of the broad-leaved surfaces and the increase of landscape fragmentation.

Table 2: Feature and patch statistics for 2000, 2006, 2012 data

year	features	f_diff	f_sum_area	f.s.a_diff	f_largest_area	f.l.a_diff	f_mean	f_st.dev.	patches	p_diff	p_sum_area	p.s.a_diff	island area	i.a._diff	p_largest_area	p_mean	p_st.dev.	top link (m)
2000	1331		632275		47707		475	2301	1393		666093		33818		51673	478	2452	13497
2006	1354	23	626515	-5760	42870	-4837	462	2147	1413	20	660051	-6042	33536	-282	46360	467	2300	13359
2012	1363	9	623587	-2928	42371	-499	457	2161	1413	0	660100	49	36513	2977	45596	467	2320	17957
	features								patches									

On the other hand, table 3 illustrates statistical data regarding the links generated by MG in the step 4. According to these records, in 2012 there are 1057 links more than 2000, and 953 more than 2006, implying the increase of fragmentation during this period. The links longer than 2 km and shorter than 5 km have increased in number by 30 % from 2006 to 2012. Referring to the mean length of the links, in 2012 the average length of all links groups increase by 25 %. This is mainly dedicated to the category of links longer than 5 km, while the other four links length classes remain almost the same.

Table 3: Links measurements as generated via Matrix Green toolbox; 2000, 2006, 2012

year	top link (m)	EE_0-top	EE_0-top_mean	EE_0-top_st.dev	EE_0-0.5 km	EE_0-0.5_diff	EE_0-5_mean	EE_0-5_st.dev.	EE_0.5-1 km	EE_0.5-1_diff	EE_0.5-1_mean	EE_0.5-1_st.dev.	EE_1-2 km	EE_1-2_diff	EE_1-2_mean	EE_1-2_st.dev.	EE_2-5 km	EE_2-5_diff	EE_2-5_mean	EE_2-5_st.dev.	EE_5-top km	EE_5-top _diff	EE_5-top _mean	EE_5-top _st.dev
2000	13497	7099	4661	3847	1168		199	131	477		745	145	716		1473	292	1298		3394	868	650		8752	2346
2006	13359	7203	4610	3804	1148	-20	200	129	461	-16	746	146	703	-13	1471	292	1300	2	3388	860	541	-109	8728	2460
2012	17957	8156	5753	4883	1168	20	204	133	455	-6	742	147	696	-7	1471	290	1691	391	3409	863	681	140	9980	3442
	distance ranges classification				very close				close				moderate				high				very high			

The third part of statistical assessment of landscape fragmentation is based on Patch Distance Analysis via MG as shown in table 4. First part of the board includes information about the connect-ability behaviour of the patches based on the threshold distance intervals (fig. 2) for each year. Number of components, largest component area, coverage percentage, are statistics for both lower and upper distances of the threshold interval. Accordingly, It can be concluded that the Albanian broad-leaved surfaces in 2012, are primarily distanced via 6000-6500 m long links. This is the interval where the connect-ability of this land cover class increases by almost 3 times (35.6 % to 87.0 %). On the other hand, the number of unconnected landscape components is reduced from 38 to 27. In 2012 there is a decrease of components areas of both lower and upper thresholds.

Table 3: PDA indicators as generated via Matrix Green toolbox; 2000, 2006, 2012

year	longest link [m]	threshold [lower]	l_components	l_comp. area	l_% coverage	threshold [upper]	u_components	u_comp. area	u_% coverage		500	largest comp [ha]	1000	largest comp [ha]	2000	largest comp [ha]	5000	largest comp [ha]	top	largest comp [ha]
2000	**13497**	**7500**	**19**	361814	**54.3**	**8000**	**15**	620720	**93.2**		**1370**	51673	**1309**	51673	**902**	51989	**102**	172738	**1**	666093
00_diff							-4	258906	38.9				-61	0	-407	316	-800	120749	-101	493355
2006	**13359**	**7500**	**17**	404945	**61.4**	**8000**	**15**	635416	**96.3**		**1393**	46360	**1327**	46580	**914**	47004	**97**	195978	**1**	660051
06_diff							-2	230471	34.9				-66	220	-413	424	-817	148974	-96	464073
2012	**17957**	**6000**	**38**	234854	**35.6**	**6500**	**27**	574253	**87.0**		**1393**	45596	**1329**	45652	**915**	45812	**96**	178297	**1**	660100
12_diff							-11	339399	51.4				-64	56	-414	160	-819	132485	-95	481803

The second part of table 4 represents the PDA indicators at each threshold length of five links groups, respectively; 500, 1000, 2000, 5000, and top length (m). There is an increase of remaining unconnected components at the first three thresholds from 2000 to 2006 and 2012, numerically indicating a rise in landscape fragmentation. Whereas, the components that remain disconnected via up to 5000 m links are less in 2012 than previous years. Thus, the fragmentation advancement seems to have happened in closer distances.

4 Conclusions

This study presents a method for visualizing and quantifying the physical landscape fragmentation utilizing the Matrix Green toolbox and density spatial analyst of ArcGIS. This is achieved by investigating the connect-ability of patches through potential edge to edge links. The specimen of this experiment is the set of broad-leaved surfaces of Albanian territory, utilizing CORINE land cover data of 2000, 2006, and 2012.

The visual results represent the spatial distribution of landscape fragmentation in the territory. Whereas, the quantitative assessment through feature-patch statistics, links measurements, and PDA indicators designate numerical proofs on the responsiveness of landscape fragmentation upon the land cover alterations.

Even though the process tested in this study is useful for landscape fragmentation assessment there is space for further improvements. A weak point of this work is the possible conflict between the scale of information provided via CLC and the objectives of LFA- as a remarkable occurrence at a gradient of spatial scales. Thus, this experiment should be considered as the first step of a multi-scale Landscape fragmentation assessment methodology.

Finally, beyond the methodological and technical achievements or failures, this paper is a contribution to the inclusion possibility of similar analysis to territorial management in general. This is crucial in countries similar to Albania, where the disconnectedness between the spatio-temporal studies and landscape management/planning strategies is an urgent handicap to overcome.

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