Relationship between forest fragmentation and management of nature reserves in Flanders

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Abstract: - Gaining a better understanding of the relation between patterns of ownership and forest cover is critical to nature resource policy. Although the importance of this link is accepted by many scientists, only a few studies analyze the interaction between nature reserves and the surrounding landscape in a spatial manner. This paper focuses on forest fragmentation in Flanders, a highly urbanized region in Europe. Pattern metrics are used to establish the relationship between the spatial forest cover pattern in a 1 km radius around the protected area, and the deforestation in this area in the period 1940-2000. The reserves are categorized based on their owners, both public authorities and nonprofit organizations. The results indicate that governmental administrations manage reserves in areas that have a dense forest cover. Nonprofit nature conservation organizations tend to manage reserves with less forest cover. When focusing on the change between 1940 and 2000, an increase in forest cover is ascertained. This trend is stronger in forest poorer, but clumped forest landscapes, and near reserves, managed by the regional Nature and Forest Administration.

Key-Words: - Land cover change, Forest landscapes, Pattern metrics, Landscape indices, Forest fragmentation

1 Introduction

Land ownership patterns are strongly correlated with forest cover patterns [1]. The observation that higher rates of forest fragmentation are on private land [2] underscores the importance of interactions between land cover change and social institutions, such as ownership, policy, etc. [3].

Both on public as privately owned land, natural resources are under great pressure. In order to preserve these, protected areas have been created. Studies wherein different characteristics of protected areas are compared, and their influence on the dynamics of land cover change in their surroundings are analyzed, are rare.

This paper looks at the relationship between deforestation and the location of nature reserves. These areas are owned and managed by different organizations, varying from regional and local governmental agencies, to a variety of non-profit organizations. In this regard, the following hypotheses are made:

- Reserves in areas where forest is non-fragmented and abundant will face less deforestation. The rationale behind this statement is that these forests are not under pressure. Reserves in forest-poor regions, on the contrary, will become increasingly isolated refuges, as forests in the surroundings disappear.
- Reserves owned by nonprofit organizations will feature more deforestation in their surroundings, since their managers have less direct access to the land use planning process.

In order to test the above-mentioned hypotheses in an objective way, numerical measures of forest fragmentation are required. A set of pattern metrics allow to quantitatively describe the spatial pattern of forest cover. Pattern metrics have been used extensively to quantify patterns of land cover and relate them to ecological processes [4,5]. In this paper the relation between these metrics and reserve management is analyzed.

2 Methodology

2.1 Study area

Flanders (Figure 1) was selected as the study area for this research project. It is a highly urbanized region with an average population density of about

450 inhabitants per square kilometer [6]. The impact of urbanization and transport infrastructure upon the landscape is severe [3] and forests are small, scattered and diverse in composition and structure. As these forests have become a scarce resource, their values (production, environmental services, conservation, recreation,…) have increased substantially.

2.2 Data

Two region wide forest maps were available in digital format. The first was derived from the topographical map of 1940. The second was made by the Flemish forest administration in 2000, based on aerial photography [7]. In order to facilitata their comparability, both maps were converted to a raster with a spatial resolution of 120m.

Nature reserves (a total of 2100 polygons) were equally available in vector format from the Flemish forests administration (Figure 2)[8]. The different management types are listed in Table 1. The first management type '0' is managed by the Nature Administration of the regional government. This serves as a reference category, to which the other types are compared. The total area of the nature reserves managed by this institution amount to 5106 ha. The forest reserves managed by the regional administration (2181 ha) were grouped in a different category, since the relation with forest in the surroundings will be different from the first category. Category 2 regroups the reserves managed by local authorities (129 ha). The owners of the areas in this category are provinces, municipalities, etc. Category 3 comprises the nature reserves of the largest nature conservation organization (NGO) in Flanders, Natuurpunt vzw, who owns 5448 ha of land. The other important nature conservation organizations are Landscape Limburg (4) with 578 ha and Durme vzw (5), managing 196 ha of land. The last category (6) regroups protected areas of various smaller nonprofit organizations, and amount to 356 ha.

As these organizations expand continuously and are active in acquiring new nature land, the above mentioned figures are likely to be outdated. They provide nonetheless an indication of the relative importance of the organizations considered and the forest fragmentation in their surroundings.

2.3 Measuring fragmentation

Landscape indices or pattern metrics are quantitative indices to describe the structure of a landscape [5]. These are based on the analysis of patches, defined as spatially consistent areas with similar thematic features [4].

The surroundings of each reserve was determined by a circle with its center in the center point of the reserve and a radius of 1 km. This corresponds with an area of 314 ha. The spatial pattern of the forest cover surrounding each protected area was measured on the forest map of the year 2000, using a set of 6 pattern metrics. This set was selected based on the results of a previous study in this area [9]. The selected pattern metrics are : total forested area (TA), number of patches (NP), mean forest size (MSP), mean value of the shape index (MSI in Equation 1), mean Euclidean distance (MNN), and the aggregation index (AI). The last index measures the degree of clumping in the landscape and is based on the probability that two adjacent pixels feature the same land cover type.

These pattern metrics were computed using the Fragstats freeware [5].

$$MSI = \left. \sum_i \frac{p_i}{2 \cdot \sqrt{a_i \cdot \pi}} \right/ N \qquad (1)$$

where p_i : perimeter (m) of the forest patch i
a_i : area (m²) of the forest patch i
N : number of patches in the landscape

2.4 Data analysis

General linear modeling is used to establish the relations between the variables. The following relation is tested:

$$\Delta F = PM + CT \qquad (2)$$

where ΔF : change in forested area (ha)
PM : the set of pattern metrics
CT : ownership category of the protected area

All variables are continuous variables, except for the ownership category, which is a factor variable. Models are tested on their significance. In a second step, the normality of the residuals is assessed using a QQ-plot. Afterwards, the coefficients are analyzed.

3 Results and Discussion

3.1 Characteristics of reserves

In Table 2, the mean values for the selected pattern metrics are listed for different ownership categories. Reserves managed by the Flemish forest administration are situated in forest-rich (45 % forest cover) landscapes. This is logical, since it is common practice to set aside a small part of larger forest complexes as forest reserves. Next follows the nonprofit organization of 'Landscape Limburg', with 30 % forest cover around the nature reserves. Since Limburg is the easternmost province, featuring a higher forest cover in general, this result is not surprising. Local and regional nature reserves, as well as reserves from the 'diverse' category witness a forest cover from the same order of magnitude, between 26 and 28 %. This leaves the reserves from 'Durme' and 'Natuurpunt' in forest-poorer landscapes, featuring 13 to 16 % forest cover.

The number of patches (NP) varies only little. Nonetheless a trend is discernable, that reserve types with the least forest area in their neighborhood, also count a higher number of patches. This is obvious from the values for 'Natuurpunt' (5.51) and 'Durme' (6.28). Reserves from 'Landscape Limburg' equally have a slightly higher average of forest fragments (4.66) in their surroundings.

Considering mean forest sizes, a reserve from category 1 has mostly large (84.5 ha) forests in its neighborhood. This can be explained by the same rationale as stated above. Category 4 and 6 are also situated amongst rather large forest fragments, of respectively 42.73 and 40.89 ha. Very small fragments occur in the landscapes around reserves of 'Durme vzw'.

AI quantifies the degree of clumping of the forest. Reserves, managed by the Forest Administration and smaller nonprofit organizations feature in landscapes where forest is abundant and non-fragmented (AI respectively 80 and 71). Reserves from category 2 (local authority) and 4 ('Landscape Limburg vzw') follow with AI of 71 and 69. The last three are the nature reserves of the Nature Administration (57), Natuurpunt vzw (48) and Durme vzw (44).

3.2 Change in forested area in the surroundings of the reserves

Table 3 lists the change in pattern metrics in the surroundings of the reserves over the last 60 years. In most categories an increase in forest cover is observed, except for the reserves managed by the local governmental agencies (decrease of 11.38 ha).

As the different types of reserves are situated in different landscapes, the impression is created that change in forest cover could be related only to the spatial forest cover pattern, and not to the ownership category. In order to test this assumption, two models were built, one containing only the pattern metrics, and one containing the pattern metrics, extended by the ownership types. The addition of the management type enhanced the model significantly. When a model excluding the management type was compared to a model containing the management variable, an F-test yielded a value of 16.66 (p=0). This indicates that the managing organization does have an explanatory power.

By means of a QQ-plot (not included), the assumption of normally distributed residuals was confirmed. Afterwards, the impact of the spatial forest cover pattern and the various management types was assessed (Table 4). The amount of forest present had a significant, negative relation with the increase of forest cover. An increase in forest thus took place in forest poor areas rather than forest rich areas. The number of patches, mean forest shape and the aggregation index did not have a significant impact. The mean patch size had a slightly positive impact. This means that, in areas with larger forests, the increase is higher (or the decrease is lower). The mean nearest neighbor index has a significant negative impact. The low value for the coefficient is explained by the fact that the distances are expressed in meters and yield thus high values.

When interpreting the coefficients of the management types, one should keep in mind that these are relative values, in relation to the first management category. The management by the local government (1), Durme vzw (4), Landscape Limburg vzw (5) and diverse nonprofit organizations yield significant results.

4 Conclusions

This paper presents a quantitative approach to analyze spatial patterns of land cover in relation to the ownership of nature reserves. The protected areas of nonprofit organizations appeared to be situated in landscapes where forest was less abundant and more fragmented.

This approach seems very coarse and one might wonder just how accurate this model estimates the change in forest cover. This is besides the question though. Not the precise estimation of forest cover is sought, but rather to analyze, in a quantitative manner, which factors have an influence on this process.

The hypothesis that areas with fragmented forests are subject to a continuing deforestation trend, was rejected. Deforestation does occur, but is compensated by afforestation elsewhere. The resulting increase in forest cover is larger in forest poor landscapes.

Regarding the ownership category, the expressed statement turned out to be true. Forest cover increases more rapidly around reserves, managed by governmental organizations, with exception of local authorities. Protected areas managed by nonprofit organizations face less forest increase in their surroundings.

The established relations offer critical information about the relation between the conservation type of nature reserves and forest fragmentation in the surrounding landscape. This kind of information can facilitate difficult decision making in nature conservation issues.

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5 Tables

Table 1: A list of different owners of protected areas in Flanders

Code	Owner	Type
0	Flemish Nature Administration	Public
1	Flemish Forest Administration	Public
2	Local Administration	Public
3	Natuurpunt vzw	Nonprofit
4	Landscape Limburg vzw	Nonprofit
5	Durme vzw	Nonprofit
6	Diverse nonprofit organizations	Nonprofit

Table 2: Description of the spatial forest cover pattern in the surroundings of the nature reserves, based on the forest map of 2000.

	forest cover (%)	NP (#)	MPS (ha)	MSI (-)	MNN (m)	AI (-)
0	26	3.58	32.76	1.54	785	57
1	45	3.34	84.50	1.48	716	80
2	26	3.60	27.20	1.32	499	71
3	18	5.51	14.11	1.34	508	48
4	30	4.66	42.73	1.52	577	69
5	13	6.28	7.45	1.22	321	44
6	29	3.06	40.89	1.57	878	76

Table 3: Mean change in spatial forest cover pattern in a 1 km radius of the nature reserves, in the period between the year 1940 and 2000.

	CA (ha)	NP (#)	MPS (ha)	MSI (-)	MNN (m)	AI (-)
0	+26.97	+0.32	+8.64	+0.03	-107	+9.24
1	+15.35	+0.14	+5.83	+0.01	-30	+5.80
2	-11.38	-0.30	-24.55	-0.27	-135	+11.77
3	+21.68	+1.50	+3.65	+0.01	-286	+11.95
4	+28.32	-0.50	+19.48	+0.16	+69	+15.74
5	+ 7.42	+2.83	-1.01	+0.08	-547	+7.27
6	+24.56	-0.50	+10.67	+0.12	+218	+25.30

Table 4: Coefficients of the general linear model, predicting deforestation between the year 1940 and 2000, based on spatial forest cover pattern in 1940 and ownership. Significant values have been marked with an asterisk (*).

Code	value	F-value
CA	-0.46	-12.14 *
NP	0.07	0.18 -
MPS	0.04	0.81 -
MSI	-0.56	-0.21 -
MNN	-0.01	-5.51 *
AI	0.19	4.59 *
1	6.54	2.88 *
2	-11.03	-2.97 *
3	-2.15	-2.08 *
4	1.69	2.11 *
5	-3.69	-4.32 *
6	1.20	1.00 -

6 Figures

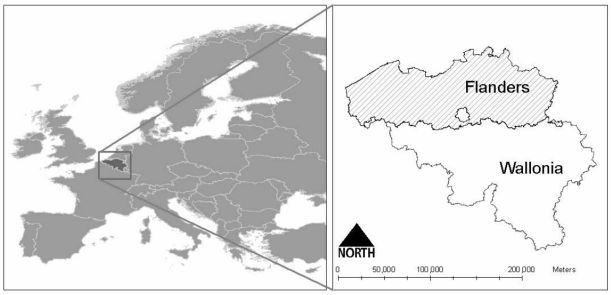

Figure 1: Geographical position of the study area Flanders, a highly urbanized region in Europe.

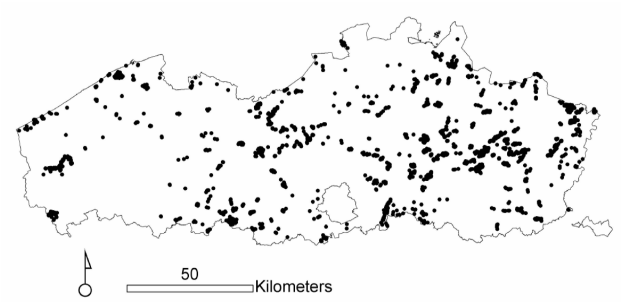

Figure 2: Map of the 2100 sample points, used in the study. The black dots represent nature reserves in Flanders.