Monitoring land cover changes inside and outside Natura2000 sites

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ABSTRACT

The paper describes the analysis of land cover changes for areas inside and outside Natura2000 sites. A case study is used to demonstrate the BIOPRESS methodology for the Netherlands using the land cover and land cover change statistics of 9 Dutch transects of 30 km2 for the 1950-2000 period. The total area changed ranges from 23.6% up to 63.4% in the period of 1950-2000 for the 9 Dutch transects. Urbanisation was found to be the most important environmental pressure in the Dutch. The areas inside and outside Natura2000 differ in the type of land cover as well as the coverage of land cover change. The areas designated as Natura2000 sites are characterised by limited land cover changes (area) and when changes occur, it was from less natural into more natural land cover types showing that Natura2000 sites are in general well protected. However, through land cover changes outside protected areas, the sites are getting more and more isolated which has implications for the quality of biodiversity in those areas.

INTRODUCTION

The European environment is changing rapidly caused by a combination of socio-economic and political developments. To protect the environment and to ensure sustainable use of natural resources a wide variety of national and international legal mechanisms (e.g. Amsterdam Treaty 1997, Habitats Directive, EU Common Agricultural Policy and Kyoto Protocol) have been established which in their turn have spurred on a wide range of environmental monitoring activities. Today Europe urgently needs to consolidate these monitoring efforts. The GMES initiative aims at achieving a 'European Capacity for Global Monitoring for the Environment and Security' by 2008. The BIOPRESS project made it possible to realise this ambitious goal by computing land cover changes in the vicinity of protected areas that are statistically representative of anthropogenic pressures on biodiversity in the different bio-geographical regions of Europe.

This paper describes the research work carried out within the BIOPRESS project and examines the final results for the Netherlands. The paper focuses on the selection of the sample sites, the acquisition, processing and interpretation of the recent and historical Dutch aerial photographs, and the production of land cover change statistics. The sample sites consisted of nine detailed transects of 15km long and 2km width where land cover changes were measured from 2000 to 1990 and 1950 at 1:20.000 scale. The transects follow a pressure gradient in the local environment and run from a Natura2000 site to a nearby urban area. Subsequently, land cover changes over the last 50 years have been analysed within the Natura2000 sites as well as outside of these protected areas.

MATERIALS

Aerial Photographs

More than 430 hard copies of Black & White (B&W) aerial photographs were ordered for the reference years 1950, 1990 and 2000. The acquired B&W aerial photographs were at a scale of 1:18.000 for 1990 and 2000, and at a scale of 1:20.000 for the reference year 1950.

Unfortunately, for some transects B&W aerial photographs were not exactly available for the years 1950, 1990 and 2000. In this case, the selection criteria was based on a minimum time span of ten years between AP's for the 1990 and 2000 time span, and a time span of +/- five years for the reference 1950. Only the transects 2 and 5 did not comply with the above mentioned criteria since B&W aerial photographs from 1958 were used instead of 1950. Flight recording of most aerial photographs from the Dutch Topographic Service (TDN) took place in early spring when trees did not have too many leaves yet and so infrastructure is better visible.

CORINE Land Cover

The CORINE Land Cover database for reference year 2000 (CLC2000) of the Netherlands was used as an additional source whether the land cover classification based on the aerial photographs was reasonable. The CLC2000 database has been visually interpreted at a scale of 1:100.000 and is based on Landsat 7 - ETM images. The database comprises 44 land cover classes of which 30 classes are present in the Netherlands (Hazeu, 2003). Minimum mapping unit is 25ha and minimum width of polygon is 100m (Heymann et al., 1994).

Top10-vector and Historic Topographic Maps

The Dutch Topographic Service (TDN) produces the 1:10.000 digital topographic map of the Netherlands (Top10-vector). Since 1998, the Netherlands is covered by around 1350 map sheets, which cover an area of 5 km to 6.25 km each. Hard copy historic topographic maps of 1950 at a scale of 1:25.000 were also obtained from TDN.

AHN

The digital elevation model of the Netherlands (AHN database) consists of altitude points measured by laser altimetry. The elevation of the points is the altitude at ground level. The AHN has a resolution of one measurement point per 4m by 4m ($16m^2$) in centimetres height. It is produced by the Ministry of Transport, Public Works and Water Management.

Natura2000 database

The database contains the description of habitats and location of areas appointed to be incorporated in the European Natura2000 database.

METHODOLOGY

Sampling Strategy

Nine transects were selected each with a length of 15km and a width of 2km. All transects were located in 5 sampling windows of 30km by 30km. Those windows cover the major landscape types of the Netherlands and cover several Natura2000 sites (Hazeu & Mucher, 2005). The transects were located in such a way that they follow a pressure gradient in the local environment. It was assumed that the specific pressures, such as agricultural intensification and urbanisation, are at their lowest in the centre of a Natura2000 site and at their highest in the immediate surrounding of urban areas.

The selection of sites was made on basis of the following criteria: 1) the location of the sampling windows, 2) the location of the Natura2000 sites within the windows and 3) the land use patterns within the CORINE land cover database. The habitat types forests, natural and semi-natural grasslands and inland wetlands received highest priority.

Processing Aerial-Photographs

The B&W AP's of the Dutch transects were scanned at 600 dpi as tiff-files. Band 1 of the tiff-files were imported and georeferenced in ERDAS Imagine, resulting in a 40 MB file. For the georeferencing of the AP's we used the Dutch digital elevation model AHN and digital topographical maps of the Netherlands at scale 1:10.000 (Top10-vector). The AP's were georeferenced to the Dutch national reference system, the Bessel Stereographic projection ("Rijksdriehoekstelsel"), using a minimum of ten well distributed ground control points (GCP's), with a RMSE of 2–5 m. For resampling the Nearest Neighbourhood (NN) resampling method was used. In ERDAS Imagine 8.7 we used the "Camera" option as the geometric correction method, which offers the possibility of creating a custom geometric correction model for a specific camera.

The overall procedure for geometric correction started with aerial photographs from the reference year 2000. These AP's were georeferenced using the above mentioned method and the digital topographic maps of the Netherlands 1:10.000 (Top10-vector). Subsequently, the AP's of 1990 were geometrically referenced to the georeferenced AP's of 2000. The AP's of the reference year 1950 were geometrically referenced to the georeferenced AP's of 1990. This procedure of retrogressive georeferencing guaranteed a maximum fit between the AP's of respectively the reference years 2000, 1990 and 1950. Finally, the mosaics of AP's were produced and clipped with the transect boundaries before the on-screen interpretations started.

Change Detection Methodology

The change detection procedure was concerned with tracking and accessing the history of important land cover changes between two successive points in time.

The B&W aerial photographs of 2000 were interpreted according to the CORINE nomenclature. Field work was carried out to verify the interpretation. After that, this land cover interpretation for 2000 was overlayed with the B&W's of the 1990's and only the changes were identified, delineated and interpreted. As a result, only new polygons were interpreted using a new attribute code for the specific reference year. This step was repeated for the interpretation of the B&W AP's of the 1950's. The final result is a set of polygons completely covering the area of interest at a scale of 1:20.000 for the transects (1950, 1990 and 2000).

Element recognition

The recognition of land cover objects was accomplished by computer-aided visual interpretation of black & white aerial photographs (B&W AP's). The seven principles used for the aerial photo interpretation were shape, shadow, pattern, association, texture, tone/colour, and size (Lillesand & Kiefer, 2000). The patterns observed on the B&W AP's by the interpreters and their associations to land cover changes played an important role to assign the right land cover type to the element. Element recognition was based on the rules and guidelines described in the photo-to-photo interpretation manual which had the objective to show

interpretation possibilities of aerial B&W photographs in the identification of land cover and land cover changes at a scale 1:20.000 (Feranec et al., 2004). On-screen aerial photo interpretation was facilitated if necessary with a stereoscopic view of the area in question.

The following criteria were used in the element recognition process of the transects interpretation (Figure 1):

- areas of land cover objects were identified by means of aerial B&W aerial photographs displayed at a 1:20.000 scale. When necessary the interpreter could zoom in on the aerial photographs to improve the capacity to identify the object. However, all delineations should be done at a scale of 1:20.000;
- the minimum size of the objects (polygons) is 0.5 ha (at a scale of 1:20.000 this corresponds to 3.5mm by 3.5 mm);
- the minimum width of a linear element is 20 m (this is 1 mm at scale of 1:20.000).

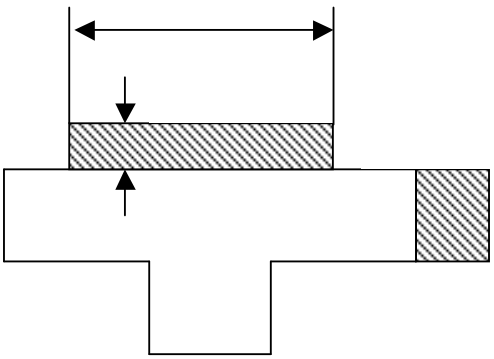

Figure 1. Criteria for the detection of the smallest LC polygon and LC change at scale 1:20.000. The most important are the minimum mapping unit (MMU) of 0.5 ha (at scale 1:20.000 it is 3.5mm by 3.5 mm) and a minimum width of 20m (at scale 1:20.000 it is 1mm).

Class allocation (labelling)

The interpreted polygons were assigned to land cover classes that correspond to one of the 44 categories of CORINE land cover nomenclature (Heymann et al., 1994). Each polygon is marked by a 3 digit CORINE code for each reference year. In the process of class allocation (labelling) the use of ancillary data, such as topographical maps (Top10Vector (1:10.000), historic topographic maps (1:25.000)) and CLC2000, was used to improve the photo interpretation results.

An addition was made to the CORINE nomenclature since the distinction of some land cover classes (e.g. arable land and pastures) was in some cases too difficult to distinguish on basis of the AP characteristics. At the CORINE nomenclature level-3 sometimes the interpreter was completely uncertain about the allocation to a specific land cover class. Meaning that identification of reliable changes was difficult in those cases. The uncertainty was made explicitly by labelling the polygon as a new “class 6” at CORINE level 1. Table 1 gives the newly defined ambiguous land cover classes.

Table 1. Newly defined ambiguous land cover classes.

Class	Confused with	Suggested solution
2.1.1 non-irrigated arable land	2.3.1 pasture	6.2.1 farmed land
3.1.1 broadleaved forest	3.1.2 coniferous forest	6.3.1 forest

RESULTS

Land Cover Changes

Land cover dynamics
The percentage of surface area that changed in land cover over the last fifty years ranges from 23.6% (transect 1) to 63.4% (transect 6), see Table 2. Especially, land cover changes between major classes (CORINE level 1 classes) have a major impact on biodiversity. These land cover changes, i.e. all changes without the internal changes of Figure 2, range between 11.8% (transect 7) and 41.1% (transect 5).

Aggregation of all land cover changes to CORINE level 1 classes, which are the classes artificial areas, agricultural areas, forest and semi-natural areas, wetlands and water bodies, revealed an area of 141.9km^2 (47.8%) that has changed between 1950 and 2000. Figure 3 clearly indicates that the main pressure in the Netherlands is urbanisation. The most important nett change is the increase of artificial areas. The increase of artificial land (14.6%) is mainly at the expense of agricultural areas. Agricultural areas showed the highest decrease. The nett increase or decrease in land cover for the other classes is minimal. The internal land cover dynamics for the CORINE level 1 classes agricultural areas and forest and semi-natural areas are high.

Rate of land cover changes
The land cover changes are smaller in the period 1990-2000 than for the period 1950-1990 (Table 2). But if one takes into consideration that the first time period (1950-1990) is four times longer than the second time period (1990-2000), the rate in changes do differ much less. For example, for transect 6 “Drentse Aa”, four times the percentage change in the period 1990-2000 (4*17.9) is 71.6% which is even larger than the 62.4% over the period 1950-1990. In other words, the land cover changes in the last ten years (1990-2000) are much severer than one first would think.

Another remark concerns the total number of changes for the period 1950 –2000, which is not equal to the summation of changes for the periods 1950-1990 and 1990-2000. Some changes disappear again for the entire period (1950-2000), due to the fact that the original land cover type turns back after a period of change, e.g. pasture – arable land – pasture (1950-1990-2000). So, the area changed twice, once from its original (1950) to a new land cover type in 1990 and afterwards back into its original land cover type in the period 1990-2000.

Table 2. Land cover changes for all transects between 1990-2000, 1950-1990 and 1950-2000 (% and km2).

		1950 - 2000		1950 - 1990		1990 - 2000	
		km2	%	km2	%	km2	%
transect 1	"Loonse en Drunense duinen"	7,8	23,6	7,0	21,1	1,4	4,2
transect 2	"Kennemerduinen"	11,0	32,9	9,9	29,7	2,0	6,0
transect 9	"Terschelling"	14,0	42,3	13,7	41,4	1,9	5,8
transect 5	"Jisperveld"	15,1	45,7	14,1	42,7	6,2	18,9
transect 7	"Dwingelerveld"	15,3	46,1	14,7	44,3	1,7	5,2
transect 3	"Bemelerberg"	17,8	56,7	17,5	55,9	6,2	19,9
transect 4	"Kampina"	19,0	57,7	18,6	56,3	4,6	13,9
transect 6	"Drentse Aa"	21,0	63,4	20,6	62,4	5,9	17,9
transect 8	"Overijsselse Vecht"	21,0	63,4	21,2	63,9	5,9	17,7
Total		141,9		137,2		35,9	
Average		15,8	47,8	15,2	46,2	4,0	12,1

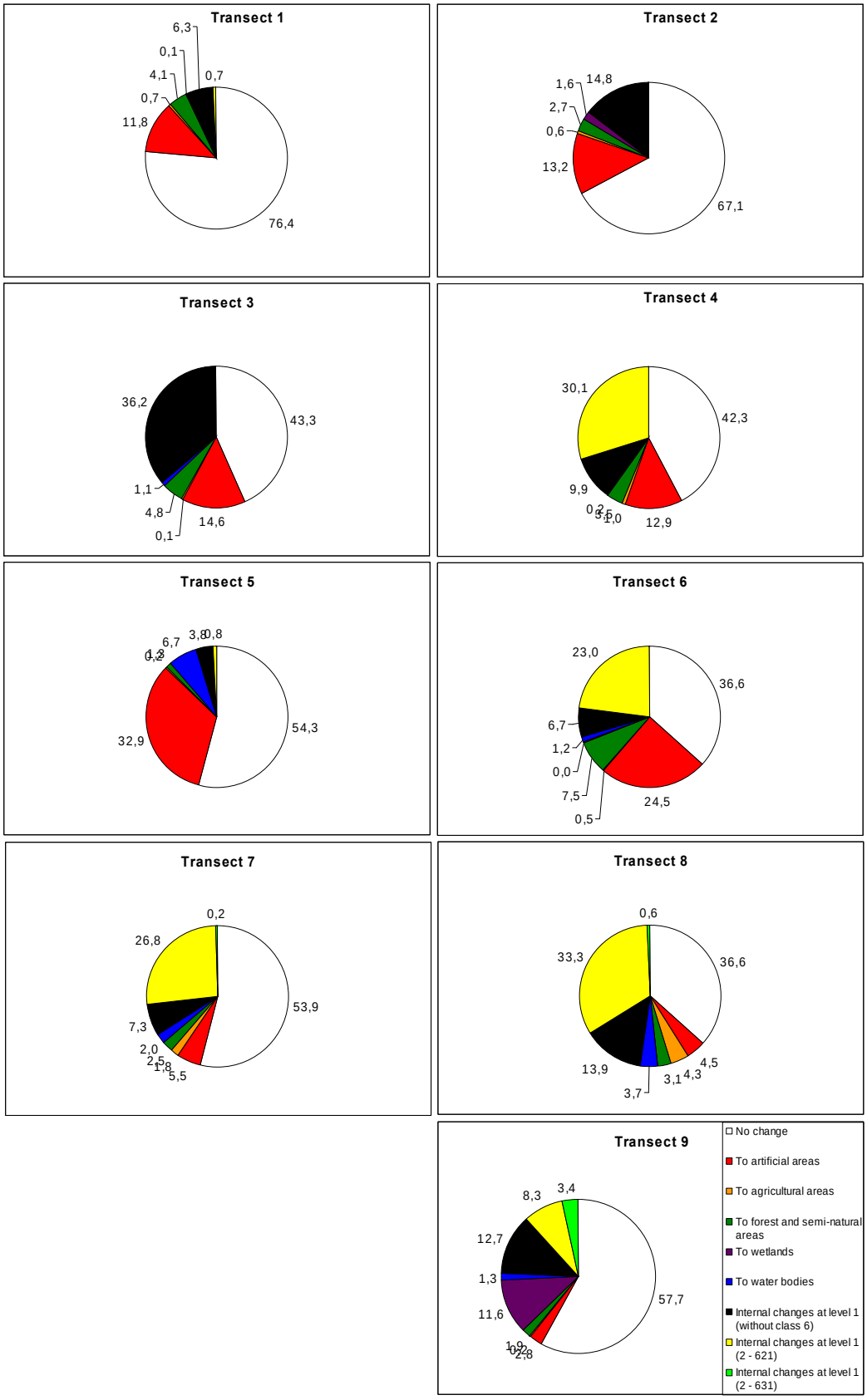

Figure 2. Land cover changes between 1950 - 2000 for 9 Dutch transects. Changes are grouped according to the land cover for the year 2000.

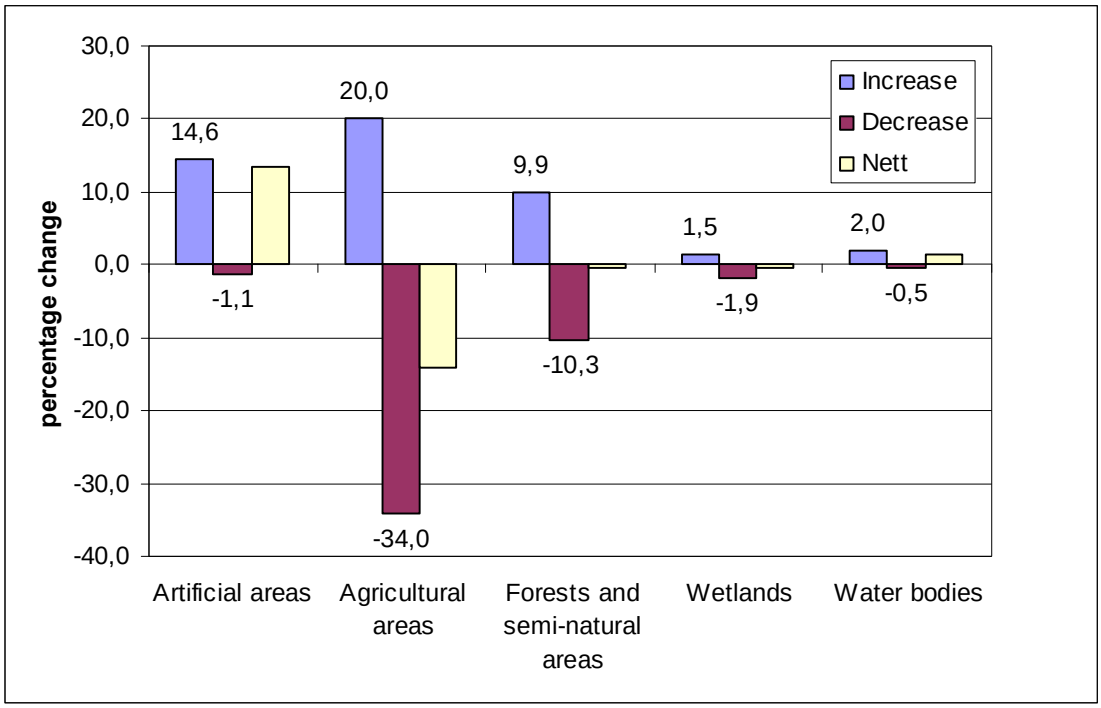

Figure 3. Nett land cover change between 1950 and 2000. Increase and decrease in land cover for CORINE level1 classes accumulated for all nine Dutch transects (%).

Changes inside versus outside Natura2000 sites

The analysis of land cover dynamics of the last fifty years indicated that 74% of all land cover changes took place outside the Natura2000 sites. However, within the Natura2000 sites still 26% of land cover changes took place in the last fifty years. The types of changes occurring inside and outside the Natura2000 sites differ significantly (Figure 4). Changes inside Natura2000 sites concern mainly changes of land cover into forest and semi-natural areas, wetlands, water bodies. But also internal changes, i.e. changes within the same CORINE level 1 class, are important. Land cover changes outside the Natura2000 sites are mainly characterised by changes into artificial areas and internal changes. For example, the total amount of land cover changes to artificial areas outside Natura2000 sites amounts 27.5%, while only 1% concerns changes to artificial areas inside Natura2000 sites. Changes into forest and semi-natural areas and wetlands are considerable higher inside the Natura2000 sites than outside the Natura2000 sites.

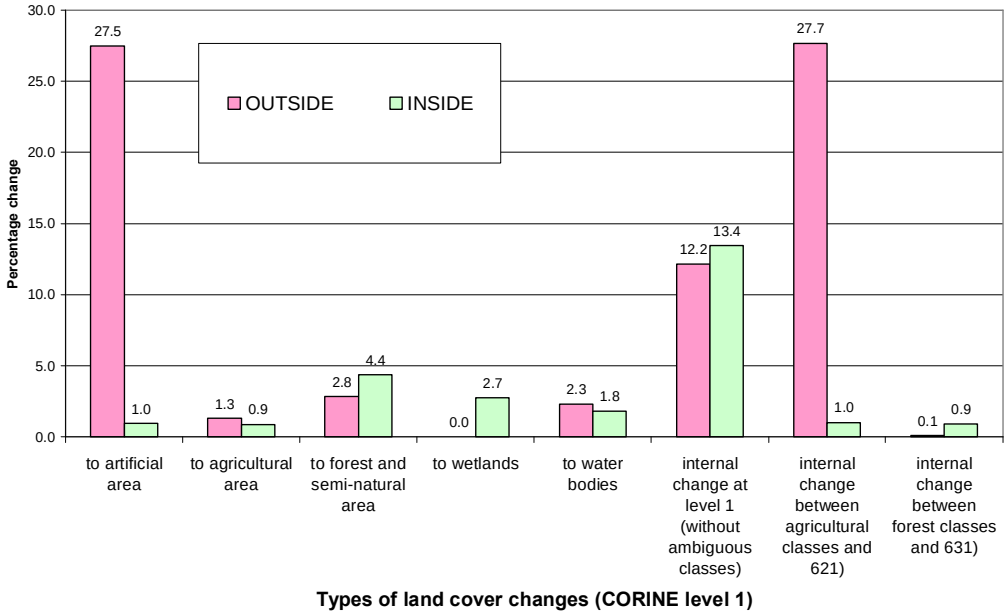

Figure 4. Types of changes occurring inside and outside Natura2000 sites. The changes are expressed in percentages change and are in total 100% (summation of inside and outside changes). A 74% of all land cover changes occurred outside the Natura2000 sites.

CONCLUSIONS

The paper shows the dynamics of land cover for the last 50 years in the Dutch countryside. Linking land cover changes to pressures on biodiversity is still under investigation, but it is clearly for pressures such as urbanisation, afforestation and deforestation.

A first major conclusion from the analysis of historic aerial photographs is that the Netherlands endured severe land cover changes over the last fifty years but with a high spatial variation. Land cover changes as a percentage of the total transect area ranged from 24% to 63% for the period 1950-2000. Most land cover dynamics occurred within the agricultural domain which implies e.g. changes from pastures to arable land and vice versa. From level one of the CORINE land cover nomenclature these are considered as "internal changes within the same major class". These changes can be reversed relatively easily.

Focusing on more relevant changes, meaning no internal changes, the range of land cover changes is between 12 and 41% for the transects. The most important change is the conversion of agricultural land into artificial areas. The fast rate of urbanisation had major impacts on the landscape and its biodiversity, not only through the loss of precious habitats but also due to increased fragmentation of remaining habitats and an increasing rate of recreation in remaining semi-natural areas. Moreover, the process of urbanisation is irreversible. The process of urbanisation is one of the most important processes that changed the Dutch landscape. A strong correlation exists between sampling transects having a high degree of artificial areas and the area occupied by new urban areas.

The rate of land cover changes seem to increase for most of the transects in the last decade. The type of changes for the period 1950-1990 and 1990-2000 needs to be investigated in more detail.

The land cover dynamics inside versus outside Natura2000 sites differ considerably (26 versus 74% of all changes). One could conclude that the sites were well protected in the last 50 years. However, the selection of Natura2000 was done recently and perhaps biased to more natural areas (and less changed). Another point of concern is that the Natura2000 sites become more and more isolated through the land cover changes outside the protected areas. Those changes can have implications on the quality of biodiversity in those Natura2000 sites.

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