Modelling the fragmentation of open space

A framework for assessing the impact of land use change on open space

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Abstract

In the Netherlands, one of the most densely populated countries in the world, urban functions are constantly claiming more space. This continuing urbanisation has led to a growing concern for the preservation of open space and therefore receives a lot of attention in the spatial planning of the Netherlands. The Dutch government strives to keep the total volume of open space at a sufficiently high level and tries to avoid its further fragmentation. The present research deals with modelling the fragmentation of open space. A GIS-oriented land use model will be used to study this subject. GIS-technology allows for a quantitative implementation of the concept of open space and furthermore facilitates the spatial analysis of the impact of land use changes. This paper presents the framework and a first outline for a method to assess the impact of land use change on open space. This impact will be assessed both as a total area loss and a geographical impact in terms of fragmentation. To study the latter a methodology will be developed that adopts experiences from spatial ecological research on habitat fragmentation.

Introduction

The Netherlands is one of the most densely populated countries in the world. Urban land use has more than doubled in the past 50 years (VROM 2001). At present, approximately 14 to 17 percent of the land can be considered built-up, depending upon the definition used (see VROM 2001, RIVM 2002 and Ottens 1999). Moreover, the combined additional demand for space for living, working and infrastructure in the coming 30 years is expected to be at least 100.000 hectares which equals approximately 2.5% of the total area of the Netherlands (VROM 2001). This continuing urbanisation has led to a growing concern for the preservation of open space. The expansion of urban land use for example puts the conservation of nature areas and historical landscapes under increasing pressure (Milieu- en Natuurplanbureau 2001).

Although non-urban land use functions at present occupy more than 80% of the Dutch surface area, large unbuilt areas are becoming scarce. In 1990 only 15 percent of the land consisted of open areas of more than 1000 hectares, as opposed to 25 percent in 1930 (VROM 2001). This clearly indicates the dispersed character of the Dutch urbanisation and infrastructure pattern. The loss of open space does not only pose problems of fragmentation for ecosystems or (potential) animal habitat but it also affects the geographical, historical and cultural qualities of the landscape. Especially the typical open polders are considered a crucial asset of the Dutch countryside.

The preservation of open space is an important theme in the spatial planning of the Netherlands. Concentrated suburbanization and a compact town policy have for decades been crucial issues in the various planning reports (Ransijn & Vreeker 2001). The Ministry of Housing, Spatial Planning and the Environment has the past decade tried to prevent the urbanization of certain open areas through a restrictive policy. Their new Fifth National Physical Planning Report however states that this policy has not really succeeded because of different interests at local level and outdated land use plans (VROM 2001). The new Planning Report therefore designates seven regions as National Landscapes to be protected. The selected regions have special cultural, historical, recreational and landscape values that are now or in the near future in danger of being urbanized. The Ministry of Agriculture, Nature Management and Fisheries stresses that peace, quiet and darkness are important themes for future nature management (LNV 2000). These values also require large areas without human presence or disturbance.

The present research deals with the modelling of future land use and will focus more specifically on the fragmentation of open space. A GIS-oriented land use model (Land

Use Scanner) will be used to study this subject. This paper describes the framework for the ongoing research. It will first dwell on the concept of open space and then present two indicators for open space. We will subsequently focus on GIS-assisted attempts to model ecological and geomorphologic fragmentation and suggest an adopted approach for assessing the fragmentation of open space.

Defining open space

Assessing the impact of land use change on open space calls for a clear definition of open space that takes into account specific landscape characteristics. This definition must be strongly related to the policy context in which we want to apply our model.

In the Dutch planning practice open space is usually defined as a large area with few visual obstacles. Open space essentially gives people the opportunity to have a free view over a relatively large area. Buildings, high vegetation and height differences may disturb this panoramic view. Single objects (high voltage or television masts) can also severely affect the experience of open space. Infrastructure is in this visual concept of openness not considered important. Elevated infrastructure on the other hand, for example flyovers, bridges or a road on a dike, will have a strong visual influence and should therefore be considered as an influence on openness.

The consequences of a strongly visual interpretation of openness can be demonstrated with the work of the Dutch research institute Alterra. They have developed a landscape classification based on the height of landscape elements (Expertisecentrum LNV 2001). By using a detailed geographical dataset they assess the amount of buildings and high-rising vegetation per gridcell of 1 x 1 km. Their scale ranges from a very open landscape (the typical Dutch polders) to a very closed landscape consisting of forests, see *Figure 1*. Villages and cities rank in between, being classified respectively as moderately open and closed landscape. This definition corresponds with the spatial planning perspective of open space as a crucial element of spatial quality indicators such as spatial and cultural diversity (VROM 2000). These indicators stress the importance of a visually open landscape to preserve the contrast between rural and urban areas and to retain the cultural and historical values that are attached to it.

The visual concept of openness however produces the remarkable result that extensive woodlands without much human presence are considered to be more closed than the big Dutch cities. When this definition is used to assess the impact of land use change on open space, the transition of woodland into urban areas will be considered as an improvement of the openness of the landscape. We regard this as an undesirable implication and will therefore explore a different concept of open space that corresponds better with the general notion of openness.

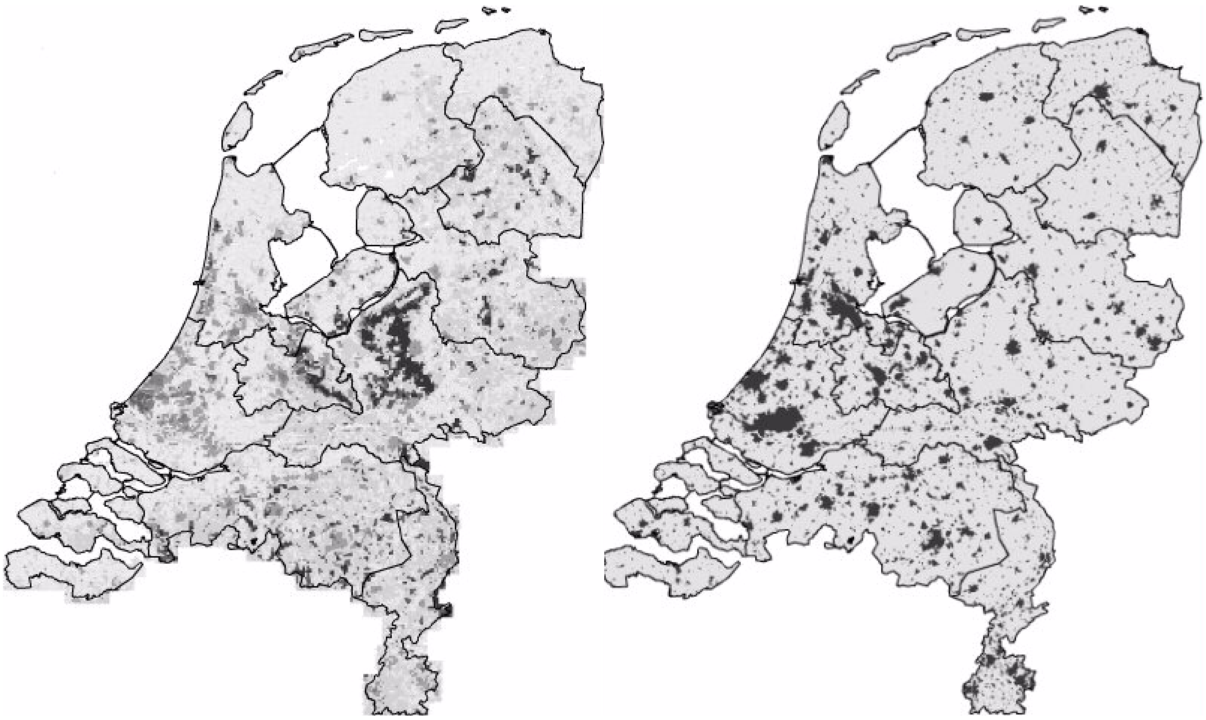

Figure 1 The openness of the Netherlands (left) compared to the urban areas (right). The openness at left is presented by using a grey scale in which the lighter shades indicate open areas (sourceAlterra).The dark areas at right show the urban areas of 1993 (Source RPD). The figures are adapted from VROM (2000).

As opposed to the aforementioned visual interpretation, open space can alternatively be interpreted as a large area without human interference. This moreperceptional approach confronts the busy, urban areas with the quiet, green countryside. Open space can then be defined as being free of buildings and other proofs of human presence, e.g. greenhouses or infrastructure. One could also choose to include human disturbance (e.g. air pollution or light production) in this definition, but we will limit ourselves initially to the direct impact of land use change on open space. This concept of openness corresponds roughly to the inverse of urbanisation and is demonstrated in *Figure 1* at right. The non-urban areas in this figure can be considered as open spaces. The two pictures in *Figure 1* clearly show the divergent outcomes of the two alternative interpretations of open space.

The interpretation of open space as an area that provides peace and quiet in an increasingly more urban environment fits in well with the spatial quality indicators of sustainability and beauty that were introduced by the Dutch planning agency (VROM 2000). Sustainability deals in their interpretation amongst others with ecological qualities and these are of course mostly found in the non-urban areas. Beauty is related to the public appreciation of landscape and natural areas. Non-urban and especially wooded areas are generally highly appreciated. It is interesting to note that the open polders in the western and northern part of the country are least valued by the general public, implying that the visual concept of open space is not well suited to incorporate public preference.

We will adopt both the visual and perceptional interpretation of open space here and develop two different indicators for the description of open space.

Implementing indicators for open space

For our research we will use the Land Use Scanner, an integrated land use model that has been used for various policy related research projects. Applications include the simulation of future land use following different spatial planning perspectives (Schotten et al. 1997), the evaluation of alternatives for a new national airport (Scholten et al. 1999) and more recently the preparation of the Fifth National Physical Planning Report (Schotten et al. 2001). The Land Use Scanner is a GIS-based logit model that simulates future land use and offers an integrated view on all types of land use. It deals with urban, natural and agricultural functions, normally distinguishing 15 different land use categories. The model is grid-based and uses almost 200,000 cells of 500 by 500 meter to cover the Netherlands. For every cell the number of hectares for each of the 15 distinguished land use types is registered. It thus presents a highly disaggregated description of the whole country. A full description of the model is given by Hilferink and Rietveld (1999).

The possibilities for constructing indicators are limited because relevant information on for example height differences or eye-catching objects is lacking. The data however allow for the calculation of basic indicators. Following the two concepts of open space described before, we will introduce an openness and an urbanisation indicator. Both indicators point in fact at the inverse of openness. So high values indicate a lack of open space.

Led be the visual concept of open space we can define openness as the percentage of each cell that is covered by the total of the following land use functions: housing, working, airports, greenhouses and woodland. Corresponding with the perceptional concept of open space we can define an urbanisation indicator as the percentage of the cell that is covered by the land use functions: housing, working, railways, roads, airports and greenhouses.

Indicator values can be calculated for the base year situation and the simulation results. By subsequently comparing these the loss of open space can be obtained in terms of a total or average change. This approach focuses on the changes in individual cells and does not take any regional impacts into account. Fragmentation is one of the most obvious regional impacts and describes the division of a large area into several smaller areas. The value of the separated areas is in some cases considered to be less than their original value. This may certainly be true for the loss of open space. Consider for example the simulation of future land use for a rectangle of 5 x 5 cells, that is presented in *Figure 2*. The simulation result shows a long corridor with high urbanisation values, possibly caused by a new motorway and related construction of houses and offices. One could argue that the small stretch with low urbanisation values in the upper part of the figure at right does not any longer contain the original values of open space such as limited visual disturbance or peace and quiet.

The following section will briefly introduce the way fragmentation is handled in some ecological and geomorphologic studies. Based on these ideas we will develop a method for modelling the fragmentation of open space.

10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10

base year

10	10	10	10	10
80	80	80	80	80
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10

simulation result

Figure 2 Indication of urbanisation-values (%) in a land use model, showing the initial situation (left) and the result of the simulation

Modelling Fragmentation

Fragmentation of habitats has been a subject of ecological study for over 20 years, see for example Geneletti (2002) for an overview. Many of these studies use quantitative models and geographical information systems to assess habitat fragmentation. A habitat is a location where a (group of) animals or plants lives. These locations may correspond with landscape types. Fragmentation of habitats leads to a decrease in habitat size and an increase in isolation and exposure to external influences (Geneletti 2002). Smaller habitats provide animals with too little space to live in. Increased isolation and exposure negatively influence vulnerability and living conditions. Many different measures exist for describing landscape patterns and fragmentation (Bogaert 2000), but most have in common that they focus on discrete landscape units called patches. Following the reasoning behind the expected impact of fragmentation, these patches are described in terms of area, isolation and shape. Shape can for example be characterised by basic geometrical descriptions as total boundary length or a perimeter/area ratio. A specific measure for quantifying the potential disturbance impact on isolated habitats is the interior-to-edge ratio (Bogaert et al. 1999). This method divides a patch in a not or marginally influenced interior and a disturbed edge. The determination of the ratio depends heavily on habitat and disturbance characteristics and their mutual relation. Specific knowledge on the impact relations is thus needed to calculate this ratio. By using the aforementioned characteristics fragmentation can for instance be quantified as a decrease in patch area or interior-to-edge ratio or an increased boundary length or perimeter/area ratio.

A different approach has been proposed by Leeters et al. (1999) for the assessment of fragmentation of geomorphologic landscape features in the Netherlands. They describe the use of a geographical intersection analysis to study the impact of new infrastructure on discrete morpho-elements in terms of direct destruction (disappearance) and indirect destruction (fragmentation). The severity of fragmentation is assessed through several arbitrary computations that relate the size of the remaining fragments to the size of the lost fragment, see *Figure 3*.

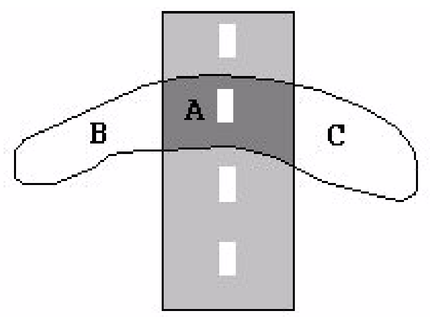

Figure 3 Assessing the impact of new infrastructure (light grey) on a geomorphologic landscape feature. Fragment A (dark grey) will disappear, the severity of the impact on remaining fragments B and C depends on their size in relation to fragment A (afterLeeters et al. 1999).

The presented research on the modelling of fragmentation can not directly be used to draw up a model for the fragmentation of open space since the impact relations are not necessarily the same. The human reaction to the fragmentation of open space can be expected to differ significantly from the way animals react on the deterioration of their habitat. Humans are for example not directly depended on the size of their living area for food and possible partners. A second, minor limitation is the fact we are dealing with raster data and continuous indicator values instead of vector data and discrete patches. This makes it more difficult to do a geographical analysis of fragmentation. Raster data do not allow for standard intersection methods and continuous values do not directly provide clear boundaries of open areas. We will therefore propose an adjusted method for the assessment of fragmentation in the following section.

Modelling the fragmentation of open space

Two separate impacts of land use change affect the fragmentation of open space in our opinion. We firstly expect a certain radiation of urban influence. The visual disturbance or the influence on quietness of an urban mass stretches further than its exact limits. This influence can be accounted for in our model through a weighted moving average. The use of this technique for spatial analysis has amongst others been described by Burrough and McDonell (1998). This method computes a distance-weigthed average for a group of data-points. The value of a cell can for example be calculated as the average of its initial value and the values of the eight neighbouring cells in which the central cell receives a weight-value of 8 and the others a standard weight-value of 1. The outcome of this calculation for the modelresults introduced in *Figure 2* is shown in *Figure 4*. This method not only expresses the influence of high urbanisation values on lower ones, but also reflects the opposite. Implying that areas with low urbanisation values mitigate the urban appearance or perception in neighbouring areas with high urbanisation values. Further research will focus on the optimisation of this function and most notably on finding distance-weights that are relevant for the influence of either urban or closed areas on openness.

10	10	10	10	10
80	80	80	80	80
10	10	10	10	10
10	10	10	10	10
10	10	10	10	10

simulation result

33	31	31	31	33
52	54	54	54	52
24	23	23	23	24
10	10	10	10	10
10	10	10	10	10

weighted moving average

Figure 4 Indication of urbanisation-values (%) in a land use model, showing the original simulation result and its weighted moving average to express the urban influence on open space.

We furthermore expect a minimum dimension in which openness can be appreciated. The size of this minimum area may differ for the visual or the perceptional approach of openness. The minimum dimension criterion can for example be implemented through a search operation in which we look for an area of at least 20 km^2 with a weighted moving average indicator value of 20 or less. To implement this minimum size we can also make use of the kind of moving window technique described above. This however has the drawback of using a predefined, normally rectangular shape that makes it difficult to detect large open spaces with an irregular form.

Issues for further research

This paper offers our first thoughts on the modelling of open space fragmentation. Further research will focus on a meaningful application of the openness and urbanisation indicator we described. An important issue is to strengthen the rational foundation of the proposed distance-weighted average function and its weight values to account for the radiation of urban influence. We will furthermore look for accepted values for the minimum dimensions of open space from both a visual and a perceptional perspective. A practical comparison of the model results with expert opinions on the fragmentation of open space might provide some guidelines for the implementation of the presented criteria and general usability of our approach in a policy-context .

An interesting issue with the implementation of the proposed minimum area for open space is how to account for irregular shapes. The study could also be extended with the use of extra data that for example represent the height or disturbance characteristics of certain objects. This would allow for more precise indicator values but would also mean a considerable adjustment of our land use model.

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