

Landscape fragmentation by urbanization in the Netherlands: options and ecological consequences

W. Bert. Harms

Department of Landscape Ecology, Winand Staring Centre DLO, Wageningen, The Netherlands

Abstract—In the western part of the Netherlands due to several economic factors there is a strong pressure to extend the urban activities. This means that a large open peatland area of special ecological interest, the so called green heart, will be threatened more and more by urbanization. In this area dairy farming predominates and the ecological value is largely dependant on this land use (meadow birds).

Scenarios for future landscapes have been developed for this area taken into account different spatial lay-out of urbanization. The consequences for nature were evaluated with a decision support system. The so-called LEDESS (landscape ecological decision support system) links available landscape ecological knowledge to a geographical information system (GIS) to evaluate the scenarios. LEDESS is based on a deterministic concept of the ecotope dependent on physiotope, vegetation dynamics, target vegetation and management, and of faunal habitat requirements that are also dependent on vegetation structure. It also take 02/12/98s into account the accessibility of the landscape for migrating fauna species.

It turns out that urbanization will deteriorate the existing fragmented landscape. As an answer to the scenarios of urbanization different options for nature restoration have been elaborated in additional scenarios. The consequences were evaluated again with the same computer model. The study has concluded that fragmentation can be compensated to some extent by enlargement of habitats, but the effectiveness depends highly upon the spatial allocation of the new habitats.

Keywords: urbanization, landscape fragmentation, fauna, nature compensation, decision support system.

1 Introduction: the study area

The economic activities of the Netherlands are concentrated in the west of the country, the so-called Randstad, a loose conurbation consisting of Amsterdam, Rotterdam, The Hague, Utrecht and the smaller cities in between. Half of the country's population of 15 million lives here. This economic core extends to link up with the cities of Arnhem and Nijmegen in the east and the southern cities of Eindhoven, Tilburg and Breda. This Central City Belt contains several traffic axes connecting the Randstad by rail, road and waterways with the German conurbation in the "Ruhrgebiet". This Central City Belt encloses the green heart and the river areas of Rhine and Meuse, called the central open space. Peatland, marine and fluvial clay lowlands predominate in this Holocene area. In the early middle ages the area consisted of swamps and mudflats formed by sea and rivers, before it was reclaimed for farmland. It was gradually enclosed, dike and drained, enabling permanent settlements and agriculture to become established. The area contains also the coastal dunes in the west, Pleistocene ice-pushed ridges in the northeast and aeolian sand deposits from the Pleistocene in the south. The slopes and the levees have long been favorite sites for settlements (Fig. 1).

Today the area is under stress. First, there is strong pressure towards urbanization. A half million dwellings is

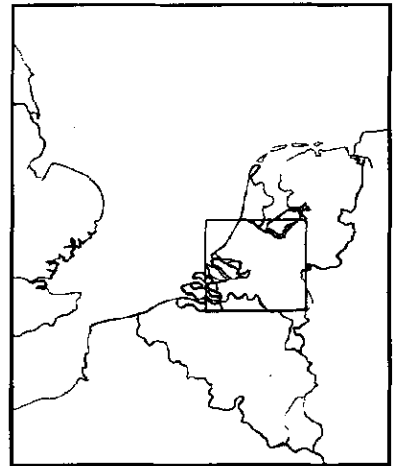


Fig. 1 The study area

planned for the Randstad extension in 2015 (Min. VROM, 1994). Glasshouse horticulture, one of the most important national industries, is expanding and threatening the open space. Most of the area is under grass, and dairy farming largely determines the appearance of the landscape. In the peat grassland areas there will have to be a particularly drastic economic change in agriculture. Because of the surpluses produced and the continuing costs of draining and land consolidation a withdrawal from agriculture up to 20% of land is expected. So the future of dairy farming on peat areas is very uncertain. However, the peat grasslands have great international value for the conservation of meadow birds. The central open space is also affected by the growth of infrastructure: broadening of motorways, the construction of a new railway for the high speed train, widening of the important canal between Amsterdam and the Rhine. All this will also fragment the landscape.

Since the issue of the National Nature Policy Plan (Min. LNV, 1990) the concept of the ecological main structure (EHS) is the backbone of nature policy in the Netherlands. In the ecological main structure existing nature areas, new areas for nature development and ecological corridors are connected in a network. At this moment the plan is in execution. However, the question raised is what are the consequences for nature when urbanization is so rapidly increasing. Is the concept of the ecological main structure still reliable in the near future or does it have to be adjusted or extended in order to compensate for the loss of ecological value.

On the other hand there are developments that seem to be more in-line with nature conservation and which give new opportunities for landscape development; for example, the burgeoning of outdoor recreation. There is a great demand for enlarging and improving recreational facilities, especially in the "Green Heart" in the middle of the Randstad. The Government wishes to exploit the characteristic features of the lowlands more efficiently in the future. In areas with large areas of water a better balance between the various land use types, such as water supply, nature reserves, water recreation and transport is being stimulated. Clay extraction in the river flood plains will also be an important issue related to nature and recreational developments. The Randstad Green Structure Plan (Min. VROM, 1985; Min. LNV, 1985) states that more than 10000 hm² of new forests and green areas are required for outdoor recreation around the urban agglomerations. The landscape needs to be reconstructed by planning, to guide these processes and to find a new balance for all interests. The scenario approach has been introduced as a methodology to support the decision making on those spatial planning problems.

2 Four scenarios

The central city belt study was commissioned by the Spatial Planning Agency of The Netherlands and executed in co-operation with Vista Consultant (Harms, 1995).

Based on the need for housing of half a million dwellings in the year 2015 four scenarios for the urbanization of the central part of the Netherlands were developed. In addition, within the scope of the urbanization concept of the particular scenario, the possibilities were examined to compensate for the expected losses of nature due to the building of houses. Taking into account the opportunities to extend the ecological main structure a total surface for new nature areas of 25000 hm² has been postulated. This led to four new scenarios for landscape development, which mean for each both a layout for urbanization and an adjusted and extended ecological main structure in order to restore, mitigate or compensate the negative impacts of urbanization on the ecological value. Moreover, the scenarios for the new landscapes concern other interests as well, as far as they strengthen the ecological goals. The four scenarios are called belt, shuffle, infra and diffuse (Fig.2).

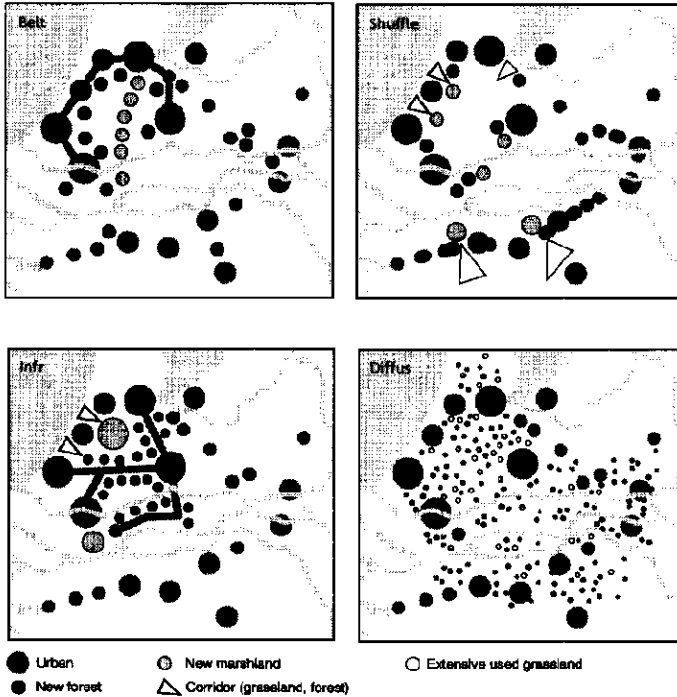


Fig. 2 Four scenarios for landscape development: outline

2.1 The belt scenario

In the scenario belt the traditional policy of urbanization is continued according to the fourth report on Physical Planning Extra (Min, VROM, 1990). In consequence the urban city belt will condense especially in the Randstad, which means an almost perfect enclosure without any gap enabling exchange of species from outside to inside or vice versa.

In the landscape development alternative of this scenario new forests and marshes created in the green heart compensates the loss of nature. The new forests are situated in the polders, which have good soil conditions for attractive and productive forests, and the marshes are planned on the waterlogged peat soils.

2.2 The shuffle scenario

Scenario shuffle is based on the assumption that economic activities will move gradually to the eastern and southern provinces of the Netherlands. In turn, urbanization will concentrate on the corresponding parts of the central city belt. This process of migration gives good opportunities to open up the city belt especially in the western part.

The landscape development alternative of the scenario shuffle puts emphasis on the establishment of new estates in the open gaps of the city belt. Moreover, in this scenario a city plan is chosen based on ecological water management. This means constructing marshes and water supply reservoirs down stream of the river valleys and nature and forest on the slopes and up stream within the same catchment area.

2.3 The infra scenario

The scenario infra is based on the idea that urbanization will develop along the infrastructure

across the green heart and the central open space. In this urbanization pattern the landscape, which is already fragmented, will be divided intensively into smaller units. On the other hand, the gaps in the city belt will remain open.

In the alternative scenario shelter belts of forests along the infrastructures are planned in order to compensate for the losses, but also for recreational purposes. Also, two large marshland complexes are situated in the remaining open spaces. As in shuffle the gaps in the city belt, especially those situated in the transition zone between the dunes and the green heart will be used to establish new estates.

2.4 The diffuse scenario

The last scenario is called diffuse. In this concept the government, national and provincial, give no steering to the urbanization process. This causes a scattered pattern of dwellings all over the study area. Each community will have their own town-development. It implies that the locals will be very involved in the design of their own environment.

The landscape development alternative of the scenario diffuse small woodlots and nature reserves will be planned in each community, which in turn will contribute to the scattered and fragmented pattern of this scenario.

3 Modelling the ecological consequences

In order to assess the ecological consequences of the scenarios, both with and without the nature compensation alternative, key animal species have been selected, particularly those which are good fragmentation indicators. Thirteen species have selected as representatives of the main habitats (Table 1). In this evaluation three criteria have been used: the habitat suitability, the population size and the accessibility of the landscape.

Table 1 Indicator species and habitats

Habitat type	Indicative animal species
Marshlands	Marsh harrier, cormorant, beaver, otter
Forest	Green woodpecker, hawk, red deer, pine-marten
Small-scale landscape	Polecat, badger, fox
Open landscape (meadow, arable land)	Black-tailed godwit, white-fronted goose

To evaluate the effect of the scenarios, the landscape ecological decision and evaluation support system (LEDESS) was used (Roos-Klein, 1991; Harms, 1993). LEDESS is a deterministic knowledge-based system, which simulates the spatial and temporal development of vegetation and fauna. The main operations of LEDESS are (Fig.3):

- checking the ecological feasibility through confrontation with the abiotic site conditions (site module);
- determining the final species composition of the vegetation, based on the expected vegetation development (vegetation module);
- determining the habitat suitability for fauna species and the required population size (habitat module);
- determining the accessibility of the suitable habitats (dispersal module).

Development of vegetation is determined by physiotope, target vegetation and management. Physiotopes are spatial abiotic units characterised by a specific set of parameters. The scenarios are formulated in terms of nature target types, i.e. a set of the desirable nature types according to the nature policy plan. Together, physiotopes and nature target types determine the vegetation succession, which may also be influenced by management. Land use and management can change

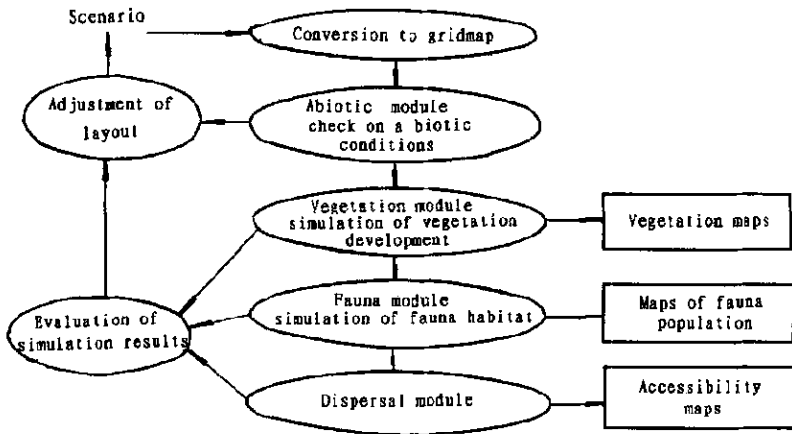


Fig. 3 The operation of the LEDESS

the direction of vegetation development. The development of the vegetation determines the conditions for the fauna by changing the area suited for breeding, foraging or refugal.

To evaluate the effects of scenarios on the three criteria mentioned above data on the actual situation and on the planned developments were stored in a grid-based geographical information system (GIS), with $1\text{ km} \times 1\text{ km}$ grids. The present-day situation was the starting point for the simulation. Data on soil type, hydrology and present-day vegetation were derived from a database of ecological variables on a national scale on a km^2 basis (Canter, 1991; Bolsius, 1994). Only the dominant vegetation and soil type in a grid cell were considered.

Evaluation of the scenarios started with checking the suitability of physiotopes for the proposed development of the target vegetation types. From the model, alternative physiotopes can be deduced, if the development proposed does not correspond with the present situation. As a result several measures were planned to change the present abiotic circumstances. Subsequently, the vegetation and fauna developments were simulated, using the present or changed physiotopes as a basis. Results of the evaluation can be expressed as the area suited for vegetation.

The effects on the fauna were established by calculating the area of potential habitat. The requirements of home range area for each species derived from literature were determined. Some of the species use different vegetation types to fulfil different needs. Most of these "shuttle species" are mainly birds, e. g. those that breed in forests and forage in grasslands or marshes. Both foraging and breeding habitat (i. e. vegetation types) of these species and area requirements were determined for both kinds of habitat. All vegetation types were classified for each species as optimal or non-optimal habitats. Then in order to evaluate the potential effects of the four scenarios on the fauna, maps of the expected vegetation were translated into maps of the potential habitat. Contiguous areas of potential habitat were aggregated, to reveal the population sizes that could be attained. Aggregates smaller than the individual home range area was rejected (too small). Larger areas were classified according to the expected population size. Finally, the accessibility of potential habitats was determined by simulating the dispersal of the fauna species, taking into account amongst others the resistance of the landscape. A special module of LEDESS makes this calculation (Bakker, 1997). Fig. 4 shows two examples of an accessibility map, the output of the dispersal simulation.

The calculations of the model and the comparison of the maps have led to conclusions on the

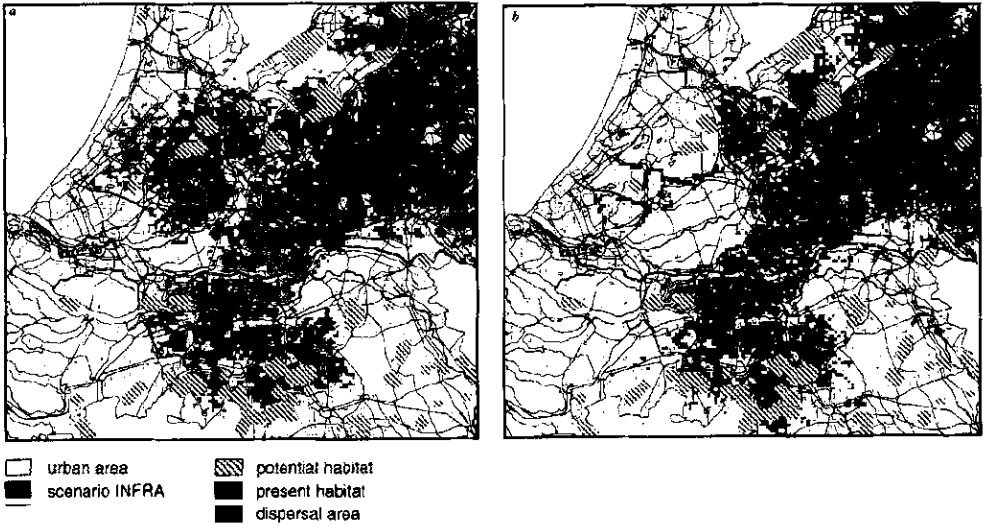


Fig. 4 Accessibility maps for the pine-marten: (a) according to the reference scenario (EHS), (b) according to the scenario infra without nature development

ecological consequences of urbanization and the effects of nature compensation for the scenarios and landscape developments alternatives concerned. Results were compared with the situation after implementation of the ecological main structure according to the nature policy plan (Min. LNV, 1990).

4 Results

The results are expressed in terms of increase or decrease of the three criteria of the evaluation: habitat suitability, population size and accessibility. In addition, attention is paid to the effect and the efficiency of the nature development to compensate the losses due to the impact of urbanization.

4.1 Habitat suitability and population size

4.1.1 Effect of urbanization without nature development

All scenarios cause decrease of suitable habitats for all key species. Relatively speaking, the loss is restricted if the total habitat surface of the species within the study area is taken into account. The scenario "diffuse" gives the greatest decrease in habitats due to the greatest edge effect of the scattered urbanization pattern. Also the population size is most effected by the "diffuse" scenario: the fragmentation causes an increase in small populations. Compact urbanization (the scenario belt) gives the fewest loss of habitats.

4.1.2 Effect of nature development

The nature development in the alternative scenarios means without exception an increase in habitat suitability for most of the selected species compared with both the present situation and the implemented nature policy plan. This is the direct impact of the additional area of nature in each scenario. Subsequently, especially for specially for species of forests, marshes and small-scale landscapes, more suitable habitat can be expected. In contrast, species of open landscape, such as meadow birds and geese, will diminish. The gain of suitable habitats means also an increase in population size in most cases. However, the question is whether the increase in population size is sufficient for a sustainable population. The results illustrate that, for instance, the landscape

development alternative of scenario infra does not effect a lasting population of the otter in spite of a considerable enlargement of the marshlands. The connection with the adjacent habitat is cut off due to the urbanization pattern along the infrastructure. The general conclusion can be drawn that for species with a large home-range, fragmentation of its habitat following urbanization can be very difficult to compensate for by enlargement within that fragment.

Table 2 De-/increase of habitat to species of different landscapes

Scenario	Diffuse		Infra		Belt		Shuffle	
	Without	With	Without	With	Without	With	Without	With
Nature development								
Open landscape	---	---	---	---	---	---	---	---
Marshland	---	---	---	++	-	+++	-	++
Small-scale landscape	--	--	-	-	-	+	--	+
Forest	--	-	-	++	-	++	-	+++

Note: ---/+++ = de-/increase > 5% ; --/++ = de-/increase 2%—5% ; -/+ = de-/increase < 2%

4.2 Accessibility

Accessibility is calculated by means of the dispersal module. The effects are presented as a degree of connectivity along the major corridors within the study area according to the ecological main structure of the Nature Policy Plan (Min. LNV, 1990), i. e. :

- Sandridge of utrecht-green heart, a corridor for terrestrial animals ("green" or terrestrial corridor);
- Dunes-green heart, also a corridor for terrestrial animals ("green" corridor);
- East-west Brabant, also a corridor for terrestrial animals ("green" corridor);
- Main rivers (Rhine, Waal and Meuse), a corridor for aquatic animals ("blue" or aquatic corridor);
- "The blue axe", an aquatic connection across the green heart between the rivers and the IJsselmeer ("blue" corridor).

4.2.1 Effect of urbanization without nature development

The effects of the scenarios "belt" and "infra" on further isolation of local species populations are considerable. The accessibility of potential habitats for different species coming from existing core areas decreases due to the extending urbanization in-between. The ecological connectivity is cut of for both the "green" corridors to the green heart and the "blue" corridor across the green heart.

4.2.2 Effect of nature development

The expected positive effects of nature development are discouraging. This can be explained by the present situation, which is already very fragmented. The building of new wildlife passages (ecoducts) in the landscape development alternatives of the different scenarios can barely improve this isolated situation (Table 3).

Table 3 Effects on the corridors of the ecological main structure according to the Nature Policy Plan (Min. LNV, 1990)

Scenario	Diffuse		Infra		Belt		Shuffle	
	Without	With	Without	With	Without	With	Without	With
Nature development								
Sandridge-green heart	-	-	---	---	--	-	0	+
Dunes-green heart	-	-	0	+	--	-	-	0
East-west brabant	-	-	0	0	0	0	0	+
Main rivers	0	0	0	0	0	0	0	0
The blue axe	-	-	---	---	-	+	-	0

Note: 0 = no effect; -/+ = moderate effect; --/++ = strong effect; ---/+++ = very strong effect

5 Conclusions

Continuing policy to condense urbanization within the central city belt (the scenario belt) gives good opportunities for nature development in the green heart on a large scale (new forests and marshlands). However, the condensed urbanization gives bottle-necks in connectivity on the belt, especially concerning the exchange of species along the "blue" corridors. A reshuffle of the urbanization to the eastern and southern parts of the city belt (scenario shuffle) diminishes the pressure on the green heart corridors. The strong fragmentation of the present-day situation hampers the positive effects of new ecological connections (wildlife passages), especially for the "green" corridors.

Increasing isolation due to on-going urbanization can be compensated by enlargement of habitats. Enlargement of habitats can lead to sustainable populations if a critical size is exceeded. A good layout and location choice of urbanization and new nature areas can enhance the efficiency of nature development. That means that less area can be used for nature development.

Both the urbanization process and nature development on a large scale can cause a decrease in suitable habitat for geese and meadow birds. Taking into account the international significance of those species a careful planning and design have to be considered.

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