6 Applications of spatial metrics for environmental monitoring and planning, exemplified by afforestation scenarios for Vendsyssel, Denmark

6.1 Introduction/background

In the previous chapter, methods for quantification and visualisation of forest- and landscape structure were described. As an example of the possible use of spatial metrics and moving-windows methods in planning at regional level, the impact on landscape structure of different afforestation strategies is assessed in the present chapter. A number of common GIS and image processing operations were used to create different scenarios that represent very different afforestation strategies. Changes in spatial metrics and Hemeroby index values were compared with the present situation.

In Europe, afforestation has become an important issue during the last few decades. Partly as a response to changing conditions for agriculture, partly following a demand for nature conservation, environmental protection and recreational facilities. The national goal for Denmark is a doubling of the current forest cover of 11% in a “tree generation”, i.e. 80 to 120 years, as expressed in the Forest Act of 1989 (Jensen 1999).

The study site used in this study is similar to the area used in chapter 5, Vendsyssel in Northern Jutland. Today, the average forest cover within the study area is 9.5 per cent, but even within this limited area forests are very unevenly distributed. The western part of Vendsyssel is poor in forest, a situation that dates back to pre-historic times, when the forest were cleared for cropping and grazing, mostly on the Yoldia plains (Hansen 1964, p. 13). Some less fertile areas soon turned into heathlands, most of which have later been reclaimed for agriculture or turned into plantations, mostly spruce. On the other hand, parts of the extensively used, hilly areas are though to have remained more or less constantly forested.

The main agents for actually planting new forest are farmers/land owners and public authorities. The tools for control of the afforestation activities on private land are grants and tax deductions (Jensen 1999). They are given when forest is established in designated afforestation areas, which are outlined at the national level and incorporated as parts of the regional development plans. Other areas are considered neutral, and planting of forest is allowed but not encouraged, and finally some 'negative areas' have been pointed out, where afforestation is unwanted. The criteria for selection of afforestation areas include protection of ground water resources, where the quality of these is threatened, for instance through leaching of manure and pesticides from intensive agriculture (Nordjyllands Amt 2001, p. 159). Also outdoor life activities have high priority, and it is thus attempted to create larger coherent forest areas rather than forest patches on small and difficultly accessible marginal agriculture areas. Negative areas include cultural environments, in particular around churches, but also areas designated for wind farms should have a distance of up to 2 km from forests (ibid, p. 161).

Given the potential of thematic mapping and application of moving windows for extraction and display of spatial metrics, it was considered appropriate to use such metrics as indicators of structural change for different afforestation scenarios, as an example of the potential use of landscape-ecological spatial analysis in a real-world setting.

For this study, only the base map area is used (see Figure 5.2), not the entire area of the region Nordjyllands Amt, thus this is not a full investigation of the effects of afforestation at region level. Four different scenarios have been established, based on the following criteria:

1. All of the designated areas are afforested;
2. Connectivity between existing forest areas are improved through planting of forest corridors;

3. Hemeroby is minimised through planting of forest in the areas with highest Hemeroby index values;
4. Public access to forest is optimised through planting of forest on the available lands closest to urban concentrations.

These imaginary afforestation scenarios represent extreme cases of weighting interests, and are not to be taken as recommendations for future land use.

6.2 Objectives

Objectives for this study include:

- Creation of afforestation scenarios in the form of modified AAK land use/land cover maps with 25 m grain size, based on existing AAK maps, assumptions on afforestation strategies and supplementary data on terrain and population.
- Assessment of the resulting changes in landscape structure expressed through variations in spatial metrics and Hemeroby values, and display of the results for overview of where the most significant changes take place.
- Comparison of Forest Concentration (FC) profiles from the current situation and the different scenarios.

6.3 Data

The data used for this study are basically same as in chapter 5, supplemented by information on soil texture, population density and location of areas designated for afforestation. Each of the additional data sets are briefly described below.

6.3.1 Soil type maps

The data on topsoil types were acquired (for the cultural environment atlas project) as vector data at a nominal resolution of 1:50,000 and converted to a raster image with 25m grain size. Twelve soil classes are defined, according to texture/grain size distribution but normally only eight classes or colour codes are used (Breuning-Madsen et al 1999). The definition of the classes are shown in Table 6.1.

Colour code	SOIL TYPE	JB nr.	Clay	Silt	Fine Sand	Total Sand	Humus
1	Coarse sand	1	0-5	0-20	0-50	75-100	<= 10
2	Fine sand	2			50-100		
3	Clayey sand	3	5-10	0-25	0-40	65-95	
		4			40-95		
4	Sandy clay	5	10-15	0-30	0-40	55-90	
		6			40-90		
5	Clay	7	15-25	0-35		40-85	
6	Heavy clay or silt	8	25-45	0-45		10-75	
		9	45-100	0-50		0-55	
		10	0-50	20-100		0-80	
7	Organic soils	11					> 10
8	Atypic soils	12					

Table 6.1 Definition of soil types and colour codes for the soil classification of Denmark (after Breuning-Madsen et al 1999).

6.3.2 Dwellings density maps

One of the base maps for the Danish Area Information System (AIS) is a classification of the built environment (Nielsen et al 2000a). Here data from the national Building and Dwelling Register are aggregated to 100*100m (one hectare) grid cells, for use with other applications (Hvidberg 2001). One type of information herein is the density of floor space in the buildings within the grid cell. This area is used as a proxy of population density. The data are available from the National Environment Research Institute (DMU) in vector Arc-View or MapInfo format[36]. Using the Vertical Mapper (R) module of MapInfo, these data could be converted to a 'building density' raster map of Denmark, from which a subset for the study area was extracted. The data and the procedure for creation of an image to be used in scenario building is illustrated in Figure 6.1. The apparent 'cutting off' of the northernmost part of the region owes to the output from filtering including only pixels within the filter radius from the edges.

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[36] From this URL address: http://www.dmu.dk/1_viden/2_miljoe-tilstand/3_samfund/ais/4_Download/MIdownload/aisdownload.htm (accessed 19/2 2004)

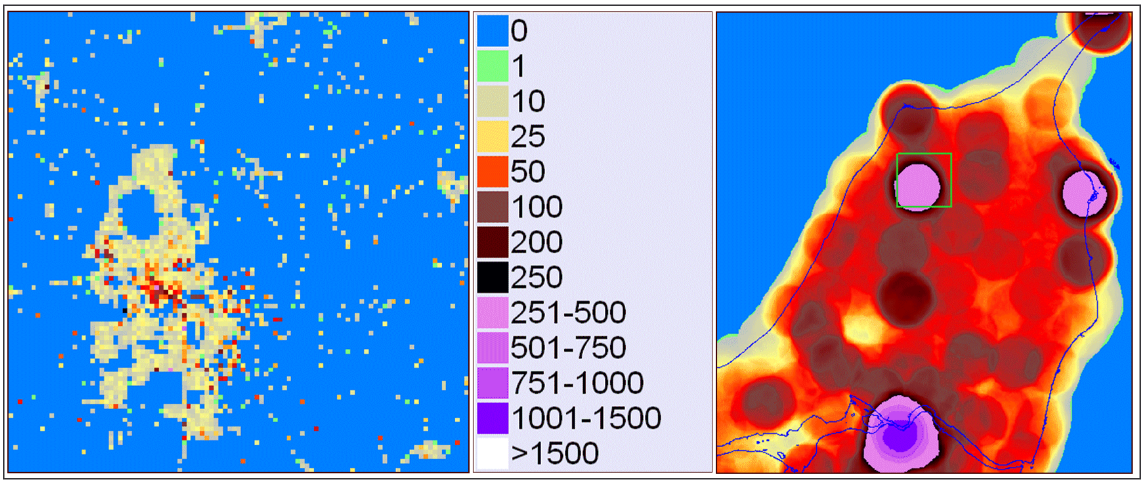

Figure 6.1 Creation of dwellings/floor space density surface with 25m grain size. To the left the density grid imported to image at 100m grain size. In the middle the legend for colour coding of density values, applied to both images. To the right the density image re-sampled to 25m grain size and filtered using a circular 'kernel' with radius 5km. Coasts inserted as blue lines, the sub-area of 10*10 km around Hjørring, used in Figure 6.2, is marked by the light green box.

6.3.3 Designated afforestation areas

These areas can be viewed on the regions web site[37], but the data are not yet available for download. However, data were available on request, and were delivered as Arc-Info shape files, and ready for use in the image processing routines for generation of the hypothetical forest maps.

6.4 Methods

Simple ways to create theoretical maps of future land cover are described, along with the approach to comparison of derived spatial metrics with similar metrics from the current situation.

6.4.1 Creating afforestation scenarios

The four different criteria for development of the scenarios are listed in the introduction. Common to all the scenarios, is that the forest cover is increased to 14.4 per cent. This figure is reached by using all of the area, which is available for afforestation within the designated zones where afforestation is promoted – i.e. Scenario 1, using the designated areas. This

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[37] Interactive map available at: http://www.gis.nja.dk/lodsejerjava/default1.htm. Implementation in "ESRI Map Café", Java must be installed. Tick "Skovrejsning" to activate afforestation layer. Accessed 8/3 2004.

corresponds to establishing forest on 17226 hectares or 172 square km. Also common to all the scenarios is the relative proportion of different forest types, measured as area (number of pixels). According to the generally accepted goal of Multi-Purpose Forestry (Jensen 1999, Nordjyllands Amt 2001, section 5.2), an even distribution of coniferous and deciduous forest is aimed for, with some areas of mixed forest as well and small areas of the bush-forest class, though still relatively larger than the current presence of these land cover types. The distribution within the afforested areas thus becomes: Bush-forest 2%, Coniferous 44%, Deciduous 44% and Mixed 10%.

The AAK classes which were used as possible afforestation sites include:
Mineral extraction areas (being mostly gravel pits), Arable land, Pastures, Grass in urban areas, Sparsely vegetated areas and the ‘unclassified’ class, which by comparison the LCM data appeared to be mostly arable land. These classes were used to create a (mask) layer representing possible ‘target areas’ for afforestation. No patch size limit was applied, thus patches of one or a few pixels could be identified as potential afforestation sites.

It was furthermore assumed that current forest areas remain as they are, i.e. that they keep the current land use/cover, so the natural (managed) dynamics of these areas are not modelled. The same applies to other land use types, so for instance urban sprawl and nature restoration is not modelled either.

A generalised method for creation of a scenario map can be summarised as follows:

- Create potential surface (e.g. proximity to corridor, population density, Hemeroby)
- Multiply by potential afforestation area mask
- RANK result in order to find areas best suited for afforestation
- RECLASS to select overlay (selecting pixels with highest ranking)
- Multiply overlay (true) with forest index
- RANK to sort according to forest type index (defined below)

- RECLASS to assign to resulting forest classes
- Assign non-zero values to original AAK-map, result: selected forest classes replaces 'suitable classes' (agriculture etc.).

Where RANK and RECLASS are Idrisi functions (Eastman 1997), image arithmetic operations were performed in WinChips (Hansen 2000). The creation of potential surfaces and the forest index is described below.

Forest type index:

In order to make the most realistic map of future forest scenarios, a simple model for prediction of forest type from landscape parameters was applied. A "Forest type index" was defined as:

$$\mathbf{FTI = GMT + ST + ALT/15}$$

where GMT is the "textural equivalent" of the geomorphological landscape type (i.e. moraines have high clay content, dunes low), ST is the textural soil class (low values = gravel/sand, high values=silt/clay, range from 1 to 8, see Table 6.1) . ALT is the altitude from the 25m-cell DEM, where the maximum value in the test area is 130.4 m. The composition of the index is based on the following assumptions:

- Deciduous forest is mostly found at higher elevations on finer soils (moraine hills).
- Coniferous forest is mostly found at lower elevations on coarser soils (near the coast, plantations in dune areas).

The assignment of 'afforestation pixels' to different forest types, as described above, should thus be possible according to their FTI value. The distribution of the current forest types found in the AAK maps was tested against a model based on ranking of pixels based on FTI values and the results are shown in Table 6.2. Though the agreement is not truly convincing numerically, application of the FTI was found to produce realistic patterns within the areas assigned for afforestation, see Figure 6.2.

	0: Non-forest	2: Bush-forest	3: Deciduous	4: Coniferous	5: Mixed	Total
1:Land/matrix	5106122	0	0	0	0	5106122
2: Bush-forest	0	**0**	78	479	1	558
3: Deciduous	0	26	**30104**	85058	312	115500
4: Coniferous	1	530	85006	**333176**	1049	419762
5: Mixed	0	0	313	1049	**0**	1362
99: Background	5588694	2	0	0	0	5588696
Total	10694817	558	115501	419762	1362	**11232000**

Table 6.2 Cross-tabulation of test image with forest types assigned according to pixel ranking by FTI (columns) against actual forest map from AAK at 25m (rows). Kappa index of agreement for class 3 is 0.252, for class 4 it is 0.786.

Improved Connectivity is modelled by manually drawing centre lines for forest corridors to connect existing large forest areas. The lines are converted to a raster image and the DISTANCE function of Idrisi (Eastman 1997) is used to assign highest values to pixels closest to the lines. Thus, an image of proximity to corridor centres functions to determine priority for afforestation. The total length of the proposed corridor lines was 384 km, This approach turned out to produce broad corridors with a width of 800 to 850m in open land, making them forest habitats in their own right to most species, rather than merely corridors for movement.

Proximity to population centres was modelled by creating a ‘building density surface’, through application of an average filter with a radius of 5km or 50pixels in the 100m-grain image. The choice of such a large filter size was based on the intention to include areas around the larger centres in the region, especially Hjørring and Aalborg. This approach also contributes to segregation of residential/recreational areas from agricultural ones. More advanced models have been developed, that take into account accessibility (Skov-Petersen 2001).

Highest current Hemeroby was found using the smoothed Hemeroby index map produced for illustration purposed in the precious chapter, based on averaging of NDP values in a circle with radius 1.25km or 50 pixels in the 25m-grain AAK-based image. It is assumed here, that establishing forest in the areas with current highest Hemeroby index values will lead to the greatest possible over-all decrease in Hemeroby index values for the region as a whole. The possible high costs associated with using the best (most intensively used) arable land and areas close to urban centres are not considered, though in reality some cost-benefit analysis would be carried out in the context of such a radical land-use change.

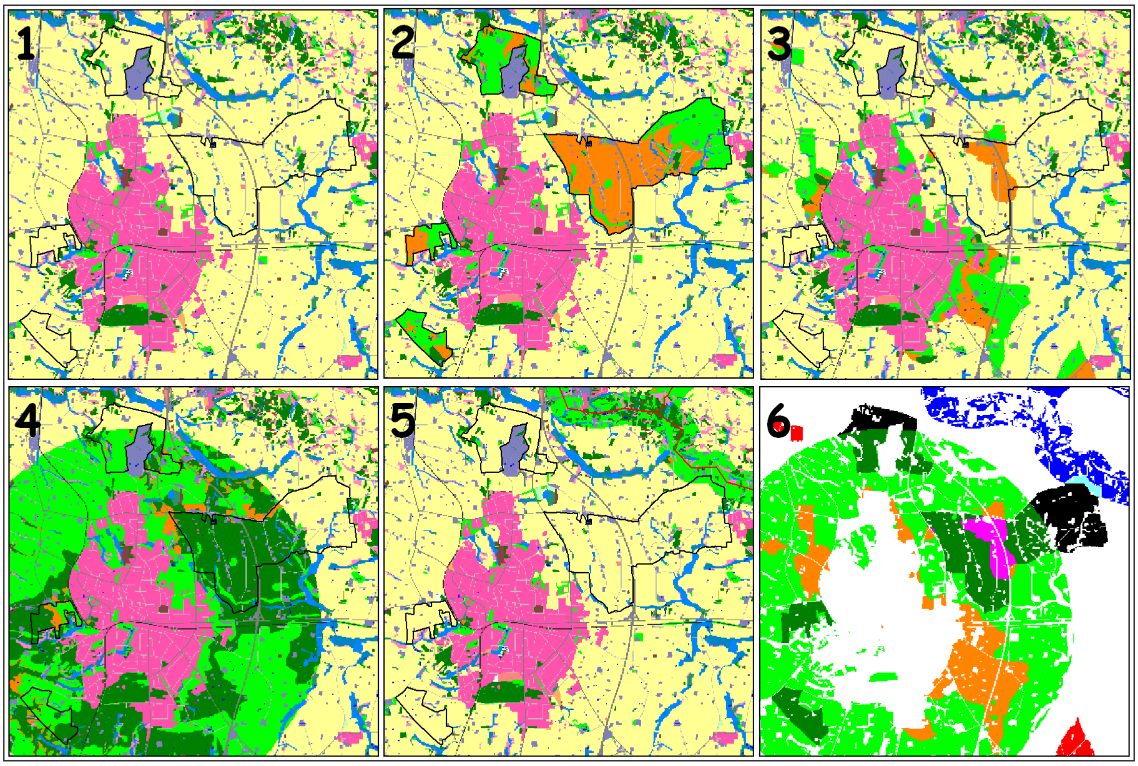

Figure 6.2 Local effects of different theoretical afforestation scenarios around regional centre town Hjørring. Image 1 shows the current situation, image 2 afforestation of the designated areas, image 3 the minimised Hemeroby scenario, image 4 the proximity to urban centres scenario, image 5 the connecting-corridor scenario and image 6 a combination of the appointed areas in image 2 to 5, indicating only little overlap between the different scenarios. Image 1-5 follows the standard AAK legend, shown in Figure 5.4, in image 6 the afforestation areas from image 2 are black, from image 3 red, from image 4 green and from image 5 blue, other colours indicate overlaps of two or more scenarios.

6.4.2 Calculating and comparing metrics

Moving-windows calculations of spatial metrics were performed on the scenario-maps, using the methods and IDL-scripts described in the previous chapter. In this study, focus was on the 1*1 km output cells, as it was found that this resolution gave the best basis for comparing the effects of the different scenarios and most significant changes. Change was assessed in two ways: by comparing average metrics values for the entire test area and by creation of change images by subtraction of the M-W image representing the current situation from the scenario-based M-W output (so that positive values come to represent increases in metrics values and negative values decreases). For extraction of these change values, degraded versions of the afforestation maps for the different scenarios were used as masks, in order to work only on cells affected by ‘afforestation’ (this is the reason that forest cover increases in all instances in Table 6.3). Finally, the cover metrics were calculated for window sizes ranging from 500 to 5000 or 5500m at 500m increase, and the results were used to create forest concentration (FC) profiles for the different scenarios.

Hemeroby maps were created in the same way as in the previous chapter. NDP value maps were created from AAK land use maps, with the new forest imposed. This was done through an Idrisi re-classification routine. The Hemeroby index maps were created using the IDL-script for averaging byte values and returning an Idrisi real-values image (see Appendix 1.5).

6.5 Results

6.5.1 Changes in metrics values

Table 6.3 shows the differences between the spatial effects of the different scenarios, compared to the present. In all cases 172 km^2 of additional forest was created, but how concentrated they are differs widely. For the Near Urban (NU) scenario only 373 windows of 1km^2 are affected, corresponding to adding 46 hectares of forest per km^2, while for the Maximum Hemeroby (MH) cells scenario the number is 808, corresponding to adding 21 hectares of forest per km^2. These differences are not surprising, since there was no mechanism for spatial concentration of the selected pixels in the MH scenario. Still, the structure of the new forest areas is surprisingly spatially coherent – distinctively non-random. The Improved Connectivity (IC) scenario falls between the NU and MH scenarios in terms of number of windows affected. Here the elongated shape of the new forest areas, stretches the effect across a number of windows. The changes in cover percentage seen in Table 6.1 also reflect this.

	Designated Areas N = 492			**Improved Connectivity N = 668**		
	Min.	Max.	**Mean**	Min.	Max.	**Mean**
Cover	1	95	**35.197**	1	100	**26.171**
Edge	-1800	20750	**5742.683**	-8550	23950	**5122.193**
M	-3.743	1.625	**-0.153**	-2.711	31	**-0.11**
NP_back	-2	31	**4.242**	-6	30	**3.846**
NP_total	-3	43	**6.366**	-7	29	**5.79**
Richness	0	3	**0.677**	0	3	**0.531**
SHDI	-0.931	1.096	**0.17**	-0.619	1.08	**0.165**
SIDI	-0.567	0.665	**0.1**	-0.472	0.655	**0.103**
SqP	-0.961	0.562	**-0.042**	-0.943	0.717	**-0.036**

	Maximum Hemeroby cells N = 808			**Near urban/popultaion N = 373**		
	Min.	Max.	**Mean**	Min.	Max.	**Mean**
Cover	1	100	**21.402**	1	100	**48.432**
Edge	-500	29050	**5377.042**	-3150	29850	**9341.22**
M	-3.613	2.971	**0.355**	-3.357	4.419	**0.302**
NP_back	-1	19	**2.079**	-3	22	**4.957**
NP_total	0	37	**4.663**	-1	56	**10.257**
Richness	0	4	**1.053**	0	4	**1.097**
SHDI	-0.647	1.348	**0.231**	-0.708	1.345	**0.261**
SIDI	-0.484	0.73	**0.138**	-0.458	0.729	**0.149**
SqP	-0.979	0.748	**-0.085**	-0.894	0.723	**-0.009**

Table 6.3 Observed values of *changes* in metrics values per 1*1 km window for the four different scenarios – compared with the current situation. N describes the number of windows/output cells changed under the scenario.

The greatest change in Edge Length is seen for the near urban scenario, where the greatest increase in patch count metrics is also found. This is because new forest is placed in the smaller patches that characterise the near-urban landscape, compared with the open land where agriculture dominates, giving fewer and larger patches (a more coherent landscape matrix). The Matheron fragmentation index decreases for the Designated Areas (DA) and the improved connectivity scenarios, where forest is placed in rural areas, whereas increases are seen for the MH and NU scenarios. The greatest change in NP_back, the count of background patches *within* forest is seen for the NU scenario, but the greatest increases relative to the NP metric is seen for the IC and DA scenarios. This is because land use elements like small biotopes and rural settlements that currently seem like ‘islands’ in the agricultural matrix will appear as gaps in a modelled coherent forest cover.

The forest type *richness* increases the most for the MH and NU scenarios, where new forest is placed in areas with low forest cover and relatively low diversity, whereas for the DA and IC scenarios, additional forest is placed in areas already diverse and ‘natural’, leading to falling diversity at forest and possibly landscape thematic level. The diversity metrics change in a way similar to richness, most for areas that previously had little forest. The SqP metric shows a slight decrease on average for all scenarios, most for the MH scenario, indicating that the afforestation leads to more natural (more complex/less square) shapes of the (lower thematic level) layer consisting of the combined forest classes.

The visual appearance of the changes in metrics values and their distinct spatial distribution is shown in Figure 6.3. The changes in the Matheron index (M) and Shannon’s Diversity Index (SHDI) are used for illustrations, as these metrics are practically un-correlated (see section 4.5.3) and indicate different aspects of forest structure. It should be noted that an ‘inverted’ look-up table is used for M – positive values indicate more fragmented landscapes, negative values less fragmented.

The spatial distribution of changes in metrics values shows some distinct patterns, especially for the IC scenario. Here afforestation leads to decreasing diversity in areas which already has high proportions of forest and nature classes. Finally, it should be noted that the quantification of the changes in metrics values, summarised in Table 6.3, are calculated only for the cells that are affected – thus *not* the values for the entire landscape[38]

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[38] That could readily be done using Fragstats or similar software, for evaluation of all sorts of consequences of the scenarios.

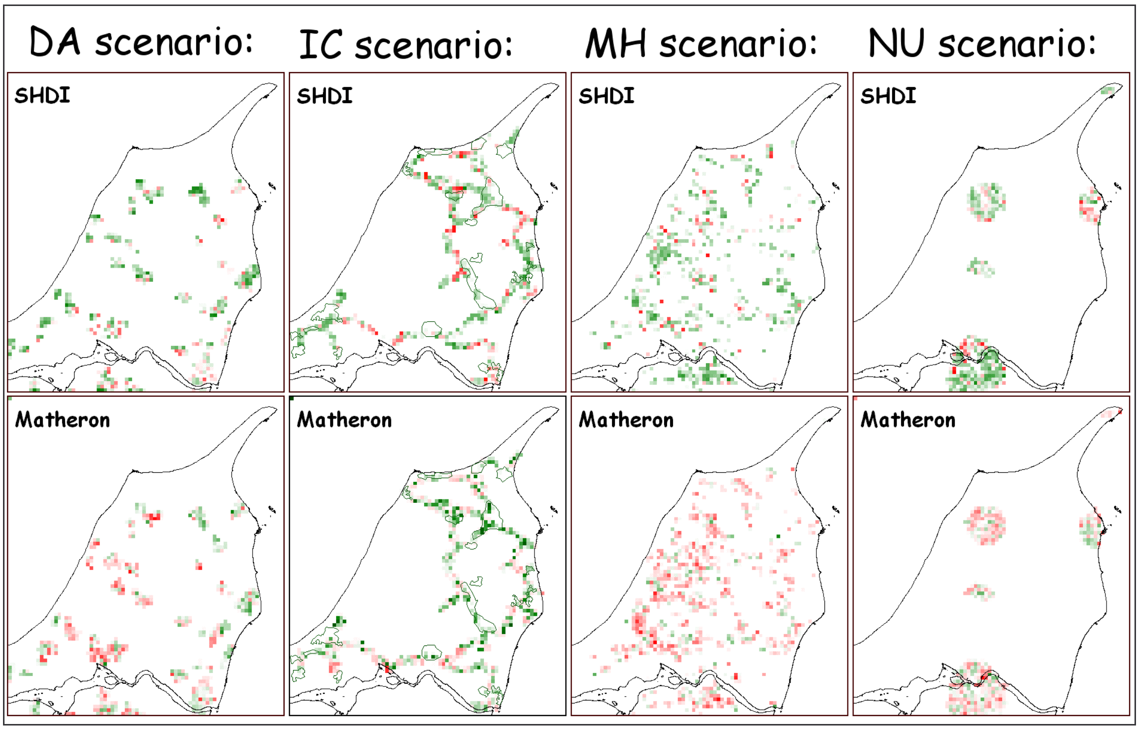

Figure 6.3 Summary of effects on spatial metrics from different afforestation scenarios. Red colours indicate decreasing diversity (SHDI values) and increasing fragmentation (Matheron index values), green colours indicate increasing diversity and decreasing fragmentation, white indicate no change or pixels outside the actual afforestation zone. In addition to coastlines, existing larger forest areas are shown for the 'connectivity' scenario.

6.5.2 Changes in Hemeroby

Average Hemeroby index values from the four different afforestation scenarios are very similar, as seen from Table 6.4, which shows a decrease in the average index value from 67 to 65.

1*1 km windows	Values for entire scene (non-background)					Change in affected windows			
	current	DA	IC	MH	NU	DA	IC	MH	NU
Min.	15	15	15	15	15	-46.15	-37.34	-47.89	-48.13
Max.	90	90	90	90	90	-0.025	0.094	1.297	12.075
Mean	67.079	65.045	65.048	65.049	65.035	15.308	11.129	8.877	20.012
Std. Dev.	15.483	16.176	16.352	14.96	16.329	12.126	9.353	9.857	14.197
N.obs.	3808					506	695	871	389

Table 6.4 Changes in Hemeroby values following implementation of different afforestation scenarios.

All scenarios apart from DA produce some cells with increasing Hemeroby index values. This is surprising, since afforestation is normally meant to increase naturalness, thus lowering the Hemeroby values. The reason that it is possible to have higher Hemeroby index values in some cells from the simulated maps is that two ‘land use types’ from the AAK get higher NDP values when they are ‘afforested’: sparsely vegetated areas (NDP 15) and unclassified pixels (with NDP 0, which it was chosen to include in the afforestation scenarios in order to make more coherent forest areas). It appears contradictory, that the Maximum Hemeroby scenario (intended to minimise landscape Hemeroby through afforestation) does not produce a greater decrease in the averaged Hemeroby index values. This is due to the effect mentioned above and the similarly high NDP values of the other grains of the AAK map that change use in the scenarios: Mineral extraction areas have NDP value 90, Arable land have NDP 80, Pastures have NDP 60 and Grass in urban areas have NDP 70, while the forest classes have NDP values between 30 and 40, see Table 5.9. This shows the problems associated with assigning a single number to characterise land cover properties (quality).

The changes in Hemeroby index values are illustrated in Figure 6.4, where the current Hemeroby pattern is also seen. For the DA scenario, clear differences are seen between sites, with the most marked decreases in large areas where agriculture dominates. This is also apparent for the MH areas, where the largest decreases are seen in the western parts of the study area, where reclamation of heaths, lakes and wetlands have produced a landscape of large fields with little interruption – which following the scenario will be turned into large forests with little interruption. The DA scenario has appointed a number of smaller forest areas in this part of the region, as well as a larger area between Aalborg and the rural town Aabybro, which could possibly function as a stepping-stone for connecting existing forests and plantation. In the DA scenario this area stands out with great decrease in Hemeroby index value. The change image for the NU scenario shows the difficulties with simulation afforestation near urban centres (red colours indicating increased Hemeroby) but also illustrates the creation of (recreational) land use buffer zones between the towns and the surrounding open land.

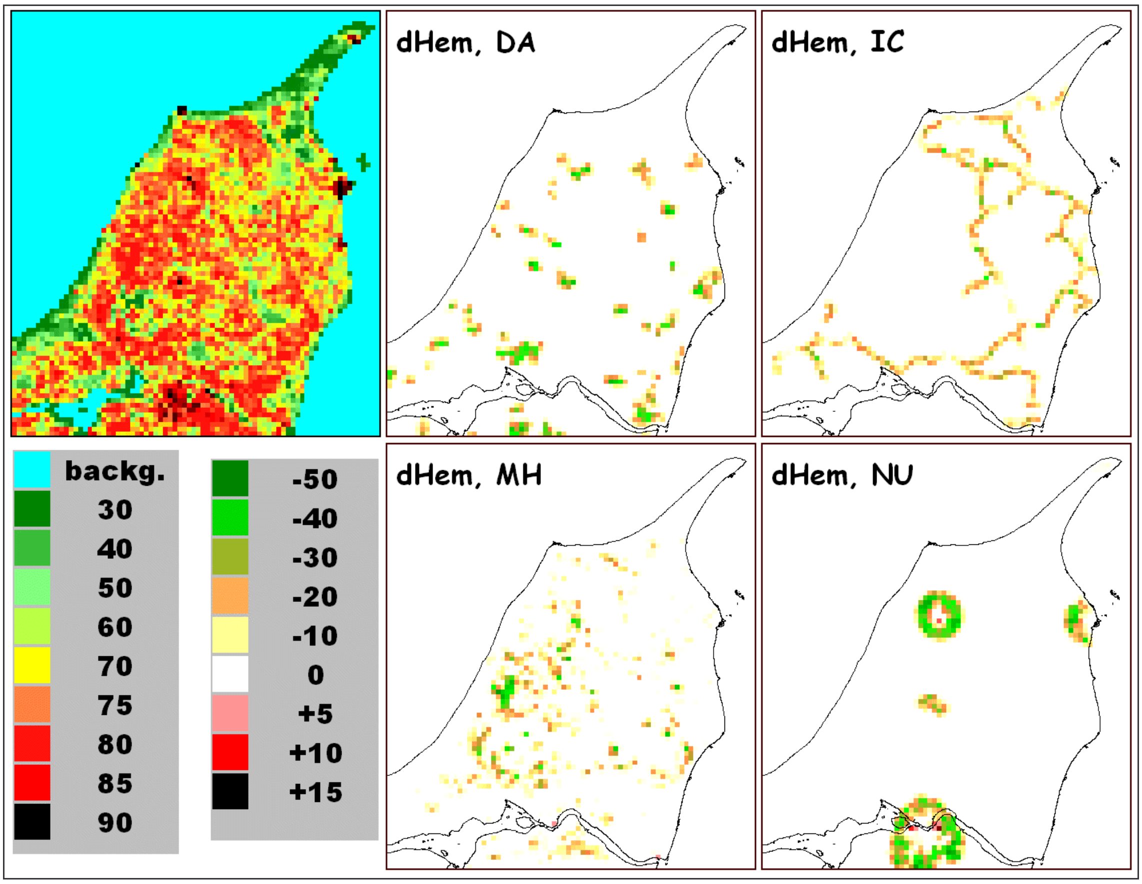

Figure 6.4 Changes in Hemeroby index values (averages within 1*1 km windows) with the different scenarios. The upper left image shows the current situation, according to the legend to the lower left, while the legend to the right of that shows the colours assigned to the changes.

6.5.3 Forest Concentration profiles

In the previous chapter, the choice of window sizes for the calculation of F.C. values resulted in a logarithmic-like x-axis for the F.C. profiles. Since this was not possible to do in a similar way here, due to the larger number of window sizes, at smaller intervals, a more linear shape of the profile curves was obtained by plotting the square root of the F.C. values. The result is seen in Figure 6.5. The F.C. curves appear very similar for the different scenarios, mostly because they represent the entire study area, where the existing forests and their spatial distribution are included in the scenario-based forest maps from which the curves are made. The current forest pattern thus influences the position and shape of all of the scenario curves. The FC curve for the MH scenario however stands out from the rest and shows the more scattered/less concentrated distribution of the forest patches across the study area. The current situation has the highest FC-values, thus all the afforestation scenarios contribute to spreading forest across the study area, into parts of the region that were previously without forest – and reduce the concentration of forest into certain areas – at least according to this definition.

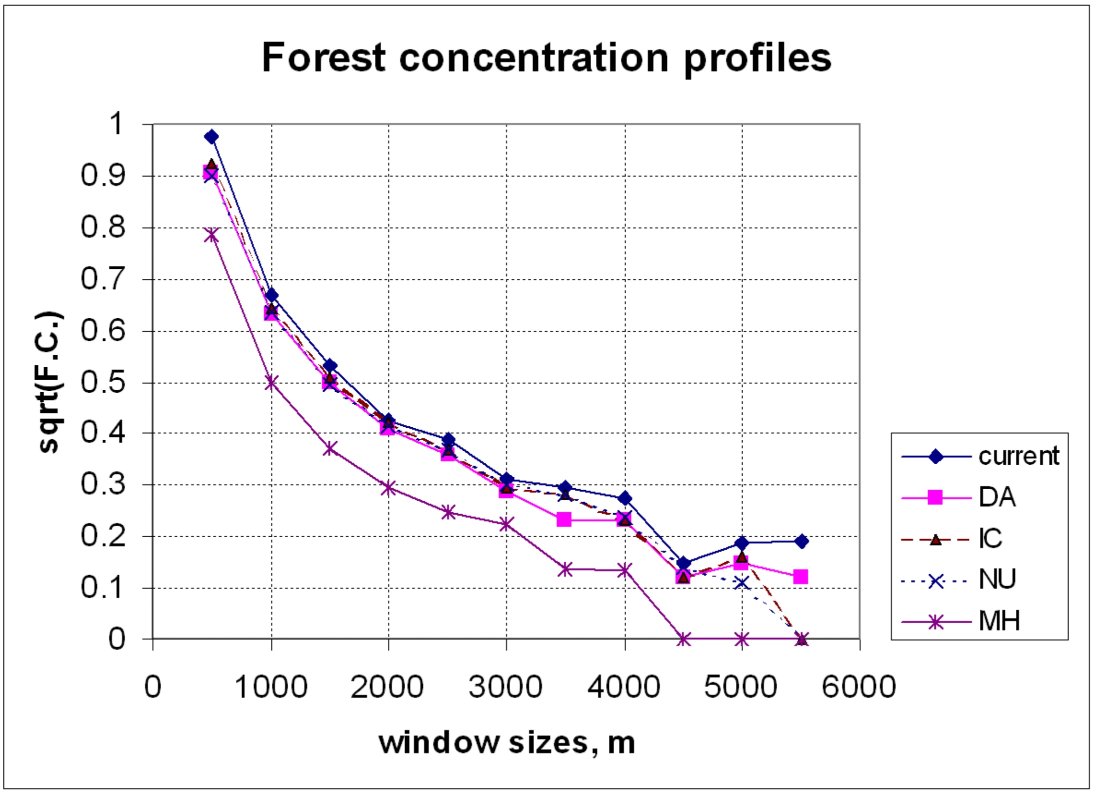

Figure 6.5 FC profiles for the different scenarios used in this study, with the abbreviations defined in the text.

6.6 Discussion/conclusion

The use of the Forest Type Index (FTI) for assignment of forest type to selected afforestation areas ensured that large coherent patches of the different forest types were created, but did not give a completely realistic picture, as seen by the forest patches created in the scenarios being relatively larger and more compact, i.e. less scattered and with larger patch size than existing forest (as they appear in the AAK maps, see Figure 6.2). This is possibly because altitude was too dominating a factor in the FTI, and it must be concluded that this method does not yet provide fully realistic forest patterns - different definitions should be tested and applied to structurally different regions. An alternative might be the use pattern generating software such as SimMap (Saura and Martinez-Millan 2000) or RULE (With and King 1999) for distributing different forest types into the ‘designated’ areas.

In general, a clear advantage of using this kind of scenario “modelling” is that a planner is forced to consider not only the immediate structural effects of changed land use, but also *why* they are reflected in the metrics values as they are. For instance, does the increased patch count and fragmentation metrics from the Near-Urban scenario point to the fact that the open land here is already fragmented by human activity and that planted forest will also be so?

When the outcome of the spatial analysis of the different scenarios are compared, some characteristics can be identified:

- For the areas designated for afforestation in the regional development plan (DA), all metrics show changes that are beneficial according to the patch-matrix-corridor model of landscape ecology, i.e. decreasing fragmentation and increasing diversity.
- For the improved connectivity (IC) scenario, the same trends are seen, but they are less pronounced than for the DA scenario, probably because here more new forest are placed in areas that already have a certain amount of forest.
- The Maximum Hemeroby areas (MH) scenario places forest near towns, which assures a radically new distribution of forest across region and increased diversity, although the pseudo-random placing of new forest patches result in increased fragmentation. An argument against using this method to assign areas for afforestation could be that it takes the best (most intensively used) agricultural lands out of use.
- The Near Urban (NU) scenario creates large, apparently coherent forests around the largest towns, and result in the greatest increase in forest diversity in the affected areas. These forest areas however turn out to be relatively fragmented by roads, railways etc.

The suite of metrics that was used to quantify landscape structure turned out to be useful for characterisation of current and future patterns as well as detection of changes. The combination of reporting metrics values in tables and showing their spatial distribution on (groups of) maps can aid identification of zones undergoing large changes, following different scenarios for land use planning.

The scenarios approach has proven useful in this study, which was limited in extent, spatially as well as thematically. For the purpose of describing basic changes in landscape structure, the relatively simple spatial metrics used were found appropriate. Analyses of temporal developments in metrics values, using statistical methods similar to the ones described by Luque (2000) would allow monitoring of structure and diversity of the afforested areas. However, if more detailed assessments of the influence of the changes in land use and land cover following the different scenarios are needed, correspondingly advanced techniques should be applied. Spatial analyses methods as implemented in common GIS systems allow calculation of parameters of ecological importance such as distance of forest patches to roads or towns, as well as incorporation of information from ecological inventories such as the small biotopes database described by Brandt et al (2002). If provision of habitats for species which are endangered or otherwise of special interest is included in the goals of afforestation, Gap Analysis approaches are relevant to identify that kind of forest/woodland to establish – and where they would be most beneficial (Scott el al 1993, Smith and Gillet 2000).

Furthermorel, for evaluation of the impacts of new forest for particular species, detailed ecological modelling that incorporates knowledge about mobility and feeding ranges might be needed (Verboom 1996, Petit and Usher 1998). If land cover information is available at relevant scales (Dreschler and Wissel 1998), meta-population models could help assess the viability of forest dwelling species (Wu and Vancat 1995, Hanski and Ovaskainen 2000), assuming that the established forests will provide habitats of a quality similar to existing areas (Diamond 1988). For the current study of land use in Vendsyssel, the single most important factor influencing environmental quality and development of forests is undoubtedly agricultural practices, which are again strongly influenced by socio-economic factors such as the Common Agricultural Policy (CAP) of the EU (Gallego, ed. 2002). In order to predict future developments in forest structure and quality, it might thus be necessary to include economic and social science (Roe 1996, Jensen 1999).

The study described in this chapter serves as an example of, how spatial metrics and the moving-windows method can be applied in regional planning, and the results point to subjects worth studying more in-depth. For instance, the impacts of the different scenarios could be analysed at the landscape as well as the forest thematic level; the changed pattern of metrics values could be reported and mapped at different window sizes (besides what was already done for the FC-profiling), and finally efforts could be directed towards creation of more realistic afforestation scenarios, following dialogue with foresters, biologists and regional planners.
