

Niels Christian Nielsen  
*B.Sc. Copenhagen University 1993,*  
*M.Sc. Copenhagen University 1998:*

**Spatial Metrics of  
Structure and Diversity:  
Calculation from Earth Observation  
and map data, for use as indicators  
in environmental management**

Submitted to Lancaster University,  
Department of Geography  
for the Ph.D. degree, May 2004

**Niels Christian Nielsen**

B.Sc. Copenhagen University 1993, M.Sc. Copenhagen University 1998.

**Spatial Metrics of Structure and Diversity: Calculation from Earth Observation and map data for use as indicators in environmental management**

*Submitted to Lancaster University, Department of Geography for the Ph.D. degree  
May 2004.*

## **0.1 ABSTRACT**

The use of spatial metrics for characterisation of landscape structure was investigated, and their application as indicators for biological diversity, sustainable land use and forest management evaluated. The main objective was to define and select spatial metrics to be derived through processing of satellite images and from map data existing in Geographical Information Systems. Metrics applied as indicators should be insensitive or predictable with respect to scale changes, appropriate for description of landscape diversity and structure and mutually uncorrelated, thus ensuring that they describe different aspects and functions of landscapes.

From eight types of spatial metrics identified in the literature survey, five were applied in this study, namely Area, Edge, Shape, Patch (count) and Diversity metrics. EO based forest maps and land use/land cover data, mainly from Italy and Denmark, were analysed. Shape metrics, especially the Matheron index, proved usable for quantification of fragmentation, while Patch metrics should be used with care due to sensitivity to grain size.

The hierarchical structure of landscapes and the Modifiable Areal Unit Problem were addressed through application of the Moving Windows method. No direct solutions to the effects of these phenomena on the values of metrics of landscapes and their representation in images and maps could be devised. Rather, it was found that multi-level descriptions of landscapes using presence-absence masks from different window sizes, metrics from a number of watershed-levels and scalograms provide useful information on forests and landscapes.

A Hemeroby index was introduced for assessment of degree of disturbance at landscape spatial and thematic level. The thematic resolution of the forest classes was however found insufficient to allow calculations of Hemeroby of forests *per se*. However, the Hemeroby index appeared to be a promising tool for summarising the amount of human influence expressed in land use maps.

## 0.2 Contents

<b>0.1</b>	<b>ABSTRACT .....</b>	<b>1</b>
<b>0.2</b>	<b>Contents.....</b>	<b>2</b>
<b>0.3</b>	<b>List of figures .....</b>	<b>4</b>
<b>0.4</b>	<b>List of tables .....</b>	<b>7</b>
<b>1</b>	<b><i>Introduction.....</i></b>	<b>10</b>
<b>2</b>	<b><i>Literature review .....</i></b>	<b>15</b>
<b>2.1</b>	<b>Sustainability and Biodiversity in environmental policy .....</b>	<b>16</b>
2.1.1	The need for definitions.....	16
2.1.2	Criteria and Indicators .....	17
2.1.3	Sustainability – the concept applied to forestry.....	19
2.1.4	Biodiversity – definitions and assessment .....	21
<b>2.2</b>	<b>Use of landscape ecology concepts in forest and landscape assessment and monitoring .....</b>	<b>26</b>
2.2.1	Forest management information use and needs .....	27
2.2.2	A biotope approach: Habitat quality .....	29
2.2.3	Approaches to spatial structure in ecology – the landscape perspective.....	33
2.2.4	Scale issues in landscape ecology.....	36
2.2.5	Application of landscape ecology in landscape monitoring .....	37
<b>2.3</b>	<b>Spatial approaches to analysis of structure and diversity at landscape level..</b>	<b>41</b>
2.3.1	Use of Geographical Information in environmental management.....	41
2.3.2	Uses of Earth Observation techniques in landscape analysis .....	50
2.3.3	Scaling issues related to raster GIS and EO derived image data .....	61
2.3.4	An example of quantification of spatial structure using EO data: description and measurement of fragmentation.....	73
<b>2.4</b>	<b>Conclusions on the use of spatial and Earth Observation data for monitoring of sustainable land use and biological diversity .....</b>	<b>77</b>
2.4.1	Forest mapping and monitoring.....	77
2.4.2	Land cover mapping and Landscape monitoring.....	79
2.4.3	Applications of spatial metrics in an EO-GIS framework .....	80
<b>3</b>	<b><i>Measures of forest fragmentation at varying spatial resolutions, a study from central Italy .....</i></b>	<b>83</b>
<b>3.1</b>	<b>Methodology.....</b>	<b>83</b>
<b>3.2</b>	<b>Data.....</b>	<b>87</b>
<b>3.3</b>	<b>Results.....</b>	<b>90</b>
3.3.1	Synthetic images, scaling properties.....	90
3.3.2	Synthetic images, metrics behaviour .....	93
3.3.3	Satellite images, classification and mapping .....	97
3.3.4	Satellite images, metrics derivation and display.....	99
<b>3.4</b>	<b>Discussion and Conclusion.....</b>	<b>104</b>
<b>4</b>	<b><i>Comparison of Corine Land Cover and FMERS-WiFS raster images for description of forest structure and diversity over large areas .....</i></b>	<b>107</b>
<b>4.1</b>	<b>Introduction: .....</b>	<b>107</b>
4.1.1	Large area forest mapping and M-W analyses .....	108
<b>4.2</b>	<b>Objectives .....</b>	<b>111</b>

<b>4.3</b>	<b>Data.....</b>	<b>112</b>
4.3.1	Study area.....	112
4.3.2	Raster data.....	113
4.3.3	Vector data.....	120
<b>4.4</b>	<b>Methods.....</b>	<b>121</b>
4.4.1	Selection and definition of spatial metrics.....	121
4.4.2	Implementation of Moving Windows and analysis of outputs.....	126
4.4.3	Local variance and autocorrelation.....	130
4.4.4	Masking and Forest Concentration.....	132
<b>4.5</b>	<b>Results.....</b>	<b>133</b>
4.5.1	Response of metrics to window size.....	134
4.5.2	Variability and autocorrelation of the metrics.....	139
4.5.3	Relationships between different metrics.....	144
4.5.4	Relationships between metrics derived from the two different data types.....	153
4.5.5	Comparisons of metrics values with different regionalisation approaches.....	156
<b>4.6</b>	<b>Discussion of results from application of Moving-Windows.....</b>	<b>179</b>
4.6.1	Evaluation of results.....	179
4.6.2	Evaluation of methods.....	182
<b>4.7</b>	<b>Conclusions – implications for forest monitoring.....</b>	<b>185</b>
<b>5</b>	<b><i>The influence of thematic and spatial resolution on metrics of landscape diversity, structure and naturalness – an analysis of Land Use and Land Cover data from Vendsyssel, Denmark.....</i></b>	<b>187</b>
<b>5.1</b>	<b>Introduction.....</b>	<b>187</b>
5.1.1	Background – a cultural environment project.....	188
5.1.2	Background – the study area.....	190
<b>5.2</b>	<b>Objectives.....</b>	<b>194</b>
<b>5.3</b>	<b>Data.....</b>	<b>196</b>
5.3.1	The AIS data.....	197
5.3.2	Elevation model and supplementary data.....	201
<b>5.4</b>	<b>Methods.....</b>	<b>202</b>
5.4.1	Creating base-maps and geo-referencing the data.....	203
5.4.2	Thematic levels and re-classifications.....	204
5.4.3	Selection and extraction of test areas for assessment of AAK data.....	214
5.4.4	Selection and mathematical implementation of metrics.....	218
5.4.5	Metrics calculation and statistical analysis.....	220
5.4.6	Hemeroby – definition and calculation.....	224
<b>5.5</b>	<b>Results.....</b>	<b>229</b>
5.5.1	Scaling properties of AAK data.....	230
5.5.2	M-W analysis of land cover data of different origins with different thematic resolutions 239	
5.5.3	Hemeroby calculation and mapping.....	257
<b>5.6</b>	<b>Discussion.....</b>	<b>268</b>
<b>5.7</b>	<b>Conclusions – implications for landscape monitoring.....</b>	<b>273</b>
<b>6</b>	<b><i>Applications of spatial metrics for environmental monitoring and planning, exemplified by afforestation scenarios for Vendsyssel, Denmark.....</i></b>	<b>275</b>
<b>6.1</b>	<b>Introduction/background.....</b>	<b>275</b>
<b>6.2</b>	<b>Objectives.....</b>	<b>277</b>

<b>6.3</b>	<b>Data</b> .....	<b>277</b>
6.3.1	Soil type maps .....	277
6.3.2	Dwellings density maps .....	278
6.3.3	Designated afforestation areas .....	279
<b>6.4</b>	<b>Methods</b> .....	<b>279</b>
6.4.1	Creating afforestation scenarios .....	279
6.4.2	Calculating and comparing metrics .....	283
<b>6.5</b>	<b>Results</b> .....	<b>284</b>
6.5.1	Changes in metrics values .....	284
6.5.2	Changes in Hemeroby .....	287
6.5.3	Forest Concentration profiles .....	289
<b>6.6</b>	<b>Discussion/conclusion</b> .....	<b>290</b>
<b>7</b>	<b>Conclusions</b> .....	<b>294</b>
7.1	Summary of key findings .....	294
7.2	Limitations to the study .....	295
7.3	Possible future work.....	296
<b>8</b>	<b>References</b> .....	<b>298</b>
<b>9</b>	<b>Epilogue and Acknowledgements</b> .....	<b>320</b>
<b>10</b>	<b>Appendices 1 – IDL scripts for image processing</b> .....	<b>324</b>
10.1	Appendix 1.1 - Calculation of cover percentage, diversity, edge and fragmentation metrics .....	324
10.2	Appendix 1.2 – Patch counting in M-W.....	332
10.3	Appendix 1.3 – Spatial degradation of binary maps .....	339
10.4	Appendix 1.4 – Spatial degradation of thematic maps.....	341
10.5	Appendix 1.5 – Per-window averaging of continuous field value images.....	343
<b>11</b>	<b>Appendix 2 - Software used during the study</b> .....	<b>348</b>

^^^^

### 0.3 List of figures

Figure 2.1.	Compositional, structural and functional biodiversity.....	23
Figure 2.2	Levels of biological diversity as defined by Whittaker (1972) .....	25
Figure 2.3	Examples of the eight main types of spatial metrics .....	48
Figure 2.4	A hierarchical representation of forest dynamics and the role for Remote Sensing in monitoring of forest environment. ....	60
Figure 2.5	Conceptual model of how fragmentation is related to habitat loss.....	74
Figure 2.6	Conceptual model for integration Earth Observation data with other information sources for environmental monitoring in a habitat based approach.....	80
Figure 2.7	Proposed schedule for landscape analysis using EO and spatial metrics. ....	82
Figure 3.1	Aggregation of pixels from synthetic forest-non-forest image.....	84
Figure 3.2	Extraction of edge (count) data from binary (forest-non-forest) images.....	86
Figure 3.3	Location of the test areas, shown on false colour WiFS image .....	88
Figure 3.4	Geo-rectified subset of the Landsat TM scene .....	89
Figure 3.5	Synthesised forest mask, pixel size 12.5 m, after edge detection .....	91
Figure 3.6	Synthesised forest mask, pixel size 200 m, after edge detection .....	92

Figure 3.7 Patch density in synthetic forest map plotted against forest cover .....	93
Figure 3.8 Pixel size influence on Matheron index values .....	93
Figure 3.9 SqP as function of pixel size and forest cover for synthetic images.....	94
Figure 3.10 PPU as function of pixel size and forest cover .....	94
Figure 3.11 M values as function of pixel size and forest cover for synthetic image.....	96
Figure 3.12 M values as function of pixel size and number of patches for synthetic image ...	96
Figure 3.13 Scatter graph for Landsat TM band 3 and 4 .....	98
Figure 3.14 Scatter graph for WiFS band 1 and 2.....	99
Figure 3.15 Forest -non forest masks from classified images.....	99
Figure 3.16 Spatial configuration of the values of the Matheron index.....	100
Figure 3.17 Comparison of metrics values between data sources.....	101
Figure 3.18. Forest cover in windows with forest cover >0.....	101
Figure 3.19 Metrics derived from WiFS data plotted against metrics derived from TM data	103
Figure 3.20 Spatial metric maps displayed together as different ‘channels’ in a false colour image.....	103
Figure 4.1 The selected subset .....	113
Figure 4.2 FMERS forest map for area of interest, with NUTS-level 2 regions.....	114
Figure 4.3 Subsets of CLC and FMERS maps located in Umbria and Toscana.....	115
Figure 4.4 CLC image for the area of interest, after re-classification to forest map.....	116
Figure 4.5 Cross-tabulated image from CORINE and FMERS forest masks .....	119
Figure 4.6 Digital Elevation Model of Italy.....	121
Figure 4.7 Example of how maps of forest presence are combined for masking in extraction of statistical parameters. ....	126
Figure 4.8 Moving windows concepts with and without overlap. ....	127
Figure 4.9 Simplified flowchart showing how results presented below are derived .....	128
Figure 4.10 Land cover ”richness”, i.e. count of different land cover types.....	134
Figure 4.11 Metrics ‘response curves’ or scalograms.....	134
Figure 4.12 Average values of the SqP metric for the two data types plotted against window size in pixels resp. meters .....	136
Figure 4.13 Avg. patch density plotted against window size, CLC and FMERS .....	138
Figure 4.14 Avg patch density plotted against the avg. forest cover. ....	138
Figure 4.15 Background patch count applied as possible fragmentation metric.....	139
Figure 4.16 Standard deviation of the values in output cells, CLC data.....	140
Figure 4.17 Standard deviation of the values in output cells, FMERS data. ....	140
Figure 4.18 Local variability of CLC data .....	141
Figure 4.19 Local variability of FMERS forest map data.....	142
Figure 4.20 Local variability of spatial metrics from CLC data, expressed with Moran’s I .	142
Figure 4.21 Local variability of spatial metrics from FMERS with Moran’s I. ....	143
Figure 4.22 Plots of different metrics values from the same data source, 2400*2400 m windows.....	148
Figure 4.23 Plots of different metrics values from the same data source, 19200*19200 m windows .....	151
Figure 4.24 R-square, expressing agreement between metrics values from CLC and FMERS data.....	154
Figure 4.25 R-square-plot, window size transformed logarithmically.....	155
Figure 4.26 Forest cover and SHDI in 1200*1200 m cells from CLC forest map .....	158
Figure 4.27 CLC data with high-order catchment polygons.....	158
Figure 4.28 Examples of landscape metrics values reported at catchment level .....	160
Figure 4.29 SHDI and Matheron metrics, extracted from CLC data to catchments .....	163
Figure 4.30 SHDI and Matheron metrics extracted from FMERS data to catchments.....	165
Figure 4.31 SHDI and Matheron metrics from CLC data, administrative regions .....	168
Figure 4.32 SHDI and Matheron metrics from FMERS data, regions.....	169
Figure 4.33 CLC and FMERS inputs compared for creation of FC-profiles of selected catchments in northern and middle Italy. ....	172

Figure 4.34 CLC and FMERS inputs compared for creation of FC-profiles of selected administrative (NUTS-level 2) regions .....	172
Figure 5.1 Land use in Vendsyssel around the year 1800.....	190
Figure 5.2 Subset with Denmark from CLC map, base-map area marked .....	191
Figure 5.3 Geomorphological map of Vendsyssel.....	193
Figure 5.4 Legends for land use – land cover data used in this study.....	200
Figure 5.5 Subset of 5*5 km from image data sets used in this chapter .....	201
Figure 5.6 Tentative re-classifications into thematic levels.....	206
Figure 5.7 Test block 1 to 3 as KMS traffic maps and AAK LUC maps .....	216
Figure 5.8 Matheron index and Edge Density maximum values .....	220
Figure 5.9 Average elevation and slope based on values in 25m cells, averaged to 1km cells for comparison and correlation with spatial metrics values.....	224
Figure 5.10 Example of the ‘processing chain’ from Land Use to Hemeroby map.....	228
Figure 5.11 8*7 km subset of TB1 at the landscape thematic level, AAK images with the grain sizes used in this study – plus the corresponding subset from the CLC .....	229
Figure 5.12 Scaling behaviour of the rasterised AAK data set in the test blocks. ....	234
Figure 5.13 Scalograms for the number of matrix/background patches in test blocks .....	237
Figure 5.14 1.5*2.5 km subset from the northern part of Test Block 1 .....	237
Figure 5.15 Scaling effects of changing grain size for the Matheron index., AAK data .....	238
Figure 5.16 Two different approaches to depicting the scale dependence of the SqP metric.....	239
Figure 5.17 Example of pair-wise comparison of metrics maps from the different sources. ....	247
Figure 5.18 Output (5km) cell-by-cell plots of patch count metrics values between the landscape thematic level and the forest and nature levels for AAK and LCP data.....	249
Figure 5.19 Output (5km) cell-by-cell plots of patch count metrics values between nature and forest thematic levels and between landscape and forest thematic levels, AAK data.....	249
Figure 5.20 Changing relation between the Matheron index for forest and for nature thematic layers with increased window size.....	250
Figure 5.21 Scatter-plots of selected relations between terrain features and structural metrics for the forest theme from the AAK map in 1km windows. ....	254
Figure 5.22 Scatter graphs of combination of the NP and SHDI metrics values in geomorphological strata for AAK and LCP data, nature thematic level .....	256
Figure 5.23 Relationship between Hemeroby values derived from AAK and CLC as scatter plots.....	258
Figure 5.24 Combined histograms of Hemeroby values distribution for AAK and CLC data for window sizes from 1 to 5 km .....	265
Figure 5.25 Approaches to creating Hemeroby maps of the study area .....	266
Figure 5.26 "Hemeroby map" of Denmark based on CLC data.....	267
Figure 6.1 Creation of dwellings/floor space density surface with 25m grain size. ....	279
Figure 6.2 Local effects of different theoretical afforestation scenarios around Hjørring.....	283
Figure 6.3 Summary of effects on spatial metrics from different afforestation scenarios .....	287
Figure 6.4 Changes in Hemeroby index values (averages within 1*1 km windows) with the different scenarios .....	289
Figure 6.5 FC profiles for the different scenarios used in this study .....	290

\*\*\*



## 0.4 List of tables

Table 2.1 Forest management information needs as function of forest use .....	28
Table 2.2. Summary of concepts for diversity mapping / modelling .....	35
Table 2.3 Levels of Hemeroby for description and evaluation of biotopes .....	39
Table 2.4 Working concept for forest diversity assessment .....	56
Table 2.5 Features considered relevant to forest diversity and the potential of different sensor types to monitor them .....	58
Table 3.1 Satellite data used for forest mapping.....	88
Table 3.2 Correlation of the SqP metric derived from different pixel sizes .....	95
Table 3.3 Correlation of the PPU metric derived from different pixel sizes .....	95
Table 3.4 Correlation between M derived at varying pixel sizes.....	97
Table 3.5 Correlations between initial forest area and the three spatial metrics from synthetic images at resolutions corresponding to imagery from the TM and WiFS sensors.....	97
Table 4.1 Matching CORINE and FMERS forest cover classes for the current study.....	116
Table 4.2 Distribution of land cover classes in the two data sets.....	117
Table 4.3 Co-occurrence of pixel values in FMERS and CORINE land cover maps.....	118
Table 4.4 Theoretical values of PPU and PPUN for varying window sizes and number of patches.....	124
Table 4.5 Patch count values from different window sizes .....	137
Table 4.6 Critical R values for varying number of observations with $\alpha=0.05$ .....	144
Table 4.7 Correlation coefficients between metrics, CLC 12*12 pixels window.....	145
Table 4.8 Correlation coefficients between metrics, FMERS 6*6 pixels window. ....	145
Table 4.9 Correlation coefficients between metrics, CLC 24*24 pixels window.....	147
Table 4.10 Correlation coefficients between metrics, FMERS 12*12 pixels window .....	147
Table 4.11 Correlation coefficients between metrics, CLC 48*48 pixels window.....	149
Table 4.12 Correlation coefficients between metrics, FMERS 24*24 pixels window .....	149
Table 4.13 Correlation coefficients between metrics, CLC 96*96 pixels window.....	149
Table 4.14 Correlation coefficients between metrics, FMERS 48*48 pixels window .....	150
Table 4.15 Correlation coefficients between metrics, CLC 192*192 pixels window.....	150
Table 4.16 Correlation coefficients between metrics, FMERS 96*96 pixels window. ....	151
Table 4.17 Summary of correlation coefficients between cover proportion and metrics values at increasing window sizes for CORINE land cover data.....	152
Table 4.18 Summary of correlation coefficients between cover proportion and metrics values at increasing window sizes for FMERS forest map.....	152
Table 4.19 Agreement between metric values from different image sources at varying window sizes.....	154
Table 4.20 Agreement between the two data sources on number of "background patches".	156
Table 4.21 Summary at catchment level of spatial metrics from the CLC map, with medium window size 4800m .....	162
Table 4.22 Summary at catchment level of spatial metrics from the FMERS map, with medium window size 4800m .....	164
Table 4.23 The hierarchical approach illustrated.....	166
Table 4.24 Summary at administrative region level of spatial metrics from the CLC map, window size 4800m .....	167
Table 4.25 Summary at administrative region level of spatial metrics from the FMERS map, window size 4800m .....	168
Table 4.26 Comparison of forest proportion values and derived diversity metrics from the input data for two administrative regions. ....	170
Table 4.27 FC values for catchments in Northern Italy for window size 1200m. ....	171
Table 4.28 FC values for same catchments as above, window size 4800m.....	171



Table 4.29 Correlation coefficients for agreement between CLC and FMERS based values of the SHDI diversity index at different window sizes for selected geographic areas.....	173
Table 4.30 Correlation coefficients for agreement between values of the Matheron index, based on CLC and FMERS data, at different window sizes, selected geographic areas .....	175
Table 4.31 Mean values of coefficients of variation for selected metrics from the CLC data and elevation from DTM.....	176
Table 4.32 Mean values of coefficients of variation for selected metrics from the FMERS data and elevation from DTM.....	176
Table 4.33 Spearman’s rank correlation coefficients for agreement between spatial metrics from CLC and FMERS forest maps, for 12 administrative regions in Italy .....	178
Table 4.34 Spearman’s rank correlation coefficients for agreement between spatial metrics from CLC and FMERS forest maps, for 13 selected 4 <sup>th</sup> level catchments.....	178
Table 5.1 Proportion of forest land cover types from different mapping sources.....	205
Table 5.2 Relative area of non-matrix and non-background classes.....	206
Table 5.3 Aggregation of Land Cover Map (LCM) and Land Cover Plus (LCP) image data for landscape analysis at varying thematic resolutions.....	208
Table 5.4 Step-wise re-classification of land use data from the AAK.....	209
Table 5.5 Step-wise re-classification of land use classes from the CLC.....	211
Table 5.6 Kappa index of agreement for forest-non forest and nature-non nature images derived from the datasets at 25m grain size.....	212
Table 5.7 Percentage of land use types in the three test blocks, collected from 5m grain images with the “landscape” thematic resolution as described above.....	217
Table 5.8 Metrics used in this chapter, categorised according to type.....	219
Table 5.9 Hemeroby types with estimated NDP values and corresponding AAK classes .....	226
Table 5.10 Hemeroby types with estimated NDP values and corresponding CLC level 3 classes.....	226
Table 5.11 Proposed assignment of rough Hemeroby classes to output from averaging.....	227
Table 5.12 Total count of separate patches of selected classes with different responses to image grain size (scaling behaviour).....	231
Table 5.13 Cover proportions and average patch size in hectares for Test Block 1 .....	232
Table 5.14 Diversity metrics values expressed as SHDI for the entire test block .....	235
Table 5.15 Diversity metrics values expressed as SHDI for the entire test block, only patches/objects of interest.....	236
Table 5.16 Diversity values expressed through the SIDI metric.....	236
Table 5.17 Average values of spatial metrics for the forest theme from the available data types – for windows where forest was present.....	240
Table 5.18 Average values of spatial metrics for the landscape theme from the available data types under respective presence masks.....	241
Table 5.19 Correlations between output cell values of spatial metrics from the AAK and LCM maps with grain size 25m.....	243
Table 5.20 Correlations between output cell values of spatial metrics from the AAK and LCP maps with grain size 25m.....	245
Table 5.21 Correlations between output cell values of spatial metrics from the AAK and CLC maps with 25m and 250m grain size.....	246
Table 5.22 Correlations between metrics values for different thematic levels, AAK data....	248
Table 5.23 Correlations between metrics values for different thematic levels, LCP data .....	248
Table 5.24 Correlations between metrics values and average elevation and slope, AAK forest theme.....	251
Table 5.25 Correlations between metrics values and average elevation and slope, LCP forest theme.....	252
Table 5.26 Correlations between metrics values and average elevation and slope, AAK landscape theme.....	252
Table 5.27 Correlations between metrics values and average elevation and slope, LCP landscape theme.....	253

Table 5.28 Spatial metrics from AAK, Nature theme values by (dominant) geomorphologic type in 1 km windows .....	255
Table 5.29 Spatial metrics from LCP, Nature theme values by (dominant) geomorphologic type in 1 km windows.....	255
Table 5.30 Values of integrated Hemeroby index from AAK and CLC data respectively....	258
Table 5.31 Correlations between output cell values of Hemeroby and the suite of spatial metrics for AAK land use data.....	260
Table 5.32 Correlations between output cell values of Hemeroby and the suite of spatial metrics for CLC land use data.....	262
Table 6.1 Definition of soil types and colour codes for the soil classification of Denmark ..	278
Table 6.2 Cross-tabulation of test image with forest types assigned according to pixel ranking by FTI against actual forest map from AAK at 25m .....	282
Table 6.3 Observed values of <i>changes</i> in metrics values per 1*1 km window for the four different scenarios – compared with the current situation .....	285
Table 6.4 Changes in Hemeroby values following implementation of different afforestation scenarios.....	287

