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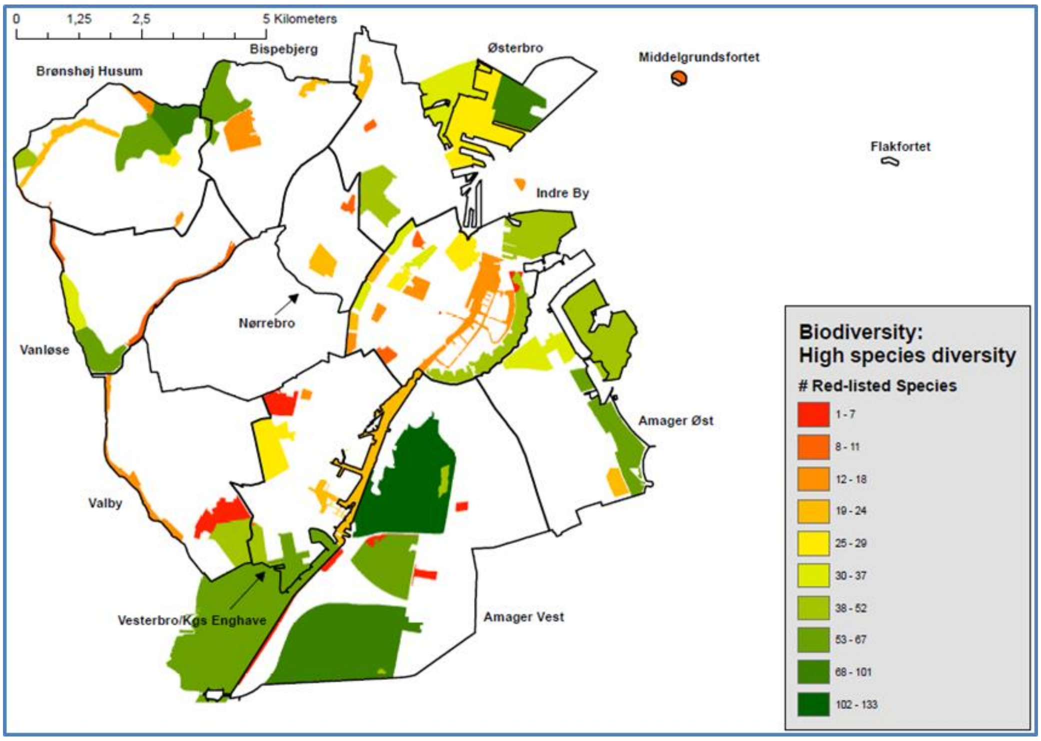
GIS AND THE GREEN SPACE FACTOR

USING GIS TO CREATE A BASELINE FOR THE GREEN SPACE FACTOR IN COPENHAGEN MUNICIPALITY



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Copenhagen Municipality is developing a Green Space Factor tool. The aim is to have more urban nature in new city development areas, increase biodiversity, improve climate adaptation and increase the nature experiences for the citizens of Copenhagen.

The Green Space Factor in Copenhagen focuses on four qualitative subjects: biodiversity, climate adaptation, recreation and site characteristics like cultural and landscape elements.

This project will use GIS and remote sensing in form of Orthophotos and Lidar to calculate and extract the data necessary to create a baseline for the Green Space Factor in Copenhagen.

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1. INTRODUCTION

Even though the area of nature in Denmark has increased since 2011, the amount of nature per residents in Copenhagen has decreased (Danmarks Statistik 2017). This is problematic, since there are numerous studies proving the benefits of urban nature to people and the environment. Recreational qualities, increased physical and mental health (Tyrväinen 2005, 82), stormwater interception, reduction of the heat island effect ((Lin 2015, 66) (Moffat 2016, 68)), and greater biodiversity (Tyrväinen 2005) are just some of the benefits received by humans from experiencing urban nature.
Copenhagen Municipality has agreed on a strategy for urban nature (Bynatur i København: Strategi 2015-2025 2015), where two main visions for are declared:

- Create more urban nature in Copenhagen
- Increase the quality of urban nature in Copenhagen (Bynatur i København: Strategi 2015-2025 2015).

One of the ways the municipality wants to achieve this is by incorporating urban nature in all phases of new city development. The municipality would like 90% of the residents in new city development areas to be able to walk to a park, beach, nature area or harbour bath in less than 15 minutes. One way to achieve this is by setting demands to the quality and extent of urban nature in local planning and by prioritizing conservation of existing nature in new development areas (Bynatur i København: Strategi 2015-2025 2015, 5-27).
To achieve these aims, the municipality is developing a greening tool based on a Biotope Area Factor. The planned effect of this tool is to have more urban nature in new city development areas, increase biodiversity, improve climate adaptation, and have better possibilities for nature experiences by citizens (Bynatur i København: Strategi 2015-2025 2015, 28).

1.1 Review of the Biotope Area Factor/The Green Space Factor

The Biotope Area Factor was originally developed in Germany and the method has since been renamed to the Green Space Factor, and has been adopted by cities around the world (Table 1). The process behind the method is to assign values representing the type of green (e.g. trees, flower beds, ponds) to different surfaces, which are then divided by the total area.
The original formula for the Green Space Factor is:

$$\text{GSF} = \frac{Ecological\ Effective\ Areas}{Total\ Land\ Area}$$

(Mohren 1990, 2).

The result of the Green Space Factor is a value ranging from 0 to 1. The Green Space Factor can be used to set demand to the developers for the amount of green areas that should be present. For example, in Malmø's Bo01 area, the aim was to have a Green Space Factor of at least 0.5 ((Kruse 2011, 5) out of 1 (Beer 2001)).
The Green Space Factor has been used in Berlin, Hamburg, Seattle (Kruse 2011, 4) and Southampton (McCulloch 2015), and London has recently put out a tender for a Green Space Consultancy Contract (Mayor London 2017).
The background to the tool arises from the idea that city development should compensate the loss of green areas by the development of new green spaces (COWI A/S 2009). The Green Space Factor tool stems from the German planning law for the recreation of green spaces in areas of development. This planning law should ensure that the city will still have a high amount of green areas, and in addition, have areas for rainwater infiltration (COWI A/S 2009, 9).

The purpose of the green space factor is to ensure that no developed area is falling short of the minimum standard, and it might therefore be necessary to utilize vertical walls and roofs as green space (Mohren 1990, 3-5).

Currently, several cities using the green space factor as a tool for urban green development are not integrating the method in GIS. Several cities, such as Cape town (WDC466 2014), Southampton (McCulloch 2015, 5) and Copenhagen are using the tool in an excel spreadsheet, rather than an interactive GIS tool.
Each city has adapted the tool to their own areas and ecosystems. The different criteria might develop and change over time (Kruse 2011, 10), as well as having different target-levels for different land use areas ((Järvelä 2014, 2-3) (Seattle Department of Construction & Inspections u.d.)). Table 1 is displaying some of the differences between the Green Space Factor tool in different cities.

Cities	Range	Score sheet	Integrating GIS	Priorities	Year implemented
Norrtälje Hamn[1]	0-1.5	X	NA	• Social: recreation and aesthetics • Climate adaptation • Biodiversity	2016
Berlin[2]	0-1	NA	X	NA	1990
Oslo[3]	0-1	X	NA	NA	2013
Seattle[4,5]	0-1	X	NA	• Liveability • Ecosystem services • Climate change adaptation	2006
Southampton[6,7,8,9]	0-1	X	X	NA	2015
Malmø[10]	0-1	X	NA	NA	NA
Helsinki[11]	NA	X	NA	• Ecology • Functionality • Landscape • Maintenance	NA

Table 1 The difference in the Green Space Factor tool between the different cities

Several cities are using the Green Space Factor as a tool to display the amount of greenery, as opposed to measuring the quality of the green area. Huang et al. studied the relationship between the ecological values and the Green Space Factor. This study was done using ground surveys of plants and insects. They concluded that the current biotope area factor/green space factor could not accurately reflect the ecological conditions of the landscape (Huang 2015, 148). Unlike the study performed by Huang 2015, which manually measured the ecological quality of the green areas, this project will use remote sensing data and GIS to estimate the quality, as well as the size, of the green areas.

1.2 Copenhagen Green Space Factor

In 2009, Copenhagen Municipality agreed on the plan "A green Copenhagen", with the aim to secure that green recreational areas should be at least the same size as they were in 2008 (Teknik og Miljøforvaltningen 2015). The population in Copenhagen is increasing and, even though new green areas are being developed, the total amount of green space per citizen is decreasing. Copenhagen Municipality is currently developing a Green Space Factor tool, which will be used in future city planning and development. The aim of the tool is to secure a certain amount of green areas as well as a certain quality of urban nature in e.g. development plans for the municipality. The Copenhagen Green Space Factor focuses on four qualitative subjects: biodiversity, climate adaptation, recreation, and site characteristics such as cultural and landscape elements. The tool will be central in achieving the aims that the city has specified for their urban nature, and will transform their strategic document *Bynatur i København* to concrete action. In addition, the city wants to use the tool as a communication tool amongst planners, architects and politicians, which can create a common "language" regarding urban nature in Copenhagen Municipality (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 2).
The Green Space Factor in Copenhagen will range from 0-2, where 0 represents no urban nature and 2 represent a high quantity and quality of urban nature. For example, if a medium green space factor is to be achieved, there should be urban nature on at least 30% of the project area, and the quality of the nature should be above average. If a high green space factor is to be achieved, the project area should have at least 50% urban nature of high quality, or 70% urban nature of a lower quality (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 2).
The GSF of Copenhagen Municipality is based on this formula:

$$\text{GSF} = \frac{Area\ of\ urban\ nature}{Area\ of\ project} * \frac{Acheived\ qualities}{Potential\ qualities}$$

(Teknik og Miljøforvaltningen, Københavns Kommune 2017, 4)

The qualities that are being incorporated in the Green Space Factor tool have the following parameters:

- Recreation
    - Larger grass areas
    - Connected green areas
    - Variation in the terrain
    - Public access
    - Small green spaces
    - Water elements
    - Sensory plantings
    - Edible plants
    - Food Gardens

- Biodiversity
  - Habitat
  - Structural variation
  - High species diversity
  - Ecological corridors
  - Wild unmanaged areas
- Climate adaptation
  - Infiltration of rainwater
  - Delay and containment of rainwater, SUDS (Sustainable Urban Drainage System)
  - Evapotranspiration from roofs
  - Evapotranspiration from trees and bushes (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 15-19)

"Egenart", the distinctive character of the area, is also an important parameter in the Green Space Factor tool. Copenhagen Municipality wants the urban nature to be developed with the distinct character of the area in mind, such as the existing architectural landscape, soil types and landscape patterns. This parameter should be supported by "Københavns Kommune's egenarts analyse" (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 14).
In addition, the size of green areas will be represented with these parameters:

- Urban Nature
  - Grass areas
  - Permeable surfaces
  - Water elements
  - Flowerbeds
  - Hedges and bushes
  - Heritage trees
  - Other trees
  - Planting on vertical structures
  - Planting on horizontal structures
  - Planting on the edges of buildings (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 11-12)

2. RESEARCH QUESTIONS

The research question is: how to use GIS to visually and interactively display and qualify the extent of urban green and blue spaces in Copenhagen Municipality using the framework of the Green Space Factor.

2.1 Sub-questions:

What are the potential benefits and drawbacks of integrating GIS in the use of the Green Space Factor in Copenhagen?

Is there enough data on the quality of nature and green and blue areas in Copenhagen to create a baseline for the quality of urban nature based on the Green Space Factor?

3. SOFTWARE

3.1 ArcGIS

This study uses ArcGIS, which is a GIS software developed by ESRI (ESRI n.d.). In this project, *italics* will be used to describe the different functions used in ArcGIS. ArcGIS was the chosen software used for this project based on experience and availability.

3.2 LasZip

LASzip is an open-source product, which transforms LAZ files to LAS files (Isenburg 2014), so the Lidar data can be viewed and used in ArcGIS.

4. DATA

Data has been downloaded from numerous sources, such as Kortforsyningen (Styrelsen for Dataforsyning og Effektivisering n.d.) and Open Data København (Københavns Kommune n.d.). In addition, data was retrieved from Københavns Kommune and my colleagues at Rambøll. An overview of all the different data sets and which were used for the different parameters can be found in Appendix 22.

4.1 Orthophoto

The orthophoto was downloaded from Kortforsyningen. The photo had been recorded between March and May 2016 (Styrelsen for Dataforsyning og Effektivisering u.d.), and it was therefore sufficiently good to identify green areas. Not all trees show up on the infrared band, due to the season, however, tree data was collected with the Lidar data.

4.2 Lidar

Lidar data was downloaded from Kortforsyningen. DHM/Punktsky is the basic Lidar data with all the relevant classifications:

1. Created Never classified
2. Surface
3. Terrain
4. Low vegetation 0-0,3m
5. Medium vegetation 0,3-2m
6. High vegetation <2m
7. Buildings
8. Noise
9. Model key points
10. Water
11. Bridges (SDFE 2016)

For this project, classification points 1, 2 and 5 was used.

4.3 Digital Surface Model

The DHM/Overflade is the Digital Surface Model (DSM), which displays the surface of objects above sea level (Produktbeskrivelse Danmarks Højdemodel u.d.). The cell size is 0,4 m (SDFE u.d.). The DSM (Figure 1) will be used in combination with the Normalized Difference Vegetation Index (NDVI) image to identify green roofs and hedges.

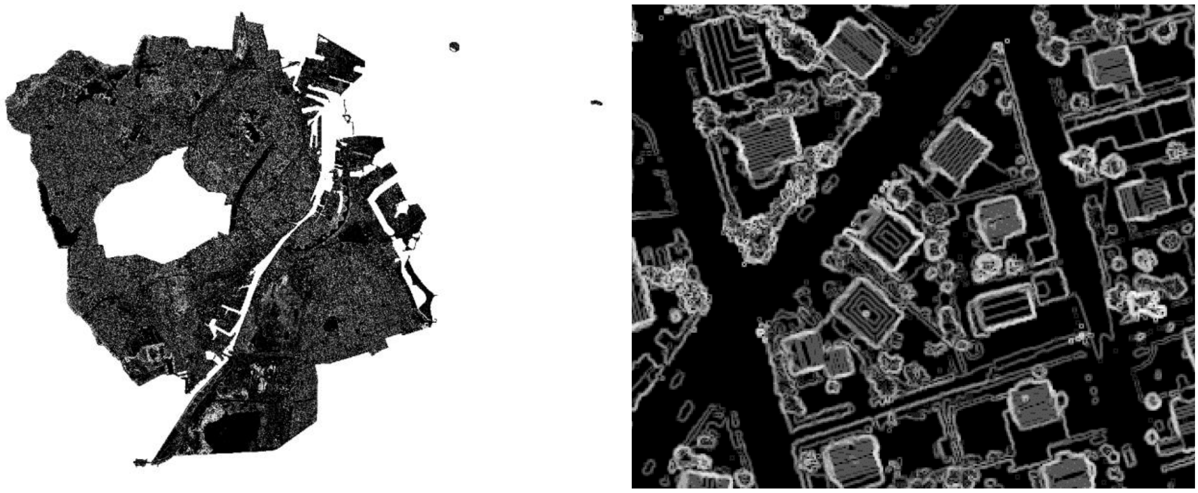

Figure 1 DSM for all of Copenhagen and a close-up of a residential area. The darker represents the lower areas, while white represents higher areas, in this case, the buildings.

4.4 Digital Elevation Model

The DHM/Terræn is the Digital Elevation Model (DEM), which displays the topography of the landscape in relation to the sea level. It has a cell size of 0,4 m (Styrelsen for Dataforsyning og Effektivisering 2016). This data will be used to calculate the variation in the terrain.

4.5 Vector data

Vector data was downloaded from Open Data Copenhagen (Københavns Kommune n.d.), Kortforsyningen (Styrelsen for Dataforsyning og Effektivisering u.d.), retrieved directly from the municipality, and from Byhøst.

5. METHOD

In order to start the analysis, an NDVI image was necessary, along with vector data for the outline of the municipality and the different boroughs.

5.1 Orthophoto

Using *Merge Raster*, the five different images covering Copenhagen Municipality were merged to one large image.

The normalized difference vegetation index is commonly used to separate vegetated surfaces from other surfaces. The chlorophyll will absorb the red light and then reflect the near-infrared wavelengths (Al-doski 2013), which results in an image of all the green vegetation. The NDVI formula is:

$$NDVI=(IR-R)/(IR+R)$$

where the IR is the infrared band and R is the red band. The pixel values range from -1.0 to 1.0 (NDVI Function n.d.).

To create an NDVI image, the *Image analysis* tool was used. Band 4 was selected as the infrared band and band 1 was selected for the red band. This resulted in an output from -1 to 744 (Figure 2). The output was then exported.

The image was clipped to the Copenhagen outline polygon.

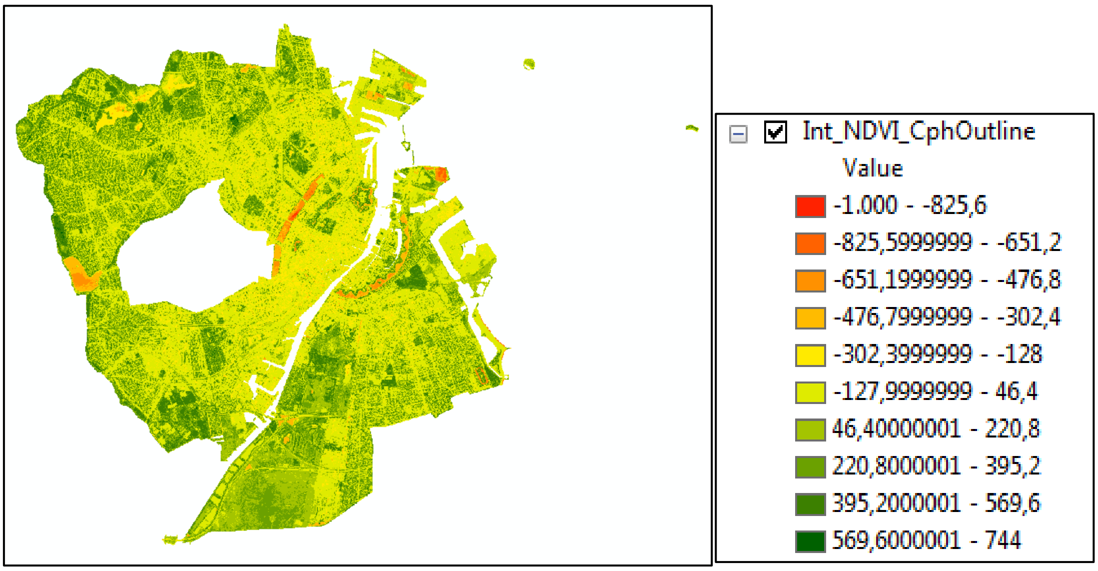

Figure 2 NDVI image of Copenhagen

This image was used to identify all green areas in Copenhagen. This would include trees, shrubs, informal green spaces, herbaceous vegetation and lawns. In addition, this data would be used to locate green roofs.

5.2 Vector data for the municipality

To split the shapefile for the municipality into different parts of the city, *Select Layer by Attribute* was used, with the expression: "rode_nr" >=66 AND "rode_nr" <= 109. Other vector data for Copenhagen municipality, such as paths, water, and houses were clipped to the Copenhagen outline polygon. In order to work with Lidar data, it was necessary to first clip the Lidar data to the individual boroughs in the city. This made the work process more efficient.

6. IMPLEMENTATION

6.1 Recreation

6.1.1 Large grass Areas (Appendix 1)

For recreational activities, large grass areas are a requirement. The municipality has divided grass areas into three different size classes: 75-150 m^2, 150-225 m^2 and over 225 m^2 (Teknik og Miljøforvaltningen, Kvaliteter 2017).

To find these areas, three sets of green vegetation and park data was used; the NDVI image with a threshold of 125 and two different shapefiles with park data from the municipality.
The NDVI image was first processed, which involved erasing the polygons of hedges and bushes from the file, erasing the buildings that might potentially overlap the NDVI image, and erasing the canopy cover layer. The end result was a shapefile with only ground vegetation.
The ground cover NDVI file and the park data were then merged. To find the green areas in the three different size categories, *Select layer by attribute* was used, and the result was exported and saved as a new file. *Multipart to singlepart* was used on each green file with the different size classes, and again, *Select layer by attribute* was used to select the correct sized green areas.

Vector data was available for different ownership; private, public and state areas. These files with green areas in different size classes were then intersected with the data for private areas, public areas and state areas. This resulted in nine different files with large green areas:

- Private
    - $75m^2$ – $150m^2$
    - $150m^2$ – $225m^2$
    - Over $225m^2$
- Public'
    - $75m^2$ – $150m^2$
    - $150m^2$ – $225m^2$
    - Over $225m^2$
- State owned
    - $75m^2$ – $150m^2$
    - $150m^2$ – $225m^2$
    - Over $225m^2$

The different areas were then merged, to display three different green layers; 75-150m^2, 150-225m^2 and over 225m^2.

6.1.2 Connected green areas (Appendix 2)

The municipal description of this criterion is the connection of green areas to public path systems within a distance of one kilometre or less (Teknik og Miljøforvaltningen, Kvaliteter 2017).

The green areas were first separated into different size classes, which was done to make the data more manageable, since there were so many individual polygons. *Select by attribute* was used to separate the green areas into these size classes: smaller than 1000m^2, 1000m2 - 5000m^2, 5000m^2 - 10000m^2, 10000m^2 - 20000m^2 and larger than 20000m^2. A buffer of 490 meters was created around the polygons in each of these categories, in order to select areas with overlapping buffers which are less than one kilometres apart. *Dissolve type LIST* was used, so that buffers which were overlapping would be dissolved. Three types of data on paths were chosen: cycling path, main path and path. *Select layer by location* was used to find the different paths which were intersecting the five different buffer areas. These intersecting paths were then cut to the buffer polygons. To identify the green connected areas, *Select layer by location* was used to find all green areas that would intersect with the paths that were inside the green area buffers.
The result of this was a map displaying green areas which are within a distance of one kilometre of each other, and are connected by a path.

6.1.3 Variation in the terrain (Appendix 3)

The municipal description of this parameter is that there should be a variation in the terrain, which encourages movement and play (Teknik og Miljøforvaltningen, Kvaliteter 2017).

A digital elevation model was downloaded from Kortforsyningen. Two raster tiles of 10 km^2 had to be downloaded, and they were then merged. First, *Create Mosaic Dataset* was used, then *Add raster to Mosaic dataset* was used to populate the dataset. Statistics was calculated, and then the whole raster was cut to the polygon outline of Copenhagen Municipality.
The tool *Slope* was used to calculate the slope from the digital elevation model (Figure 3).

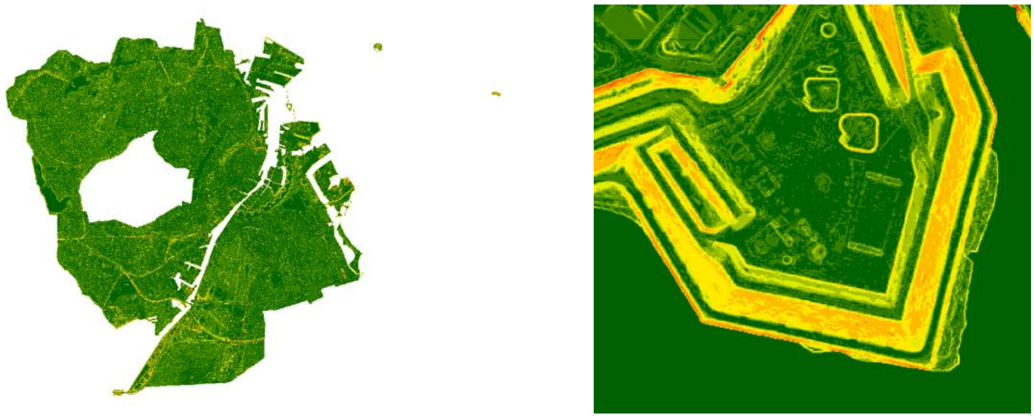

Figure 3 Slope calculations of the Digital Surface Model. The green is the lowest degree of slope.

Block Statistics was used to calculate the statistics on the terrain. Since the output from the slope calculations was a floating point, the raster file first had to be converted to an integer. This was done using the tool *Int*. When using the *Block Statistics* tool, the neighbourhood was set to *Rectangle* with a height and width of 76 cells. This corresponds to 100 x 100 m. The statistics type was set to *Variety*, which calculates the number of unique values of the cells in the neighbourhood. The output therefore showed which 100 x 100 meter areas had a high variety of differences in the slope and terrain, as opposed to areas where there was little variation in the terrain.

6.1.4 Public access to green spaces (Appendix 4)

The municipal description of this parameter is related to access to green areas in "time and space" (Teknik og Miljøforvaltningen, Kvaliteter 2017). However, since this parameter was quite vague in its description of the criterion, access points to the park was chosen as a key factor. The parameter is not focusing on "who" has access to green areas, but rather the green areas itself, and it therefore seemed appropriate to use the number of access points as an indication of public access.

For this layer, all the green areas were merged using the tool *Merge*, followed by *Multipart to Singlepart* in order to separate multipart features into singlepart features. *Select layer by location* was then used to identify all the paths that were "crossed by the outline of" the green areas. The paths used were cycle path, main path and paths. *Spatial join* was used to identify the number of intersections between the green areas and the paths that were crossing the boundary of the green areas. The result could be found in the attribute table to the output polygon of the green areas, which was then converted to a raster, using the value field: *Join_Count*. In addition, churchyards were included in this layer, since they have a limited public access, due to the churchyards closing in the evening.

6.1.5 Small Green Spaces (Appendix 5)

The municipal description of this parameter is that there should be small green spaces containing grass, trees and hedges/bushes with a minimum size of 25m^2 (Teknik og Miljøforvaltningen, Kvaliteter 2017).

All the green files were merged: NDVI image, park data from the municipality, hedges and bushes, and canopy polygon. *Select layer by attribute* was used to find the areas that were between 25 m^2 and 75 m^2. The Green Space Factor tool says "Small green spaces" should be minimum 25 m^2, but it was decided to set it between 25 m^2 and 75 m^2. The uppermost value of 75m^2 was chosen because "Large Grass Areas" had a minimum range of 75m^2 – 150m^2. These polygons were then converted to a raster using the tool *Polygon to raster*. *Block Statistics* was used to calculate the *Variety*. The neighbourhood was set to *Rectangle* with a height and width of 76 cells, which corresponds to 100 x 100 meters. The result shows a raster which is classified in order of how many small green spaces there are in a 100 x 100 meter area.

6.1.6 Water elements (Appendix 6)

The municipality does not have a fixed description of this criterion, however, they emphasise that access to water and water elements is one of the nature experiences that the citizens of Copenhagen value the most (Teknik og Miljøforvaltningen, Københavns Kommune 2017, 18).

Data showing open water surfaces was retrieved from Kortforsyningen, Open Data København, Copenhagen Municipality and from colleagues at Rambøll. The data was retrieved as both polygons and polylines. To merge all this data into one file, the polylines was given a buffer of 0.5 meter on each side of it. This means that the polylines representing watercourses was changed to polygons with a width of one meter, which is a reasonable size for watercourses in Copenhagen. In addition, volume of water is not being calculated, hence it is not a problem adding width to the watercourses. Data for this layer also included access to the harbour, in terms of infrastructure like Bølgen at Kalvebod Brygge, as well as paths. It was decided that paths (cycling paths, path and main path) 20 meter from the water would provide an experience of being close to the water. This was discussed in collaboration with the municipality, and 20 meters was decided as a reasonable distance from the water.

6.1.7 Edible plants (Appendix 7)

The municipal criterion for this parameter is related to having areas with edible plants, fruits and nuts (Teknik og Miljøforvaltningen, Kvaliteter 2017).

Data was received from Byhøst, which is an NGO working with finding edible food in nature. The organisation does several events for citizens focusing on edible nature. In addition, Byhøst has an interactive map where residents can plot the locations of edible plants. (Byhøst 2017). The data from this interactive map was received as a JSON file. This file was then converted to an Excel file, and added in ArcMap. The data was displayed using *Display XY Data*. The data was then cut to the boundary of Copenhagen Municipality.

6.1.8 Food Garden/Urban farming (Appendix 8)

This criterion for this parameter is to have areas that are set aside for food cultivation.
The data for this layer has been retrieved from Open Data Copenhagen, and represents areas that have urban farming gardens.

6.2 Biodiversity

6.2.1 Structural variation (Appendix 9)

The municipal description for this parameter is the presence at the same locality of several different types of vegetation and landscape types, for example grass areas, water, hedges, bushes or green roofs. In addition, half of the areas should be connected to another green area to achieve a medium score, or the majority of the areas should be connected to another green area to achieve a high score (Teknik og Miljøforvaltningen, Kvaliteter 2017).
This layer consists of data on water, canopy cover, hedges, NDVI, green roofs and "wild unmanaged areas".

The rasters were each reclassified to represent a binary bitmask string:

- Hedges = 1
- Trees = 2
- NDVI/Ground Vegetation = 4
- Water = 8
- Green Roof = 16
- Wild unmanaged vegetation = 32

This was done so it was easier to identify the different vegetation structures once the rasters were added together, using *Raster Calculator*. The raster was then reclassified again, to represent the different vegetation structure in each cell:

- No vegetation
- Hedges/Bushes
- Trees
- Hedges/Bushes and trees
- Ground vegetation
- Hedges/Bushes and ground vegetation
- Trees and ground vegetation
- Hedges/bushes, trees and ground vegetation
- Water
- Trees and water
- Water and ground vegetation
- Green roofs
- Wild unmanaged vegetation
- Wild unmanaged vegetation and hedges
- Trees and wild unmanaged vegetation
- Trees, hedges/bushes and wild unmanaged vegetation
- Trees, water and wild unmanaged vegetation

Block statistics was used on this raster. The neighbourhood was set to *Rectangle* with a width and height of 76 cells, which corresponds to 100 x 100 m. The statistics was set to *Variety*. The output raster displays the structural variety in a 100 x 100 m area. The classification should be used as an indication of areas with high structural variety, rather than a literal interpretation of the amount of different vegetation structures.

6.2.2 Ecological corridors (Appendix 10)

For this parameter, the municipality is referring to specific ecological corridors which they have already defined (Teknik og miljøforvaltningen 2017).

Data on ecological corridors was downloaded from Kortforsyningen, and data on potential corridors was retrieved from the municipality. In addition to this data, it was decided to use the tool *Corridor* to identify other ecological corridors, based on the new map of green spaces in the Municipality.
In order to identify ecological corridors, rasters had to be created with land cover data and habitat score. All the different data which makes up habitat and land cover was transformed into rasters with a cell size of 1.32. This cell size was decided upon, since the raster from the Canopy calculations was already in this size. These rasters were used for both the land cover and habitat score:

- Canopy
- Water
- Ground vegetation
- Road
- Hedges
- Buildings
- Parks
- Green Roofs
- Wild unmanaged areas

In order to produce land cover and habitat cover rasters, using the *Weighted Overlay* tool, the raster cells had to align correctly to each other.To achieve this, the *Clip* tool was used.

Each raster was clipped to the same raster, in this case, the canopy cover raster. In the environment settings, the canopy cover raster was set as the *snap raster*, the *output coordinate* raster as well as the *cell size* being set to the canopy cover.
The data in the land cover data (Table 2) and the habitat score data (Table 3) had to be assigned a percentage influence and a scale representing the importance of the data as land cover and habitat.

Land Cover	Percentage	Scale
Canopy	15	9
Water	14	7
Ground vegetation	15	9
Road	3	3
Hedges	15	9
Buildings	3	3
Parks	15	9
Green Roofs	5	8
Wild unmanaged areas	15	8

Table 2 Data to produce the Land Cover raster

Habitat Score	Percentage	Scale
Canopy	15	8
Water	15	6
Ground vegetation	15	8
Road	3	3
Hedges	15	9
Buildings	3	3
Parks	20	9
Green Roofs	4	5
Wild unmanaged areas	10	7

Table 3 Data to produce the Habitat Score raster

These two rasters were then used in the tool *Corridor*, where the output is a raster showing potential corridors. A threshold of over 7 was decided upon to create a raster only showing the potential corridors in Copenhagen. This was based on the current ecological corridor that had already been downloaded from Kortforsyningen.

6.2.3 Wild unmanaged areas (Appendix 11)

The description for this parameter is the presence of extensive management natural areas, or areas undergoing natural succession (Teknik og Miljøforvaltningen, Kvaliteter 2017).

Thresholds for wild unmanaged areas were developing using the method in 6.4.5. A threshold was first decided for areas that have been managed or moved. This was based on an infrared orthophoto (Figure 4), and personal local knowledge of the area.

Figure 4 Infrared image of the test area for threshold for "wild unmanaged areas". The darkest red areas are trees, and the dark red areas around the circles have been moved to prevent the spread of *Solidago canadensis*. The lighter red areas are unmanaged ground vegetation. The reason it is lighter in colour is due to dead vegetation from the previous season lying on top of the current vegetation.

To identify the best threshold, five different rasters were chosen: 150, 175, 200, 225 and 250. Of these five rasters, 175 was the best fit to represent all the moved areas including the trees. Two more rasters were produced; 163 and 187. Of these two, 187 was the best fit, and therefore another two raster were produced; 181 and 193. 193 were chosen as the raster that best would represent areas that had been managed or were trees and bushes (Figure 5).

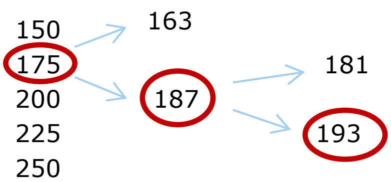

Figure 5 Threshold for the wild unmanaged areas

Using the same method as in Figure 5, threshold 25 was decided to be the raster that represent all the green vegetation. Hence, the tool *Minus* was used to subtract the threshold 193 from the threshold 25. This raster would then represent wild unmanaged areas. This raster was then transformed to a polygon using the tool *Raster to polygon*, and *Erase* was then used to erase hedges and buildings from this polygon. The polygon was again transformed to a raster, using *Polygon to raster*. *Block statistics* was used with a *Rectangle* neighbourhood of 76 X 76 cells, which corresponds to 100 X 100m. The statistics was set to *Variety*.

6.2.4 High species diversity (Appendix 12)

This parameter is related to the number of native species and insect pollinated species.
This parameter is split up into three maps; red-listed species, other species and "species score". The "species score" was downloaded from MiljøGIS (Miljø- og Fødevareministeriet u.d.), and are displayed as a raster with the weighted number of species being displayed as a colour gradient. "Species score" is a weighted score for species which takes into consideration the presence of characteristic species for a certain nature type as well as the presence of invasive and other negative impact species (Miljøstyrelsen u.d.).
The red-listed species and other species data are retrieved from the municipality (Københavns Kommune n.d., 10), and are also displayed as a raster with the number of species as a colour gradient. The red-listed species range from 1 species to 133 species for a particular area. They are classified using Natural breaks (Jenks) (Esri u.d.), since there is not data for each individual number between 1 and 133.

6.3 Climate Adaptation

6.3.1 Infiltration of rainwater (Appendix 13)

The municipal description of this parameter is related to impermeable surfaces (Teknik og Miljøforvaltningen, Kvaliteter 2017).
This data layer therefore consists of water data, hedges data, wild corners and the NDVI image. All the rasters were reclassified so the cells had the same value and *Raster calculator* was used to add all these raster layers together. *Block statistics* was used to calculate the *Sum*, using a *Rectangle* neighbourhood of 76 x76 cells, which corresponds to 100 x 100 m. The resulting map should not be taken literally, since the output raster is indicating how many cells of the relevant data there is in each neighbourhood. Therefore, the classification should just be used as an indication to which areas have high infiltration of rainwater, and which areas have low infiltration of rainwater.

6.3.2 Delayment and containment of rainwater, SUDS (Appendix 14)

The municipal description of this parameter refers to Sustainable Urban Drainage Systems (Teknik og Miljøforvaltningen, Kvaliteter 2017).
Data on detention ponds, and specific roads related to cloudbursts were retrieved from Open Data København. In addition, green roofs were included in this layer, due to their ability to delay rainwater. This data layer is displaying the mentioned vector data.

6.3.3 Evapotranspiration from roofs (Appendix 15)

The municipal description of this parameter is related to the thickness of the growing medium (Teknik og Miljøforvaltningen, Tage 2017).
This layer only consists of the file with the green roofs. It has not been possible to retrieve data on the thickness of the growing medium.

6.3.4 Evapotranspiration from trees and bushes (Appendix 16)

The municipal description of this parameter is related to the amount of transpiration from the different species of trees and bushes (Teknik og miljøforvaltningen 2017).
Since there is no data for all the tree species in Copenhagen, this layer consist of the canopy cover data and the hedges/bushes data. These two raster layers were first combined using *Raster Calculator*. This file was then reclassified, so that all the cells with either trees or bushes had the same value. *Block Statistics* was then used, with the *Rectangular* neighbourhood of 76 x76 cells. This corresponds to areas of 100 x 100 meters. The statistics type used was *Sum*. The output was a raster file with a classification that indicates which areas has high evapotranspiration and which areas have low evapotranspiration. This output should not be taken literally, since the output raster is indicating how many cells there are in each neighbourhood of trees and bushes.

6.4 Urban Nature

6.4.1 Grassy areas (Appendix 17)

The municipal description of this layer refers to all grass areas, for example sports areas, lawns, ornamental lawns, road verges, and commons grass (Teknik og miljøforvaltningen 2017).
This layer consists of the NDVI image, where the building polygon, hedges polygon and canopy cover polygon have been erased. The file was converted to a raster, and *Block statistics* was used with a *Rectangular* neighbourhood of 76 x 76 cells. This corresponds to 100 x 100 meters. The statistics type used was *Sum*.

6.4.2 Water elements (Appendix 18)

The municipal description of this parameter is the presence of lakes and ponds and other water elements (Teknik og miljøforvaltningen 2017).

This layer consists of data on watercourses, standing water and general water map. This layer is the same as “Water elements” in section 6.1.3.

6.4.3 Hedges and bushes (Appendix 19)

The municipal criterion of this parameter is related to different types of hedges, for example *fagus* hedges, *Acer campestre* hedges, *Carpinus betulus* hedges and other flowering ornamental hedges (Teknik og miljøforvaltningen 2017).

A digital elevation model (DHM/Terræn), a digital surface model (DHM/Overflade) and the NDVI image was used for this calculation. The individual digital elevation model files were merged and the individual digital surface model files were merged and both rasters cut to the Copenhagen Outline following the same procedure as the for the terrain model in section 6.1.3. *Raster Calculator* was then used, with the expression “(DSM_CphOutline)-(DEM_CphOutline)”. *Raster Calculator* was used to find the height range of 1 to 2 meters, using the expression “Con((DSMminusDEM >=1) & (DSMminusDEM<=2), 0, 1).

The NDVI image was used to identify the green areas, with a threshold of 350 (Keller 2016, 26). The threshold raster and the height range raster was both transformed to polygons using the tool *Raster to Polygon*. *Select layer by location* was used to find all the green areas that were intersecting with the height range of 1 – 2 meters. To avoid false results, the building polygon was erased from the final polygon result.

To perform statistics on this layer, the final polygon with hedges was converted to a raster. *Reclassify* was used to give all the cells the same value. *Block statistics* was used with a neighbourhood *Rectangle* of 76 x 76 cells, which corresponds to a 100 x 100 meter area. The statistics method used was *Sum*.

6.4.4 Other trees (Appendix 20)

The municipal description of this parameter is related to healthy established trees with a size over 16m^2 (Teknik og miljøforvaltningen 2017). However, there is no data on the size or health of all the trees in Copenhagen municipality. Instead, the canopy cover has been calculated using Lidar, which was downloaded from Kortforsyningen.

Model builder was used to calculate the canopy cover for the different parts of the city (Figure 6).

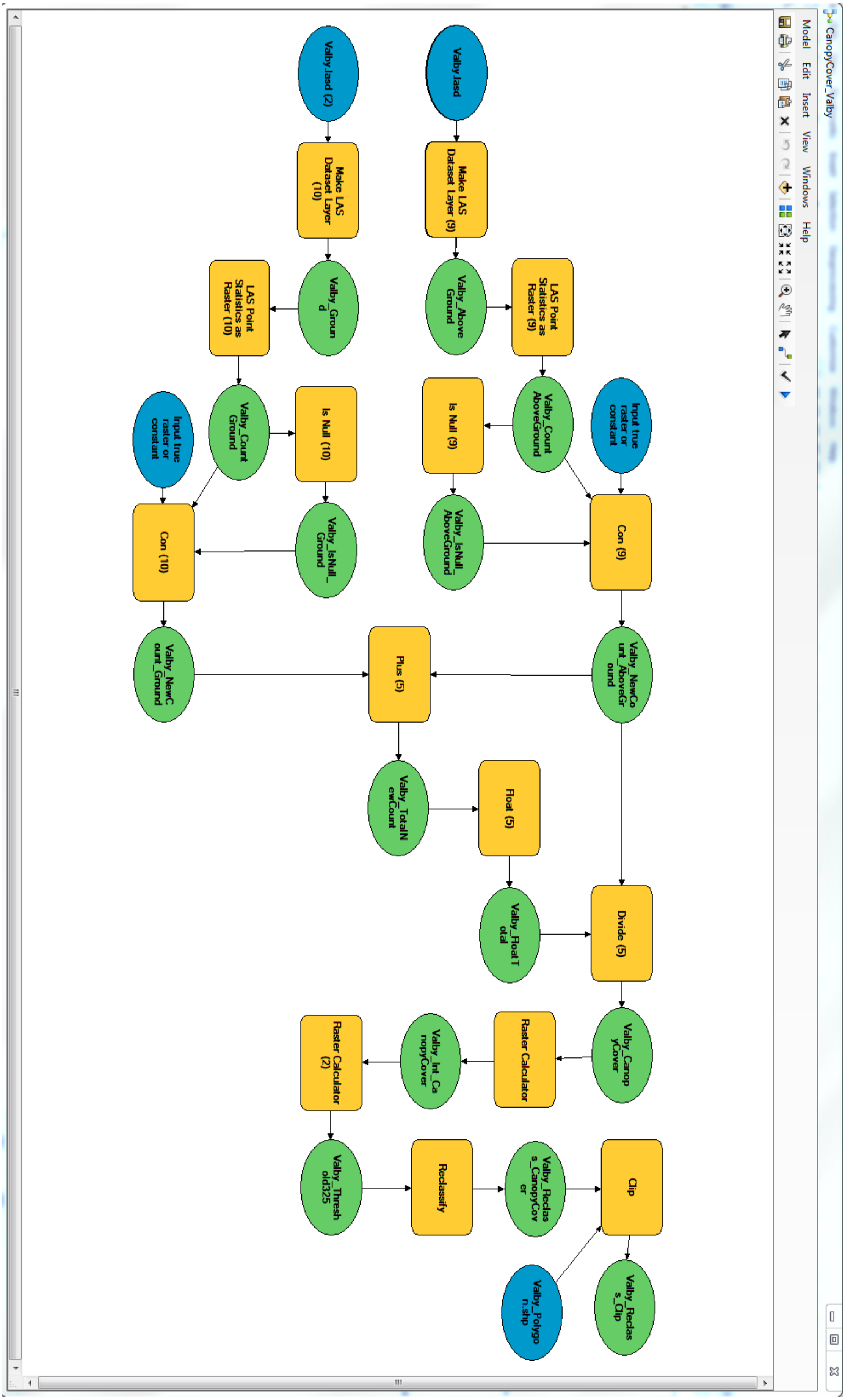

Figure 6 Model Builder used to calculate canopy cover

Two LAS dataset layers were created using the tool *Make LAS dataset layer*. One LAS dataset was filtering the classification points 5; high vegetation, and the other LAS dataset for the classification points 1 and 2; surface and ground. These LAS datasets were created for each part of the city; Amager Vest, Amager Øst, Bispebjerg, Brønshøj, Vanløse, Valby, Nørrebro, Indre By, Vesterbro/Kgs Enghave, Østerbro, Middelgrundsfortet and Flakfortet.

All the canopy cover rasters were merged. First, *Create Raster Dataset* was used to create an empty dataset. *Mosaic (data management)* was then used to populate this empty raster dataset. The raster was then reclassified, to only display the trees. *Raster to polygon* was used to transform the raster to a polygon. The building polygon was erased from the canopy cover polygon, to avoid green roofs being registered as trees. In addition, there was an issue with black tiled roofs being registered as green areas using the NDVI layer and the threshold of 350. This was also removed when erasing the building polygon layer.

The polygon was converted to a raster again, so that *Block statistics* could be used. First, reclassified was used, so all the cells had the same value. A *Rectangle* neighbourhood of 76 x 76 cells was used in *Block statistics*, which would correspond to a 100 x 100 m area. The statistics method used was *Sum*.

6.4.5 Plantings on horizontal structures (Appendix 21)

The municipal criterion of this parameter is sedum, moss and herbs on roofs, carparks, bicycle sheds and bus stops (Teknik og miljøforvaltningen 2017).

A threshold had to be decided upon to identify the green roofs. The issues with identifying the green roofs in the project "*Using Lidar data to estimate canopy cover in Copenhagen Municipality*" (Keller 2016, 48-49) was related to the building polygon not being updated and black tiled roofs showing up on the infrared band. The threshold for the project by Keller, 2016, was 50, which was first identified using *Raster Calculator* and this expression: Con("Int_NDVI">=50,1).

To identify the threshold better, several different threshold rasters was produced: 25, 50, 75, 100, 125, using the *Raster Calculator* and the expression: Con("Int_NDVI">= X,1). Each of these rasters was then compared to a number of different green roofs (Figure 7), to identify the best fit. Once the best threshold was decided; 75 in this case, another two rasters were produced, using the *Raster Calculator* and the same expression. This continued until the best fit had been identified (Figure 8).

Figure 7 Green roofs for the threshold analysis; Amager strand, Borgergade and Nørre high school

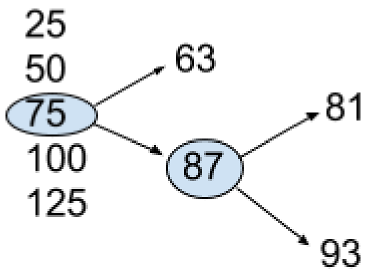

Figure 8 Threshold for the green roofs

A threshold of 87 was decided to be the best fit.
To avoid the NDVI polygon from overlapping on the building polygons, which was an issue in the project "*Using Lidar to Estimate Canopy Cover in Copenhagen Municipality*" (Keller 2016, 46), a buffer was created and since erased from the NDVI image. To achieve this, the building polygon was first transformed to a polyline using the tool *Polygon to polyline*. A two meter buffer was then created around this buffer zone, using the tool *Buffer*.
Another issue in the project by Keller (Keller 2016, 48) was the exclusion of certain row houses. This was due to the buffer being used, and towards the end of the analysis, polygons of a particular size would be chosen. This resulted in some very narrow green roof polygons on the rowhouses, which meant they were not included in the final result. To avoid this, *Dissolve* was used to aggregate the building polygon.

The digital surface model from Kortforsyningen was transformed to a slope raster using the tool *Slope*. The output is a raster with a slope gradient in degrees in each cell (ArcGIS n.d.). The purpose of the DSM was to use it to identify flat roofs, since green roofs are more likely to be flat. Initially, roofs less than 20 degrees were chosen. However, after consulting green roof manufactures, these two ranges were chosen; less than 5 degrees and between 5 and 15 degrees (LLC 2017). However, it turned out there was no data for the range 5 to 15 degrees, and therefore this study only focused on green roofs that were less than 5 degrees. *Raster Calculator* was first used to identify the differently sloped areas. This was done using the expression: "Con(Slope_CphOutline<X,1)". To find the range between 5 and 15, the expression "Con((Slope_CphOutline >=5) & (Slope_CphOutline <=15), 1, 0))" was used. The rasters were then changed to a polygon using the tool *Raster to polygon*.*Intersect* was used on the slope polygons to find all the buildings with a roof angle of less than 5 degrees. The buildings with a slope on the roof less than 5 degrees was then intersected with the threshold layer with a one meter buffer. *Multipart to singlepart* was used, which resulted in 99379 polygons. This was followed by *Select layer by attribute* where polygons larger than 15 m^2 were chosen. This resulted in 1020 polygons. 15 m^2 was chosen, since 20 m^2 were used in the project by Keller, 2016. This led to very small polygons being excluded (Keller 2016, 47), and to try to avoid this, several changes were made, for example by using the *Dissolve* tool, focusing on the slope of the buildings and decreasing the size of the polygons being included in the study.

The green roof polygons were manually checked compared to the orthophoto from 2016. The green roof results from the project by Keller, 2016, were merged with these results. This was done to include as many green roofs as possible, especially since the two methods used were slightly different.

7. RESULTS

Results, displayed as maps, are shown in appendix 1-21.

8. DISCUSSION

For this project, GIS has been used to display and extract the information necessary for the required parameters for the Green Space Factor for Copenhagen Municipality. The extent of all the different types of green areas have been extracted, and shown in individual maps in the appendix. The qualities of the green areas have also been extracted and displayed. However, there were a few of the quality parameters that were not possible to display, due to lack of data. Overall, the result show that GIS is a very effective tool for calculating the parameters of the Green Space Factor.

There are several benefits to integrating GIS into the use of the Green Space Factor in Copenhagen:

- Data can create the background for a baseline map for the Green Space Factor, which means that it would be easier to get an overview of the Green Space Factor for a particular area.
- Integrating GIS is an overall time saving exercise. Currently, the Green Space Factor is only in an excel sheet, meaning that it is necessary to manually measure all the different parameters for a particular area. A few of the parameters calculated in this project need to be double checked in the field and a few parameters needs to be completely checked on the field. However, despite this, several parameters are already pre-calculated, which proves GIS to be a very useful tool for the Green Space Factor.
- Easier for developers to use to the tool.

Some of the drawbacks of integrating GIS are related to the available data. It was not possible to retrieve data for sensory gardens, habitat, permeable surfaces, flower beds, heritage trees, plantings on vertical structures and plantings on the edges of buildings (Table 4). The ideal situation would be to have data for all the parameters. However, it is not possible to retrieve all the data and certain parameters would have to be mapped in the field.
One of the sub questions to this project was related to whether there would be enough data available to retrieve data related to the four qualities. Data on "egenart" has not been possible to retrieve; however, several of the parameters for the three other qualities have been calculated and presented in maps. A clear overview of which parameters are completed, partly completed or could not be obtained are available in Table 4.

Parameter		Complete	Partly Complete	No data
Recreation	Larger grass areas	X		
	Connected green areas		X	
	Variation in the terrain	X		
	Public access		X	
	Small green spaces		X	
	Water elements	X		
	Sensory plantings			X
	Edible plants		X	
	Food gardens		X	
Biodiversity	Habitat			X
	Structural variation		X	
	High species diversity		X	
	Ecological corridors	X		
	Wild unmanaged areas		X	
Climate adaptation	Infiltration of rainwater		X	
	Delay and containment of rainwater		X	
	Evapotranspiration from roofs		X	
	Evapotranspiration from trees and bushes		X	
Urban Nature	Grass areas	X		
	Permeable surfaces			X
	Water Elements	X		
	Flower beds			X
	Hedges and bushes	X		
	Heritage trees			X
	Other trees		X	
	Planting on vertical structures			X
	Plantings on horizontal structures	X		
	Planting on the edges of buildings			X
"Egenart"				X

Table 4 The completion of the different parameters

8.1 Recreation Parameters

It was possible to complete several of the parameters for the criterion "Recreation".

The parameter *large grass area* is intended for recreation and physical activity. However, the data for this layer is mainly from the NDVI image. This means that the individual green areas that are derived from this data are not in normal straightforward squares and rectangles, which is the typical shape for grass areas aimed at recreation. In addition, the data also includes all private gardens, as well as private gardens between several houses (Figure 9).
Hence, this layer can be divided up into private, public and state owned areas, which could make the layer easier to use. When using this layer to estimate the Green Space Factor, one needs to consider the purpose of this layer, when estimating the size of this parameter. It might be necessary to use the layer which is divided into private, public and state owned areas, depending on what the layer is needed for.

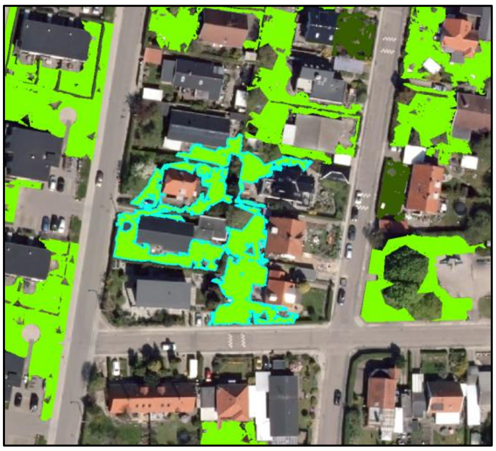

Figure 9 Large grass areas in a private area. The highlighted area is one individual area.

The parameter *Green Connected Area* is related to the ability to move from one green area to another green area within 1 km, using a path system. The paths that are used for this analysis are cycling paths, path and main path. There was no data on pavements, and cycling paths next to roads were not included. Therefore, the result is limited to green areas close to each other that are connected by these particular types of paths. In addition, this data also includes planned cycling paths, and projected cycling paths. Hence, this information needs to be considered when evaluating the result of this layer.

Another recreation parameter is *differences in terrain*, which encourages play and movement. This layer is based on a Digital surface model, and the slope is then calculated based on this. Therefore, this layer is complete, and provides a good and accurate image of the differences in terrain in Copenhagen.

The description for the recreation parameter related to *public access* is only related to access in "time and space" (Teknik og miljøforvaltningen 2017).
There are a number of different methods used when calculating public access to parks:

- Euclidean distance to the nearest centroid in any green space
- Euclidean distance to the nearest boundary point of any green space
- Euclidean distance to the nearest access point of any green space
- Network distance to the nearest centroid in any green space
- Network distance to the nearest boundary point in any green space
- Network distance to the nearest access point of any green space (Higgs 2012).

Access points to the parks were chosen as an indication of public access to parks in time and space, as mentioned in section 6.1.4. Since churchyards normally lock up at night, these areas have a limited time when the public can use the area. Hence, data on churchyards was being used to describe "access in time".

As with the other parameters, the types of paths entering a green area were restricted to what was available; hence this would be cycling paths, paths and main paths. One issue here was the merging on these paths. Some paths would be registered two times, for example, cycling path and main path. However, the main path is represented as two polylines, one on each side of the path, while the cycling path is represented by one polyline. When these two shapefiles are merged, three lines are then representing one path, which also means that there are several polylines intersecting the edge of the green area (Figure 10).

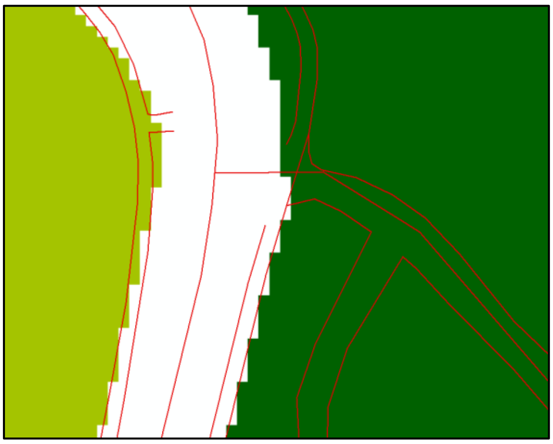

Figure 10 Green areas intersected by paths, represented by red polylines

Therefore, the legend for this layer should be used as an indication of which green areas have a high number of paths intersecting the green area, and not to be interpreted literally (Figure 11).

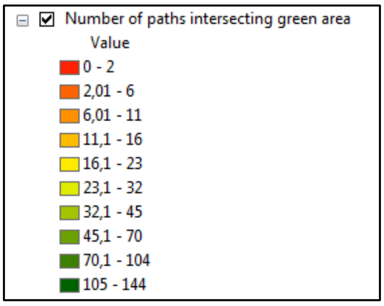

Figure 11 Legend for public access to green areas

Other limitations to public access could be the presence of walls around a green area. However, data on this was not available. In addition, allotment gardens are represented as public green areas; however, they often have a fence around them and a gate. Even though they are open for the public, they might not indicate it, and one would not enter the individual small gardens since these are indicated as a private area. This issue has not been resolved in this layer.

A *small green space* is described as a smaller place where bushes, trees and hedges provides shelter and creates a place for recreation and relaxation. Therefore, these three different data layers were merged. However, the result therefore also reflects small green spaces that only contain trees, only hedges/bushes or only grass. Ideally, the small green spaces should have been extracted from a layer which contained only overlapping areas of trees, bushes/hedges and ground cover. However, less than 1% of the trees, bushes and ground cover vegetation were overlapping, so this would not be a viable method. This layer would have to be re-checked in the field when being used for calculating the Green Space Factor for a particular area.

Water as a recreational value is only described in the manual for the Green Space Factor: "Begrønnings-værktøj: Vejledning i anvendelse af Københavns Kommunes begrønningsværktøj" (Teknik og Miljøforvaltningen, Københavns Kommune 2017). This parameter is not described in the document where all the other parameters are described: "Beregning af eksisterende begrønningsfaktor" (Teknik og Miljøforvaltningen, Kvaliteter 2017). The description of this parameter was related to the presence and access to water. Due to the vague description of the parameter, the analysis of the parameter is quite open to interpretation. It can therefore be argued that this layer is complete, since the interpretation of "access to water" is subjective. The distance of 20 meters to represent closeness to water, was done in collaboration with supervisors at Rambøll and the municipality of Copenhagen, and it was therefore decided upon as a valid distance.

In the recreation category, the municipality also had a criterion for *sensory plantings*. The criterion for sensory plantings is related to species which produce flowers, are fragrant plants/flowers or have different types of foliage. Since species data for the entire municipality does not exist, this parameter is not included in the project.

The parameter for *edible natural vegetation* is related to the amount of different edible plants, and the season for these plants. As mentioned in 6.1.7 this data is retrieved from Byhøst, and is being utilised as static data, as opposed to how it is being used by Byhøst itself. Hence, this data might not be completely correct due to city development, and it does not cover all of the edible plants that are present in the city. This layer therefore needs to be re-checked in the field.

The last parameter in the category for Recreation is related to *food cultivation*. This data layer is based on the municipal's data, and one can therefore assume it is not complete due to there likely being several private gardens for growing food.

8.2 Biodiversity Parameter

It has been possible to use GIS to retrieve several of the biodiversity parameters. However, one parameter had to be completely excluded, and three other parameters were only partly represented in the analysis.

The municipality has a parameter for *habitat*; however, this parameter had to be completely excluded since it was not possible to find any data for this. This parameter relates both to natural habitats and man-made habitats.

The data for *high species diversity* was related to the amount of species (red-listed and non-red listed) in the major green areas. There was no data related to which types of species this was, the data just contained the number of species. The criterion for this parameter specifies "plant species" and "insect-pollinated species" (Teknik og Miljøforvaltningen, Kvaliteter 2017). In addition, there might be several important species in other parts of the city, which might not be included in this dataset. Hence, this parameter is only partly complete.

The parameter for *structural variation* is only missing one factor, ecological connectivity, for it to be complete. There are 17 different layers in this parameter that fits well with the criterion. To achieve a medium or high score for structural diversity, the different green areas needs to be physically connected. Currently, the map for this parameter is only showing the different structural layers, and not which green areas are connected. Hence, the data for this parameter can only be used to achieve a low score, since the ecological connectivity is missing.

Another parameter for biodiversity is the presence of *ecological corridors*. The municipal already has data on some corridors and potential corridors. Several new potential corridors were identified for this layer, making this parameter complete.

The last parameter for biodiversity is related to *wild unmanaged areas*. This dataset is partly subjective, since the threshold for what is "unmanaged areas" was decided by the author. However, local knowledge of the "test area" for the threshold makes this layer quite reliable. This parameter is also related to areas which have natural succession, which was not possible to identify. The areas that have been identified for this parameter are grass areas that are not managed.

8.3 Climate Adaptation Parameter

Using GIS it was possible to retrieve and calculate much of the data related to climate adaptation.
The parameter for *infiltration of rainwater* is partly complete. For this parameter there is data lacking on permeable surfaces that are not green, for example pebbles and gravel.

The *evapotranspiration from roof* and *evapotranspiration from trees and bushes* is defined to include parameters related to the thickness of the growing medium, and the different tree species. This however, it has not been able to get hold off due to the lack of data on tree species in Copenhagen municipality. These two parameters are therefore incomplete.

The last parameter for climate adaptation*; the delay and containment of rainwater,* is incomplete as well. The municipality wanted data on the size of dips in the terrain that can hold water in case of cloudbursts. This has partly been retrieved from the Open Data Copenhagen, where data on detention ponds were found. However, other potential detention ponds have not been discovered. This might be possible to extract from a Digital surface model.

8.4 Urban Nature Parameter

The urban nature parameters are all related to the extent of the green areas.
The parameters that are complete are: *grass areas*, *hedges and bushes*, *water* and *plantings on horizontal structures*. The parameter related to *trees* is partly complete due to the lack of species data. It was not possible to find data on the parameters for *plantings on vertical structures*, *planting on the edges of buildings*, *flower beds* and *heritage trees*.

8.5 Integrating GIS in the Green Space Factor tool

Integrating GIS into the Green Space Factor tool is a useful, but also challenging task. With the current criteria defined for the different parameters, there are several parameters that cannot be completed in GIS and several parameters that are missing data. However, the municipality will re-evaluate the Green Space Tool at the end of 2017. In order to integrate GIS in the Copenhagen Green Space Factor tool, it can be helpful to look to other cities for inspiration, for example Berlin.

In order to best incorporate GIS into the Green Space Factor tool in Copenhagen, an integrated database with information about all the green infrastructure in Copenhagen would be beneficial. For example, a limitation to using GIS with these parameters is the distinction of trees. The lidar data used only displays trees, however, species, condition, and age are not included. This would therefore limit the parameter related to trees. A functioning tree database, for example, would improve the Green Space Factor tool. However, obtaining a functional database of all green areas in Copenhagen would be a huge amount of work, and could probably include citizen monitoring, as have been done in New York City (NYC Parks u.d.) and Boston (Konijnendijk 2012, 26).

GIS is already integrated in the Green Space Factor tool in Berlin (Senate Department for the Environment, Transport and Climate Protection u.d.), and it is an essential component of the Green Space Information System (GRIS) (Sentsverwaltung for Umwelt, Verkehr und Klimaschutz n.d.). It is used together with an Oracle database, where the spatial data is linked directly to the graphic object on a map. All the green spaces, trees and playgrounds that are registered with in the GRIS database form the background for an overall evaluation as well as being integrated into the city planning of the green areas and tree population of Berlin (Senatsverwaltung für Umwelt, Verkehr und Klimaschutz u.d.). The database and GIS is closely linked to make sure the data is consistent and to avoid redundant data. The creation of new objects in GIS, for example the planting of new trees or creating a new lawn, would immediately update the database with the required information (Sentsverwaltung for Umwelt, Verkehr und Klimaschutz n.d.).

The importance of integrating the different departments of the municipality so they can cooperate has been emphasized by several authors. Osseni, A.A. (Osseni 2015, 152) emphasize the need for cooperation and the necessity for a database where data can be shared and edited in GIS. In addition, Medhi (Medhi 2012) writes about the role of green spaces in French urban policies, and that the accumulation of documents regarding urban green spaces have changed the frame of mind to encourage local authorities to set up spatial databases using GIS. Another article writes about the process of designing their own green space management system in

ArcGIS (Randall 2003), while India is also using ArcGIS to monitor nature, in this case, their wetlands (Garg 2015). Wang mentions the capability of GIS to undertake overlay and suitability analysis of green areas in connection with the management of sustainable urban construction in China (Wang 2013). In Korea many local governments store their urban green space data as spreadsheets without using a particular system. In a study by Cho and Shin (Cho 2016, 118) it was discovered that only seven local governments currently use a spatial information system-based management system for storing their urban green space data.

9. CONCLUSION

This project has shown that a large amount of data necessary for the Green Space Factor tool is available. This project has proven that the integration of GIS is a useful tool into the Green Space Factor tool. The project has also provided a great deal of data on green spaces that do not have municipal ownership. Traditionally, the municipality has data over their own areas; however, this project provides data on green areas for all of Copenhagen, regardless of ownership.
Using GIS for the Green Space Tool would be much more effective if it was all linked up with a spatial database, like it is in Berlin. With an automated process where new measurements are automatically updated in the database, the data would be transformed from static to dynamic. This would be much more beneficial for the municipality and for the Green Space Factor tool.

9.1 Limitations

Integrating GIS into the Green Space Factor tool with the current data available will provide certain limitations. For example, when measuring the canopy cover using Lidar Data, the undergrowth is not recorded. The data on ground vegetation from infrared orthophotos have not measured the surface type underneath trees. Hence, trees with a hard surface underneath them will receive the same amount of points as trees with ground vegetation underneath them, even though the combined effect on climate adaptation or visual green impression will be different.

Another limitation to the use of GIS with the tool as it is now, is the lack of data. Ground work will still have to be performed to get data on all the parameters, or complete some of the parameters that could not be completed using only GIS data.

The data sets that has been calculated for this project are all static. This means that the data does not get updated when changes are happening to the landscape. This in itself could provide a challenge to using GIS for the Green Space Factor tool. If there is no chance to update the data, or adding additional data to a database, the data will eventually be outdated.

A limitation to this project is the lack of peer reviewed articles that have been written on the Green Space Factor. In addition, there also seems to be a limit of peer reviewed articles regarding integrating GIS into municipal green space management. There are several other topics related to green areas and GIS with numerous peer reviewed publications, such as accessibility ((Nicholls 2001) (Yunliang 2015) (Neutens 2010) (Higgs 2012)). However, due to the lack of studies and assessments of the tool, the Green Space Factor needs to be evaluated to assess whether it is an effective planning tool for urban nature. As mentioned in 7.5, the tool will be evaluated at the end of 2017, and which parameters are necessary, which are redundant or do not work and which needs changing, will be assessed.
Literature for the project was also made slightly challenging due to the various names available for each green space factor in the different countries (Table 1).

9.2 Further development

The next step in this project would be to produce a baseline map for Copenhagen showing areas with the current Green Space Factor. This could be done using an overlay analysis (ESRI n.d.). The formula for the Green Space Factor is dependent on a project area; hence creating a baseline map would also require a project area. For this baseline map, a 100 x 100 m project area would be suitable. This would be the same cell size as the maps that are displaying statistics, and would give a detailed overview of the Green Space Factor in Copenhagen. Several of the rasters would also have to be reclassified, since the weighted overlay tool only uses discrete integer rasters.

Following the production of a baseline map, it would be ideal if an integrated database for all the different green areas was developed. Ideally, this should be used between departments, even though the ownerships of green spaces are split between departments in the municipality. To achieve this, the baseline map could be used as a communication tool to secure funds for such a large project.

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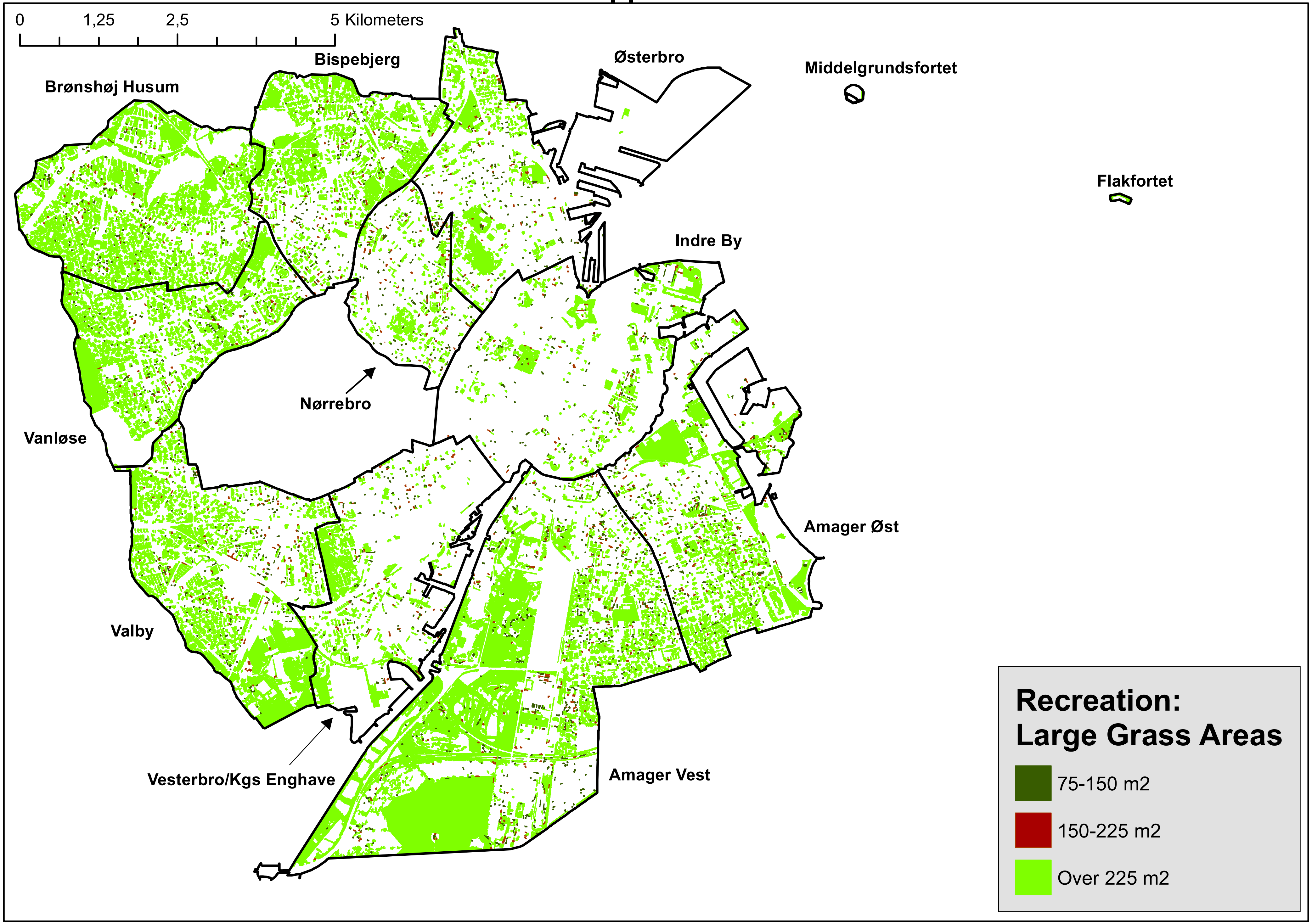
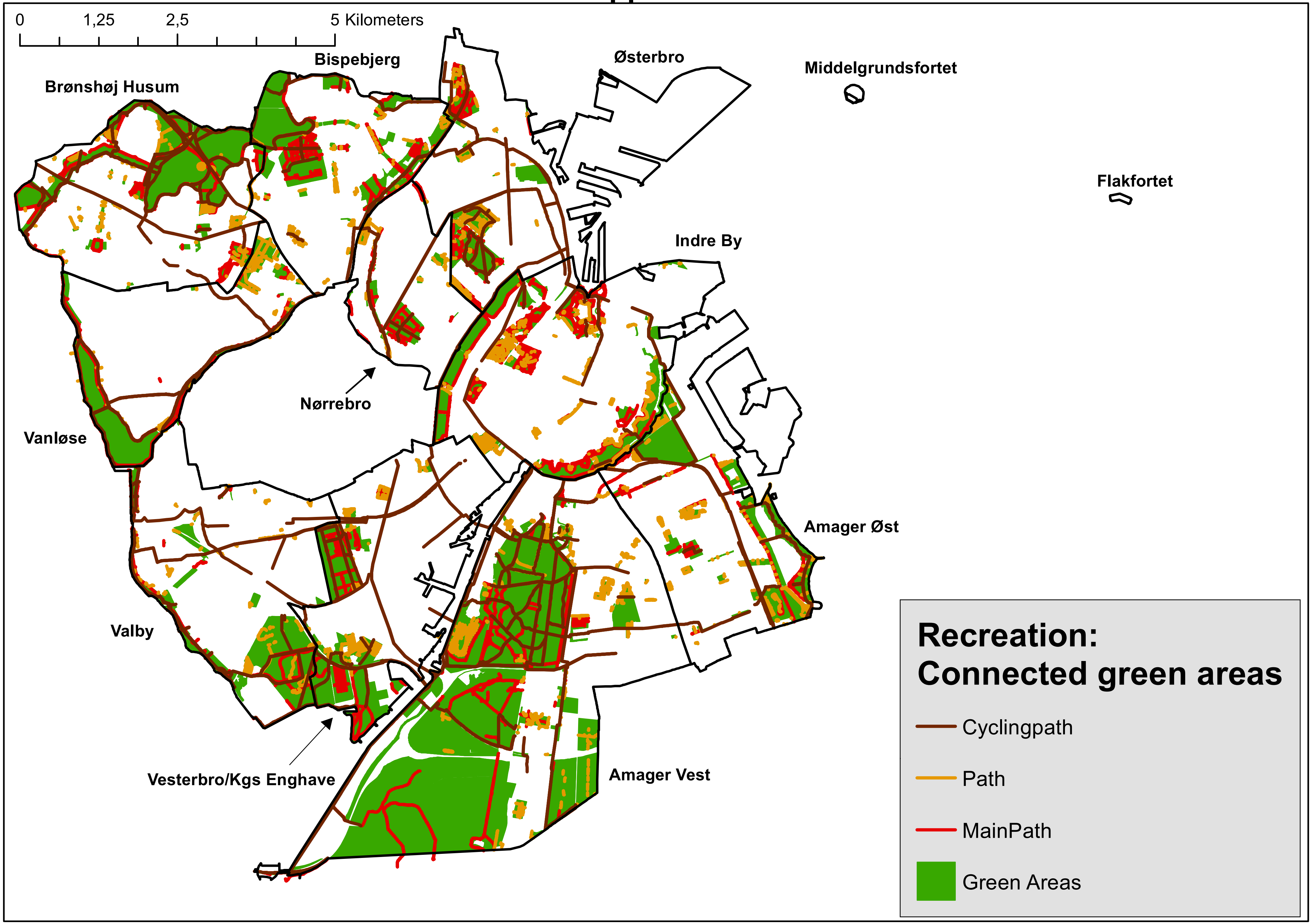
Appendix 1



0
1,25
2,5
5 Kilometers
Brønshøj Husum
Bispebjerg
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Recreation:
Large Grass Areas
75-150 m2
150-225 m2
Over 225 m2

Appendix 2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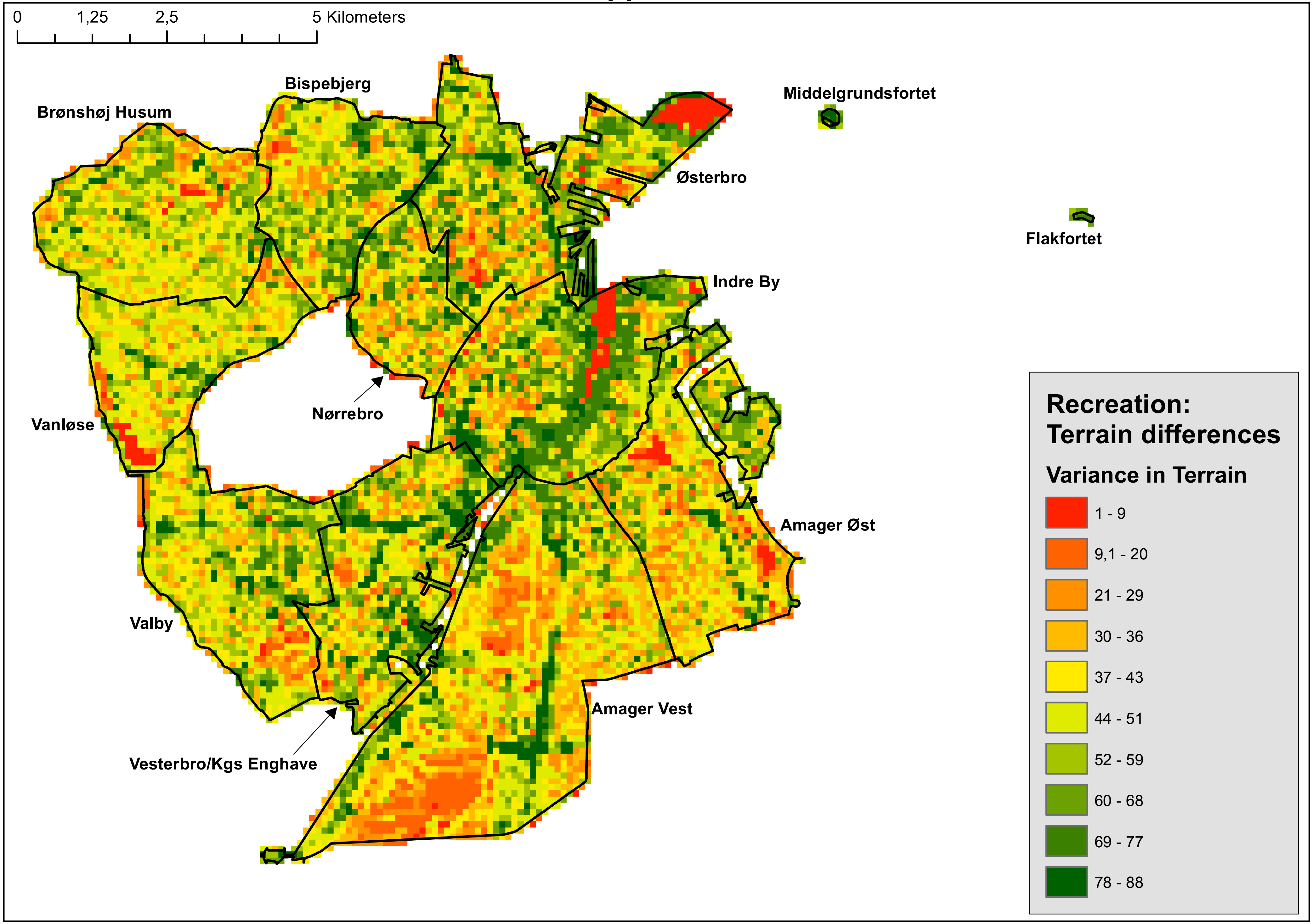
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Recreation:
Connected green areas
Cyclingpath
Path
MainPath
Green Areas

Appendix 3



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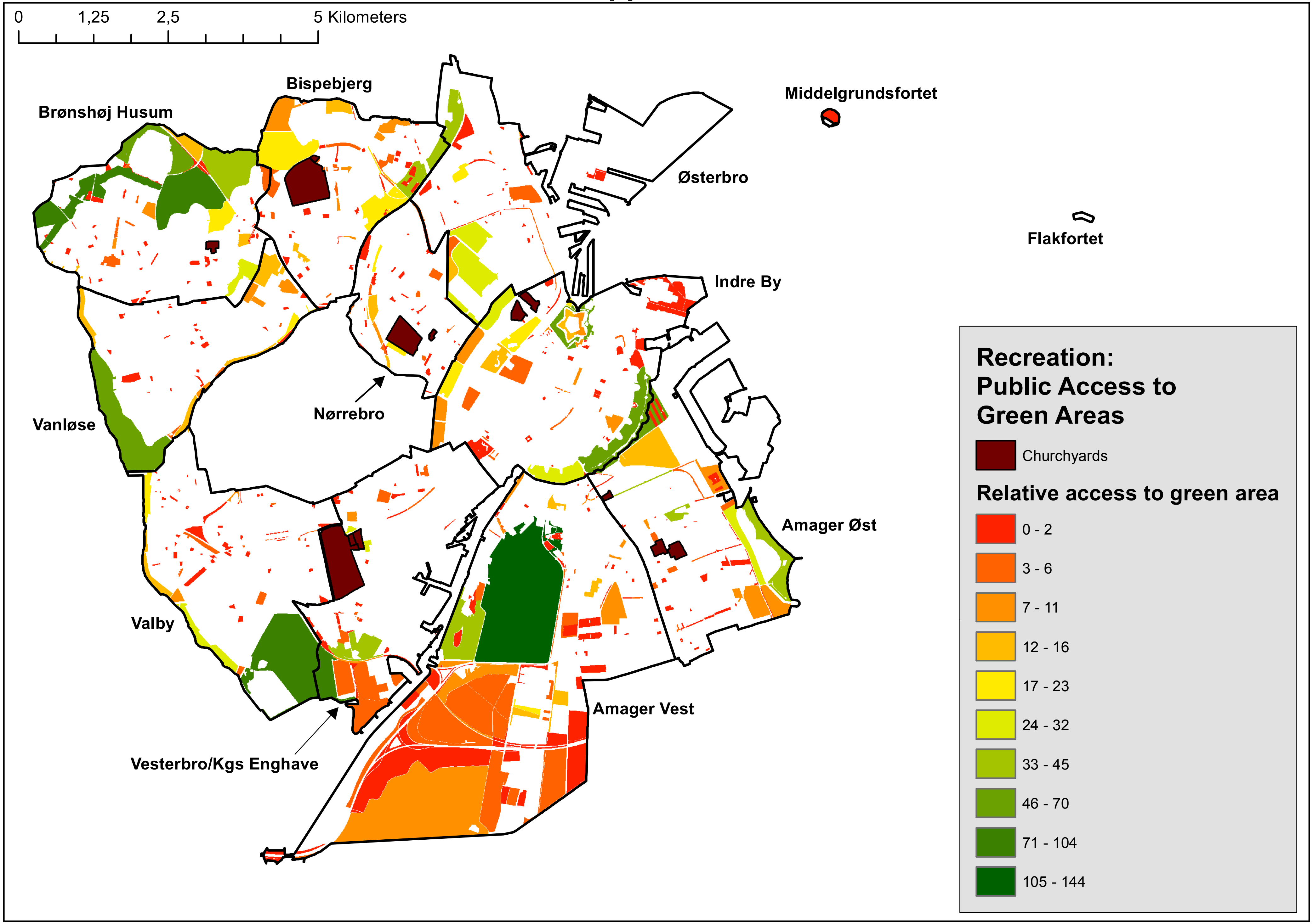
5 Kilometers
Bispebjerg
Brønshøj Husum
Middelgrundsfortet
Østerbro
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Amager Vest
Vesterbro/Kgs Enghave
Recreation:
Terrain differences
Variance in Terrain
1 - 9
9,1 - 20
21 - 29
30 - 36
37 - 43
44 - 51
52 - 59
60 - 68
69 - 77
78 - 88

Appendix 4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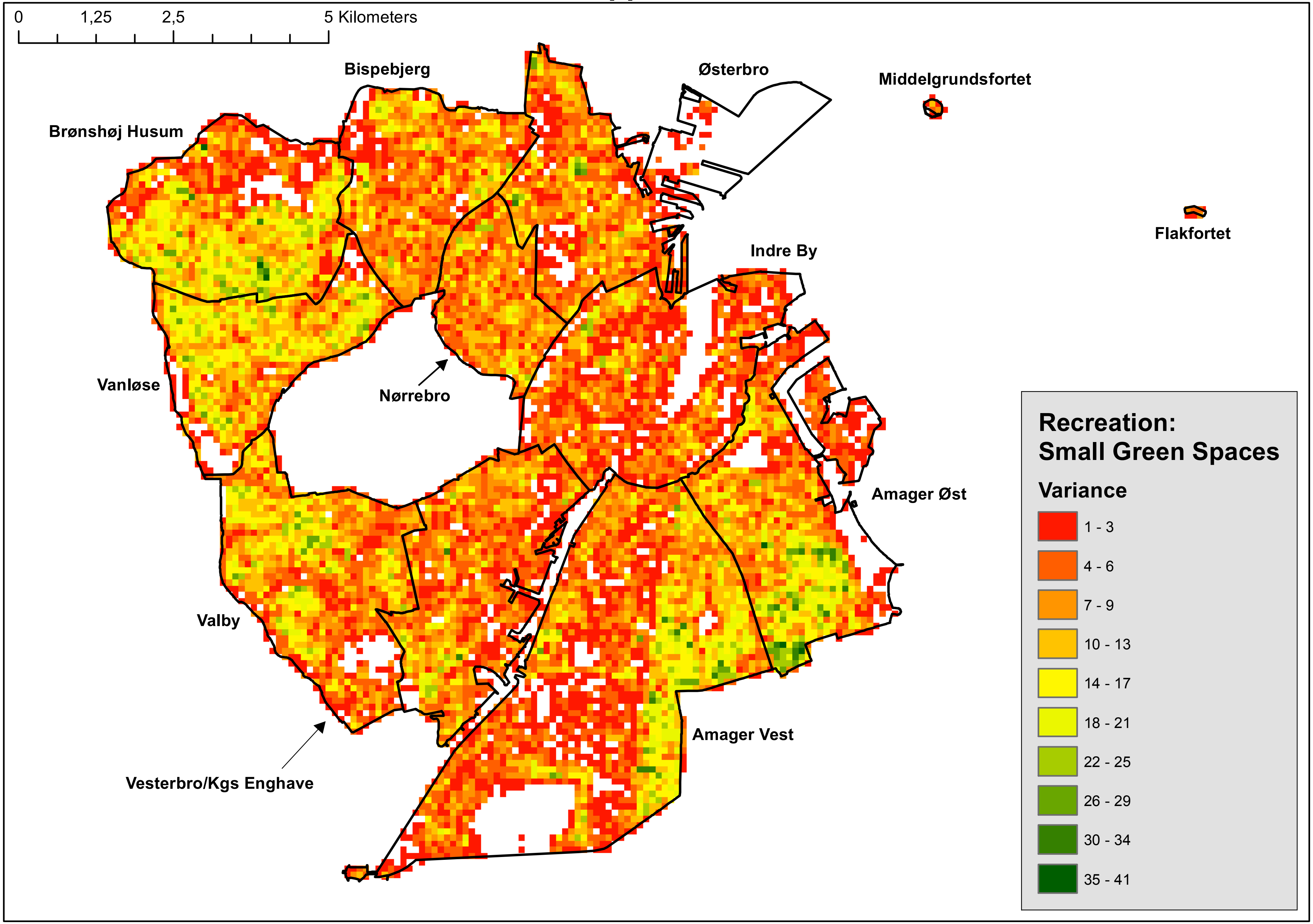
1,25
2,5
5 Kilometers
Brønshøj Husum
Bispebjerg
Middelgrundsfortet
Østerbro
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Amager Vest
Vesterbro/Kgs Enghave
Recreation:
Public Access to
Green Areas
Churchyards
Relative access to green area
0 - 2
3 - 6
7 - 11
12 - 16
17 - 23
24 - 32
33 - 45
46 - 70
71 - 104
105 - 144

Appendix 5



0
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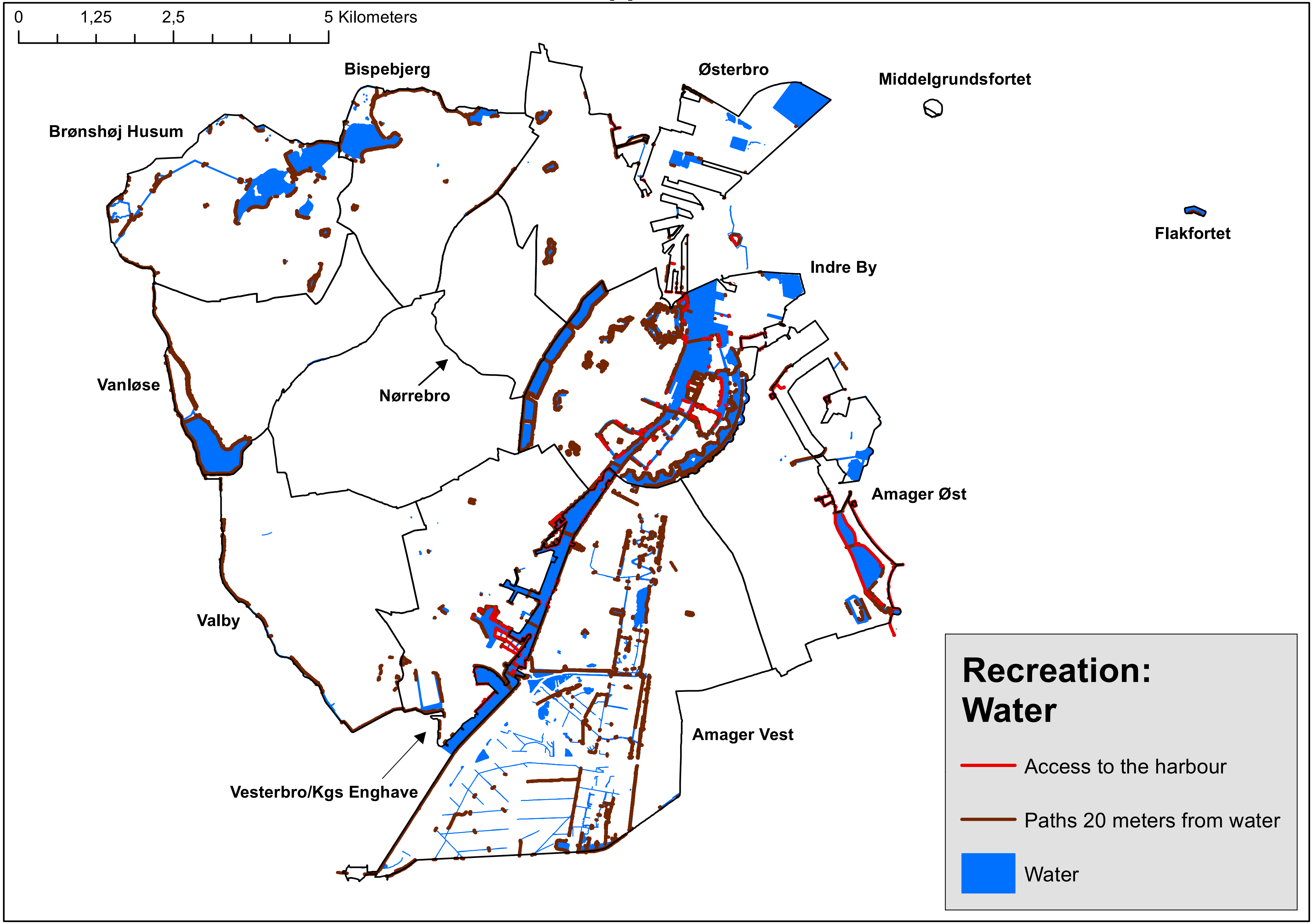
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Vanløse
Nørrebro
Amager Øst
Valby
Amager Vest
Vesterbro/Kgs Enghave
Recreation:
Small Green Spaces
Variance
1 - 3
4 - 6
7 - 9
10 - 13
14 - 17
18 - 21
22 - 25
26 - 29
30 - 34
35 - 41

Appendix 6



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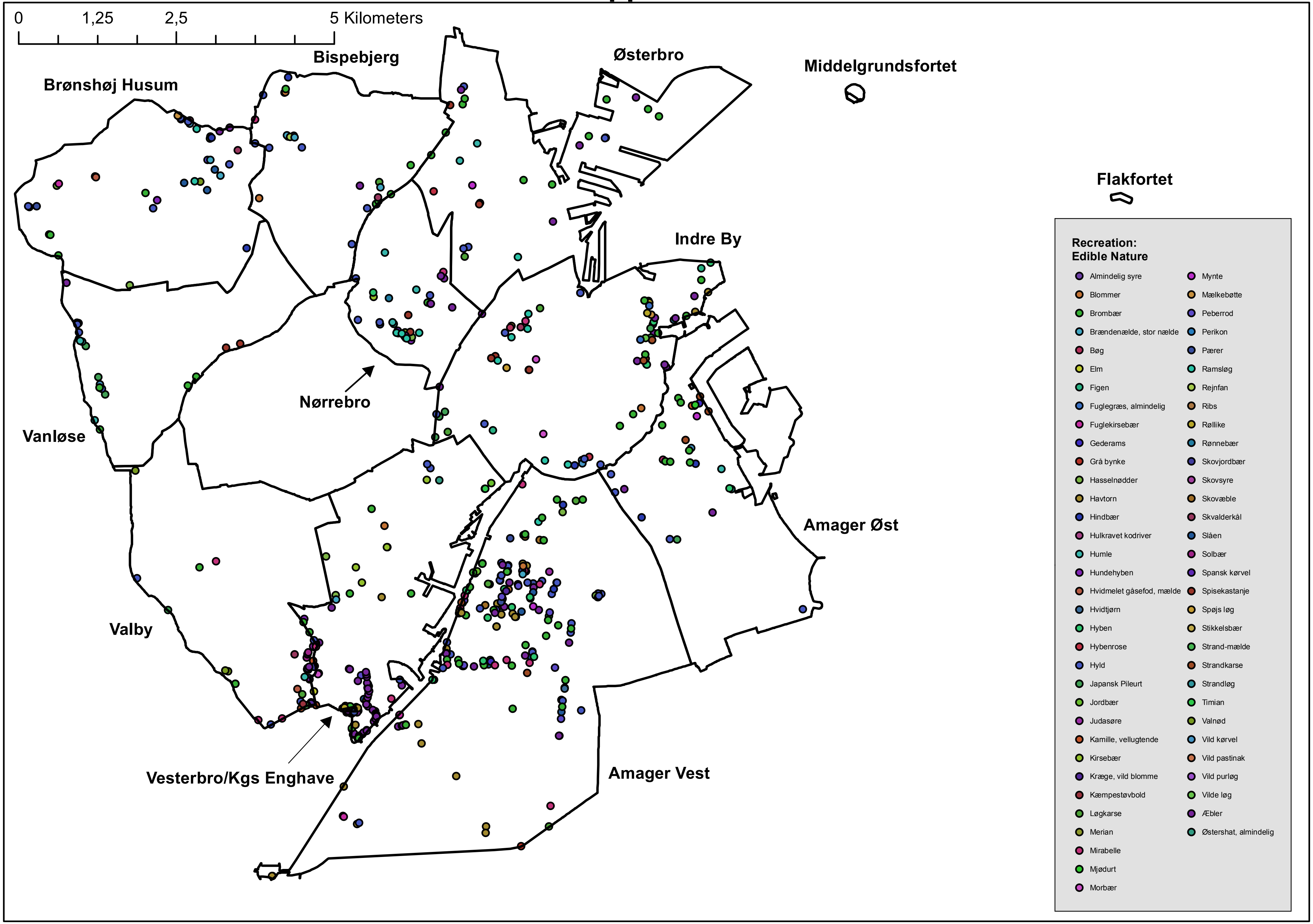
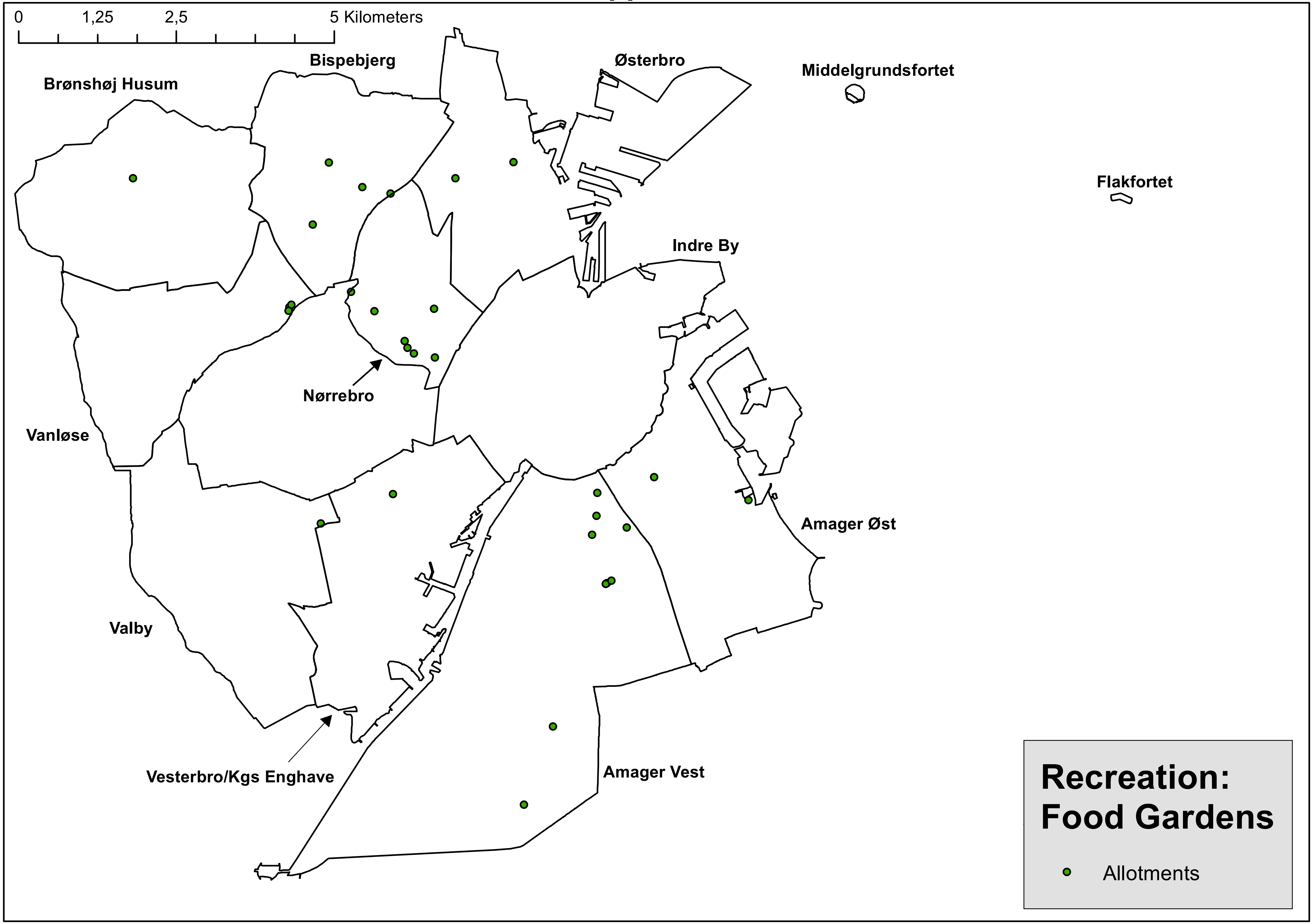
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Vanløse
Nørrebro
Amager Øst
Valby
Amager Vest
Vesterbro/Kgs Enghave
Recreation: Water
Access to the harbour
Paths 20 meters from water
Water

Appendix 7



0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Recreation:
Edible Nature
Almindelig syre
Blommer
Brombær
Brændenælde, stor nælde
Bøg
Elm
Figen
Fuglegræs, almindelig
Fuglekirsebær
Gederams
Grå bynke
Hasselnødder
Havtorn
Hindbær
Hulkravet kodriver
Humle
Hundehyben
Hvidmelet gåsefod, mælde
Hvidtjørn
Hyben
Hybenrose
Hyld
Japansk Pileurt
Jordbær
Judasøre
Kamille, vellugtende
Kirsebær
Kræge, vild blomme
Kæmpestøvbold
Løgkarse
Merian
Mirabelle
Mjødurt
Morbær
Mynte
Mælkebøtte
Peberrod
Perikon
Pærer
Ramsløg
Rejnfan
Ribs
Røllike
Rønnebær
Skovjordbær
Skovsyre
Skovæble
Skvalderkål
Slåen
Solbær
Spansk kørvel
Spisekastanje
Spøjs løg
Stikkelsbær
Strand-mælde
Strandkarse
Strandløg
Timian
Valnød
Vild kørvel
Vild pastinak
Vild purløg
Vilde løg
Æbler
Østershat, almindelig

Appendix 8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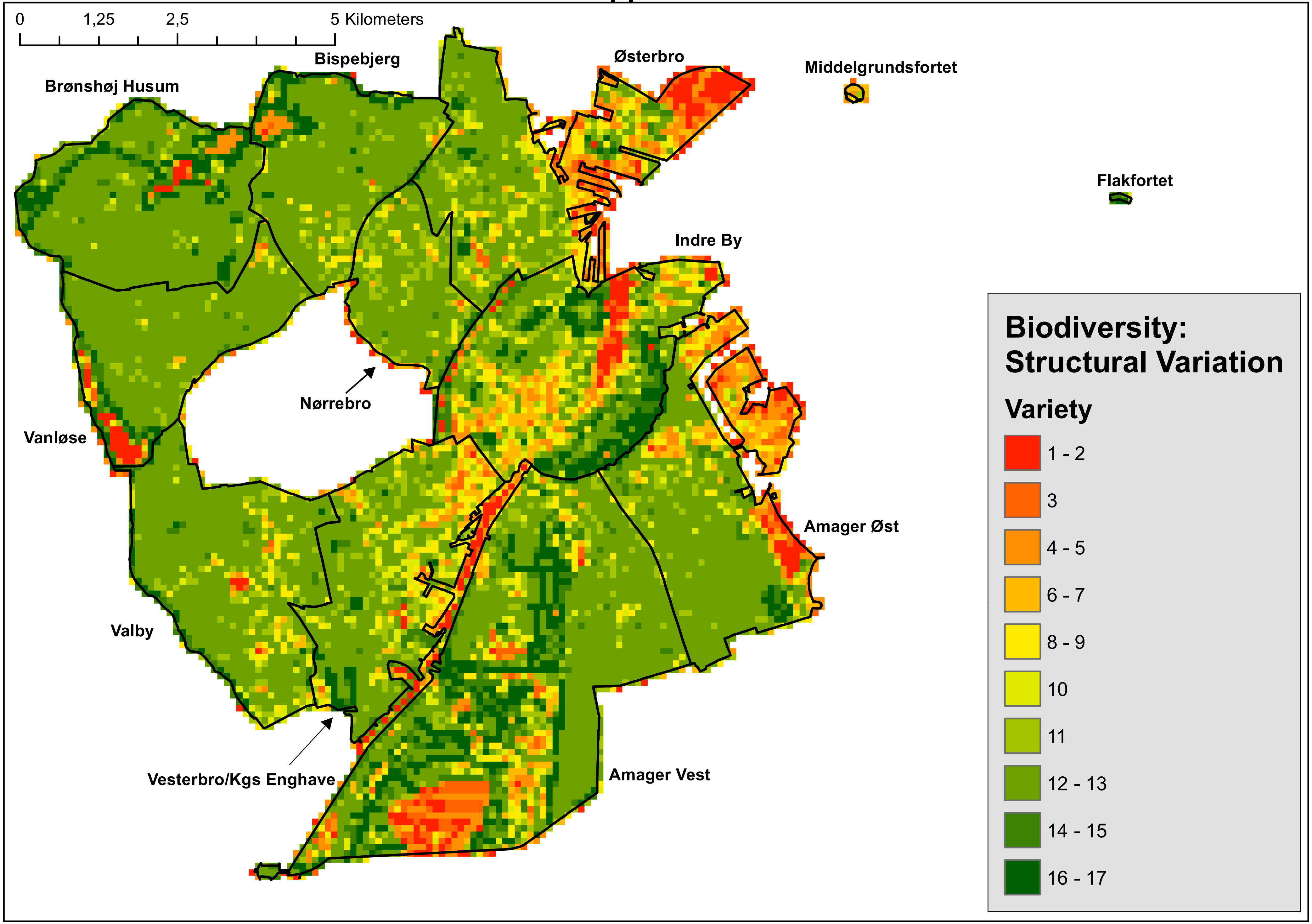
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Recreation:
Food Gardens
Allotments

Appendix 9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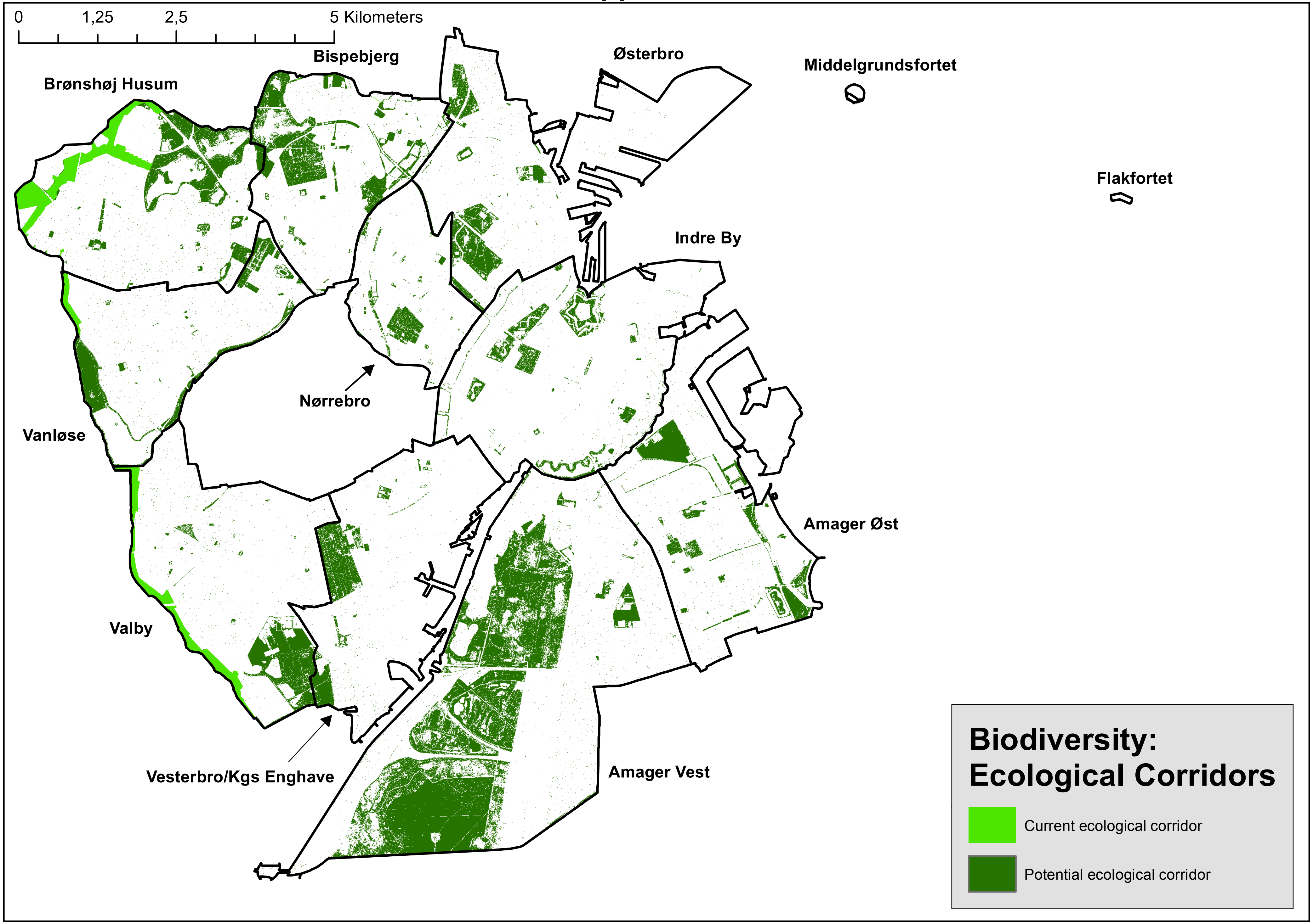
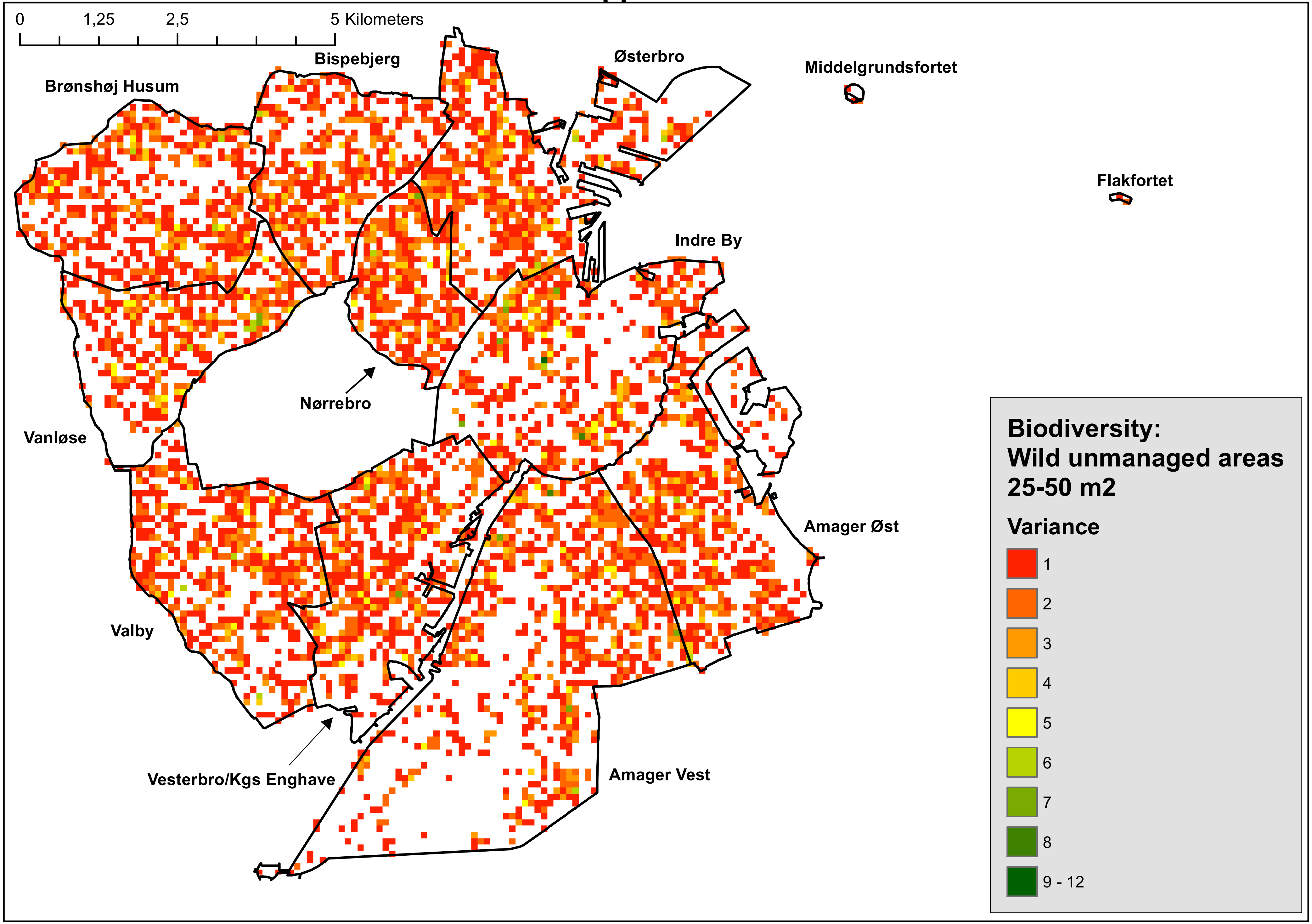
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Valby
Vesterbro/Kgs Enghave
Amager Øst
Amager Vest
Biodiversity: Structural Variation
Variety
1 - 2
3
4 - 5
6 - 7
8 - 9
10
11
12 - 13
14 - 15
16 - 17

Appendix 10



0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
Ecological Corridors
Current ecological corridor
Potential ecological corridor

Appendix 11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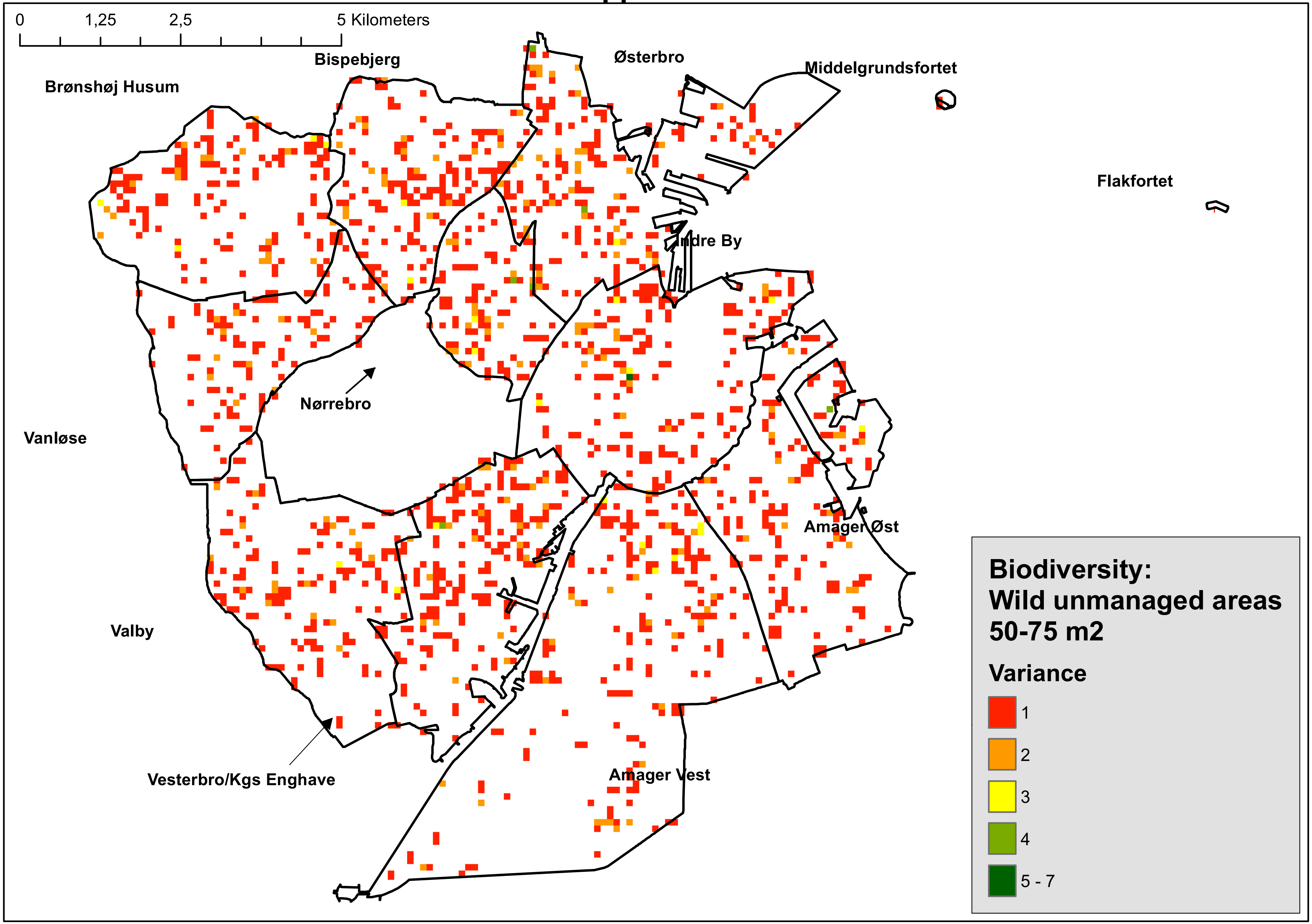
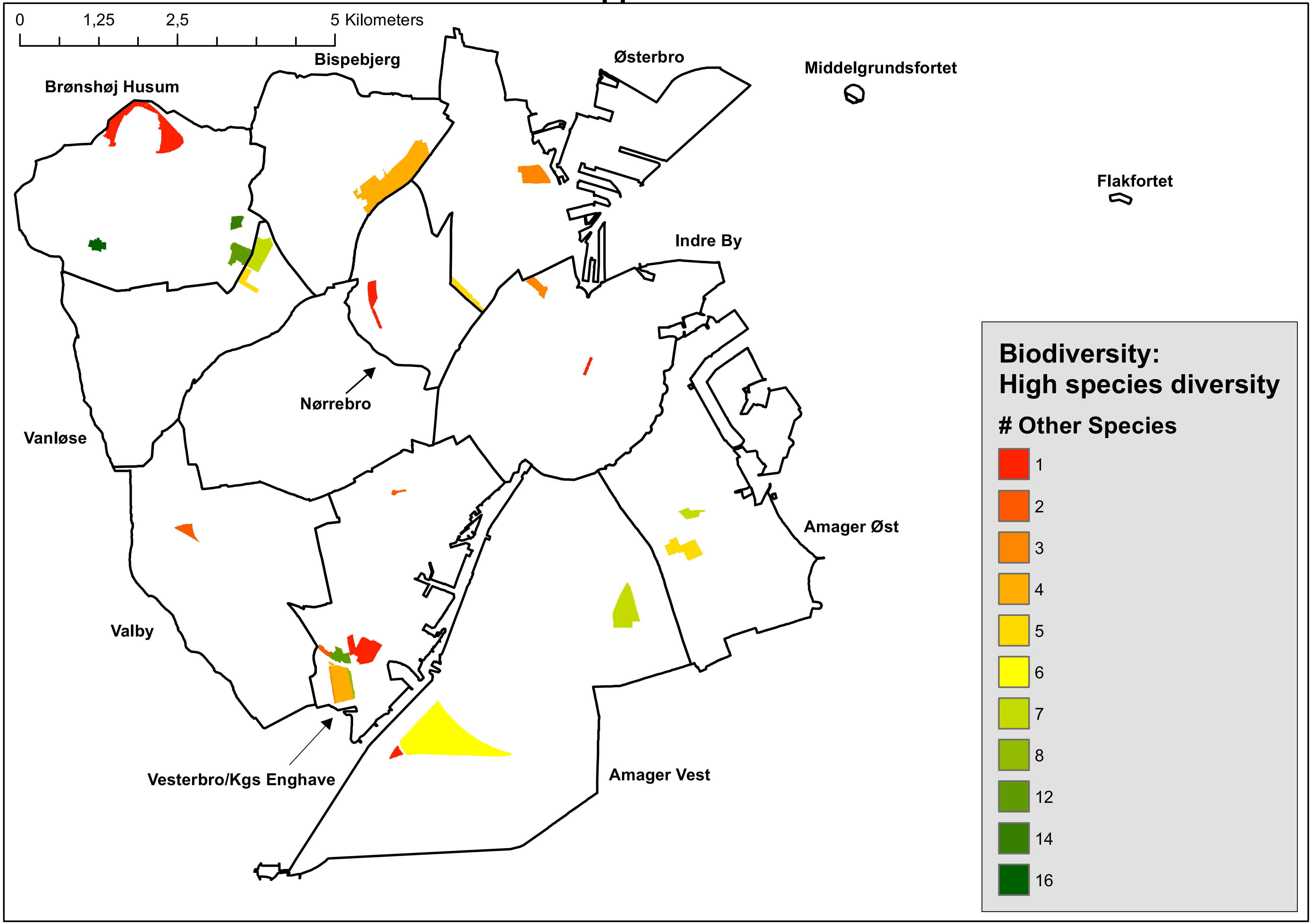
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
Wild unmanaged areas
25-50 m2
Variance
1
2
3
4
5
6
7
8
9 - 12

Appendix 11

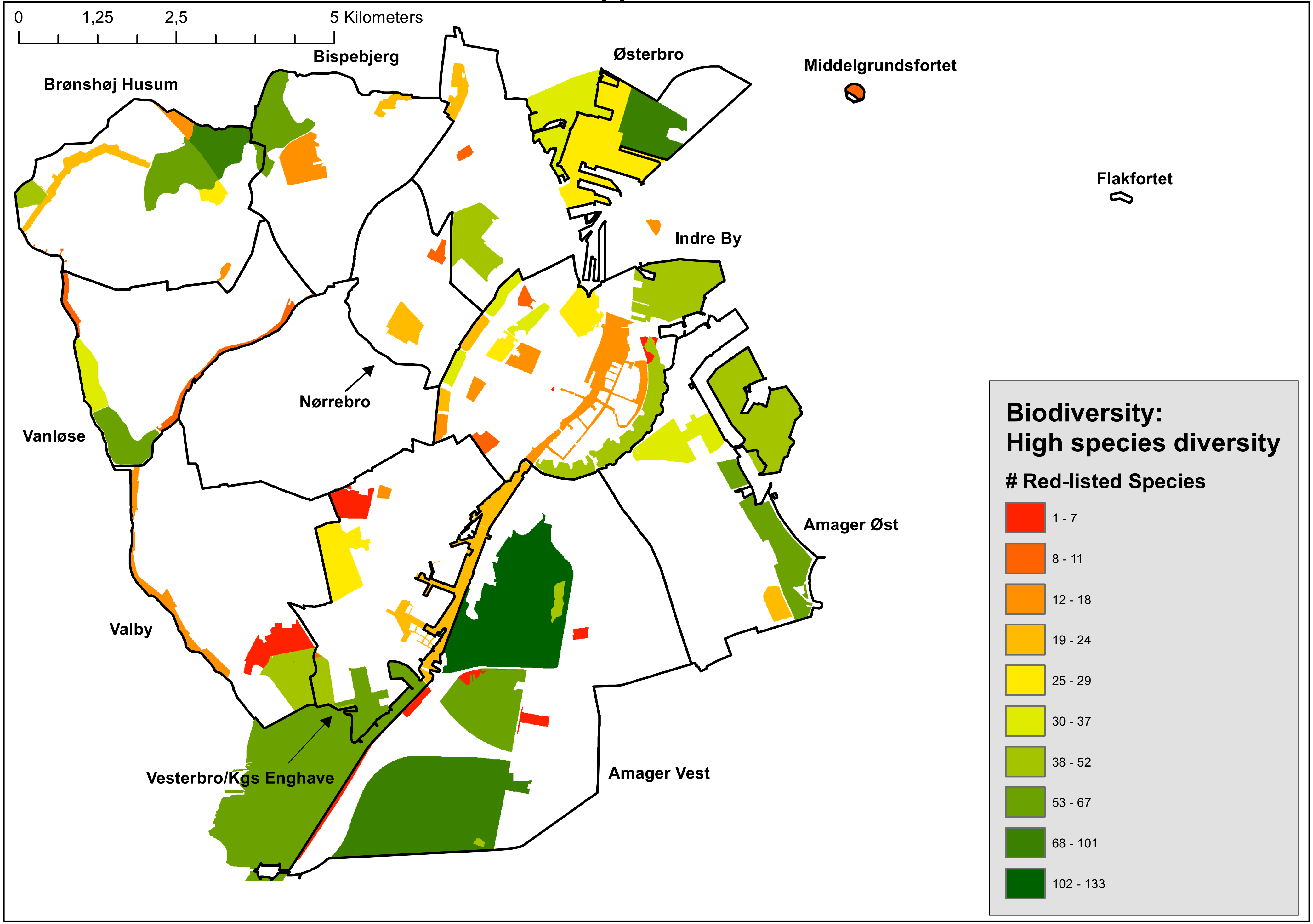

0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
Wild unmanaged areas
50-75 m2
Variance
1
2
3
4
5 - 7

Appendix 12



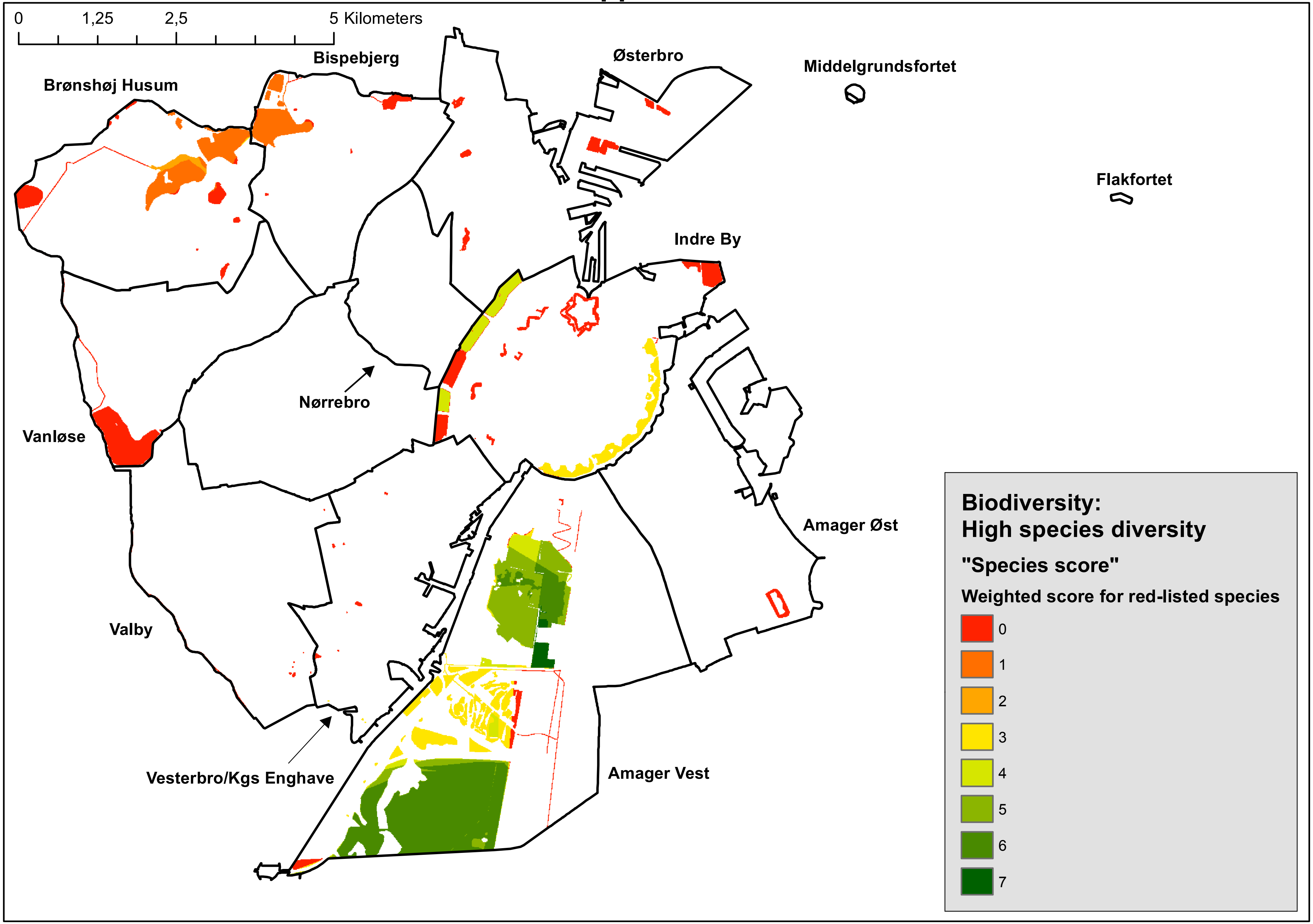
0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
High species diversity
Other Species
1
2
3
4
5
6
7
8
12
14
16

Appendix 12



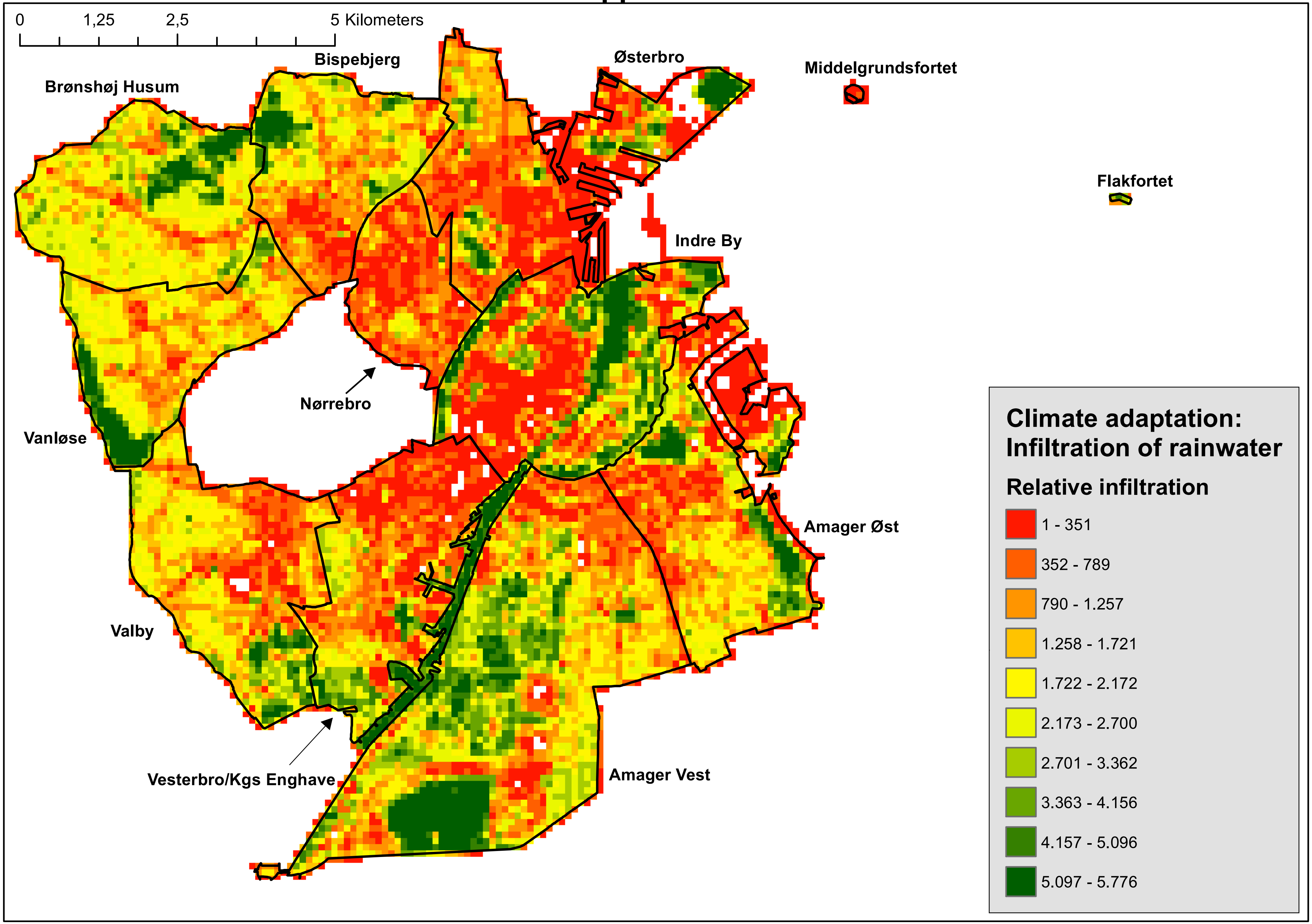
0
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
High species diversity
Red-listed Species
1 - 7
8 - 11
12 - 18
19 - 24
25 - 29
30 - 37
38 - 52
53 - 67
68 - 101
102 - 133

Appendix 12

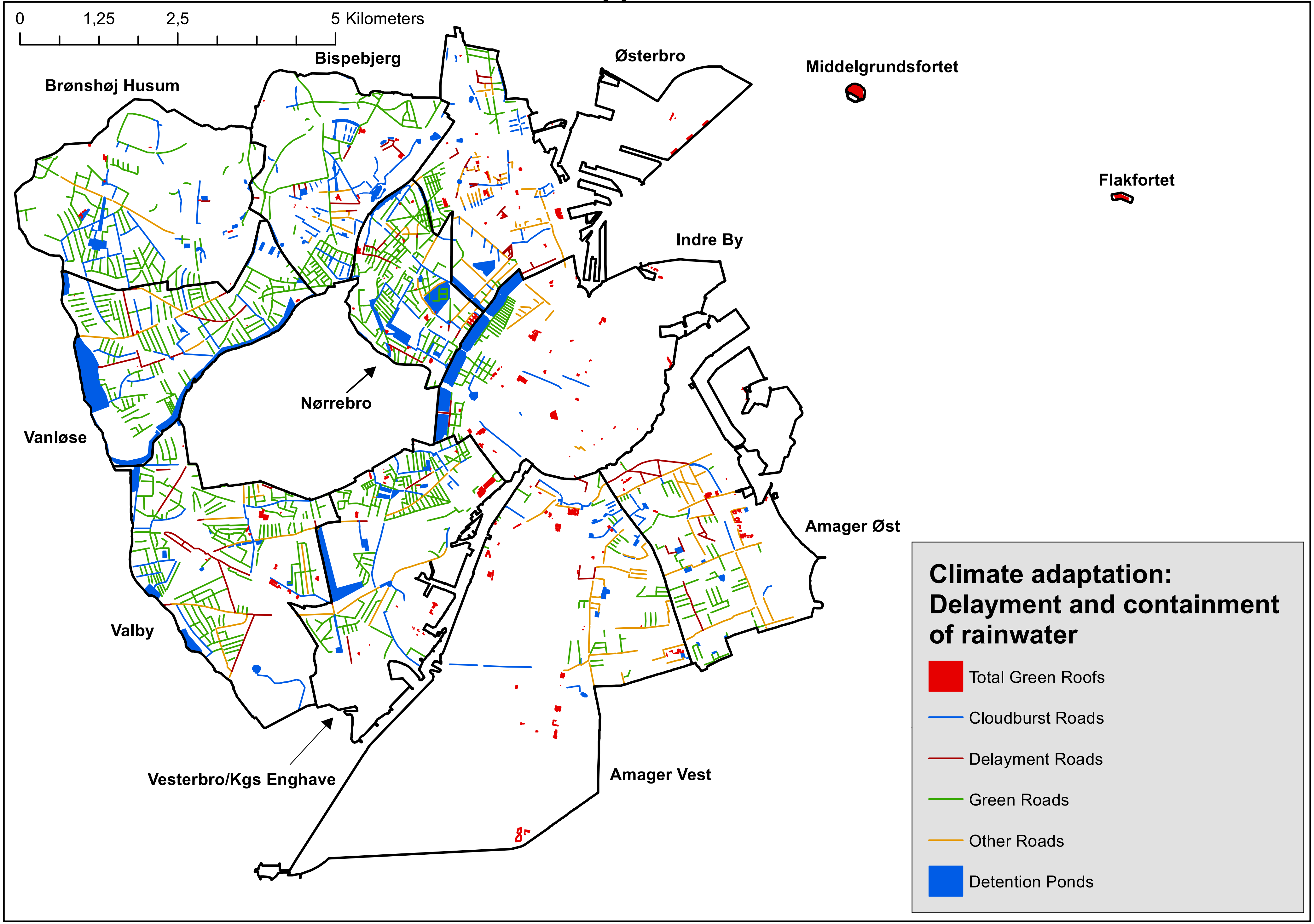


0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Biodiversity:
High species diversity
"Species score"
Weighted score for red-listed species
0
1
2
3
4
5
6
7

Appendix 13

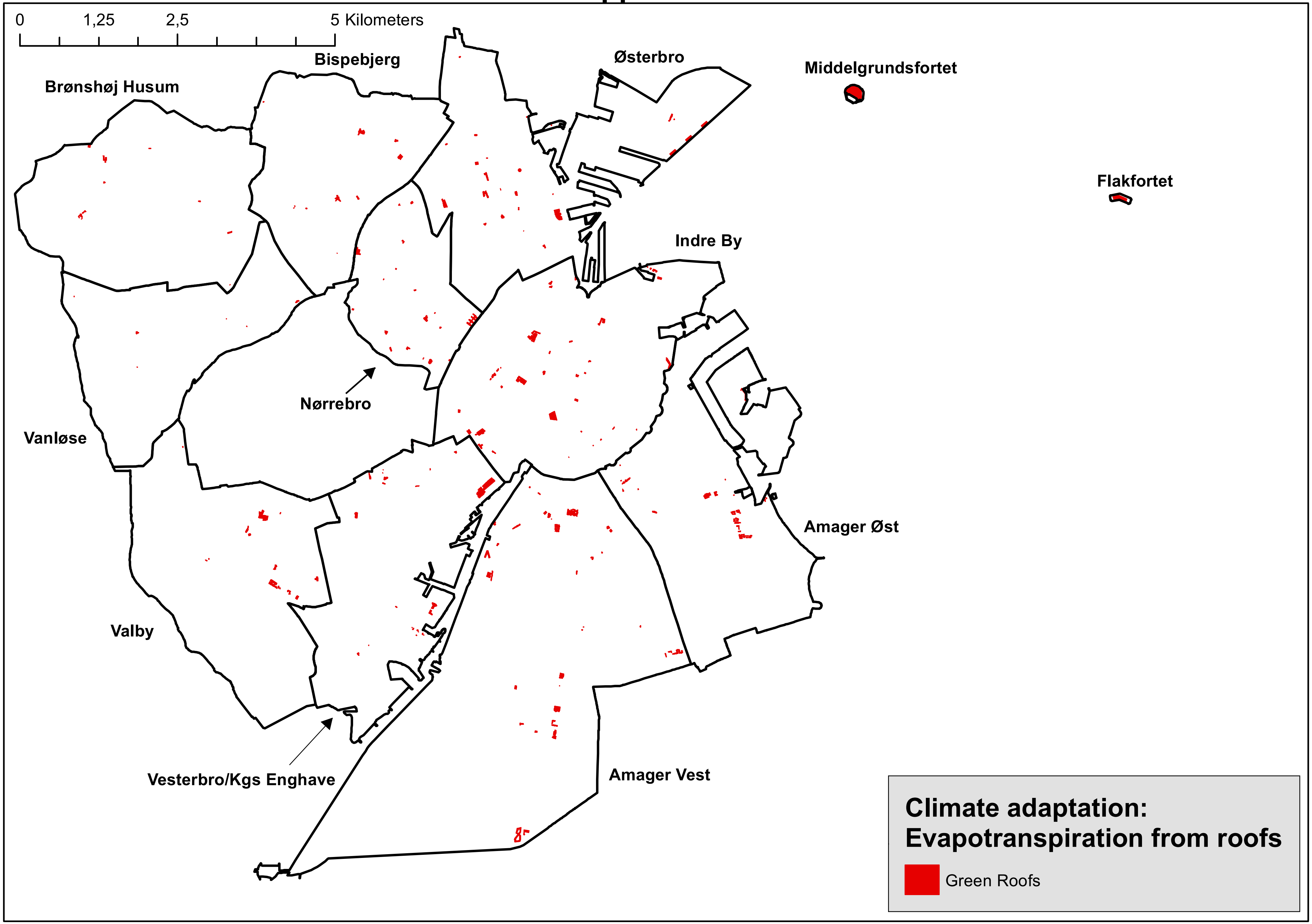

0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Climate adaptation:
Infiltration of rainwater
Relative infiltration
1 - 351
352 - 789
790 - 1.257
1.258 - 1.721
1.722 - 2.172
2.173 - 2.700
2.701 - 3.362
3.363 - 4.156
4.157 - 5.096
5.097 - 5.776

Appendix 14



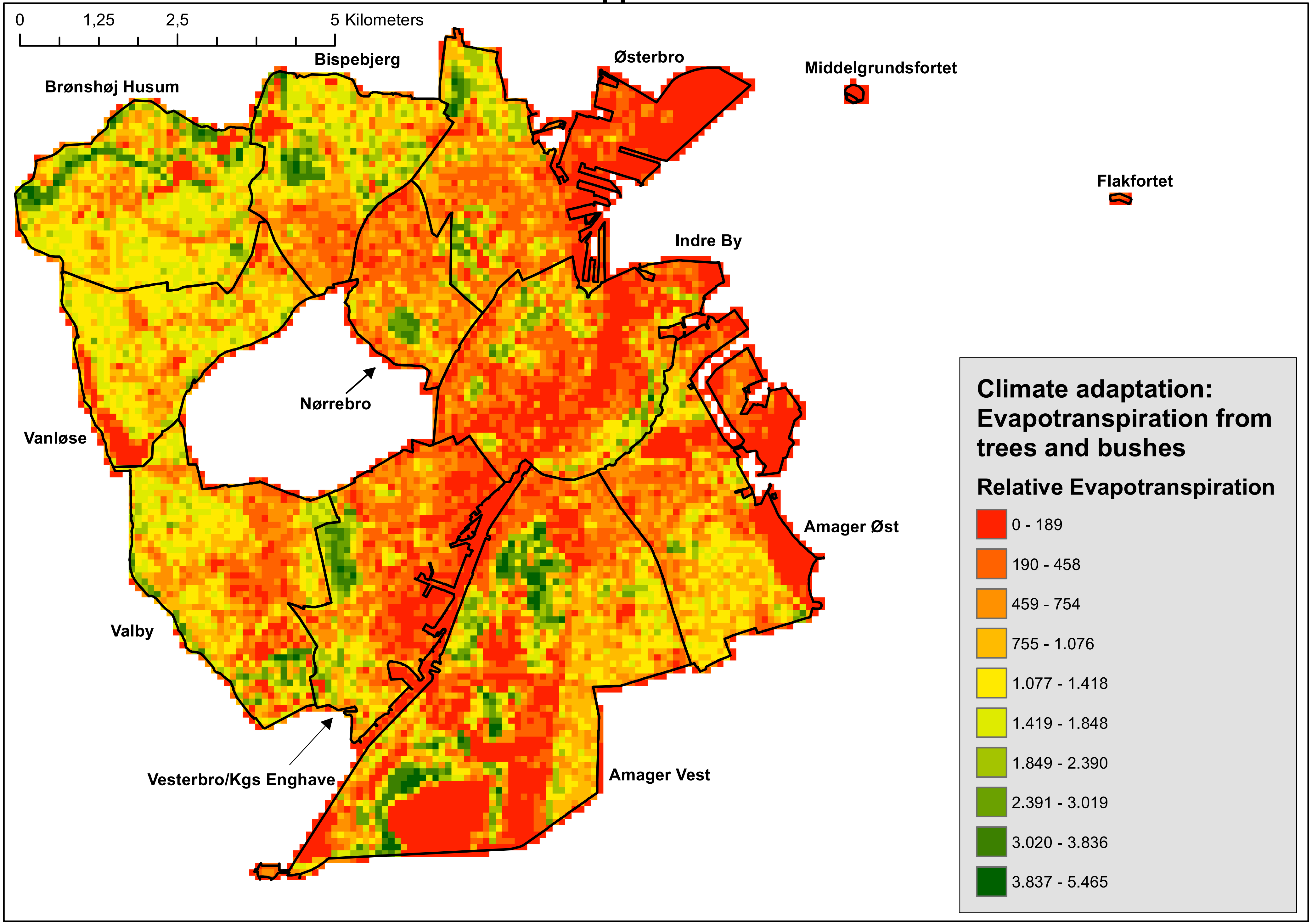
0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Climate adaptation: Delayment and containment of rainwater
Total Green Roofs
Cloudburst Roads
Delayment Roads
Green Roads
Other Roads
Detention Ponds

Appendix 15

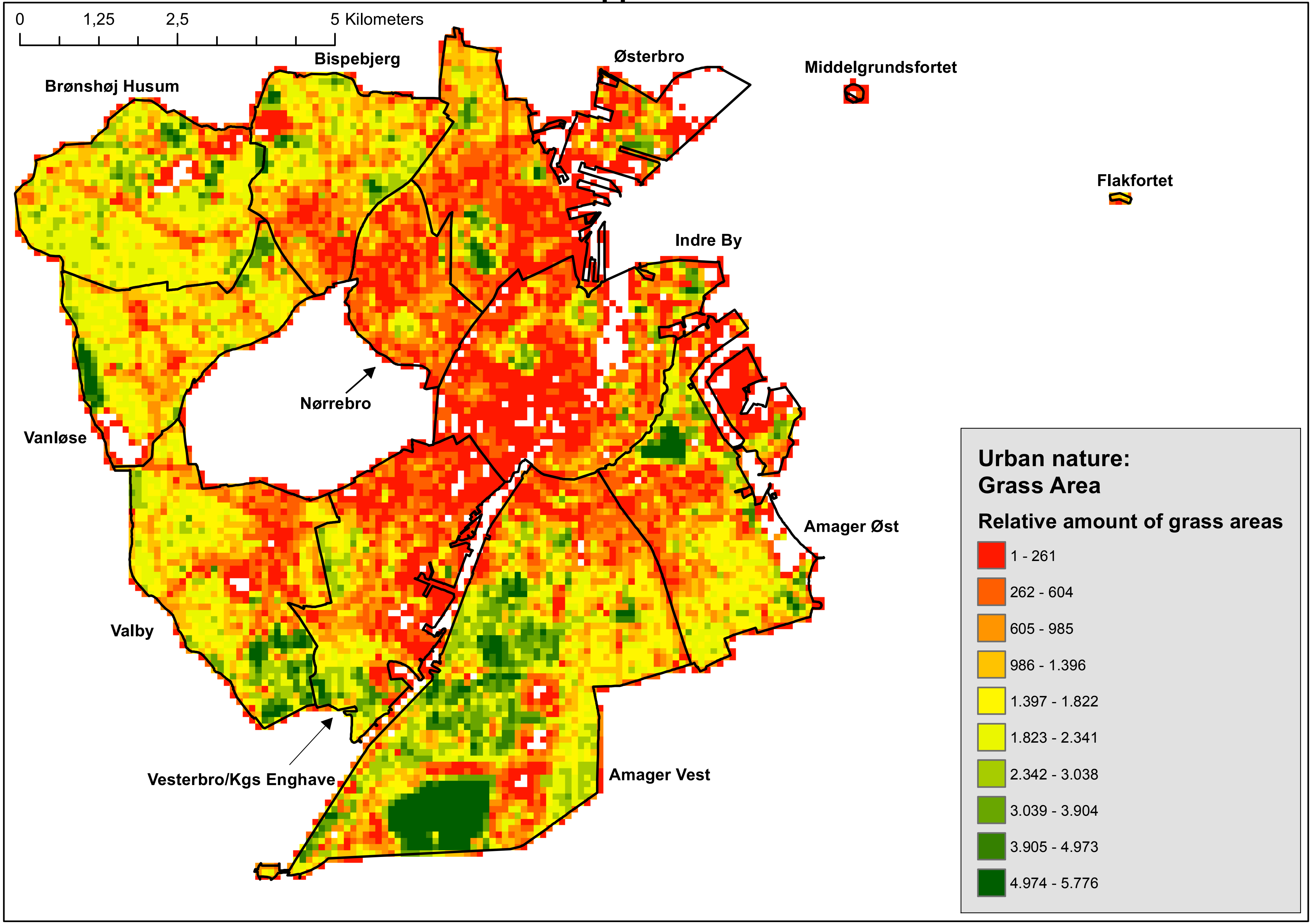


0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Climate adaptation:
Evapotranspiration from roofs
Green Roofs

Appendix 16

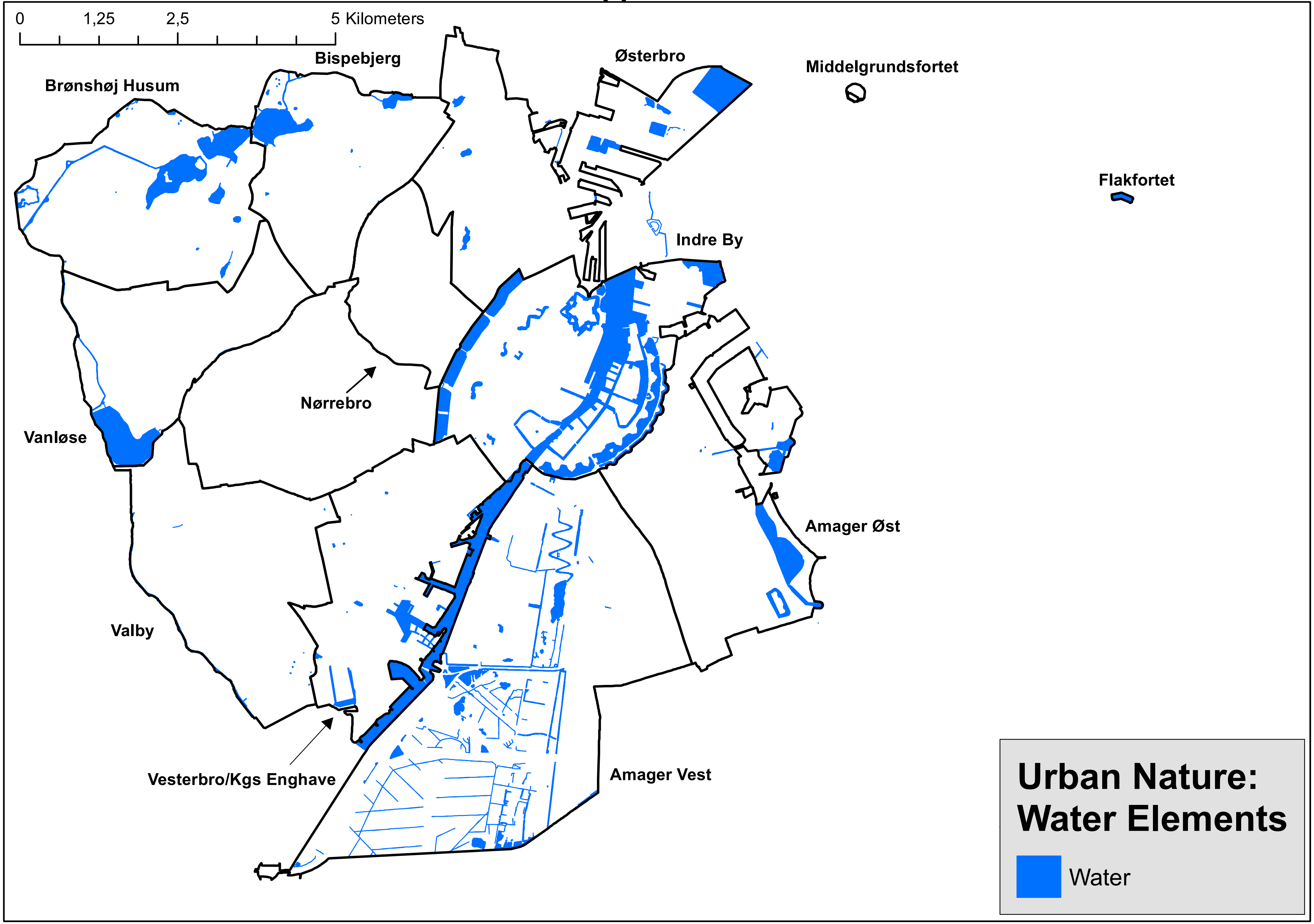

0
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Climate adaptation: Evapotranspiration from trees and bushes
Relative Evapotranspiration
0 - 189
190 - 458
459 - 754
755 - 1.076
1.077 - 1.418
1.419 - 1.848
1.849 - 2.390
2.391 - 3.019
3.020 - 3.836
3.837 - 5.465

Appendix 17

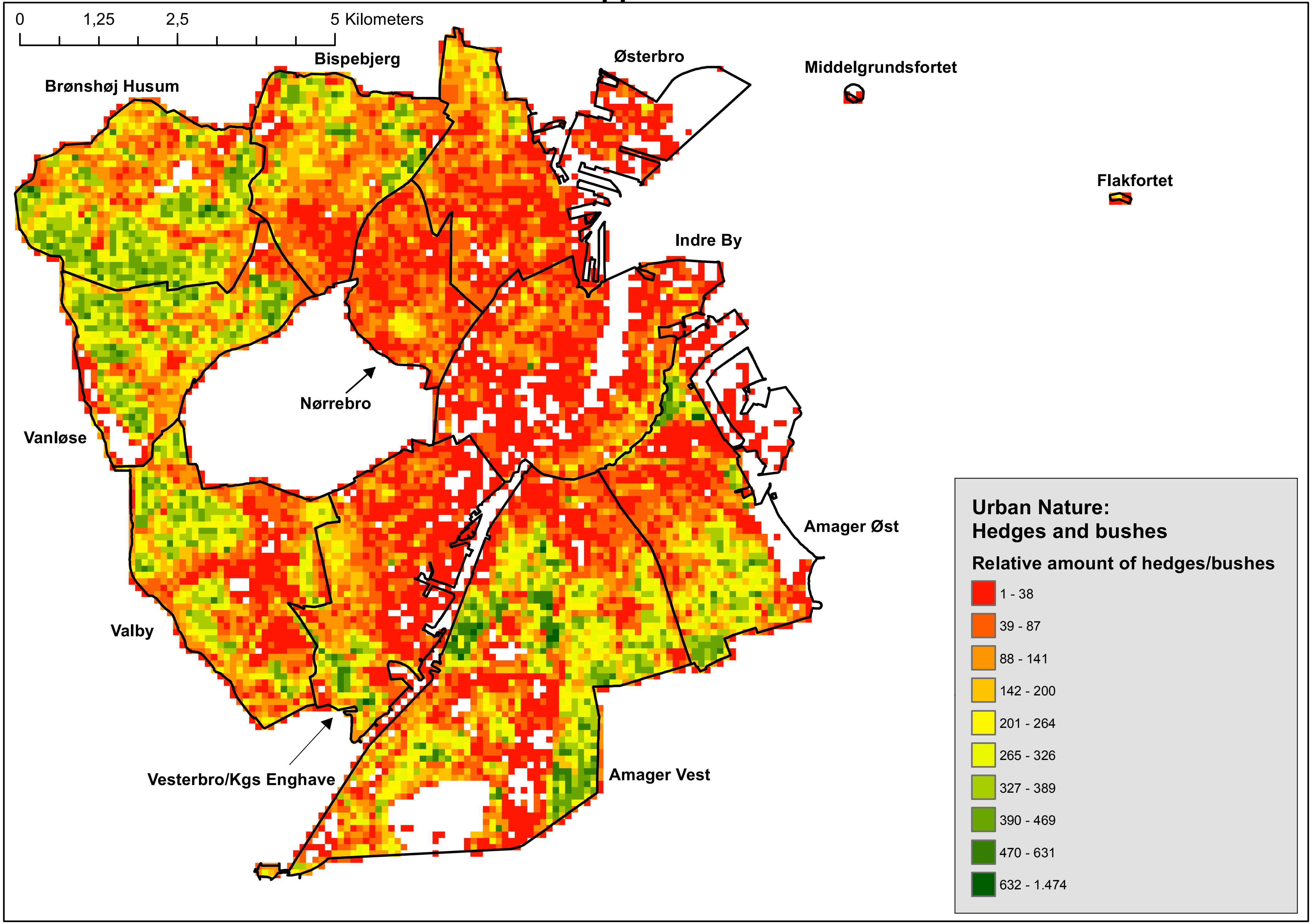


0
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Urban nature:
Grass Area
Relative amount of grass areas
1 - 261
262 - 604
605 - 985
986 - 1.396
1.397 - 1.822
1.823 - 2.341
2.342 - 3.038
3.039 - 3.904
3.905 - 4.973
4.974 - 5.776

Appendix 18

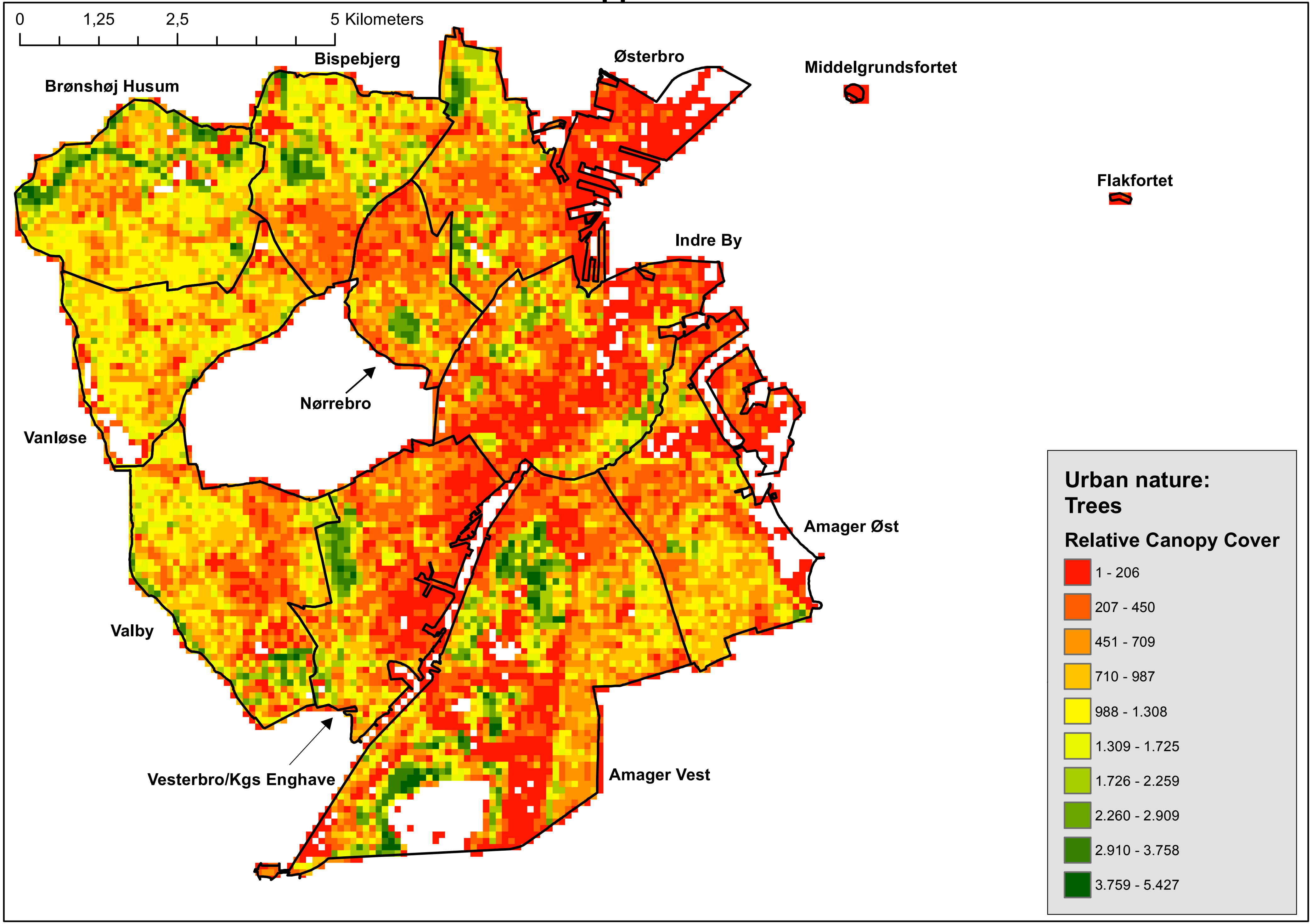

0
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Urban Nature:
Water Elements
Water

Appendix 19

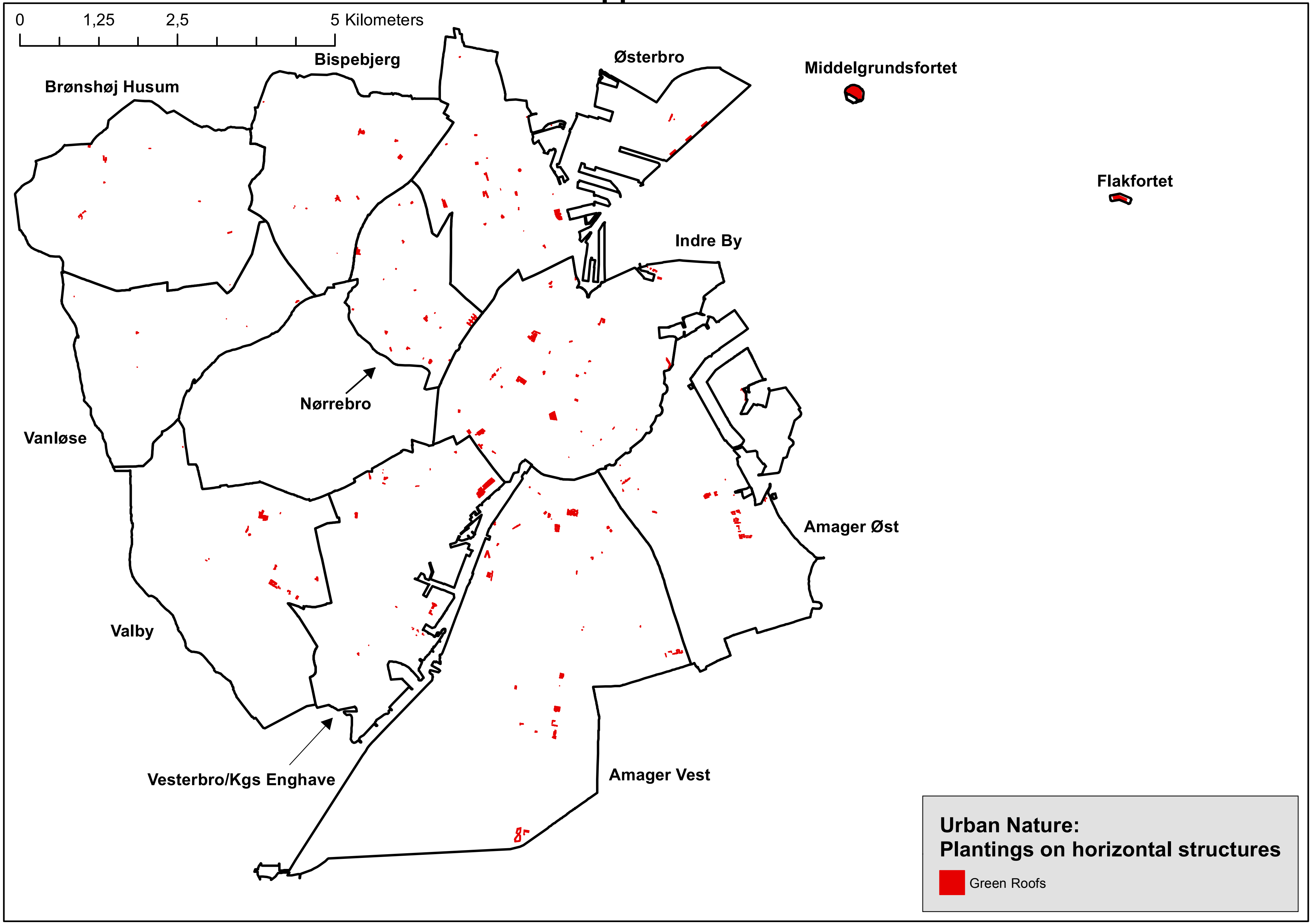


0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Urban Nature:
Hedges and bushes
Relative amount of hedges/bushes
1 - 38
39 - 87
88 - 141
142 - 200
201 - 264
265 - 326
327 - 389
390 - 469
470 - 631
632 - 1.474

Appendix 20


0
1,25
2,5
5 Kilometers
Bispebjerg
Brønshøj Husum
Østerbro
Middelgrundsfortet
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Urban nature:
Trees
Relative Canopy Cover
1 - 206
207 - 450
451 - 709
710 - 987
988 - 1.308
1.309 - 1.725
1.726 - 2.259
2.260 - 2.909
2.910 - 3.758
3.759 - 5.427

Appendix 21


0
1,25
2,5
5 Kilometers
Bispebjerg
Østerbro
Middelgrundsfortet
Brønshøj Husum
Flakfortet
Indre By
Nørrebro
Vanløse
Amager Øst
Valby
Vesterbro/Kgs Enghave
Amager Vest
Urban Nature:
Plantings on horizontal structures
Green Roofs

Appendix 22

Overview of the different data types and which data was used for the different parameters.

	Lidar data	Orthophoto	DSM	DEM	Vector data from the municipality	Other vector data
Recreation						
Large grass areas		X			X	
Connected green areas		X			X	
Variation in the terrain				X		
Public access to green spaces		X			X	
Small green spaces	X	X	X			
Water elements					X	
Edible plants						X
Food cultivation					X	
Biodiversity						
Structural variation	X	X	X		X	
Ecological corridors	X	X	X		X	
Wild unmanaged areas		X				
High species diversity					X	X
Climate adaptation						
Infiltration of rainwater	X	X	X		X	
Delayment and containment of rainwater					X	
Evapotranspiration from roofs		X	X			
Evapotranspiration from trees and bushes	X	X	X			
Urban nature						
Grassy areas		X				
Water elements					X	
Hedges and bushes		X	X	X		
Other trees	X					
Plantings on horizontal structures		X	X			X

Appendix 23

Københavns Kommunes Begrønningsværktøj

Formålet med Københavns Kommunes bynaturværktøj er at bidrage til mere og bedre bynatur i København.

- Beregning af eksisterende **begrønningsfaktorr**, gå til fanen "Eksisterende areal"

- Beregning af fremtidigt **begrønningsfaktor**, gå til fanen "Fremtidigt areal"

- For et **overblik** over kvaliteten af bynaturen, gå til fanen "Oversigt - Resultater"

Gå til "Eksisterende areal" | Gå til "Fremtidigt areal" | Gå til "Oversigt - Resultater"

Beregning af eksisterende begrønningsfaktor

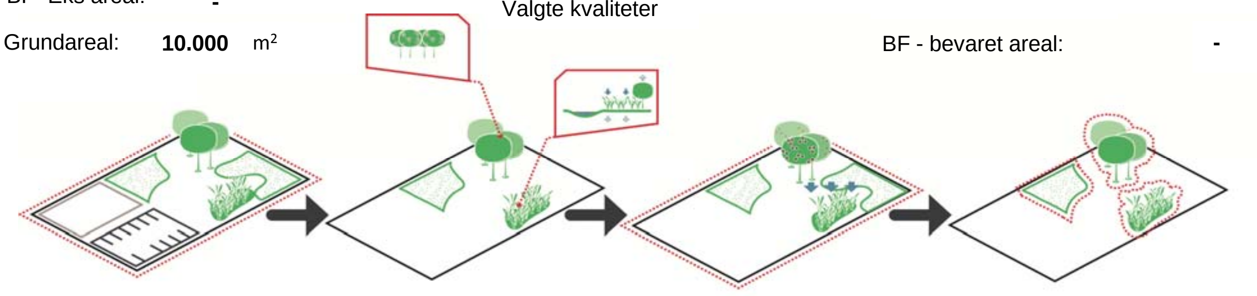
BF- Eks areal: -

Grundareal: 10.000 m²

Bevaret bynaturareal: 0 m²

BF - bevaret areal: -

Valgte kvaliteter



START ved at trykke HER

Gå til "Start - Vejledning i værktøjet"

Gå til "Fremtidigt areal"

Gå til "Oversigt - Resultater"

Trinvis g

1) Tryk p
Derved l
arealtyp

2) Angiv
eksister
samtidig
ønskes b
fremtide

3) Tryk p
vurdér k
eventue
ønsker a

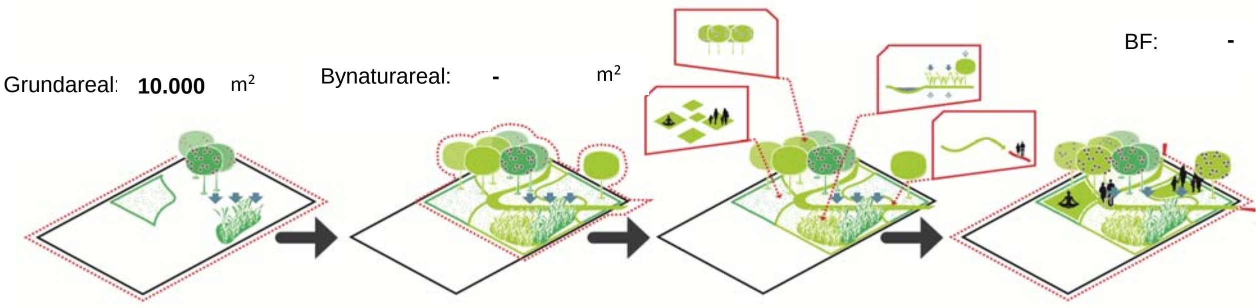
4)Vælg d
relevant
vælges i

		Projektareal m² (inkl. bebyggelse):	**10.000**		
AREALTYPE	**BYNATUR**	**BESKRIVELSE**	**M²**	**Areal ønsket bevaret**	**Noter**
FLADER	Græsarealer	Eksempelvis sportsplæne, brugsplæne, prydplæne, rabatgræs, fælledgræs eller naturgræs mm.			
	Permeable belægninger	Semipermeable/permeable belægninger, som sørger for infiltration eksempelvis grus, græsarmering og småsten mm.			
	Vandflader	Eksempelvis søer, damme, vådbassiner mm.			
	Bede	Bede med eksempelvis stauder, bunddække, blomster, høje græsser mm.			
	Hække og buske	Eksempelvis bøge, avnbøg, navrhække, div blomstrende prydbuske mm.			
ELEMENTER	Værdifulde træer	Særligt værdifulde, (store/gamle) træer (25m²/træ)			
	Øvrige træer	Andre etablerede og sunde træer (16m²/træ)			
KONSTRUKTIONER	Beplantning på vertikale konstruktioner	Sedum, mosser, urter, klatreplanter på facader, støjvægge, hegn, vægge og andre vertikale konstruktioner.			
	Beplantning på skrå og horisontale konstruktioner	Sedum, mosser og urter på tag og dæk, cykelskure, parkeringshuse og busstop mm.			
	Beplantning i kantzoner	Beplantning i kantzoner eksempelvis hække, buske og mindre træer.			
		Sum	-	0	

Beregning af fremtidig begrønningsfaktor

Valgte kvaliteter

Grundareal: **10.000** m² Bynaturareal: **-** m² BF: **-**



Gå til "Start - Vejledning i værktøjet"

Gå til "Eksisterende areal"

Gå til "Oversigt - Resultater"

Trin

1) T 'Eks er s vur

2) A for

3) T vur eve øns

4)V rele væl

		Projektareal m² (inkl. bebyggelse):	**10.000**		
AREAL TYPE	**BYNATUR**	**BESKRIVELSE**	**Bevaret areal (M²)**	**Nyt areal (M²)**	**Noter**
FLADER	Græsarealer	Eksempelvis sportsplæne, brugsplæne, prydplæne, rabatgræs, fælledgræs eller naturgræs mm.	0		
	Permeable belægninger	Semipermeable/permeable belægninger, som sørger for infiltration eksempelvis grus, græsarmering og småsten mm.	0		
	Vandflader	Eksempelvis søer, damme, vådbassiner mm.	0		
	Bede	Bede med eksempelvis stauder, bunddække, blomster, høje græsser mm.	0		
	Hække og buske	Eksempelvis bøge, avnbøg, navrhække, div blomstrende prydbuske mm.	0		
ELEMENTER	Værdifulde træer	Særligt værdifulde træer (25m2/træ)	0		
	Øvrige træer	Øvrige træer (16m2/træ)	0		
KONSTRUKTIONER	Beplantning på vertikale konstruktioner	Sedum, mosser, urter, klatreplanter på facader, støjvægge, hegn, vægge og andre vertikale konstruktioner.	0		
	Beplantning på skrå og horisontale konstruktioner	Sedum, mosser og urter på tag og dæk, cykelskure, parkeringshuse og busstop mm.	0		
	Beplantning i kantzoner	Beplantning i kantzoner eksempelvis hække, buske og mindre træer.	0		
		Sum	-	-	

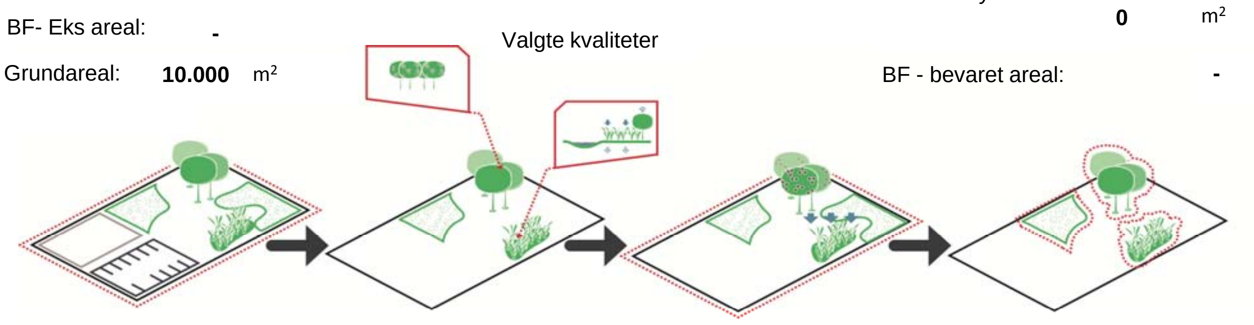
Beregning af eksisterende begrønningsfaktor

BF- Eks areal: -

Grundareal: **10.000** m²

Bevaret bynaturareal: **0** m²

BF - bevaret areal: **-**



START ved at trykke HER

Gå til "Start - Vejledning i værktøjet"

Gå til "Fremtidigt areal"

Gå til "Oversigt - Resultater"

Trinvis g

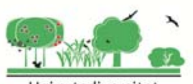
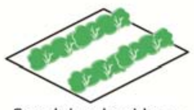
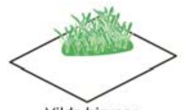
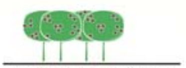
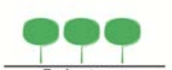
1) Tryk p
Derved l
arealtyp

2) Angiv
eksistere
samtidig
ønskes b
fremtide

3) Tryk p
vurdér k
eventue
ønsker a

4)Vælg d
relevant
vælges i

		Projektareal m² (inkl. bebyggelse):	**10.000**		
AREALTYPE	**BYNATUR**	**BESKRIVELSE**	**M²**	**Areal ønsket bevaret**	**Noter**
	Græsarealer	Eksempelvis sportsplæne, brugsplæne, prydplæne, rabatgræs, fælledgræs eller naturgræs mm.			
	Permeable belægninger	Semipermeable/permeable belægninger, som sørger for infiltration eksempelvis grus, græsarmering og småsten mm.			
	Vandflader	Eksempelvis søer, damme, vådbassiner mm.			
	Bede	Bede med eksempelvis stauder, bunddække, blomster, høje græsser mm.			
FLADER	Hække og buske	Eksempelvis bøge, avnbøg, navrhække, div blomstrende prydbuske mm.			
	Værdifulde træer	Særligt værdifulde, (store/gamle) træer (25m²/træ)			
	Klimatilpasning			**Noter**	
	Fordampningsevne på årsbasis - træer og buske	Lav: Mindst 10 % af bynaturarealet udgøres af træer og buske, men ingen arter med høj fordampningsevne (Pil, El, Hjertetræ, Sumpcypres m.fl.). Middel: Mindst 20 % af det bynaturarealet udgøres af træer og buske. Af disse er 1/4 arter med høj fordampningsevne (Pil, El, Hjertetræ, Sumpcypres m.fl.). Høj: Over 30 % af bynaturarealet udgøres af træer og buske. Af disse er 1/2 arter med høj fordampningsevne (Pil, El, Hjertetræ, Sumpcypres m.fl.).	Ingen		
	Biodiversitet				
	Levesteder	Lav: Mindst tre levesteder. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Middel: Mindst fem levesteder, hvoraf flere af dem er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Høj: Mindst syv levesteder, hvoraf hovedparten eller alle er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested).	Ingen		
	Strukturel variation	Lav: Mindst fire grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede, hække/buske, træer, grønne facader eller tage) Middel: Mindst seks grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), halvdelen af arealerne er fysisk sammenhængende, og mindst ét areal har tre vegetationslag. Høj: Mindst otte grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), størstedelen af arealerne er fysisk sammenhængende, og flere arealer har tre vegetationslag (Eksempelvis et bed med blomster, enkeltstående buske og træer = tre lag i beplantningen)	Ingen		

	 Høj artsdiversitet	Lav: Mindst ti hjemmehørende plantearter og mindst fem insektbestøvede arter Middel: Mindst 15 hjemmehørende plantearter, hvoraf mindst 10 er insektbestøvede arter, gerne med nektar/pollen hele eller hovedparten af sæsonen Høj: Mindst 20 hjemmehørende plantearter, hvoraf mindst 15 insektbestøvede arter med nektar/pollen i hele sæsonen	Ingen		
	 Spredningskorridorer	For henvisning til udpegede spredningskorridorer og potentielle spredningskorridorer henvises til (Biodiversitet i Københavns Kommune, 2016) og strukturerne i (Skybrudssikring af København, 2014). Lav: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så det ikke introducerer nye lokale spredningsbarrierer for flora og fauna (eksempelvis render med høje stejle kanter i beton eller stål mv.). Middel: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så spredningsmuligheder for almindelige mobile arter øges (eksempelvis ved at sørge for, at ny bynatur grænser direkte op til bynatur udenfor projektområdet). Høj: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes så spredningsmuligheder for én eller flere af Københavns kommunes 10 prioriterede arter øges.	Ingen		
	 Vilde hjørner	Områder med 'vild' karakter, eksempelvis ekstensivt plejet eller overladt til naturlig udvikling (succession). Lav: Mindst ét vildt hjørne på min. 25 m². Middel: Mindst to vilde hjørner på hver min. 25 m² eller ét på 50 m². Høj: Mindst tre vilde hjørner på hver min. 25 m² eller to på 50 m².	Ingen		
	Rekreation - Fysisk aktivitet				
	 Variation i terræn	Markante skråninger og niveauforskelle, som kalder på bevægelse og leg: Lav: En mindre del af projektarealet har varieret terræn. Middel: En væsentlig del af projektarealet har varieret terræn. Høj: Hovedparten af projektarealet har varieret terræn.	Ingen		
	 Offentlig tilgængelighed	Lav: Væsentlige begrænsninger af adgang i tid og rum. Middel: Mindre begrænsninger af adgang i tid og/eller rum. Høj: Ubegrænset adgang i tid og rum.	Ingen		
	Rekreation - Ro, ophold, sansning og mental sundhed				
	 Afgrænsede grønne opholdsarealer	Lav: Mindst en 'lomme'/'hjørne' af min. 25 m². Middel: Mindst tre 'lommer'/'hjørner' af min. 25 m². Høj: Mindst fem 'lommer'/'hjørner' af min. 25 m².	Ingen		
	 Sanselig beplantning	Lav: Forskellige blomstrende, duftende arter og med forskelligt løv. Blomstring gennem meget af sæsonen. Middel: Betydelig variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem det meste af sæsonen og mange farverige bær og frugter. Høj: Stor variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem hele sæsonen (særligt tidligt og sent-blomstrende) og mange farverige bær og frugter.	Ingen		
	 Spiselig beplantning	Lav: Enkelte spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter. Middel: Flere forskellige spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter. Høj: Spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter dominerer beplantningen. Arter med moden frugt/bær/nødder en stor del af sæsonen.	Ingen		
	 Maddyrkning	Lav: Mindst ét område planlagt for dyrkning af spiselige urter, grøntsager og frugt. Middel: Flere områder er planlagt for dyrkning af spiselige urter, grøntsager og frugt. Høj: Primær funktion er dyrkning af spiselige urter og grøntsager, evt. bær, nødder og frugter.	Ingen		
	Egenart - Eksisterende græsarealer				
	 Særlige karaktertræk	Lav: Understøtter bynaturarealet, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv? Middel: Understøtter det bynatur, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv og/eller er det grønne areal, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv? Høj: Bynaturarealet, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv og understøtter egenarten/karakteren af byen omkring projektområdet. Eksempelvis skaber sammenhæng og understøtter byens egenart på tværs af, i og omkring projektområdet.	Ingen		
ELEMENTER	 Øvrige træer	Andre etablerede og sunde træer (16m²/træ)			
	 Beplantning på vertikale konstruktioner	Sedum, mosser, urter, klatreplanter på facader, støjvægge, hegn, vægge og andre vertikale konstruktioner.			

KONSTRUKTIONER		Sedum, mosser og urter på tag og dæk, cykelskure, parkeringshuse og busstop mm.			
		Beplantning i kantzoner eksempelvis hække, buske og mindre træer.			
		Sum	**-**	**0**	

Beregning af eksisterende begrønningsfaktor

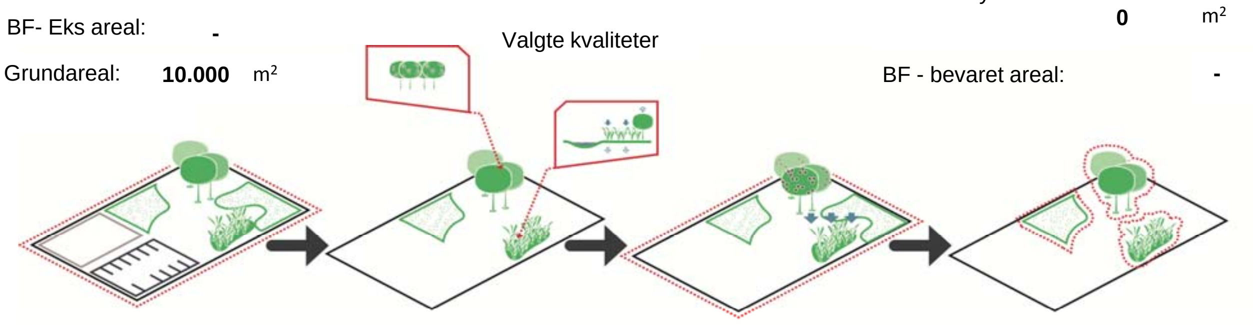
BF- Eks areal: -

Grundareal: 10.000 m²

Valgte kvaliteter

Bevaret bynaturareal: 0 m²

BF - bevaret areal: -



START ved at trykke HER

Gå til "Start - Vejledning i værktøjet"

Gå til "Fremtidigt areal"

Gå til "Oversigt - Resultater"

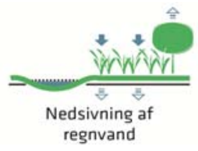
Trinvis g

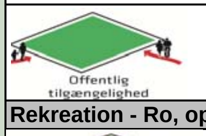
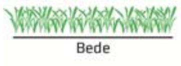
1) Tryk p
Derved l
arealtyp

2) Angiv
eksister
samtidig
ønskes b
fremtide

3) Tryk p
vurdér k
eventue
ønsker a

4)Vælg d
relevant
vælges i

		Projektareal m² (inkl. bebyggelse):	**10.000**		
AREALTYPE	**BYNATUR**	**BESKRIVELSE**	**M²**	**Areal ønsket bevaret**	**Noter**
	 Græsarealer	Eksempelvis sportsplæne, brugsplæne, prydplæne, rabatgræs, fælledgræs eller naturgræs mm.			
	Klimatilpasning		**Kvalitetskrav opfyldt?**	**Noter**	
	 Nedsivning af regnvand	Lav: Leret vejgrus og andre naturlige permeable overflader, som perlegrus, strandsten mv., men som ikke er grønt. Middel: Græsarmering og andre permeable overflader, som giver mulighed for en grøn overflade af græs eller lignende. Høj: Græs, vandflader med varierende vandspejl, bede, hække, buske og grønne tage og facader.	Ingen		
	 Forsinkelse og tilbageholdelse af regnvand	Lav: En forsænkning af arealet kan tilbageholde et volumen (en vandmængde) på mellem 15 og 30 gange arealets størrelse. Middel: En forsænkning af arealet kan tilbageholde et volumen (en vandmængde) på mellem 30 og 50 gange arealets størrelse. Høj: En forsænkning af arealet kan tilbageholde et volumen (en vandmængde) på over 50 gange arealets størrelse. Eksempelvis kan et 100 m² græsareal der er sænket 60 cm indeholde 60 m³ regnvand, og da den mængde regn, der falder på selve arealet kun udgør: 100 m² x 15 mm = 1,5 m³ kan græsarealet modtage vand fra et areal der er: 60 m³/1,5 m³ = 40 gange så stort, og vil altså være i kategori: Middel. Se evt. vejledning.	Ingen		
	Biodiversitet				
	 Levesteder	Lav: Mindst tre levesteder. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Middel: Mindst fem levesteder, hvoraf flere af dem er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Høj: Mindst syv levesteder, hvoraf hovedparten eller alle er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested).	Ingen		
	 Strukturel variation	Lav: Mindst fire grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede, hække/buske, træer, grønne facader eller tage) Middel: Mindst seks grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), halvdelen af arealerne er fysisk sammenhængende, og mindst ét areal har tre vegetationslag. Høj: Mindst otte grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), størstedelen af arealerne er fysisk sammenhængende, og flere arealer har tre vegetationslag (Eksempelvis et bed med blomster, enkeltstående buske og træer = tre lag i beplantningen)	Ingen		
	 Høj artsdiversitet	Lav: Mindst ti hjemmehørende plantearter og mindst fem insektbestøvede arter Middel: Mindst 15 hjemmehørende plantearter, hvoraf mindst 10 er insektbestøvede arter, gerne med nektar/pollen hele eller hovedparten af sæsonen Høj: Mindst 20 hjemmehørende plantearter, hvoraf mindst 15 insektbestøvede arter med nektar/pollen i hele sæsonen	Ingen		

	For henvisning til udpegede spredningskorridorer og potentielle spredningskorridorer henvises til (Biodiversitet i Københavns Kommune, 2016) og strukturerne i (Skybrudssikring af København, 2014). Lav: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så det ikke introducerer nye lokale spredningsbarrierer for flora og fauna (eksempelvis render med høje stejle kanter i beton eller stål mv.). Middel: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så spredningsmuligheder for almindelige mobile arter øges (eksempelvis ved at sørge for, at ny bynatur grænser direkte op til bynatur udenfor projektområdet). Høj: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes så spredningsmuligheder for én eller flere af Københavns kommunes 10 prioriterede arter øges.	Ingen	
	Områder med 'vild' karakter, eksempelvis ekstensivt plejet eller overladt til naturlig udvikling (succession). Lav: Mindst ét vildt hjørne på min. 25 m². Middel: Mindst to vilde hjørner på hver min. 25 m² eller ét på 50 m². Høj: Mindst tre vilde hjørner på hver min. 25 m² eller to på 50 m².	Ingen	
Rekreation - Fysisk aktivitet			
	Lav: Græsareal mellem 75-150 m² Middel: Græsareal mellem 150-225 m² Høj: Græsareal over 225 m²	Ingen	
	Lav: Mindst en sammenhæng til offentligt stisystem/fortorv. Middel: To sammenhænge til offentligt stisystem, som har kobling til bynaturområder inden for gåafstand (< 1 km). Høj: Flere sammenhænge til offentligt stisystem, som har kobling til bynatursområder inden for gåafstand (< 1 km)	Ingen	
	Markante skråninger og niveauforskelle, som kalder på bevægelse og leg: Lav: En mindre del af projektarealet har varieret terræn. Middel: En væsentlig del af projektarealet har varieret terræn. Høj: Hovedparten af projektarealet har varieret terræn.	Ingen	
	Lav: Væsentlige begrænsninger af adgang i tid og rum. Middel: Mindre begrænsninger af adgang i tid og/eller rum. Høj: Ubegrænset adgang i tid og rum.	Ingen	
Rekreation - Ro, ophold, sansning og mental sundhed			
	Lav: Mindst en 'lomme'/'hjørne' af min. 25 m². Middel: Mindst tre 'lommer'/'hjørner' af min. 25 m². Høj: Mindst fem 'lommer'/'hjørner' af min. 25 m².	Ingen	
	Lav: Forskellige blomstrende, duftende arter og med forskelligt løv. Blomstring gennem meget af sæsonen. Middel: Betydelig variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem det meste af sæsonen og mange farverige bær og frugter. Høj: Stor variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem hele sæsonen (særligt tidligt og sent-blomstrende) og mange farverige bær og frugter.	Ingen	
	Lav: Enkelte spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter. Middel: Flere forskellige spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter. Høj: Spiselige bær-, nødde-, og frugtbærende træer og buske samt flerårige urter dominerer beplantningen. Arter med moden frugt/bær/nødder en stor del af sæsonen.	Ingen	
	Lav: Mindst ét område planlagt for dyrkning af spiselige urter, grøntsager og frugt. Middel: Flere områder er planlagt for dyrkning af spiselige urter, grøntsager og frugt. Høj: Primær funktion er dyrkning af spiselige urter og grøntsager, evt. bær, nødder og frugter.	Ingen	
Egenart - Eksisterende græsarealer			
	Lav: Understøtter bynaturarealet, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv? Middel: Understøtter det bynatur, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv og/eller er det grønne areal, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv? Høj: Bynaturarealet, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv og understøtter egenarten/karakteren af byen omkring projektområdet. Eksempelvis skaber sammenhæng og understøtter byens egenart på tværs af, i og omkring projektområdet.	Høj	
	Semipermeable/permeable belægninger, som sørger for infiltration eksempelvis grus, græsarmering og småsten mm.		
	Eksempelvis søer, damme, vådbassiner mm.		
	Bede med eksempelvis stauder, bunddække, blomster, høje græsser mm.		

FLADER		Eksempelvis bøge, avnbøg, navrhække, div blomstrende prydbuske mm.			
ELEMENTER		Særligt værdifulde, (store/gamle) træer (25m^2/træ)			
		Andre etablerede og sunde træer (16m^2/træ)			
KONSTRUKTIONER		Sedum, mosser, urter, klatreplanter på facader, støjvægge, hegn, vægge og andre vertikale konstruktioner.			
		Sedum, mosser og urter på tag og dæk, cykelskure, parkeringshuse og busstop mm.			
		Beplantning i kantzoner eksempelvis hække, buske og mindre træer.			
		Sum	-	0	

Beregning af eksisterende begrønningsfaktor

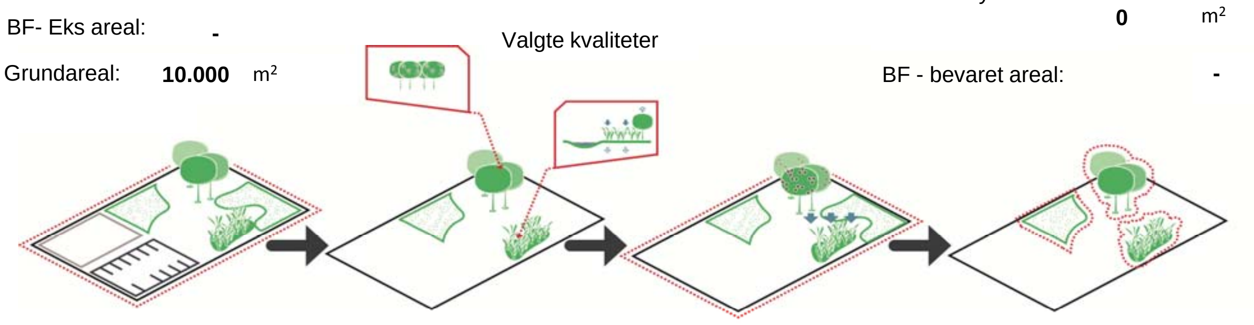
BF- Eks areal: -

Grundareal: **10.000** m²

Bevaret bynaturareal: **0** m²

BF - bevaret areal: -

Valgte kvaliteter



START ved at trykke HER

Gå til "Start - Vejledning i værktøjet"

Gå til "Fremtidigt areal"

Gå til "Oversigt - Resultater"

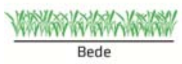
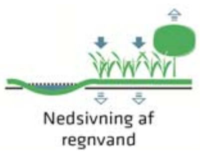
Trinvis g

1) Tryk p
Derved l
arealtyp

2) Angiv
eksister
samtidig
ønskes b
fremtide

3) Tryk p
vurdér k
eventue
ønsker a

4)Vælg d
relevant
vælges i

		Projektareal m² (inkl. bebyggelse):	**10.000**		
AREALTYPE	**BYNATUR**	**BESKRIVELSE**	**M²**	**Areal ønsket bevaret**	**Noter**
FLADER	 Græsarealer	Eksempelvis sportsplæne, brugsplæne, prydplæne, rabatgræs, fælledgræs eller naturgræs mm.			
	 Permeable belægninger	Semipermeable/permeable belægninger, som sørger for infiltration eksempelvis grus, græsarmering og småsten mm.			
	 Vandflader	Eksempelvis søer, damme, vådbassiner mm.			
	 Bede	Bede med eksempelvis stauder, bunddække, blomster, høje græsser mm.			
	 Hække og buske	Eksempelvis bøge, avnbøg, navrhække, div blomstrende prydbuske mm.			
ELEMENTER	 Værdifulde træer	Særligt værdifulde, (store/gamle) træer (25m²/træ)			
	 Øvrige træer	Andre etablerede og sunde træer (16m²/træ)			
	 Beplantning på vertikale konstruktioner	Sedum, mosser, urter, klatreplanter på facader, støjvægge, hegn, vægge og andre vertikale konstruktioner.			
	 Beplantning på skrå og horisontale konstruktioner	Sedum, mosser og urter på tag og dæk, cykelskure, parkeringshuse og busstop mm.			
	Klimatilpasning			**Noter**	
	 Nedsivning af regnvand	Lav: Leret vejgrus og andre naturlige permeable overflader, som perlegrus, strandsten mv., men som ikke er grønt. Middel: Græsarmering og andre permeable overflader, som giver mulighed for en grøn overflade af græs eller lignende. Høj: Græs, vandflader med varierende vandspejl, bede, hække, buske og grønne tage og facader.	Ingen		
	 Fordampningsevne på årsbasis - urtelag	Lav: Vækstlag/-system på < 75 mm. Middel: Vækstlag/-system mellem 75 og 150 mm. Høj: Vækstlag/-system på > 150 mm.	Ingen		
	Biodiversitet				
	 Levesteder	Lav: Mindst tre levesteder. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Middel: Mindst fem levesteder, hvoraf flere af dem er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested). Høj: Mindst syv levesteder, hvoraf hovedparten eller alle er i sammenhæng. Eksempelvis naturgræs, kvasbunker, stengærde, jordvolde, stubbe/stammer i forrådnelse. Det kan også være konstruerede levesteder som fuglekasser/insekthoteller/flagermuskasser (5 konstruerede levesteder tæller som ét levested).	Ingen		

		Lav: Mindst fire grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede, hække/buske, træer, grønne facader eller tage) Middel: Mindst seks grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), halvdelen af arealerne er fysisk sammenhængende, og mindst ét areal har tre vegetationslag. Høj: Mindst otte grønne arealtyper (græsarealer, naturlige belægninger, vandflader, bede eller hække og buske), størstedelen af arealerne er fysisk sammenhængende, og flere arealer har tre vegetationslag (Eksempelvis et bed med blomster, enkeltstående buske og træer = tre lag i beplantningen)	Ingen		
		Lav: Mindst ti hjemmehørende plantearter og mindst fem insektbestøvede arter Middel: Mindst 15 hjemmehørende plantearter, hvoraf mindst 10 er insektbestøvede arter, gerne med nektar/pollen hele eller hovedparten af sæsonen Høj: Mindst 20 hjemmehørende plantearter, hvoraf mindst 15 insektbestøvede arter med nektar/pollen i hele sæsonen	Ingen		
		For henvisning til udpegede spredningskorridorer og potentielle spredningskorridorer henvises til (Biodiversitet i Københavns Kommune, 2016) og strukturerne i (Skybrudssikring af København, 2014). Lav: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så det ikke introducerer nye lokale spredningsbarrierer for flora og fauna (eksempelvis render med høje stejle kanter i beton eller stål mv.). Middel: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes, så spredningsmuligheder for almindelige mobile arter øges (eksempelvis ved at sørge for, at ny bynatur grænser direkte op til bynatur udenfor projektområdet). Høj: Projektet ligger inden for spredningskorridor eller potentiel spredningskorridor og udformes så spredningsmuligheder for én eller flere af Københavns kommunes 10 prioriterede arter øges.	Ingen		
		Områder med 'vild' karakter, eksempelvis ekstensivt plejet eller overladt til naturlig udvikling (succession). Lav: Mindst ét vildt hjørne på min. 25 m². Middel: Mindst to vilde hjørner på hver min. 25 m² eller ét på 50 m². Høj: Mindst tre vilde hjørner på hver min. 25 m² eller to på 50 m².	Ingen		
	Rekreation - Ro, ophold, sansning og mental sundhed				
		Lav: Forskellige blomstrende, duftende arter og med forskelligt løv. Blomstring gennem meget af sæsonen. Middel: Betydelig variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem det meste af sæsonen og mange farverige bær og frugter. Høj: Stor variation i blomstrende, duftende arter og med forskelligt løv. Blomstring gennem hele sæsonen (særligt tidligt og sent-blomstrende) og mange farverige bær og frugter.	Ingen		
	Egenart				
		Lav: Understøtter bynaturarealet, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv? Middel: Understøtter det bynatur, herunder grønne facader og tage eller element i områdets egenart/lokale naturarv og/eller er det grønne areal, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv? Høj: Bynaturarealet, herunder grønne facader og tage eller element en del af områdets egenart/lokale naturarv og understøtter egenarten/karakteren af byen omkring projektområdet. Eksempelvis skaber sammenhæng og understøtter byens egenart på tværs af, i og omkring projektområdet.	Ingen		
KONSTRUKTIONER		Beplantning i kantzoner eksempelvis hække, buske og mindre træer.			
		Sum	-	0	