Nature in the Metropolis: Mapping Biodiversity Using Metropolitan Landscape Characterization Tools

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Cities can be planned and designed to reduce their effect on biodiversity loss and may even be able to sustain biodiversity levels in some instances, due to 'beta-diversity'. The heterogeneity of metropolitan regions can be expected to have a strong impact on beta-diversity. Tools such as landscape characterization can assist in the understanding of beta-diversity in metropolitan regions by mapping the extent and configuration of beta-diversity conditions, in particular micro-habitats and habitat mosaic configurations. A new tool for landscape characterization of metropolitan areas (MLC) trialled on the Rotterdam metropolitan region generated thirty-six distinctive landscape types - twelve continuous and twenty-four discontinuous (hybrid) types. Hybrid landscape types are present throughout the whole of the territory and are potential micro-habitats for flora and fauna. The interrelationship of continuous and discontinuous (hybrid) landscape types are potentially valuable habitat mosaic configurations.

1. URBAN BIODIVERSITY

Biodiversity loss is one of the major global challenges of the 21st century. International efforts to address this problem have been chartered by the Convention on Biological Diversity (CBD), now ratified by most countries. As a result of agreements made in the CBD, much of the effort put in to protecting biodiversity by participating countries focuses on halting species loss caused by habitat reduction, fragmentation and pollution, factors attributed to modifications of the natural environment caused by processes such as urbanization. While the mitigation of the impact of urbanization on biodiversity remains an imperative, the opportunities urban landscapes offer have until now received little attention in the debate on biodiversity.

Cities have an influence on flora and fauna diversity in different ways. Firstly, urban landscapes are centres of immigration and adaption of flora and fauna – so-called 'synurbanization' [Luniak et. al. 2004]. Many animal species become abundant in cities due to the ready availability of food, lack of predators and new ecological niches; the urban landscape is now critically important for a number of species such as the Rock Dove (Columba livia domestica) and the House Sparrow (Passer domesticus), who have largely traded their natural habitats for urban areas [Muller et. al. 2012]. Urban landscapes also impact on biodiversity through the introduction and naturalization of non-native species [Klausnitzer 1993]. They also function as so-called 'evolutionary laboratories' where new taxa evolve by processes of isolation, hybridization and introgression [Wittig 2004]. Lastly, there is general consensus that cities are characterized by a high number of species due to so-called 'beta-diversity', the variety of types and intensities of land-uses, materials, micro-habitats and habitat mosaic configurations [Niemela 1999, Crooks et. al. 2004, McKinney 2006, Sukopp 2006]. How patterns such as beta-diversity play out in urban territories are considerably dependant on the form and scale of the urban area being studied. Beta-diversity can be

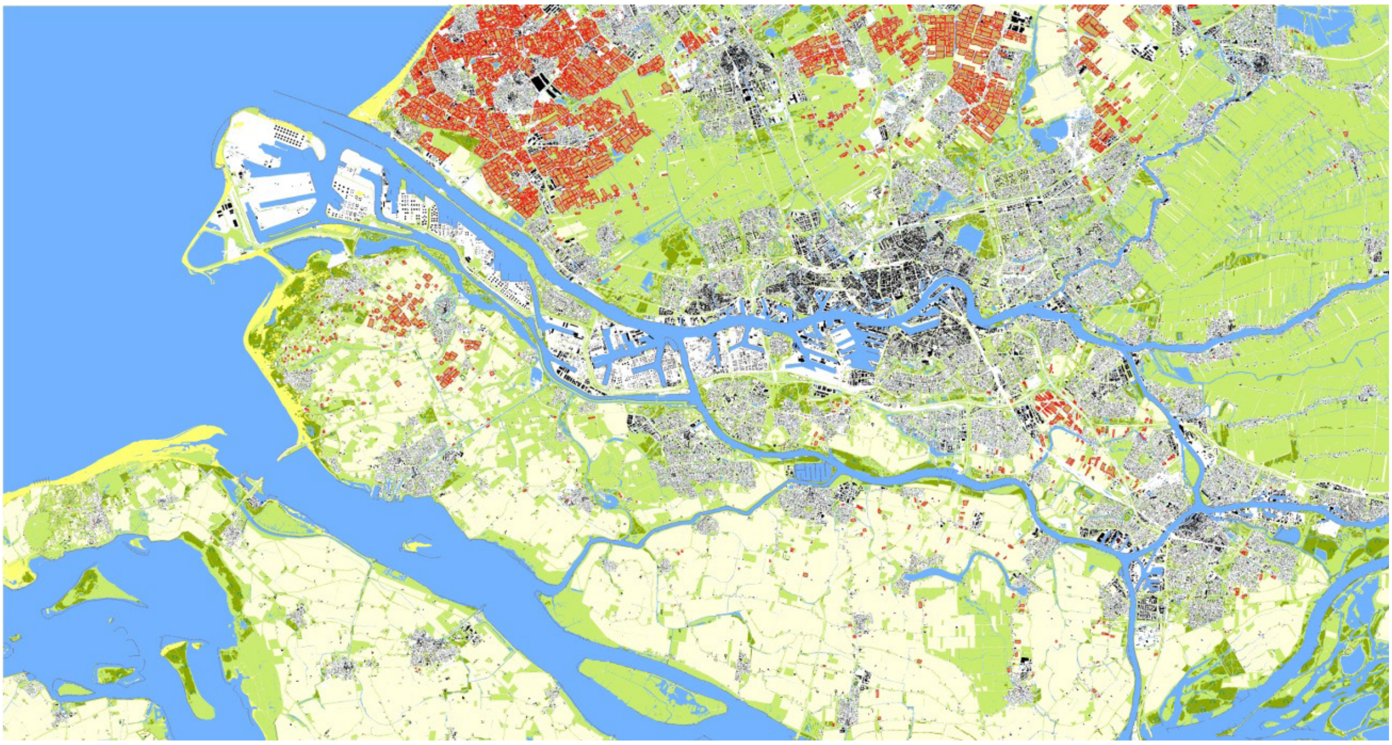


FIGURE 1. Topographic map of the metropolitan region of Rotterdam

expected to be much more complex and varied in metropolitan regions than those of smaller compact towns and cities. A study of a transect of the Flanders region in Belgium (Honnay et al., 2003) shows that the higher the degree of urbanization in the blocks of 4x4 km the greater the landscape diversity and complexity. The same research shows a clear correlation between the percentage of built-up area, spatial heterogeneity and the number of plant species. Although these findings show that mixed metropolitan environments have considerable potential for beta-diversity, the location of proper spots is not easy to determine when large territories are considered. Nevertheless, the research into the proper mapping tools on regional level is still in developing stages. This paper presents a possible method for allocation of the beta-diversity in metropolitan region(s).

1.1 Metropolitan beta-diversity

The morphology of the Metropolitan region ranges from urban conurbations with multiple concentric boundaries to dispersed urban regions made up of a vast heterogeneous field of urban, rural and natural fragments. Research into territorial arrangements of contemporary metropolitan regions have lead to a range of new terminologies such as 'Tapijtmetropool' (Neutelings, 1994), 'middle landscape' (Rowe, 1991), 'edge city' (Garreau, 1992), 'exopolis' (Soja, 1992), 'Zwischenstad' (Sieverts, 2004) and 'tussenland' (Frijters and RPB, 2004). A common theme in these studies is the shifting relationship between city and countryside. In contrast to compact homogenous cities, metropolitan regions are characterized by an amorphous patchwork of urban fragments in which the distinction between rural and urban realms is dissolving. In the European context 'dispersed urban regions' can be compared to urban areas with heterogeneous land use and fragmented structure, which is often referred to as Urban Morphological Zone or Urban Metropolitan Area (http://www.eea.europa.eu/data-and-maps/data/urban-morphological-zones-2006-umz2006-f3v0). The spatial characteristics of the metropolitan region can thus be expected to have a strong impact on beta-diversity aspects.

2. LINKING LANDSCAPE CHARACTERIZATION TO METROPOLITAN BIODIVERSITY

Understanding the beta-diversity of the metropolitan territory requires a system that accurately maps land-uses, materials, habitats and habitat mosaic configurations. A potential new tool called Metropolitan Landscape Characterization (MLC) developed at the Faculty of Architecture, TU Delft (see Tisma et al., 2014) may be used to understand the complexity and heterogeneity of the metropolitan landscape and its potential for biodiversity.

2.1 Landscape character assessment

The motivation for developing a new method of landscape characterization for metropolitan areas arose through a perceived deficiency in the understanding of the spatial complexity and heterogeneity of landscapes in dispersed urban regions. Although the term landscape etymologically also applies to urban landscapes, most landscape characterization has until now focused on cultural, natural or rural landscapes. And while the European Landscape Convention has broadened the concept of landscape character to include built components in the landscape definition, the tradition of seeing landscape as something outside cities still dominates landscape characterization practice and policy making. As a consequence, in the majority of classifications, urban areas typically remain categorized as one type, termed 'urban area' or at best divided into three categories: urban landscapes, suburban landscapes and industrial and harbour landscapes [Van Eetvelde & Antrop 2009].

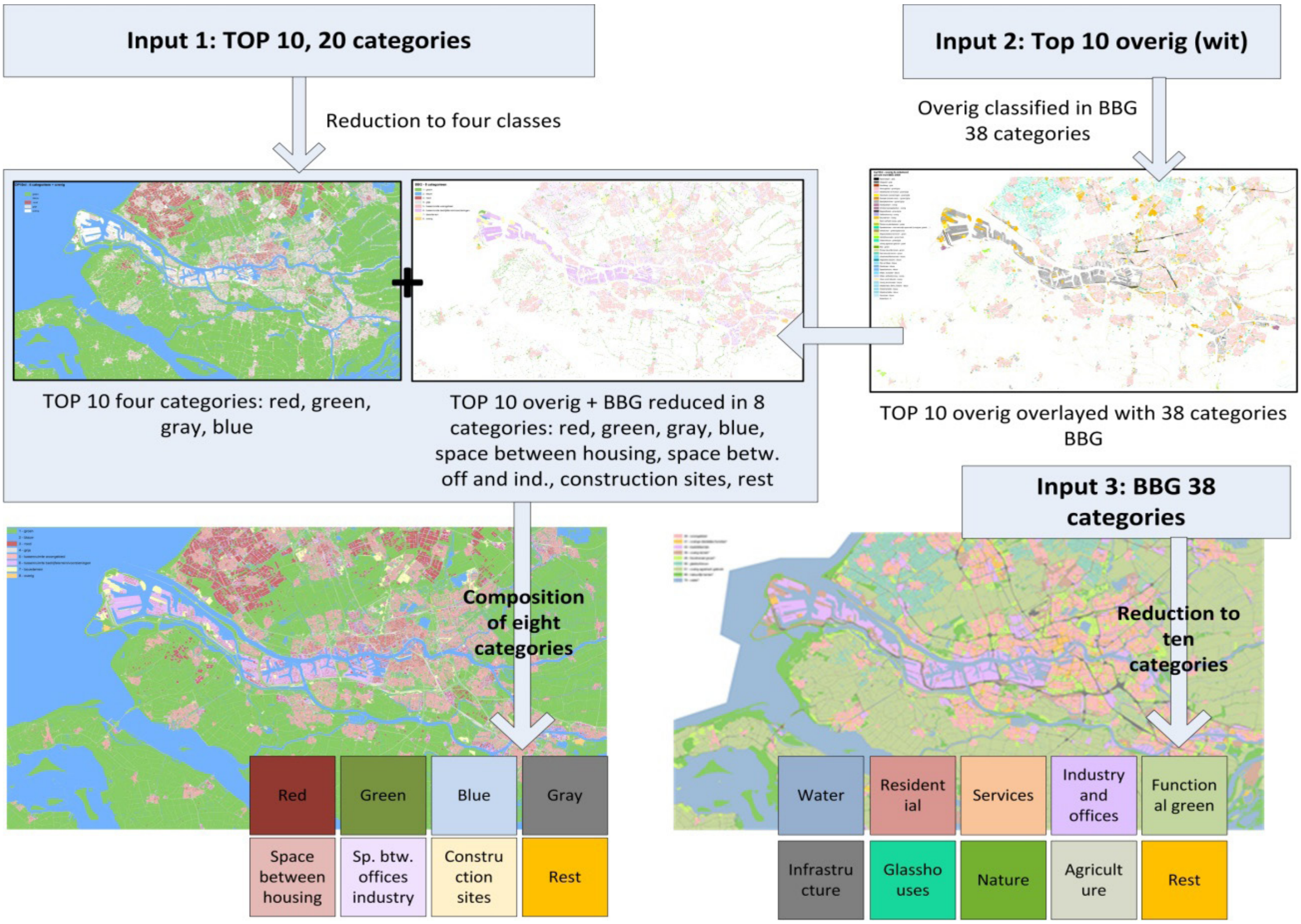


FIGURE 2. Process of selection and modification of datasets

2.2 A method for the metropolitan landscape characterization

The term 'metropolitan' as used in the method broadens the meaning of what is usually understood under urban and peri-urban and includes the entire territory of the city-region, from the dense inner-city tissue and the sub-urban up to rural territories. In these areas, processes of urbanization[1] also lead to 'hybridization' of spatial tissue: mixes of industrial, residential, infrastructural, recreational and agricultural land-use characterized by varying densities and forms of built and un-built space.

The proposed new method for metropolitan landscape characterization is based on the method of Landscape character assessment developed by the Scottish Natural Heritage (2002), to which is added mapping/morphology and cluster analysis (see Tisma at al., 2013). The first stages of the method was developed and tested on a case study of the metropolitan region of Rotterdam, an official region of the Province of South-Holland consisting of 16 municipalities with a total population of approximately 1.3 million (Figure 1).

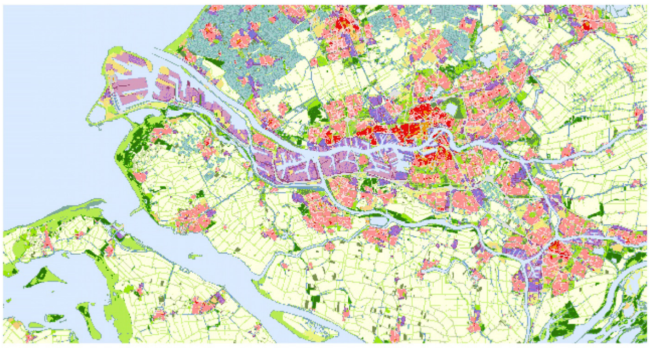
In order to effectively incorporate the entire metropolitan area, the study area was set as twice the extent of the existing urban area calculated on the basis of existing administrative, planning and geographic border data. The borders of the study area were furthermore set by a rectangular frame measuring 60 km x 30 km. No distinction was made between rural and urban areas, as municipal borders were not used for the calculations.

2.3 Landscape characterization of Rotterdam metropolitan region

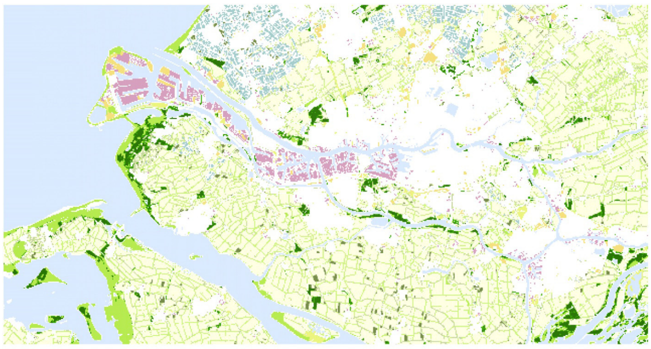
When there are many layers of spatial information it is difficult to handle them and draw conclusions by simple overlay methods using GIS. That was the reason why for the characterization of Rotterdam we applied cluster analyses. For each cluster we had as input eight categories from the topographic map of the Netherlands (Top10) and ten categories of the Land use map of the Netherlands (BBG). The third input was two categories of height - below and above eye level (Figure 2).

The cluster analyses resulted in three variants of number of landscape types: 39, 42 and 49 clusters. By studying the underlying topographic data we concluded that 42 clusters best represent the situation in the Rotterdam metropolitan region. Afterwards we manually adjusted the clusters merging those that were similar, which resulted in a total of 36 clusters. Further study resulted in a division into twelve continuous types and twenty-four discontinuous types. The results of the cluster analyses (Table 1) shows that almost 70% of the study area is covered by continuous spatial types and the remainder by discontinuous spatial types. The continuous types are dominated by one type of land-use and topography, like for instance agricultural areas or water bodies. Discontinuous types consist of a mix of different land-use and topography, such as housing, infrastructure, green space, water, reminding ground, high of low etc. This latter category represents the 'hybrid' landscape types.

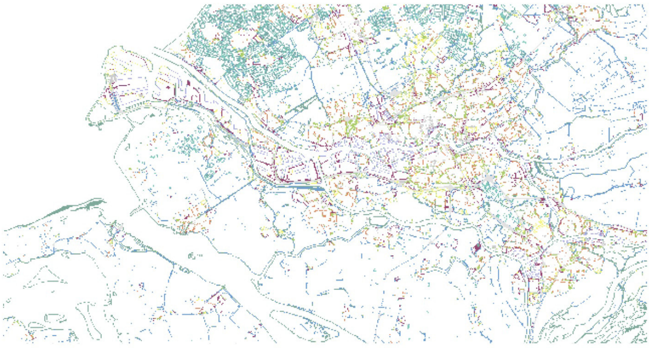
Within the hybrid clusters we further isolated twelve 'patch' types and twelve 'edge' types (see Figure 3 and Table 1).



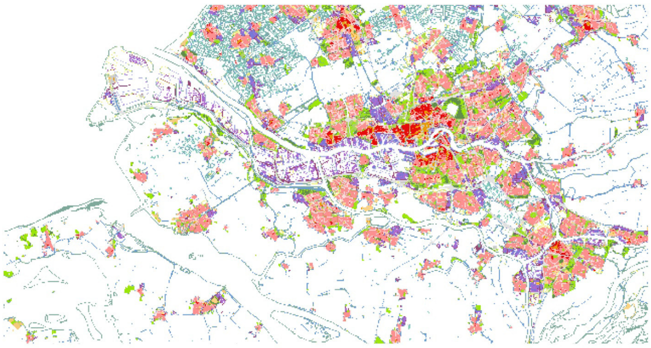
3a. 36 Clusters



3b. 12 Continuous clusters



3c. 12 Edge clusters



3d. 12 Patch clusters

FIGURE 3. Preliminary results of the cluster analyses showing 36 clusters, 12 continuous and 24 discontinuous from which 12 are edges and 12 are larger patches

The dominant land use types in the continuous category are agriculture (26%) and water (24%).

3. MAPPING LANDSCAPE POTENTIAL FOR BIODIVERSITY USING MLC

3.1 Patches

Many studies have confirmed the "island theory", a hypothesis that the larger the area the greater the number of species to be found (MacArthur & Wilson, 1967). Nevertheless, the value of small patches shouldn't be underestimated. Several studies have shown that there is positive correlation between landscape heterogeneity and number of species (Honnay et al. 2003; Zoest, 2007; Muller et al., 2012). Design of such spaces is even becoming a new trend in landscape architecture (Muller et al., 2012). In that sense MLC can be used to select the potential locations where especially hybrid landscape types offer opportunity for biodiversity development. Looking at the typology of Rotterdam landscape types such as mixed-low density residential areas in the discontinuous patch category and in-between industrial area in the continuous category can be the most interesting ones.

3.2 Edges

Edge landscape types in the discontinuous category are potentially important for increase in species abundance not only in the urban areas where they can serve as green-blue infrastructures, but also in the rural area. It is known that the agricultural areas are poor in biodiversity due to large-scale monoculture production. In MLC typology all the small country roads and waterways are pointing at the locations for potential increase of biodiversity. Although those areas are narrow and line-shaped and therefore not interesting for (larger) fauna, they can be places where biodiversity is increased by mixed planting so to attract more insects and birds.

4. CONCLUSIONS

Cities can be planned and designed to reduce their effect on biodiversity loss and may even be able to sustain biodiversity levels in some instances. Potential areas for sustaining biodiversity include syn-urbanization, naturalization of non-native species, new taxa evolution and beta-diversity aspects: the types and intensities of land-uses, materials, habitats and habitat mosaic configurations. The spatial heterogeneity of the metropolitan region can be expected to have a strong impact on beta-diversity. Spatial analysis tools such as landscape characterization can assist understanding the beta-diversity of the metropolitan territory. A new tool for Metropolitan Landscape Characterization (MLC) designed to map the complexity and heterogeneity of the metropolitan landscape developed at the TU Delft has resulted in some important preliminary indications of beta-diversity.

Cluster analysis of Rotterdam metropolitan area combining different data-sets generated a total of thirty-six distinctive landscape: twelve continuous types and twenty-four discontinuous (hybrid). This is a significant increase in the number character types drawn from existing landscape characterization and urban typology studies. The twelve continuous types roughly correspond to existing characterization and classification methods. The twenty-four discontinuous types are new categories not occurring in existing characterization and classification methods. The number of character types reveal the extent of heterogeneity of the metropolitan landscape in the Rotterdam urban region.

TABLE 1. Percentage of landscape type per total area of the Urban Region of Rotterdam

Cluster	Preliminary description	%
	Continuous	
10	10 - in-between industrial with some grey, low	1,60
104	104 - 11+26 - glasshouses	1,54
105	105 - 15+23 - construction and remaining, low	0,83
14	14 - agriculture, low	26,14
31	31 - agriculture, with some grey, low	6,90
1	1 - agriculture, with some grey or high red elements	2,97
21	21 - green agriculture, predominantly high	0,49
2	2 - green remaining, low	0,61
29	29 - green nature, mostly low	2,62
22	22 - green nature, mixed high/low	1,13
7	7 - green nature, high (forest)	1,35
103	103 - 9+12+40 - water	24,40
		70,58
	Disontinuous - patch	
39	39 - red residential, in-between residential and grey, mixed high/low	0,68
16	16 - red residential, lots of in-between residential, predominantly low	5,62
27	27 - residential with some in-between, grey and green, predominantly low	2,69
28	28 - buildings, urban services, mixed high/low with grey	0,30
101	101 - 4+18 - services mix	0,58
35	35 - in-between industrial with buildings, predominantly low	1,46
41	41 - red, industry/offices, mixed high/low	0,74
20	20 - functional green (bungalow park)	0,15
38	38 - functional green, mixed high/low with some grey elements (park)	0,85
19	19 - functional green, predominantly low (recreational area, park)	1,98
36	36 - construction green, remaining, predominantly high	0,11
		15,15
	Disontinuous - edge	
3	3 - green residential, grey, predominantly low	0,96
33	33 - in-between industrial with grey infrastructure, green, predominantly low	1,11
37	37 - industry/office water, low	0,50
42	42 - grey with urban services, mostly high	0,41
30	30 - grey infrastructure with surrounding green, mostly low	1,38
106	106 - 17+25 - glasshouses mix	1,20
32	32 - glasshouses with some in-between industrial	1,11
6	6 - blue in green, agricultural areas, some grey, low	2,76
34	34 - green grey, functional green, predominantly low	0,98
24	24 - green grey, infrastructure remaining, low	0,50
102	102 - 8+13 - green/blue edges, low	2,81
5	5 - construction remaining, with some green, grey, low	0,57
		14,28
	TOTAL	100

FIGURE 4. 3D visualization of the landscape character types in Rotterdam metropolitan area

These character types may indicate locations for sustaining biodiversity in niches that are overlooked by existing GIS tools.

Hybrid landscape types are present throughout the whole of the territory, in different configurations and concentrations covering 30% of the region in the form of larger or smaller patches and edges. Within those categories the most interesting to look in detail are low-density housing, industry and edges. Nevertheless, 70% of the area is still occupied by entities of continuous, mostly "green" landscape types, but 26 % of that green space is actually agricultural areas with then low potential for biodiversity. In that sense edge landscape types detected by the MLC method may play important role in increasing biodiversity in these areas.

The characterization of non-urban landscapes is already established tradition in most European countries, but the results of this study indicate a shift of focus needed towards the possible benefits of using characterization for metropolitan areas. The results of the study presented in this paper refer to the regional scale and detailed field studies of the preliminary discovered 36 landscape types and their potential for beta-diversity is a next step.

[1] These processes are described as seven types of urban developments by Nabielek et al. in the SPOOL journal 1, special issue Landscape Metropolis 2014.

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