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Integration of biodiversity data in urban assessments

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1 Introduction

Over 75% of the EU population currently resides in or lives in close proximity to cities (World Bank, 2015), with foreseen increases by 2050 (Eurostat, 2016b). A frequent consequence of this ongoing urbanization process is the loss of urban green spaces and biodiversity amidst densification processes, which has been shown to decrease human well-being and health, amongst other consequences (Regional Public Health, 2010). Given these potential negative repercussions for society, there is growing interest in assessing urban biodiversity as a tool to foster conservation measures and ensure the continued supply of integral ecosystem services. However, the urban environment, human well-being and the health and diversity of the species and habitats contained therein are part of a complex and intricate system and are thus challenging to evaluate. While some indicator frameworks look at specific aspects of local development and a restricted set of environmental parameters, there is no standardised methodology or dataset existing to date for conducting an urban biodiversity assessment.

In response to this gap, the present report continues the effort to investigate the potential of integrating Copernicus layers and biodiversity-related European datasets as well as additional city-specific data into urban assessments. One of the main goals of these activities is to develop a concept and derive indicators for a European Urban Biodiversity Index (EUBI) based primarily on these available datasets as well as building on existing urban biodiversity frameworks.

2 Conceptualizing the European Urban Biodiversity Index

2.1 Goal/Objective

The goal of the present task is to develop and test an index that integrates a set of core indicators for urban biodiversity (e.g. Copernicus and data from Art. 12 Birds directive reporting) as well as additional local indicators which utilise and build on existing assessment frameworks. This index is to ultimately serve as a tool for the analysis of urban biodiversity across European cities.

In this context, the index should serve as an evaluation or assessment tool that enables potential biodiversity-related changes to be highlighted within a given urban area.

2.2 Functional urban area: The basic spatial reporting unit for the index

The goal of the index is to enable a comparison self-assessment tool for urban areas across different bioregions in Europe. The most convenient choice for the basic spatial unit of the analysis is given by the Functional Urban Area (FUA). A FUA encompasses the urban city perimeter and its commuting zone (Eurostat, 2016a). Given the complexity of distinguishing urban from peri- and non-urban areas using the FUA as basic spatial unit has the advantage that urban population and commuting dynamics are represented in the sampling unit. However, this comes at the cost of data availability, which is rather tied to administrative boundaries.

Due to their focus on population and transit patterns, FUA’s may vary considerably in size, shape and population density and distribution.

Currently, there are 697 FUA´s defined for Europe. Given the amount of resources allocated for the current task it is only possible to process indicators for a subset of these existing FUA`s.

2.3 Index structure

The availability of datasets relating to biodiversity-relevant issues can vary between municipalities, both within and between countries. Due to the high diversity of data availability and content, it would be a challenge to find datasets that offer comparability between different cities. On the other hand, Copernicus offers harmonised, high quality, validated European datasets across different regions.

In order to combine the potential of the Copernicus products and the more detailed local datasets, the indicators within the index are structured into two components:

1. **Core Index** - based on Copernicus products and Art. 12 data
2. **Local Index -** ancillary indicators depending on availability within each city

The local index is thus a flexible component for which only guidelines will be proposed in the current report. The advantage of separating the index into two components is to enable cities to increase their potential to perform more holistic, low-cost self-assessments regarding biodiversity issues. As evidently some cities are also quite restricted in terms of geographical and environmental factors future intentions and actions should also be considered as they are the drivers of change. These are best portrayed and outlined by municipal actors as they require more in-depth local knowledge.

The rationale, indicators selected, and examples of each tier’s potential application in select cities are outlined in the subsequent sections.

2.4 Considerations for selecting indicators

2.4.1 Core index

For information on the potential of the Copernicus dataset for urban biodiversity assessments, please refer to Task n°1.7.5.B iv (2016). Here, a SWOT analysis was performed to determine the potential of the individual datasets for biodiversity assessments. In summary, most remote sensing derived indicators can be used to describe landscape structure, which is an important aspect of biodiversity. Therefore, the indicators developed from remote sensing products rather focus on spatial information rather than actual species abundance and distribution.

Many potential links between biodiversity and habitat availability are therefore indirectly inferred by the structure of habitats rather than directly assessed. Although there are specific European wide datasets for species presence such as Art.12 /17 data, these are only available at coarse resolution (>10km) and for this reason their direct use for very high resolution urban assessments is somewhat limited. Nonetheless, given, the importance of these Europe-wide and validated species data for biodiversity assessments, the current task aims to test incorporating species-based indicators.

There is a multitude of possibilities to derive biodiversity and environmental indicators from Copernicus and other European-wide datasets. However, when it comes to indicators, more is not always better. Non-essential indicators may increase the degree of bias in the data and could cause more clutter or ambivalent messages, which in the end need to be disentangled by the user.

Keeping track of priorities is therefore essential within the selection of indicators. One of the targets of the core index is to provide indicators for most of the characteristics with which one can quantify biodiversity. Table 2.1 provides an overview of the biodiversity characteristics and corresponding indicators developed within the framework of the present index.

Clearly, some important biodiversity parameters such as species abundance cannot be directly addressed due to the lack or confidentiality of pertaining data. Yet, the most important aspects of biodiversity at the species and landscape levels are incorporated.

Based on the information conveyed by these indicators, the index should provide a tool for quick analysis of the urban biodiversity status of cities. Given the fact that most of the indicators are based on continuously updated and freely accessible Copernicus products, there is a large potential for the index to be updated along with the datasets, thus allowing for time series to be created.

Table 2.1 List of addressed biodiversity themes and corresponding potential Copernicus and Art. 12 derived indicators.

Level	Characteristic	Indicator name/s	Description
Landscape-diversity	Habitat availability	Proportion of Green, Blue and protected (N2K) area	Proportion and/or size of semi-/ natural and protected areas acting as potential refugia within urban zones.
	Landscape heterogeneity	Simpson Diversity Index	Habitat diversity measured in terms of diversity of different land-cover classes or ecotones. Ecotones present transitional zones between two ecosystems.
	Habitat Connectivity	Length of ecotones	Length of transitions between natural and agricultural classes.
	Habitat pressure	Pop density on green areas	Population per FUA divided by available green area.
Species-diversity	Species density	Bird species density	Calculated on the basis of count of bird species per FUA divided by square-root of FUA area.
	Occupied potential habitat	Utilized bird habitat	Ratio of area of occupancy and suitable habitat area within FUA; Indicates the utilized habitat resources.

2.4.2 Local index

While a diversity of indicator frameworks exists for assessing specific aspects of local development or environmental parameters, there are only limited frameworks and awards for measuring urban biodiversity. These frameworks are useful to recognize progress and success in conservation efforts, as well as to provide an indication of potentially relevant indicators for assessing urban biodiversity. Accordingly, some of the most relevant examples and the types of biodiversity-relevant indicators and categories were explored as a basis for developing this report’s proposed index. The scope and thematic areas covered by the respective frameworks, as well as limitations and further considerations in designing an implementable city-level biodiversity index are summarised below (see Table 2.2).

Table 2.2 Overview of indicator frameworks focusing on urban biodiversity.

Name	Aim	Application	Indicators and/or categories	Source
City Biodiversity Index (CBI)	To support cities in gathering standardized and comparable data to evaluate progress in reducing the rate of biodiversity loss in urban ecosystems	40 cities worldwide (2009-2013)	23 indicators on: Native Biodiversity, Ecosystem Services, and Governance and Management	https://www.cbd.int/subnational/partners-and-initiatives/city-biodiversity-index
European Capital of Biodiversity Award	To motivate local authorities to increase biodiversity protection efforts and recognize their efforts	Over 500 municipalities participated in 2010/2011	19 indicators adapted from CBI are included in 'monitoring' section of application	http://www.capital-biodiversity.eu
German Federal Capital of Biodiversity Award	To motivate and support the relevant actors in the cities and municipalities to make more efforts and concrete measures to protect nature and biodiversity	124 German cities	10 CBI indicators included with descriptive information on: nature; environmental education and justice; species and biotope protection; sustainable use; concept development, communication, and cooperation	http://www.duh.de/biodiv_kommune/
European Green Capital Award	To reward cities with more than 100000 inhabitants that are making efforts to improve the urban environment and create healthier and sustainable living areas, spur cities to invest in further efforts, and boost biodiversity awareness	One European city wins per year, since 2010	12 indicator areas, e.g. 'nature and biodiversity', on available data, monitoring and management systems in place, and engagement of citizens)	http://ec.europa.eu/environment/europeangreencapital/
European Green Leaf Award	To recognise European cities and towns with populations of 20,000 up to 100,000 that commit to better environmental outcomes, with a particular focus on efforts that generate green growth and new jobs	One city/towns wins per year, since 2015 (in conjunction with the European Green Capital Award)	6 topic areas, based on a set of environmental indicators, including e.g. 'Nature, Biodiversity and Land Use'	http://ec.europa.eu/environment/europeangreencapital/europeangreenleaf/
German network 'Municipalities for Biological Diversity'	To create a network of cities committing to protecting and sustainably using biodiversity, via the signing of a declaration	Over 250 German municipalities	Description of measures on: green and open spaces in settlement areas; species and biotope protection; sustainable use; awareness raising and cooperation	https://www.bfn.de/fileadmin/BfN/klimawandel/Dokumente/ECBCC2015/2015-11-18/Session4/Vogt-Saedler_-_Nature-based_adaptation_in_urban_planning.pdf
United States STAR Communities	To assist and certify communities in setting sustainability goals and measuring progress	61 certified communities	Eight sustainability domains, including "Natural Systems" (encompassing green infrastructure, biodiversity & invasive species, natural resource protection, outdoor air quality, water in the environment and working lands)	http://www.starcommunities.org

Finally, indicators on biodiversity have also been explored within European research projects. The **GreenSurge project,** for example, collected and analysed a series of indicators on functional linkages between urban green infrastructure (GI), biodiversity and human well-being (Klemen Eler et al., 2016). These cover the diversity (patterns and configuration) of urban GI components across Europe; functional linkages between urban GI and climate change mitigation and adaptation; urban green space and urban foraging; and functional linkages between urban green spaces, activities, health and environmental justice of urban residents.

The proposed indicators for the **local index** (outlined in chapter 4.1) have been informed by the indicators and categories outlined above. However, it should be noted that there is a recognized gap existing between the optimal 'potential' for an inclusive biodiversity-centric index and that which is feasible based on available data sets. Important considerations regarding data include: scale, coverage, availability and quality. For example, aspects such as 'habitat/ecosystem quality', 'public participation in biodiversity related events', the 'amount of private funds spent on biodiversity projects' or 'number of citizens' initiative, private-public partnerships, etc could help to paint a more holistic picture of the status and support for biodiversity in a city, but challenges of how to gather the data and operationalise these indicators act as limitations.

Furthermore, the indicators presented above extend far beyond the scope of a purely biodiversity-focused index, including topics such as education, ecosystem services, human well-being, etc. While such additional indicators could provide more insights, their only indirect linkages to biodiversity make them questionable for inclusion in such a biodiversity-focused index. Examples include 'changes in the number of people suffering from diseases/sickness' (linked to green space emergence/existence), 'water quality', 'air quality', 'number of street trees', etc. Thus, the question of scope (i.e. how broad to make the index) and operationalisation (i.e. how to measure these aspects) become critical and have been considered in the design of the local index.

2.5 Overview of selected EUBI indicators

On the basis of the above considerations, a set of core and regional indicators have been selected for potential inclusion in a European Urban Biodiversity Index. Each indicator is described in more detail in the subsequent two chapters, but are outlined in Figure 2.1 as a first indication.

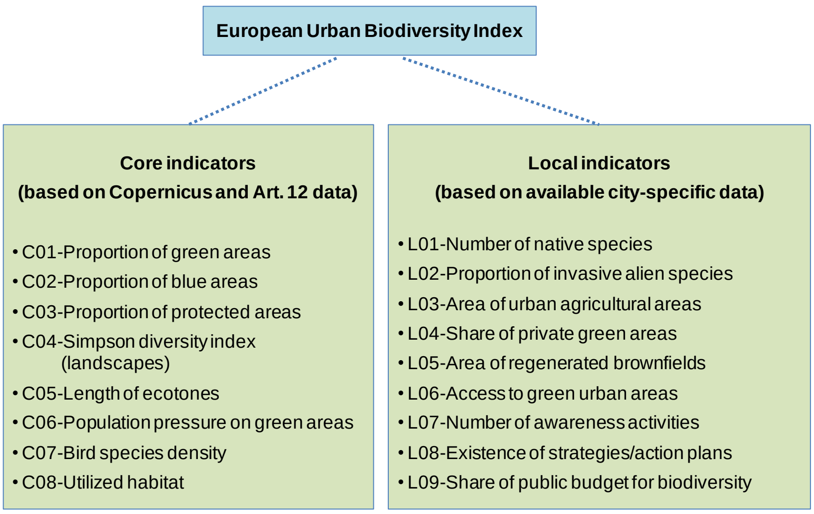

Figure 2.1. Overview of potential EUBI indicators

3 Core index: Indicator selection, rationale and testing

The following section presents the indicators that form the **core index**. Justifications are provided together with a short description and explanation on the processing steps taken in the production of the data.

3.1 Landscape diversity

3.1.1 Habitat availability

C01 Proportion of green areas		
Label	Prop. Green	
Unit / Range	%	0-100
Description	Proportion of non-sealed terrestrial UA classes within FUA.	
Rationale	Provides an overview of FUA landscape structure.	
Methodology	Proportion is calculated on the basis of below listed UA 2012 classes divided by total area including no-data areas: • 14100, 14200 • 21000, 22000, 23000, 24000, 25000, 25400 • 31000, 32000,33000 • 40000	

C02 Proportion of blue areas		
Label	Prop. Blue	
Unit / Range	%	0-100
Description	Proportion of aquatic UA class within FUA.	
Rationale	Provides insights into FUA landscape structure.	
Methodology	Proportion is calculated on the basis of UA 2012 class 50000 divided by total area including no-data areas:	

C03 Proportion of protected area		
Label	Prop. N2K	
Unit / Range	%	0-100
Description	Proportion of FUA area belonging to Natura 2000 network.	
Rationale	Areas which fall under special protection by the Natura 2000 directive may include a variety of different sensitive habitats. There are a range of restrictions to agricultural and forestry related activities within these areas which contribute to foster the development and recovery of rare species.	
Methodology	Natura 2000 End 2016 shapefile was clipped to sample city FUA extent. Thereinafter, remaining sites are dissolved to avoid site overlaps. Proportion is calculated from the amount of Natura 2000 area covering the FUA	

3.1.2 Landscape heterogeneity

C04 Simpson diversity index		
Label	Simpson Index	
Unit / Range	n/a	0-1
Description	Simpson´s biodiversity index calculated for MAES/Urban Atlas classes at level 1 (Simpson, 1949). Within the landscape diversity context, Simpson`s Index calculates the probability that any two randomly selected patches would be of a different land	

	cover type. Therefore, the higher the value the greater the likelihood that two randomly selected patches belong to a different class and thus the higher the landscape variability.
Rationale	Landscape richness and evenness are measures of spatial variability and larger heterogeneity in the landscape could promote biodiversity (Levin, 2012)
Methodology	UA2012 vector datasets are recoded to MAES Level 1 (c.f. Table A.1 in Annex for crosswalk) classification and subsequently rasterized. The index for each sample city individually using the LecoS package (Jung, 2016)

3.1.3 Habitat connectivity

C05 Length of Ecotones		
Label	Ecotone length	
Unit / Range	m/km^2	>0
Description	Length of transitions between agricultural and forest classes.	
Rationale	Transitional areas between different land cover classes present highly important habitats. Highly diverse landscapes generally feature a larger degree of ecotones and thus, spatial heterogeneity. Forest fringes and hedgerow have shown to improve regional biodiversity(Duelli, 1997).	
Methodology	All UA level 2 (croplands) and 3 (forests) are extracted at FUA level and converted to line polygons. These separate line polygon layers are intersected and dissolved. Total length of transitions is calculated from length of all remaining polygons.	

3.1.4 Habitat pressure

C06 Population pressure on green areas		
Label	Pop. pressure	
Unit / Range	heads/ha	>0
Description	Density of population per non-sealed UA classes.	
Rationale	Pressure or degree of disturbance by humans have substantial impacts on biodiversity and especially in the urban context it is an ongoing struggle to tend to the housing needs of growing population centres while maintaining protected areas, parks and recreational areas which foster wildlife.	
Methodology	Population pressure is calculated on the basis of the sum of the below listed UA 2012 classes, divided by the total population within the FUA stemming from the “Population estimates by Urban Atlas Polygon”- ancillary dataset (http://land.copernicus.eu/local/urban-atlas/ancillary-data-on-population-estimates-by-urban-atlas-polygons/view). • 14100, 14200 • 21000, 22000, 23000, 24000, 25000, 25400 • 31000, 32000,33000 • 40000	

3.2 Species diversity

C07 Bird species density		
Label	Bird species density	
Unit / Range	No. Species / $\sqrt{ha}$	>0
Description	Count of bird species per square-root of FUA area, derived from modified Art 12 dataset.	
Rationale	Species richness is a crucial component of biodiversity and species density describes how many species are encountered within the FUA.	
Methodology	Art 12 10km grid GIS and tabular data are combined with UA2012 via a crosswalk, essentially converting the UA-nomenclature into MAES classes. Using the assigned MAES habitat associations from the Art12 tabular data and the provided 10km GIS-grid dataset intersected UA it is possible downscale the dataset, thus, eliminating the	

	problem of 10km Gridcells which only partially overlap with the FUA (c.f. Table A.1Table A.1 for crosswalk and workflow). Especially in coastal regions translation of UA into MAES classes is only possible with the help of ancillary datasets and for this reason the selection of sample cities does currently not include coastal areas. The indicator itself is then calculated as follows: $$\text{Bird species density} = \frac{S}{\sqrt{A}}$$ S = Number of species per FUA A = FUA area (ha)	
C08 Utilized bird habitat		
Label	Utilized bird habitat	
Unit / Range	%	0-100
Description	Ratio of area of occupancy and suitable habitat area within FUA. Indicate the utilized habitat resources	
Rationale	Gives an indication of how much suitable habitat within the FUA is actually inhabited by the respective bird species.	
Methodology	Art.12 10km grid GIS and tabular data are combined with UA2012 via a crosswalk, essentially converting the UA-nomenclature into MAES classes. Using the assigned MAES habitat associations from the Art.12 tabular data and the provided 10km GIS-grid dataset intersected UA it is possible downscale the dataset, thus, eliminating the problem of 10km Gridcells which only partially overlap with the FUA (c.f. Table A.1 and Figure A.1 in Annex for crosswalk and workflow). Especially in coastal regions translation of UA into MAES classes is only possible with the help of ancillary datasets and for this reason the selection of sample cities does currently not include coastal areas. The indicator itself is then aggregated as follows: $$\text{Utilized bird habitat} = \frac{\sum A_{\text{Occupied}}}{\sum A_{\text{Suitable habitat}}}$$ $A_{Occupied}$ = Area that is currently occupied by all bird species in the FUA $A_{Suitable}$ = Area of suitable habitat for all bird species located in FUA	

3.3 Testing the core index

3.3.1 City selection

Biodiversity in urban areas is affected by a range of natural and anthropogenic factors. Ensuring a representative sample by means of stratified sampling to test the core index therefore requires a multitude of factors or strata to be considered. Under consideration of the amount of additional processing required to account for these factors, test cities were selected on a simple non-representative quota approach. The final test phase sample includes a total of twelve cities of approximately similar population density spread over six different biogeographic regions.

The current selection (see Figure 3.1) only includes inland cities with no direct coastline. This selection was necessary to avoid additional processing steps of ancillary datasets which are required to distinguish the UA water class into marine and freshwater for the combination with Art12 data in order to derive the species diversity indicator.

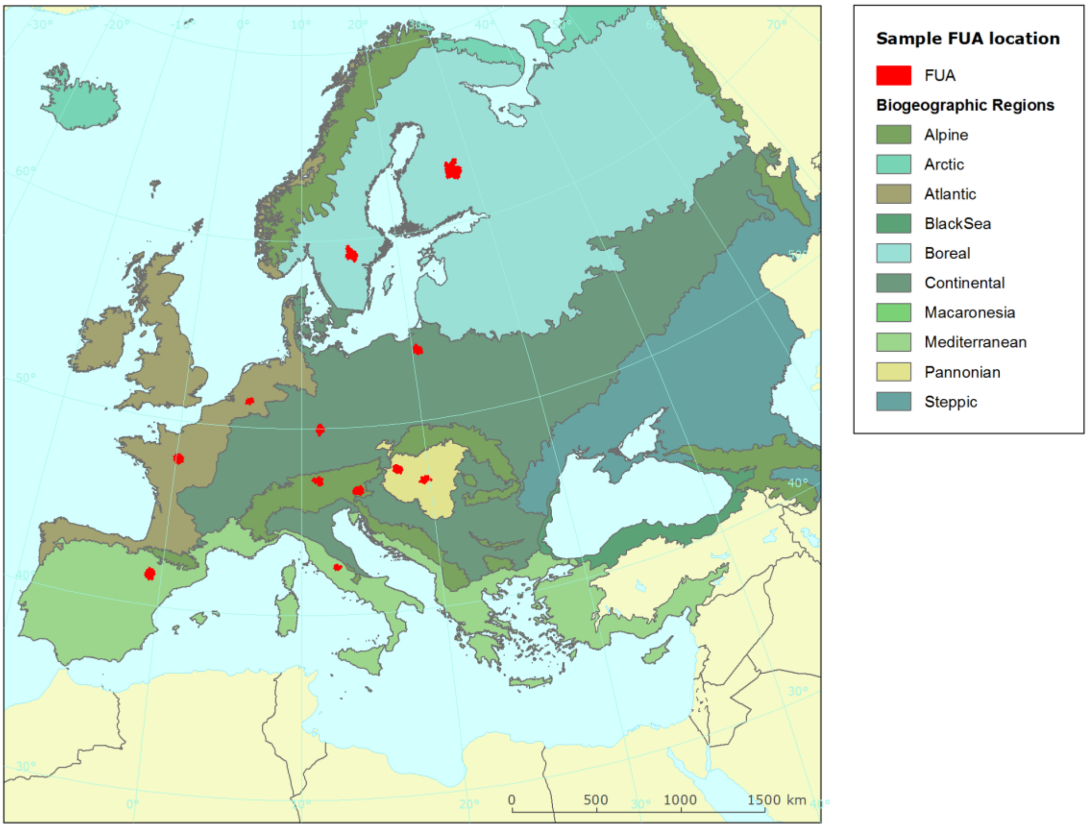

Figure 3.1 Sample selection overview. Pairs of samples were selected for 6 biogeographic regions (n=12).

3.3.2 Results

The indicators which were calculated and transformed for the twelve test cities are presented in Figure 3.2. Please refer to Table A.2 in the annex for the raw calculated indicator values. The former provides an overview of how the cities compare to each other. The intention here is to give s simplified visual overview on potential spatial patters and not to establish a general ranking. The latter table contains the raw calculated values.

Most cities feature a relatively large proportion of green areas (M = 87.02, SD = 6.38). This is not surprising given that most non-sealed classes can be considered as green area. The Finnish FUA of Kuopio (FI008L1) featured the lowest values of non-sealed area, however, due to its many small lakes ranks highest in terms of its “Blue”-area. In comparison to this, the more urbanised Eindhoven FUA (NL005L2) has a similarly low amount of green area but no substantially higher proportion of blue areas to compensate natural habitat. Kuopio is a much more rural FUA with the lowest population density of the sample. Eindhoven on the other hand, is highly urbanised and characterised by the highest population density of 7.7 heads per hectare

The Kuopio FUA is approx. six times as large as its Netherland counterpart. Despite this, the degree of protected area within the Eindhoven FUA is twice as high as the Finnish FUA. In this case, the larger availability of natural areas does not facilitate a corresponding higher degree of protected area.

Furthermore, the amount of protected area does also not have to be reflected in a higher species diversity which can be seen in the two alpine FUA´s located in Austria (AT005L2, AT006L1). These FUA´s feature large difference in protected area proportion but do not show large differences in terms of their bird wildlife. The largest amount of protected area can be found in the Spanish FUA (ES005L2). Although the heterogeneity within this site is comparably high the length of ecotones is comparably small which indicates that there are few transitions between agricultural and natural patches.

The largest amount of transitions between these two biodiversity relevant classes occur in the Finnish site. This is interesting considering that the FI008L1 FUA is also the most homogeneous site in terms of its land-cover classes. The Dutch FUA is located on the opposite end of the indicator range and features the highest values for heterogeneity. Although the Kuopio features a higher bird density, the total area of utilized habitat is almost half of the Dutch FUA. Whereas this could be explained by the more monotonous landscape encountered within the Finnish site it could also be simply caused by the better documentation of bird species in densely populated areas. Furthermore, whether the Art.12 dataset derived indicators bird species density and utilized habitat area fully reflect the on-ground situation is questionable in some cases. The Polish FUA PL014L2 shows extremely small values for both of these indicators. This is very likely a result of the national designation patterns within the Art. 12 dataset which oftentimes display variations along country borders that are caused by national rather than ecological differences.

The two Hungarian FUA´s are the most homogenous in the sample and do not show large differences in any of the produced indicators.

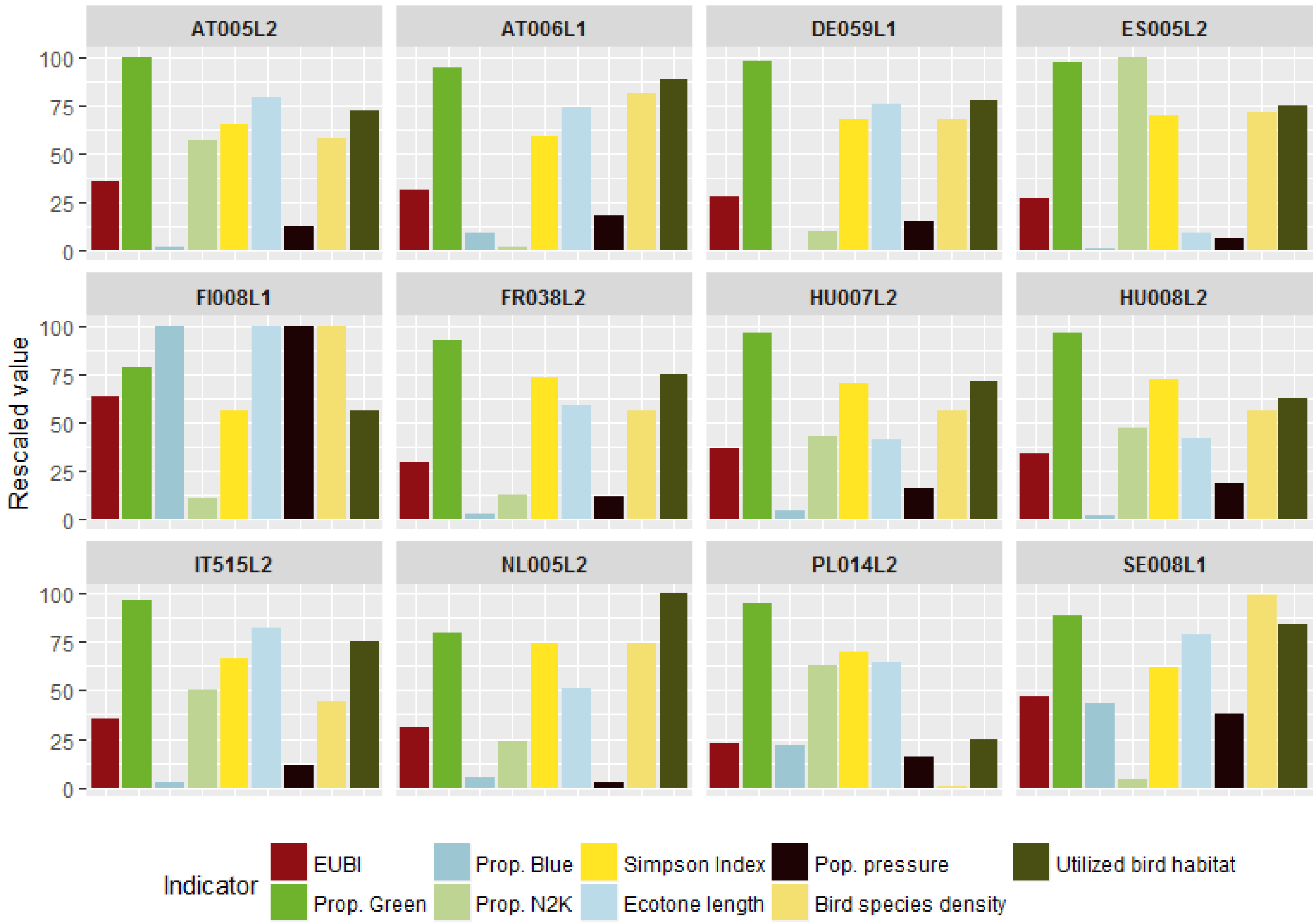

Figure 3.2 Representation of rescaled indicator values and calculated EUBI for all sample FUA´s.
Population pressure is represented as its inverse value in order to reflect that low pressure is considered beneficial for biodiversity.

3.4 Indicator aggregation, weighting and ranking

Aggregation is a crucial aspect within the development of indices. Combining different indicators to derive a single composite index is a widely conducted procedure (e.g. Human Development Index), as it facilitates the incorporation of multi-dimensional aspects into a single value. Whereas the interpretation of a single parameter is intuitive and feasible for policy makers, it has the potential to mask more complex underlying issues. Furthermore, if the composite index is calculated from absolute values rather than relative there is a large risk to mask or skew impacts.

Another issue which arises in the combination of different indicators is how to perform weighting between individual components. Weights can be assigned both by various statistical process (e.g. Principal Component Analysis, Regression analysis) but also by more subjective expert opinion. Despite the advantages of weighting, assigning weights to different indicators is oftentimes difficult to justify and may invite political debate as certain indicators may vary in their importance between regions. Furthermore, in the case of statistically assigned weighting the complexity of the task mostly requires trained experts which may simply not be at hand in all municipalities.

Some indicator networks are organised conceptually on the basis of feedback-loops such as the Drivers-Pressures-State-Impact-Response model (Kristensen, 2004). This model has been previously utilized by the EEA and other European reporting instances (e.g. Eurostat´s Agro-Environmental Indicators) to provide information on different environmental issues. However, this application is rather tied to environmental processes and not directly suitable for a self-assessment tool.

The CBI (see Table 2.2) uses a system of predefined value ranges which are associated to a point score. This has the advantage that cities can easily assess and calculate their own score. Yet, it has also been criticized that these predefined score value ranges do not offer enough sensitivity or flexibility to measure progress, as small positive changes in relation to the state of the city often go unrecognized. The CBI may therefore indicate no change despite the positive efforts the city has undertaken to promote biodiversity within its boundaries. Considering that the indicator is targeted at cities as a user-group and intended as a self-assessment tool rather than a ranking system a potential solution to this problem is to simply avoid setting predefined value ranges and weights.

Instead, these weights can be defined in a user-defined system using a geometric mean as main aggregation method for the index. The use of the geometric mean is recommended because it avoids that low scores for a certain indicator can be linearly compensated by another. Essentially, poor performance in any of the indicators is directly reflected in the index, so that 2% improvement in length of ecotones indicator has exactly the same impact as a 2% incline of green urban areas. This balance can then be modified be the user-defined weights. The geometric mean is here calculated from normalized values and is very similar to the index calculation approach used in the renown Human Development Index (HDI)[1]

For an intuitive interpretation the value range of the index should be set between 0-100. This can be achieved by rescaling the indicators to their respective minimum and maximum values (see Table 3.1) using Equation 1.

[1] http://hdr.undp.org/en/content/human-development-index-hdi

In order for the maximum and minimum values to correspond to a positive and negative situation, inverse values should be used where necessary (c.f. population pressure). In the case of indicators which are based on proportions or which are calculated as normalized value (Simpson Index), the theoretical maximum of 100 (1) is not likely to be achieved within any of existing FUA´s. Here it is more precise to define maximum values using the observed values to accurately reflect the relative value range.

Table 3.1 Minimum and maximum values for normalization of data.

Indicator	Minimum	Maximum
% Green areas	0	93.86
% Blue areas	0	23.82
% Natura2000	0	33.75
Simpson Index	0	0.74
Ecotone length	0	4.83
Population per green area	0	$\frac{1}{0.56}$
Bird species density	0	9.26
Utilized bird habitat	0	83.91

$$Rescaled\ value = \frac{(\text{actual value} - \text{minimum value})}{(\text{maximum value} - \text{minimum value})} \times 100$$

Equation 1 Rescaling of indicators

A default approach could be to assign an equal weighting for all cities ($\mathrm{RV}^{\frac{1}{8}}$) and thus for all indicators within both the core and local index and adapt where it is necessary. In order for the equation to be calculated values included must be greater than zero. If zero values are obtained the respective indicator must be excluded. If equal weighting for all indicators is applied the EUBI is simply calculated as follows:

$$EUBI = \sqrt[8]{RV_{Green} \times RV_{Blue} \times RV_{N2K} \times RV_{SI} \times RV_{ET} \times RV_{PD} \times RV_{BSD} \times RV_{UBH}}$$

Equation 2 Calculation of European Urban Biodiversity Index

Overall, the main principle is to focus on relative changes rather than establish a simple ranking although it may take some time to derive data and investigate these changes. The calculation method can be applied to both local as well as core index equally.

4 Local index: Indicator selection, rationale and methodology

The following section presents the indicators that have been selected to form the **local index**. Justifications are provided together with a short description and explanation on the processing steps taken in the production of the data. It should be noted, however, that while these

detailed indicators would be optional for cities wishing to complete the EUBI, their inclusion would provide a high added value and a far more robust snapshot of urban biodiversity status than that provided only by the Core Index.

For the indicators listed, the information should be applicable/current at the time of evaluation or - as relevant - to the year of submission as a whole.

4.1 Species diversity

L01 Native species	
Unit	No. of species
Description	The total number of native species in each of the following taxonomic groups within FUA: a. Plants b. Birds c. Butterflies d. Invertebrates e. Mammals
Rationale	Provides an overview of the species diversity, with distinctions able to be made across taxonomic groups. Moreover, some these species can also serve as an indirect “indicator” for the habitat quality.
Methodology	The sum for each taxonomic group is to be provided; additionally, it should be stated whether this is the exact number, an estimation or – if is the case – not available.
Linkages	CBI Indicator 3; European Capital of Biodiversity Indicators 4-9; Federal Capital of Biodiversity Indicators 2-7

L02 Invasive alien species	
Unit	%
Description	Proportion of invasive alien species within FUA.
Rationale	Provides an overview of the prevalence of potentially harmful species within the FUA.
Methodology	Proportion is calculated on the basis of the number of invasive alien species divided by the total number of species (i.e. the number of invasive alien species plus the total number of native species identified in Indicator 01)
Linkages	CBI Indicator 10; European Capital of Biodiversity Indicator 10

4.2 Green infrastructure

L03 Urban agricultural areas	
Unit	ha
Description	Amount of urban agricultural areas in FUA, including e.g. community gardens, roof/balcony gardens, allotments, school gardens, private backyard gardens, etc)
Rationale	Provides an overview of the extent of urban agricultural areas in the FUA.
Methodology	The ha coverage of all green areas in the FUA fulfilling the indicator description are summed together.
Linkages	European Green Capital Award

L04 Private green areas	
Unit	%
Description	Share of private green areas within FUA
Rationale	Provides an overview of the share of private green areas as compared to the total FUA area
Methodology	Proportion is calculated on the basis of the area of private green areas divided by the total area of green areas (C01).
Linkages	European Green Capital Award

05 Regenerated brownfields	
Unit	ha
Description	Total area of brownfields or derelict areas that have been regenerated into green areas within the last e.g. 10 yrs in the FUA[1].
Rationale	Provides an overview of positive restorative actions taken within the city to increase the share of green urban areas and therewith support biodiversity.
Methodology	Sum total in ha of all sites/areas which have been restored within the provided timeframe.
Linkages	German "Biological Diversity in Municipalities" declaration

4.3 Accessibility

L06 Access to green urban areas	
Unit	%
Description	Population-weighted median area of green urban areas and forests that can be reached within a 10-minute walk.
Rationale	Provides an overview of the population's access to biodiversity in the form of green areas within the city.
Methodology	Local proximity analysis based in Urban Atlas polygons and total residential population estimates; these accessibility areas are then to be intersected with the green urban areas.[2]
Linkages	Urban Atlas; European Capital of Biodiversity Indicator 14

4.4 Awareness and education

L07 Awareness activities	
Unit	No. of activities
Description	Total number of publicly funded/organised awareness-raising and education activities focusing on biodiversity within FUA, including e.g. training and capacity building, informational campaigns, public competitions, etc.
Rationale	Provides an overview of the level of effort the FUA is making regarding biodiversity education and awareness raising among its population.
Methodology	Total number of activities reported by public bodies.
Linkages	CBI Indicator 23; European Capital of Biodiversity Indicator 15

4.5 Public planning and policy framework

L08 Strategies/action plans	
Unit	Available / Not available
Description	Indication of whether or not strategies, policy or action plans are in place within the FUA which support: a. Biodiversity b. Green infrastructure c. Other (e.g. open space planning, sustainable urban development, no land take/soil sealing)
Rationale	Provides an overview of policy support for biodiversity and green areas within the

[1] This will depend to some degree on the data available in each urban area for this indicator, taking into account the reference years and update cycles.
[2] For more information see:
http://ec.europa.eu/regional_policy/sources/docgener/work/2016_03_green_urban_area.pdf

	FUA.
Methodology	A yes/no response is required for each sub-indicator (a, b and c), and further information outlining the name of the strategy, action plan or policy is to be provided.
Linkages	CBI Indicator 17; European Green Capital

L09 Public budget for biodiversity	
Unit	%
Description	Share of the municipal budget spent on biodiversity projects.
Rationale	Provides an overview of public financial support for biodiversity-related projects, as a share of the total public budget.
Methodology	Percentage of public budget dedicated to biodiversity-related expenditures, as a share of the total budget.
Linkages	CBI Indicator 15; European Capital of Biodiversity Indicator 17; Federal Capital of Biodiversity Indicator 10

5 Conclusions and outlook

The current analysis is a work in progress and provides a first conceptual baseline to establish a European urban biodiversity assessment framework based on publicly available Copernicus and Art12 Datasets as well as further locally available indicators.

A variety of indicators are proposed to act as proxy for key biodiversity components. Important elements and lessons learnt from similar assessment frameworks were considered and incorporated in the selection of core and local indicators. Whereas the computation of some indices is straightforward, others require more sophisticated data processing methodologies.

The analysis shows that there is a large potential to derive indicators from the available Copernicus datasets. Especially the Urban Atlas has provided a backbone for a large part of the included indicators. A two-component indicator system is proposed to account for the different availability of datasets between cities. Furthermore, a flexible aggregation and weighting system for the index is outlined, which roots in renowned indicator frameworks and can be applied by non-expert users. The first results of the index show that the selected indicators are capable of highlighting differences between cities. The highest scores of the $EUBI_{core}$ were calculated for Scandinavian cities with large proportions of natural areas and high species densities.

5.1 Potential user groups

As highlighted by the numerous initiatives on urban biodiversity assessments deployed at city level (see chapter 2.4.2), cities and their administrations are among the key users of such a biodiversity-focused index. Such index and data assessment can not only support cities in taking stock of biodiversity, but also support their future planning processes and help in setting priorities to enhance creation and maintenance of habitats, therewith promoting biodiversity and facilitating the implementation of existing local and national strategies on biodiversity and green infrastructure. In addition, NGOs - as a driving force for biodiversity protection - can also benefit from this work and the information generated per city in order to focus their activities, lobby for more action in certain regards, and base awareness raising campaigns off of successes or necessary further actions.

5.2 Limitations

A large challenge when it comes to international comparisons of biodiversity is to avoid incorporating indicators that vary strongly in their importance between ecoregions. This is especially relevant for species-based indicators as the density of species naturally differs between eco-regions.

Unfortunately, the most promising datasets for biodiversity which contain on-ground information on species distribution (Art12) are still somewhat unreliable to use at the urban level because derived differences between cities can be distorted by national designation patterns and spatial scale. Member State reporting on species and habitats protected by the EU Nature Legislation, for example, can only deliver partial insight on trends in urban biodiversity. Though rare and protected species do play an important role in urban biodiversity, a large portion of urban biodiversity consists of common species that are monitored less rigorously and thus not included for interpretation.

Nonetheless, these indicators may still be useful as this kind of homogeneous data is not available for all cities at comparable spatial levels. Furthermore, some indicators have to be formed on the basis of broad assumptions as not all habitat requirements can be incorporated in way that all eco-regions can be accounted for.

5.3 Outlook

Future activities will mainly focus on streamlining and improving the available indicator system. In addition to the current selection of indicators, additional Copernicus products can also be considered to improve the current selection. The Copernicus Riparian Zones layer was hitherto not included as it is currently undergoing a major revision. As of 2018 the layer should be accessible.

Concerning the Art.12 derived indicators a current limitation is their restriction to non-coastal regions. Due to thematic nomenclature overlaps the translation of UA into MAES classes in coastal regions is currently only possible with the help of ancillary datasets. Rule based translation on the basis of additional datasets could serve to extend these indicators to coastal regions if needed.

Although invasive species are included within the local component of the index it would be important to explore options on how to include this aspect into the core indicator set as alien species can disrupt natural ecosystems and pest management can invoke high costs on municipalities.

Currently there is a strong focus on habitat availability, by adding additional indicators to the remaining diversity characteristics it could be possible to provide a more holistic picture and better depict structural biodiversity components such as connectivity. The local component could be improved in the sense that guidelines and methodology for this component will be further elaborated to increase accessibility and applicability for potential users.

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Annex

Table A.1 Crosswalk between MAES Level 2 and Urban Atlas

MAES_LVL2	UA_CODE	UA_ITEM	Translation Rule	Comment
Urban	11100	Continuous urban fabric (S.L. : > 80%)	1-1	
Urban	11210	Discontinuous dense urban fabric (S.L. : 50% - 80%)	1-1	
Urban	11220	Discontinuous medium density urban fabric (S.L. : 30% - 50%)	1-1	
Urban	11230	Discontinuous low density urban fabric (S.L. : 10% - 30%)	1-1	
Urban	11240	Discontinuous very low density urban fabric (S.L. : < 10%)	1-1	
Urban	11300	Isolated structures	1-1	
Urban	12100	Industrial, commercial, public, military and private units	1-1	
Urban	12210	Fast transit roads and associated land	1-1	
Urban	12220	Other roads and associated land	1-1	
Urban	12230	Railways and associated land	1-1	
Urban	12300	Port areas	1-1	
Urban	12400	Airports	1-1	
Urban	13100	Mineral extraction and dump sites	1-1	
Urban	13300	Construction sites	1-1	
Urban	13400	Land without current use	1-1	
Urban	14100	Green urban areas	1-1	
Urban	14200	Sports and leisure facilities	1-1	
Cropland	21000	Arable land (annual crops)	1-1	
Cropland	22000	Permanent crops (vineyards, fruit trees, olive groves)	1-1	
Cropland	25000	Orchards at the fringe of urban classes	1-1	
Cropland	24000	Complex and mixed cultivation patterns	1-1	Could be subdivided into Cropland/Grassland with 2015 HRL Grassland.
Grassland	23000	Pastures	1-1	
Grassland	32000	Herbaceous vegetation associations (natural grassland, moors...)	If not overlapping with CLC322/323	
Woodland and	31000	Forests	1-1	

forest				
Heathland and shrub	32000	Herbaceous vegetation associations (natural grassland, moors...)	If overlapping with CLC classes 322/323	
Sparserly vegetated land	33000	Open spaces with little or no vegetation (beaches, dunes, bare rocks, glaciers)	1-1	
Wetlands	40000	Wetlands	Only if overlapping with CLC inland wetlands OR Located >1km from coastline.	
Rivers and lakes	50000	Water	Only if located >1km inland from coastline. Potential use of Copernicus Local Component Coastal Zone.	
Coastal	50000	Water	Only if located >1km seaward from coastline. Potential use of Copernicus Local Component Coastal Zone.	
Marine inlets and transitional waters	50000	Water	Only if located >1km seaward from coastline. Potential use of Copernicus Local Component Coastal Zone.	
Shelf	50000	Water	Only if located >1km seaward from coastline. Potential use of Copernicus Local Component Coastal Zone.	
Open ocean	50000	Water	Only if located >1km seaward from coastline. Potential use of Copernicus Local Component Coastal Zone.	
NoData	91000	No data (Clouds and shadows)	1-1	
NoData	92000	No data (Missing imagery)	1-1	

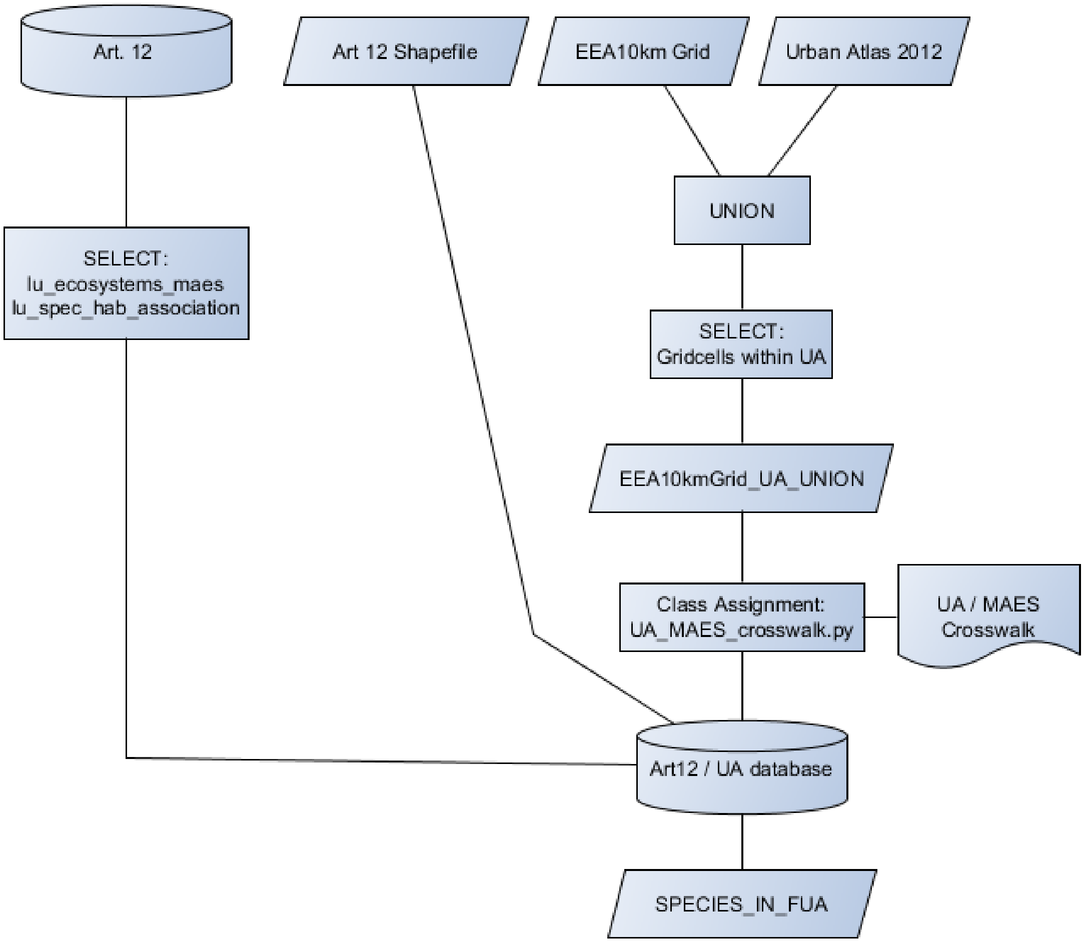

Figure A.1 Workflow to downscale Art. 12 10km grid to UA

Table A.2 Raw calculated indicator values

	Landscape diversity						*Species diversity*	
	Habitat availability			Landscape heterogeneity	Habitat Connectivity	Habitat pressure	Bird species density	Utilized habitat
URAU_CODE	**Prop. Green**	**Prop. Blue**	**Prop. N2K**	**Simpson Index**	**Ecotone length**	**Pop. pressure**	**-**	**-**
AT005L2	93.86	0.44	19.32	0.65	3.84	1.65	5.43	61.08
AT006L1	89.26	2.14	0.63	0.59	3.58	1.15	7.54	74.38
DE059L1	92.10	0.19	3.41	0.68	3.66	1.36	6.29	65.63
ES005L2	91.36	0.33	33.75	0.70	0.43	3.00	6.65	63.05
FI008L1	73.37	23.82	3.47	0.56	4.83	0.21	9.26	46.68
FR038L2	86.68	0.57	4.08	0.73	2.85	1.80	5.16	63.02
HU007L2	90.03	1.03	14.37	0.70	1.99	1.31	5.20	59.64
HU008L2	90.42	0.43	15.84	0.72	2.01	1.14	5.18	52.55
IT515L2	90.31	0.57	16.91	0.66	3.97	1.84	4.12	63.31
NL005L2	74.48	1.22	8.10	0.74	2.47	7.77	6.88	83.91
PL014L2	88.98	5.27	21.08	0.70	3.13	1.34	0.03	20.63
SE008L1	83.46	10.28	1.30	0.62	3.79	0.56	9.17	70.84