NATURVATION
cities – nature – innovation

MAPPING BENEFITS OF NATURE-BASED SOLUTIONS IN 775 URBAN AREAS - BACKGROUND INFORMATION

KEY FINDINGS

- **Spatially explicit scenario-based modelling approach to assess benefits of nature-based solutions in cities**
- **European-scale assessment of 775 urban areas**
- **Mapped benefits from nature-based solutions are as follows:**
  - o **Reducing heat stress**
  - o **Enhancing carbon storage**
- **Background information to the open access maps**

THE NATURVATION PROJECT

NATure-based URban innoVATION is a 4-year project involving 14 institutions across Europe in the fields of urban development, geography, innovation studies and economics. We are creating a step-change in how we understand and use nature-based solutions for sustainable urbanisation.

Durham University
Lund University
eco logic
GRIMMA
Utrecht University
UAB Universitat Autònoma de Barcelona
I·C·L·E·I Local Governments for Sustainability
CEU Central European University
ent environment & management
Newcastle City Council
PBL Netherlands Environmental Assessment Agency
City of Utrecht
Malmö stad
Leibniz-Institut für Länderkunde ifl

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Introduction

This document provides background information to the maps shown on https://naturvation.eu/assessment/maps. They were created as part of the H2020 NATURVATION project, which aims, to assess what nature-based solutions can achieve in cities, examine how innovation is taking place, and work with communities and stakeholders to develop the knowledge and tools required to realise the potential of nature-based solutions for meeting sustainability goals.

As part of the project, we carried out two scale-specific assessments with a spatially explicit scenario-based modelling approach to assess the full potential of urban nature-based solutions for supporting European cities to adapt to and mitigate climate change. The two different scales were: i) a European-scale assessment, including all major European urban core areas and their associated hinterlands (i.e. 775 Functional Urban Areas (FUAs) and ii) a more fine-grained city-scale assessment, including three selected case studies (i.e. Malmö, Barcelona, Utrecht). While this document concentrates on the description of the European-scale assessment, results of the city scale assessment can be found on https://naturvation.eu/assessment/cities.

Mapping methodology

To assess the current and future contribution of urban nature-based solutions to address climate change, we mapped nature-based solutions' potential to i) mitigate heat during a heatwave, and ii) store carbon in soils and vegetation. This was done across 775 Functional Urban Areas (FUAs), representing European urban core areas and associated hinterlands. We used a scenario-based modelling approach, where we developed possible futures, i.e. scenarios. We applied the Integrated Valuation of Ecosystem Services and Tradeoffs tool (InVEST, version 3.8.7, Sharp et al., 2020) to model the benefits of urban nature-based solutions under the different scenarios. InVEST is a leading open-source GIS-based modelling tool for quantifying various ecosystem services (https://naturalcapitalproject.stanford.edu/software/invest). The model provides standard quantitative relationships and values based on latest available empirical studies; however, users can also tailor key parameters to the area of interest (e.g. considering data availability, context). The resulting maps show the spatial distribution of the nature-based solutions benefits per FUA under different scenarios i.e. current situation (i.e. reference), implementation of additional nature-based solutions (i.e. green scenario) and removing of urban nature-based solutions (i.e. grey scenario). By comparing the different outcomes between FUAs or/and scenarios, possible changes in benefit provision as well as synergies and trade-offs between benefits and/or nature-based solutions types implemented can be explored.

Assessed Benefits

Benefits of nature-based solutions were calculated with assessment methods already available as InVEST modules (Table 1).

Table 1. Overview of the modelled nature-based solution benefits and assessment methods used in the European-scale assessment

NBS Benefits	Assessment methods	Indicator (unit)
Heat mitigation	InVEST Urban Cooling Model	Heat mitigation index (0 - 1), cooling potential (°C)
Carbon storage	InVEST Carbon Storage and Sequestration model	Carbon storage (ton C/km^2)

The InVEST urban cooling model is designed to quantify the potential of urban nature to mitigate the Urban Heat Island (UHI) effect by providing shade, increasing cooling through evapotranspiration, and modifying the thermal properties of the urban fabric (albedo effect). The model works with a heat mitigation (HM) index, expressed by a value between 0-1, (0) representing low and (1) high mitigation potential based on the heat mitigation, we estimated the potential cooling (°C) of the UHI. For more detail, see Sharp et al. 2020.

The InVEST carbon storage model estimates the amount of carbon currently stored in the landscape depending on the size of four major carbon pools: aboveground biomass, belowground biomass, soil and dead organic matter (for more detail see Sharp et al. 2020). The model requires an estimate of the amount of carbon in at least one of the four fundamental carbon pools for each land use/land cover (LULC) type. Based on land cover distribution and model resolution, the total amount of carbon stored is summarised into raster output maps representing ton of carbon stored per grid cell as well as aggregated totals per area of interest (e.g. whole city, ton C/km^2), of which resulting maps can be seen on this website.

Input data

The basic data requirements per FUA are a map of its extent, a LULC raster map, and look-up tables containing information on shade, evapotranspiration, albedo, presence of green areas and carbon pools per LULC class, as well as evapotranspiration and temperature raster maps and tree density cover data (Table 2).

Table 2. Input data

NBS Benefits	Spatial and temporal resolution	Source
European Urban Atlas LULC	20m x 20m; reference year 2012	https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012?tab=download
Global Aridity Index and Potential Evapotranspiration Climate Database	30 arc-seconds / 1km at the equator; reference year 2016	https://doi.org/10.6084/m9.figshare.7504448.v1
ERA5-Land dataset	9km x 9km; reference year 2016	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land?tab=overview
Tree Cover Density (TDC)	20m x 20m; reference year 2015	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/status-maps/2015?tab=download

Table 3. Parameter values

Parameter	Value	Source
Temperature	Average daytime temperature July 2016 per city	ERA5-Land dataset
Evapotranspiration	Average evapotranspiration July 2016 per city	Global Aridity Index and Potential Evapotranspiration Climate Database
Shade	Average tree cover density per LULC class per city	Tree Cover Density (TDC)
Albedo	0.15 or 0.06 (for water)	Trlica et al., 2017, Stewart and Oke, 2012, Taha, 1997
Crop coefficient	Area-weighted average value based on the composition of each LULC type based on tree cover density and baseline Kc values for certain crops (e.g. trees, turf grass, grass and shrubs) or the soil coefficient for bare soils	Nistor, 2016, Nistor and Porumb, 2015, Allen et al., 1998
Green areas	Green urban area, forests	European Urban Atlas LULC
Cooling distance	230m	Aram et al. 2019
UHI	Difference between maximum and minimum daytime temperature during the hottest day in July, per city	ERA5-Land dataset
Carbon pools	Area-weighted average value based on the composition of each LULC type based on baseline values for certain vegetation types (i.e. trees, grass, wetlands) or bare soil.	Bouwer et al. 2018

Model parameterisation

The urban heat mitigation model requires values for temperature, evapotranspiration, shade, albedo, crop coefficient and presence of green areas per LULC type while the carbon storage model requires the carbon density of four major carbon pools for each LULC class (Table 3).

Temperature as well as evapotranspiration values correspond to the month of July 2016 and were obtained from global datasets. To estimate the shade value per LULC, we estimated the average tree cover density per LULC class per city. Because albedo values of urban fabric tend to vary only little (Trlica et al., 2017, Stewart and Oke, 2012, Taha, 1997), we applied a generic albedo value of 0.15 to all LULC classes, with the exception of water, which has generally a much lower albedo (i.e. 0.06) (Stewart and Oke, 2012). We calculated a crop coefficient (Kc) per LULC type as an area-weighted average value based on the composition of each LULC type (i.e. tree, grass, build-up). To that end, we used the FUA specific proportion of canopy cover (i.e. shade value) and baseline Kc values for certain crops (e.g. trees, turf grass, grass and shrubs) or the soil coefficient for bare soils (Nistor, 2016, Nistor and Porumb, 2015, Allen et al., 1998). In case of agricultural land, water and wetlands, we adopted average Kc values from Allen et al. (1998). To assess the cooling effect of the surrounding larger green areas, LULC classes had to be classified as either green areas or not. We counted the land use classes of 'green urban areas' and 'forests' as green areas. We set the cooling distance over which large green areas (>2ha) may have enhanced cooling capabilities to 230m (i.e. medium value of Aram et al. (2019)). To estimate the cooling potential, we estimated the UHI for each FUA during the summer heatwave in 2016, when cooling demands are highest, based on the hottest day in July. UHI magnitude is typically measured by the urban – rural temperature difference, but often poorly represent site characteristics (Stewart, 2011), measuring the UHI magnitude as a difference in temperature between different zones within a city have been shown to be more accurate (Stewart and Oke,2012). Therefore, we estimated the UHI magnitude as the difference between the maximum temperature (presented by the highest value measured within a FUA) and minimum temperature (which represent the lowest value within the FUA). We then estimated the potential cooling (°C) by multiplying the UHI with the HM.

Bouwer et al. (2018) provide average carbon pool data for various LULC (e.g. agricultural land, grasslands and forests) based on several European studies. To account for the differences in vegetation cover between the various urban LULC classes in our study, we assumed no carbon storage for built-up areas (Bouwer et al., 2018) but calculated the different carbon pools per LULC based on a combination of tree cover (i.e. shade value) and an assumption on remaining land coverage (e.g. built-up, grassland). For example, if an urban LULC has a shade value of 30%, we calculated the carbon density as 0.3 times the carbon pool value of forests plus 0.7 times the baseline values for the remaining coverage, e.g. in case of an urban fabric class (e.g. 'Continuous urban fabric') we assumed this would be build-up areas (and thus the baseline value is zero), or in case of an urban park ('green urban areas') we assumed the remaining area to be covered by grass.

Scenario implementation

The reference scenario is the current situation of available nature-based solutions. In addition, we modelled two scenarios that differ in the amount and location of urban nature-based solutions when compared to the reference situation, namely one green scenario with additional trees and green spaces and one grey scenario, where trees and green spaces are largely removed from the city (Table 4).

Table 4. European-scale scenarios

Scenario name	NBS	Actions
Reference	Existing green infrastructure	no change to input data
Green scenario	Additional green infrastructure (i.e. trees, parks, forest)	In addition to the current situation, additional trees along streets are implemented, tree density in the urban fabric, parks and forests are increased, and construction sites are transformed into 'green residential areas', while 'mineral extraction sites into parks, and 'land without current use' and 'herbaceous vegetation' into forests.
Grey scenario	Removing green infrastructure (i.e. trees, parks, forest)	Parks and forests are replaced by urban fabric; tree density along streets and in the urban fabric is greatly reduced.

To implement the scenarios, we changed the land use/land cover (LULC) properties compared to the reference scenario (e.g. shade, crop coefficient, LULC type). For example, the implementation of additional trees within the city was simulated by increasing the shade values per LULC to the 95th percentile of the LULC-specific shade values across all cities, while the removal of trees was translated as a decrease of shade values per LULC class. If the reference shade value was higher than the scenario value of that specific LULC, we kept the reference value. In addition, in the scenarios we also changed selected LULC classes into 'greener' or 'greyer' classes (resulting in changes in shade values, evapotranspiration and carbon densities). For example, in the green scenario, we converted 'construction sites' into 'very low urban fabrics' (e.g. assuming new green residential areas), 'land without current use' and 'herbaceous vegetation' into new forest areas, and 'mineral extraction sites' and 'sport fields' into new green urban areas. We assumed agricultural land, wetlands and water areas to remain unchanged. With regard to the albedo effect, we assume no change for either scenario due to the minimal change in albedo with increasing canopy cover (Trlica et al., 2017).

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