



**EnhancES**  
The IMECOGIP Toolbox



# Mapping, Assessing, and Enhancing Ecosystem services for blue-green infrastructure planning

EnhancES is a QGIS-based Toolbox for Identifying and  
Quantifying Ecosystem Services in Metropolitan Areas

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IMECOGIP = Implementation of the Ecosystem Services Concept in Green Infrastructure Planning to Strengthen the Resilience of the Ruhr Metropolis and Chinese Megacities. Project partners are the Department of Geography at Ruhr University Bochum and ILS Research, Dortmund.



Research for Sustainability



## What are Ecosystem services?

Ecosystem services are the fundamental services that nature provides for human life, economic activity, and culture. Unlike finite resources, such as metals, coal, or natural gas, ecosystem services are those that nature provides continuously and sustainably and well-being of humans. Ecosystem services occur in varying intensities and combinations across different locations. This is what makes identifying them so challenging. Ecosystem services are divided into three categories:

### Provisioning services



### Regulating services

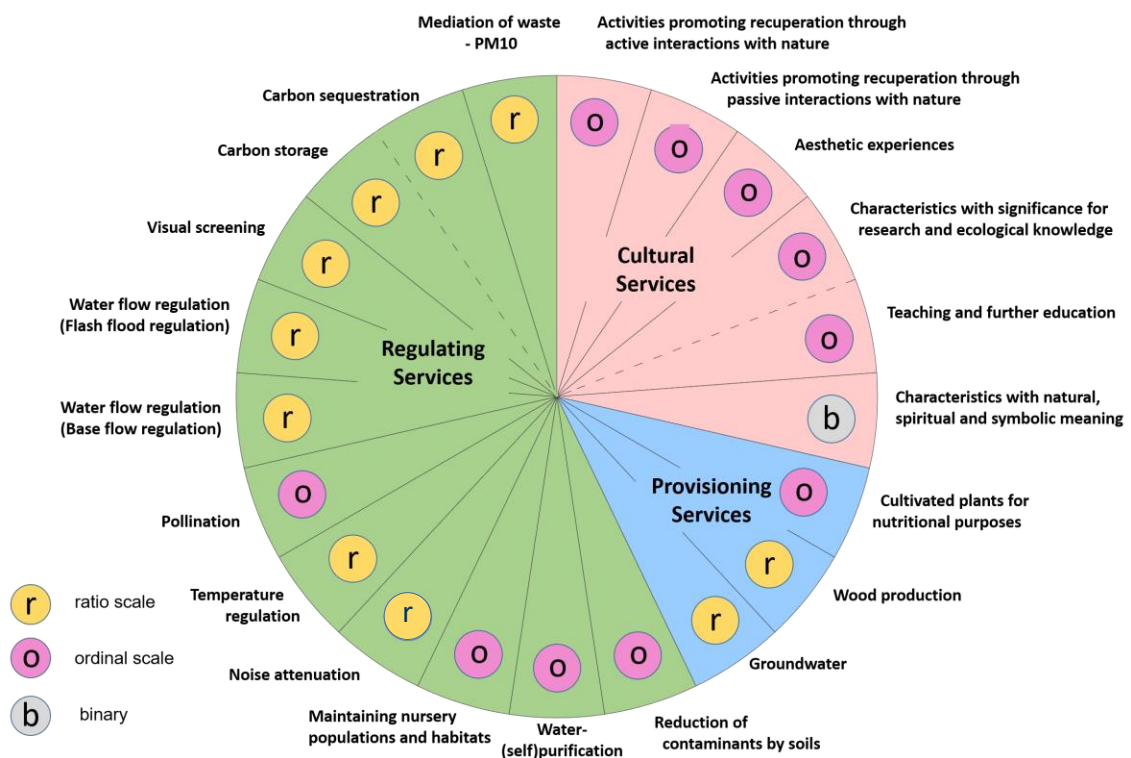


### Cultural services



## What does EnhanceES do?

EnhanceES is an open-source toolbox for the QGIS geographic information system designed to quantify and model ecosystem services. Using existing geodata (e.g., land use/land cover, soil information), users can run tools for up to twenty different ecosystem services.



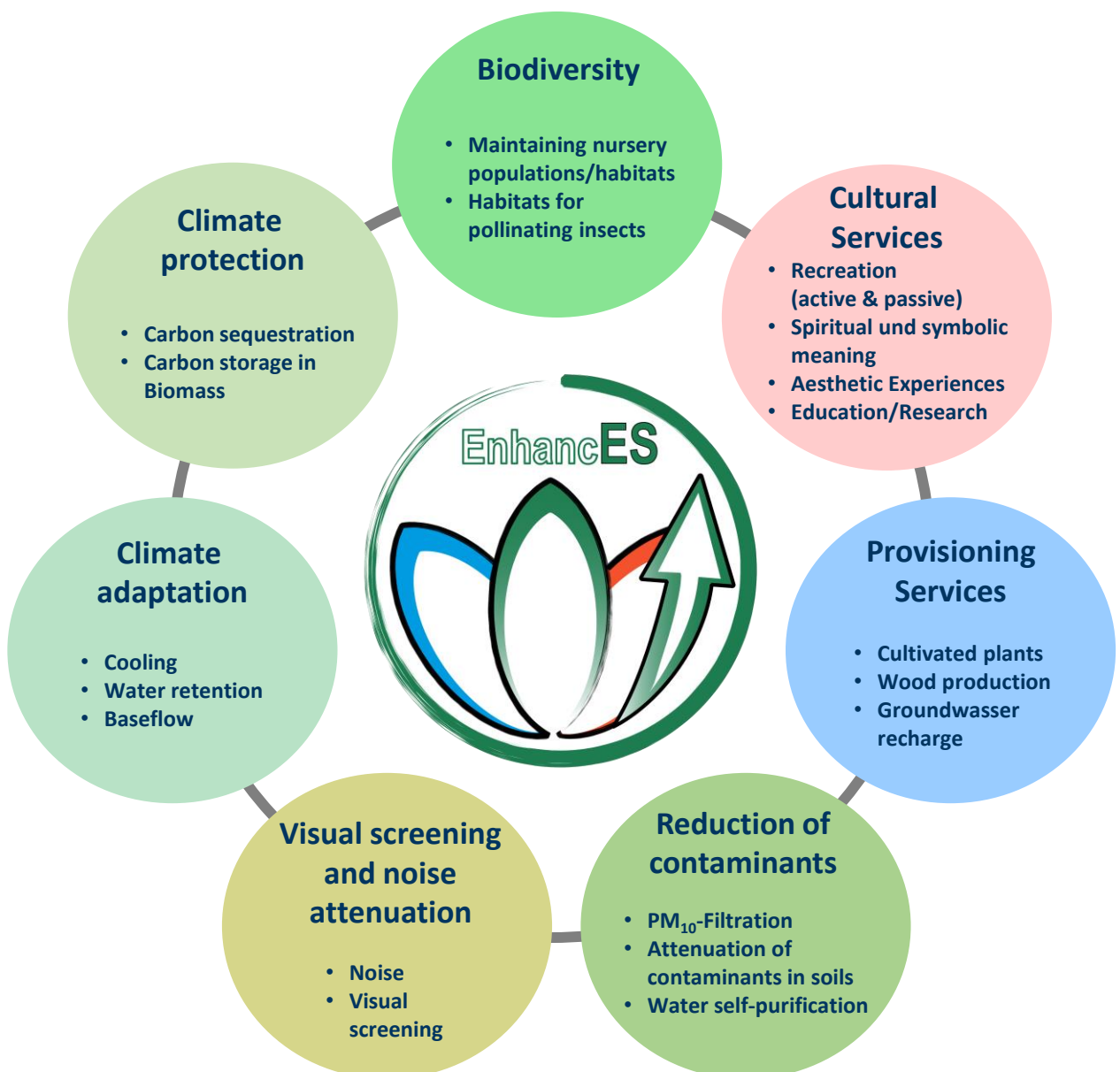
# EnhancES addresses societal challenges and applications in urban and landscape planning (Nature-based solutions, NbS)



## The Contribution of Ecosystem Services and EnhancES

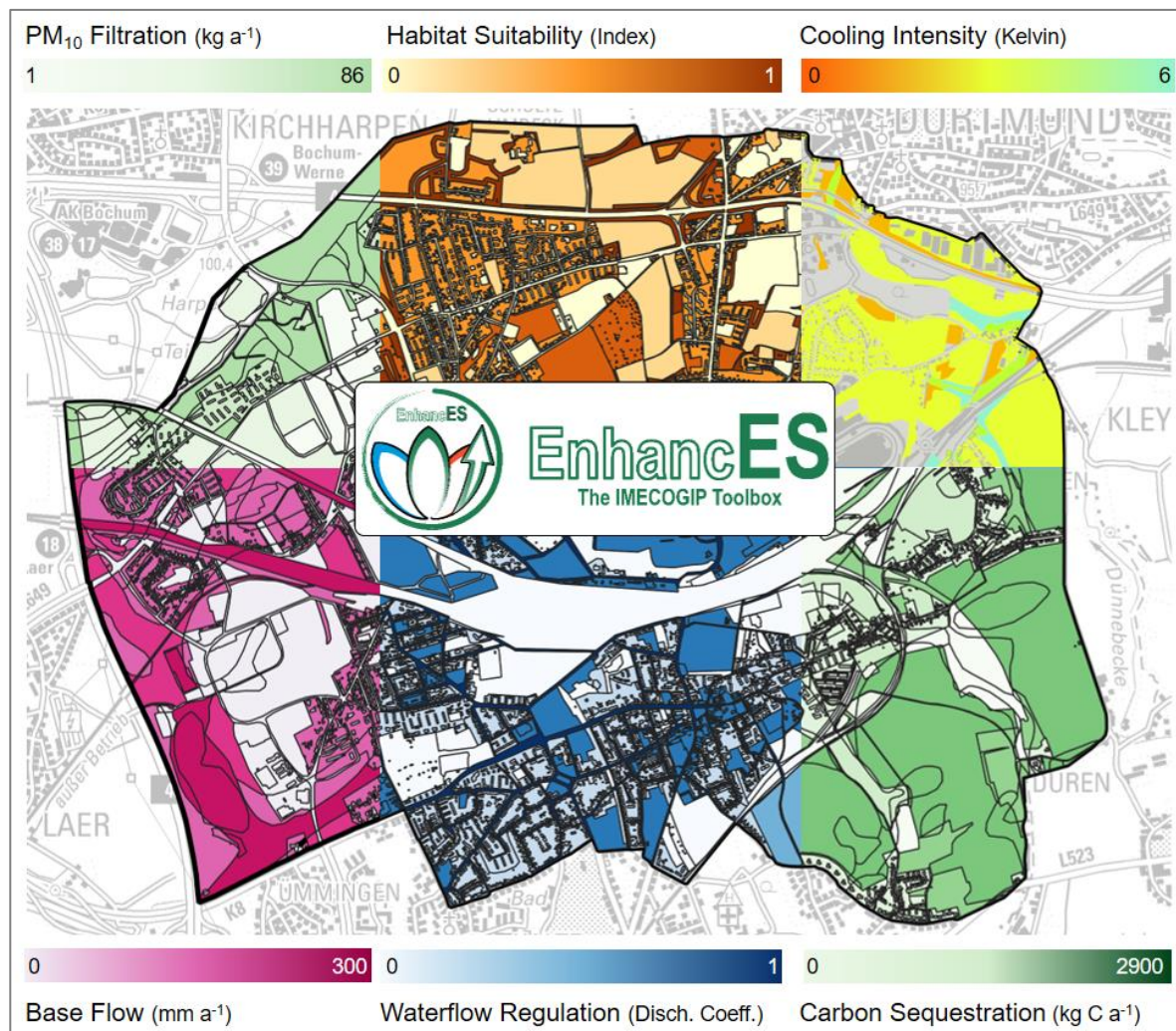
Numerous societal challenges require solutions that involve the targeted enhancement of ecosystem services. In such cases, we refer to nature-based solutions. EnhancES supports the planning of nature-based solutions by quantitatively assessing the impact of measures to strengthen green-blue infrastructure on ecosystem services. Both measures that have already been implemented and those that are planned can be evaluated.

Users can select from a pool of ecosystem services - tailored to the specific societal challenges and study area. Ecosystem services can therefore be grouped by societal challenges.





## What you get: Maps, tables and assessments

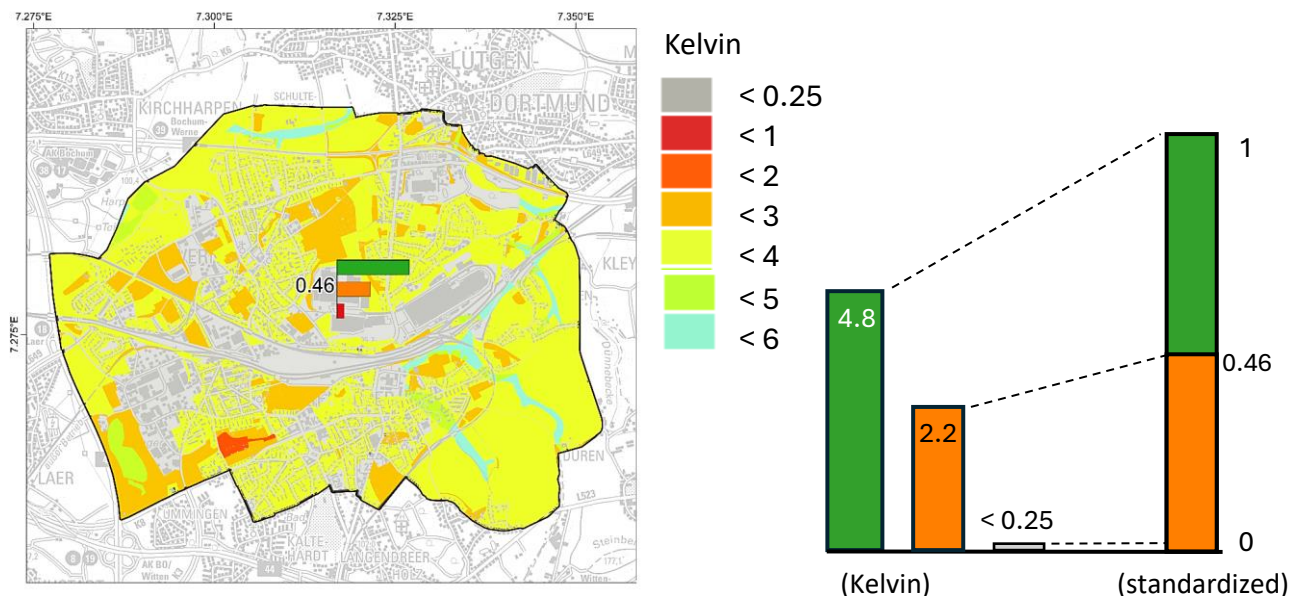


EnhanceES displays the assessments both as thematic on-screen maps and in tables. The spatial representation appears on the screen immediately after each tool has been run. Colors and legends are preset for all ecosystem services. The maps show the intensity of ecosystem services for land use or biotope units. Each in its own color scheme. For details, users can view the attribute tables (see example table on the right) and, if necessary, process them further in QGIS or a spreadsheet program.

| Nr. and LANUV-Code | Biotope type (LANUV)                  | Pollination (Habitat suitability) | Area (m <sup>2</sup> ) |
|--------------------|---------------------------------------|-----------------------------------|------------------------|
| 1 / FDO            | Non-floating small water bodies       | 0.05                              | 144                    |
| 2 / VA0            | Roads                                 | 0.1                               | 6,379                  |
| 27 / Sgr           | Settlement areas with green roof      | 0.8                               | 1,534                  |
| 69 / SB            | Residential areas                     | 0.1                               | 98                     |
| 70 / SBg           | Residential areas garden area         | 0.6                               | 143                    |
| 599 / HM4d         | Intensively cut lawn                  | 0.3                               | 271                    |
| 667 / BA1          | Small wood of mostly indigenous woods | 0.9                               | 22,307                 |
| 668 / BF           | Groups of trees, tree rows            | 0.9                               | 153                    |

# Assessing ecosystem services and making them comparable through standardization

## The example of temperature regulation



Cooling is measured in Kelvin, which roughly indicates equivalent standard degrees Celsius (°C). Put simply, this refers to the temperature of the air.

## Standardization of ecosystem service values

### Is the ecosystem service value of my area high or low ('good' or 'bad')?

EnhancES displays the standardized value for the ecosystem service of the entire area as a bar chart, relative to a theoretical optimum. This is particularly helpful for ecosystem services expressed in physical units (e.g., grams of carbon per square meter or temperature deviation in Kelvin). Standardization assigns a relative value on a scale from 0 to 1 to the absolute number: 0 means no service and 1 means a service at maximum intensity. In the example, a theoretically conceivable cooling of 4.8 Kelvin would correspond to the optimum of 1. This would be achieved if the area were completely forested. However, the modeled actual cooling is 2.7 Kelvin; this corresponds to a standardized value of 0.46.

## Comparison of Ecosystem Services

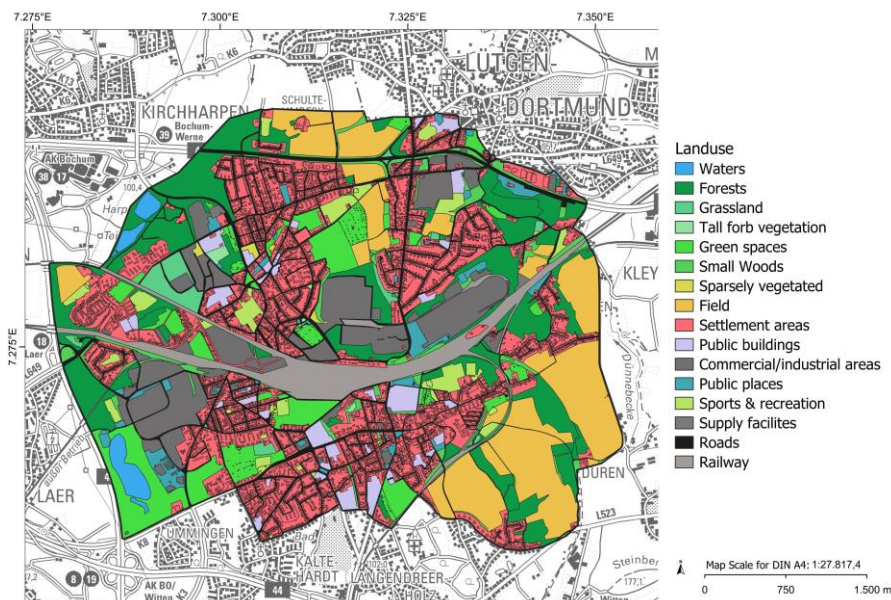
### Which ecosystem services in my area are particularly favorable or unfavorable?

For example: cooling or groundwater recharge? If ecosystem services are expressed in physical units, comparison is difficult. Standardization makes it possible to compare different ecosystem services within a given area. Similarly, we can compare the same ecosystem service across different areas or for different plans within the same area.

You can find some examples in the 'Applications' section on pages 12 and following.



## What you need ...



### Land use/Land cover or Biotope types

Optional for some  
ecosystem services:

- a) Building footprints
- b) Soil data
- c) Precipitation, air temperature during heat wave, grass reference evapotranspiration (FAO, ETo)
- d) PM<sub>10</sub>-Concentration

### Land use / Biotope type

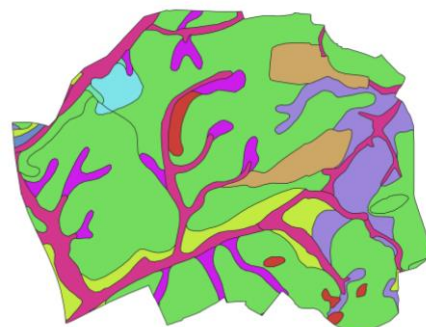
Land use/land cover or biotope types, available as precise polygonal vector data, are essential for EnhancES. For each individual area, they contain codes corresponding to the hierarchical biotope type classification system of the State Agency for Nature, Environment, and Climate of North Rhine-Westphalia (LANUV 2013). The classes are applicable to most landscapes in Central Europe, with the exception of the Alpine region and the coast. They can be adapted and supplemented as needed.

Numerous municipalities have such digital geodata, which can be imported into EnhancES as-is. If other publicly available datasets are used, such as those from the EU's Urban Atlas or the Regional Land Use Mapping by the Ruhr, tools are available to translate the classifications used in these datasets into the biotope type coRegional Association and thus make them usable for EnhancES. This also applies to the ESA WorldCover dataset, which maps the entire land area of the Earth. A translation from the German Official Topographic and Cartographic Information System (ATKIS) dataset is currently in progress.

If you have your own maps or maps that differ from these in a GIS-readable format, care must be taken to ensure that the codes are translated into the LANUV classification. The codes are the key for assigning the parameters that are pre-installed in EnhancES and which EnhancES uses.

### Soil and groundwater depth

For some ecosystem services (baseflow runoff; groundwater recharge, groundwater protection, crop cultivation for nutritional purpose), soil data is required or recommended (temperature regulation). In North Rhine-Westphalia, EnhancES is compatible with the digital soil map BK50 of the Geological Survey of North Rhine-Westphalia. Alternatively, users can enter site-specific values for soil depth, field capacity, cation exchange capacity, and groundwater level.



# How EnhancES works

## The Workflow

### Importing Data via an Input Form

EnhancES imports the geodata and supplementary climate data for the study or planning area. For example, you can import the files into a form using drag-and-drop.

### Pre-Processing

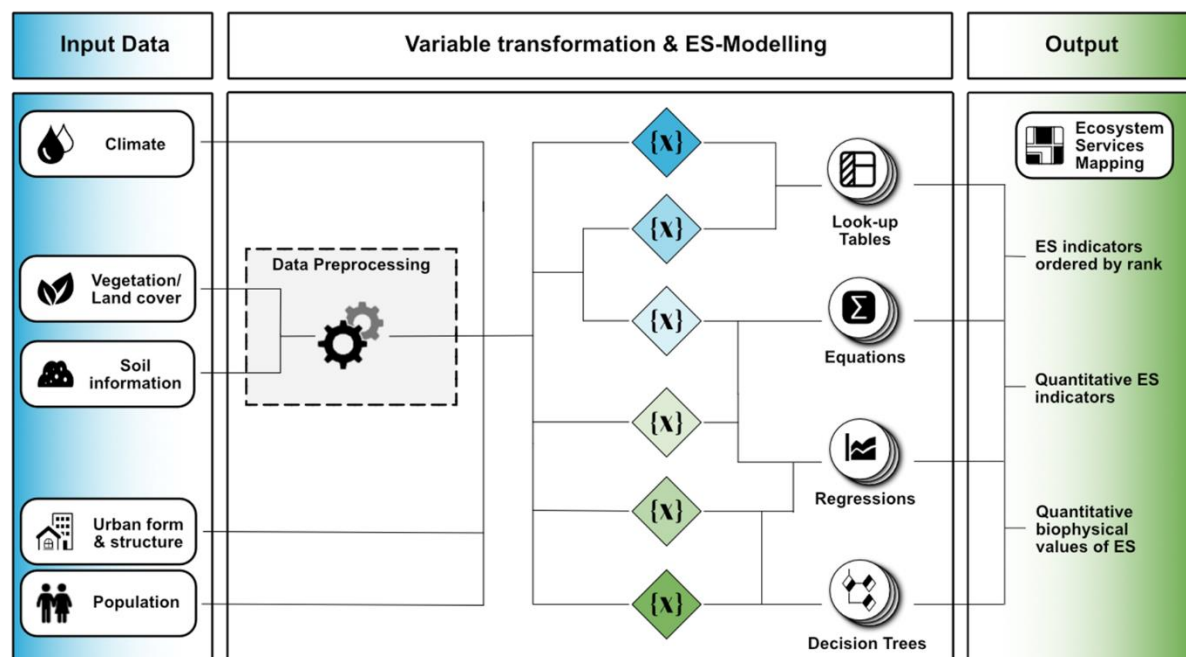
Next, run the pre-processing tool. If you are not using preset constants for climate and soil, you must also fill in these fields in the input mask. The pre-processing tool generates a geodata file containing all the geometries of the areas to be assessed. All individual areas contain the land use and biotope type codes and, where applicable, soil data that the ecosystem service tools access. Results from all tools can be saved temporarily or permanently.

### Calculating Ecosystem Services (Tools)

You calculate ecosystem services separately one after another, i.e., each ecosystem service using its own tool. For the calculation, EnhancES uses parameters stored in provided ecosystem service-specific tables, thanks to the unique land use-biotope type codes. From a software perspective, the tools are available as so-called 'model3' files.

### Viewing and checking output files

Each run concludes with the automatic display of the results map on the screen, complete with a preset legend. The bar chart showing the standardized assessment of the entire area is also immediately visible. Technically speaking, the results consist of two QGIS layers that can be turned on and off separately. Assigned to these layers are the two attribute tables, which contain all variable values for all areas or the total area. The attribute tables can be exported to other programs for further processing. Due to the recommended result verification, both layers are initially saved as temporary files that are not permanently stored. This setting is changed in the input mask.



## Hierarchy of land use / Biotope types (~ 600 Types; abridged, simplified, based on LANUV 2013)

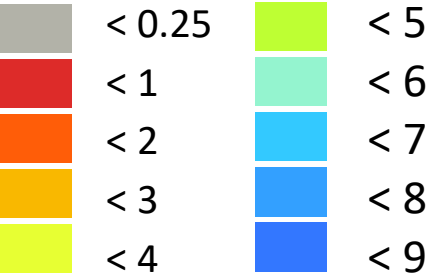
A hierarchical key is used to assess ecosystem services for maps and plans at different scales and with varying levels of detail (from overview mapping and conceptual planning down to the building block). The key allows for assessments based on very broadly defined land use units (settlements, grassland, cropland, forest, etc.) or highly differentiated data on biotope types according to LANUV (2013, partially supplemented) with up to four hierarchical levels. All approximately 600 biotope types predefined in EnhanceES are assigned parameters necessary for the calculations performed by the various tools.

|                                |                           |                                                    |
|--------------------------------|---------------------------|----------------------------------------------------|
| Settlement areas               | Urban structure           | Block development                                  |
|                                |                           | Perimeter block development                        |
|                                |                           | Terrace housing with green roof                    |
|                                |                           | Villas with park-like gardens                      |
|                                |                           | Terrace housing garden area                        |
|                                | Blue-green infrastructure | Sport and recreation facilities (with plants)      |
|                                |                           | Robust lawn                                        |
|                                |                           | Artificial ponds (park, ornamental, garden)        |
|                                |                           | Cemeteries                                         |
|                                |                           | Allotment gardens or similar                       |
|                                | Group of trees; tree rows | Trees row                                          |
|                                |                           | Group of trees                                     |
|                                |                           | Single tree                                        |
|                                |                           | Single fruit tree                                  |
|                                | Small woods               | Settlement woods                                   |
|                                |                           | Woods along traffic facilities                     |
|                                |                           | Shrubberies                                        |
|                                | Roads                     | Roads                                              |
|                                |                           | Residential roads                                  |
|                                |                           | Roadside margins                                   |
|                                |                           | Railways                                           |
| Grassland etc.                 |                           | Fertile meadows                                    |
|                                |                           | Wet pastureland                                    |
|                                |                           | Dwarf sedge reed, juncus swamp                     |
| Fields etc.                    |                           | Field                                              |
|                                |                           | Field fallow with perennial vegetation             |
|                                |                           | Field margin strip out of use                      |
| Forests                        | Beech forests             | Beech forest                                       |
|                                |                           | Beech and oak forest                               |
|                                |                           | Mixed beech forest with indigenous deciduous woods |
|                                |                           | Mixed beech forest with alien deciduous woods      |
|                                | Oak forests               | Oak forest                                         |
|                                |                           | Beech-oak forest                                   |
|                                | Spruce forest             |                                                    |
| Afforestation, pioneer forests |                           |                                                    |
| Forest fringe                  |                           |                                                    |



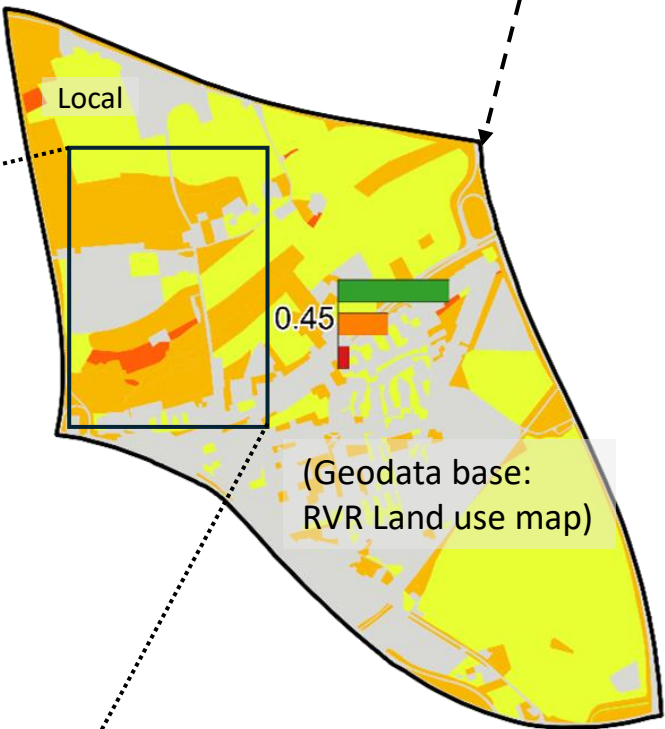
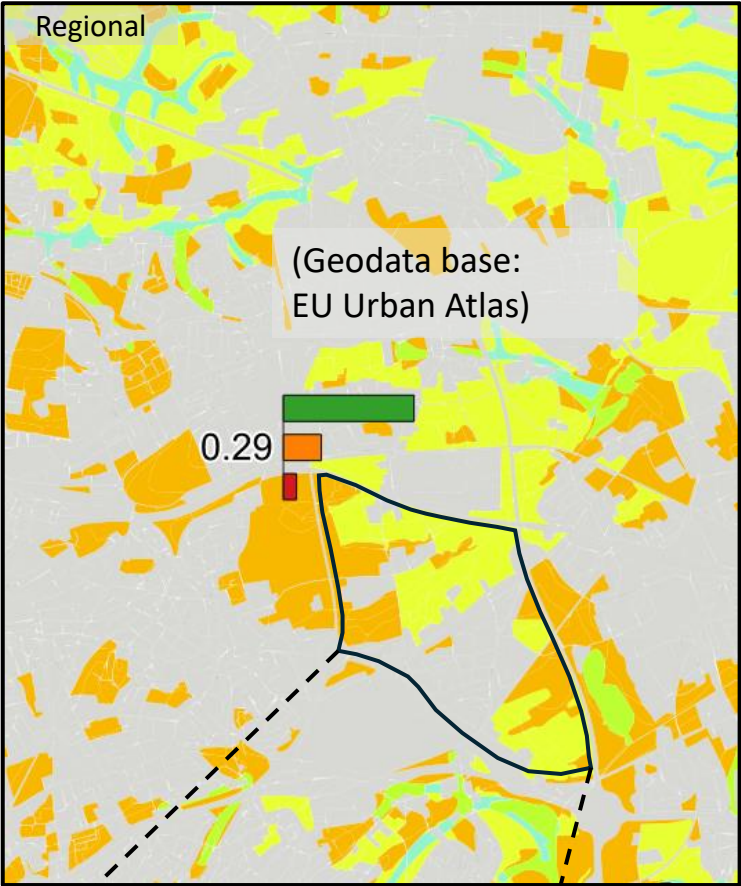
# Analyses on various scales and using various (online) publicly available geodata

Using the example of the cooling intensity [Kelvin]



The scale and level of detail of the source data influence the evaluation results:

- Spatial resolution increases.
- As the level of detail in the source data increases, the number of resulting evaluation classes also increases.



(Geodata base: Urban biotope type map and building footprints from Geobasis NRW)

## Ecosystems services covered

| Denomination                                   | Explanation interpreted and based on the generic descriptions in Haines-Young & Potschin (2018)                                                                                                       | CICESv5.1 code                                           |
|------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| <b>Provisioning ecosystem services</b>         |                                                                                                                                                                                                       |                                                          |
| Wood production                                | ... assesses the quantity of wood surplus ( $\text{g m}^{-2} \text{a}^{-1}$ ) of forest stands which can be harvested                                                                                 | 1.1.1.2                                                  |
| Groundwater                                    | ... assesses the quantity of yearly groundwater recharge ( $\text{mm a}^{-1}$ ) of soil-biotope units that can be used for drinking or nondrinking purposes                                           | 4.2.2.1 and 4.2.2.3                                      |
| Cultivated plants for nutritional purposes     | ... evaluates the site (landform, soil, climate, natural hazards) to repeatedly and sustainably bear edible plants (ranked by order)                                                                  | 1.1.1.1                                                  |
| <b>Regulating ecosystem services</b>           |                                                                                                                                                                                                       |                                                          |
| Mediation of waste - $\text{PM}_{10}$          | ... calculates how much particulate matter with a diameter of up to $10 \mu\text{m}$ is absorbed by the vegetated surfaces ( $\text{g m}^{-2} \text{a}^{-1}$ )                                        | 2.1.1.2                                                  |
| Carbon sequestration and carbon storage        | ...(or net primary production) models how much C from $\text{CO}_2$ ( $\text{g C m}^{-2} \text{a}^{-1}$ ) the biotopes take up from the atmosphere (climate mitigation)                               | 2.1.1.2                                                  |
|                                                | ... informs on how much carbon ( $\text{g C m}^{-2}$ ) is stored in the biomass of the biotopes. Carbon storage is not an ecosystem services, yet helpful to assess the value of the natural capital. | not an ES                                                |
| Visual screening                               | ... calculates percentages of a buffer area where an unsightly object(s) is screened from people's view                                                                                               | 2.1.2.3                                                  |
| Water flow regulation (Flash flood regulation) | ... indicates the capability of spatial units to retain the discharge ( $\text{m}^3$ ) of a single heavy rain event                                                                                   | 2.2.1.3a                                                 |
| Water flow regulation (Base flow regulation)   | ... assesses the yearly quantity of groundwater recharge ( $\text{mm a}^{-1}$ ) of soil-biotope units that contributes to base flow maintenance of streams                                            | 2.2.1.3b; indicator is equivalent to 4.2.2.1 and 4.2.2.3 |
| Pollination                                    | ... models the capability of biotopes to support pollinators "to do their job" (ranked by order)                                                                                                      | 2.2.2.1                                                  |
| Temperature regulation                         | ... models the cooling intensity (Kelvin or kWh) of urban green spaces (soil-biotope units) during a user-defined heat wave compared to sealed surfaces                                               | 2.2.6.2                                                  |
| Noise attenuation                              | ... assesses the ability of biotope unites to reduce noise emitted by user defined sources (ranked by order)                                                                                          | 2.1.2.2                                                  |
| Maintaining nursery populations and habitats   | ... estimates the capability of biotope types to maintain nursery populations of key species (birds) (ranked by order)                                                                                | 2.2.2.3                                                  |
| Water-(self)purification                       | ... evaluates the ability of waterways to mitigate pollutants by inherent stream characteristics and stream-accompanying vegetation (ranked by order)                                                 | 2.2.5.1                                                  |
| Reduction of contaminants by soils             | ... indicates the ability of different soil types to reduce contaminants by their buffer and filter functions (ranked by order)                                                                       | 5.1.1.3                                                  |

# Ecosystems services covered

|                                                                                                                       | Explanation interpreted and based on the generic descriptions in Haines-Young & Potschin (2018)                                                                                                                                                                                                                                                                                                                                                                                                                        | CICESv5.1 -Code              |
|-----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| Activities promoting recuperation through active interactions with nature                                             | ... evaluates delineated complex areas, such as parks, that combine characteristics of biotopes and technical infrastructure in a way that enables recuperation or enjoyment and promote health through active or immersive interactions with nature, (ranked by order)                                                                                                                                                                                                                                                | 3.1.1.1                      |
| Activities promoting recuperation through passive interactions with nature                                            | ... evaluates delineated complex areas, such as parks, that combine characteristics of biotopes and technical infrastructure in a way that enables recuperation or enjoyment and promote health through passive and observational interactions with nature (ranked by order)                                                                                                                                                                                                                                           | 3.1.1.2                      |
| Characteristics with significance for teaching and further education as well as for research and ecological knowledge | ... evaluates the active use of ecosystems as educational resources by assessing areas that combine features of biotopes and technical infrastructure (e.g. school gardens) in such a way <ul style="list-style-type: none"> <li>• that they can be used specifically to provide educational and informational opportunities, to impart knowledge and support educational processes or</li> <li>• that they can be used specifically to create knowledge and support scientific processes (ranked by order)</li> </ul> | 3.1.2.1 und 3.1.2.2          |
| Characteristics with natural, spiritual and symbolic meaning                                                          | ... evaluates complex areas that possess features of natural biotopes and, if applicable, combined with technical infra-structure in such a way that they include elements of nature with symbolic or spiritual meaning and support for cultural identity and heritage (binary scale with yes/no).                                                                                                                                                                                                                     | 3.1.2.3, 3.2.1.1 und 6.2.2.1 |
| Aesthetic experiences                                                                                                 | ... evaluates complex areas that possess features of natural biotopes and, if applicable, combined with technical infrastructure in such a way that they include elements of nature with symbolic or spiritual meaning and support for cultural identity and heritage (binary scale with yes/no).                                                                                                                                                                                                                      | 3.1.2.4                      |

The ecosystem services selected for EnhancES include key natural services in urban and peri-urban landscapes that promote human well-being and health.

EnhancES makes it possible to measure and compare ecosystem services in order to enhance them, for example through targeted measures to improve green infrastructure.

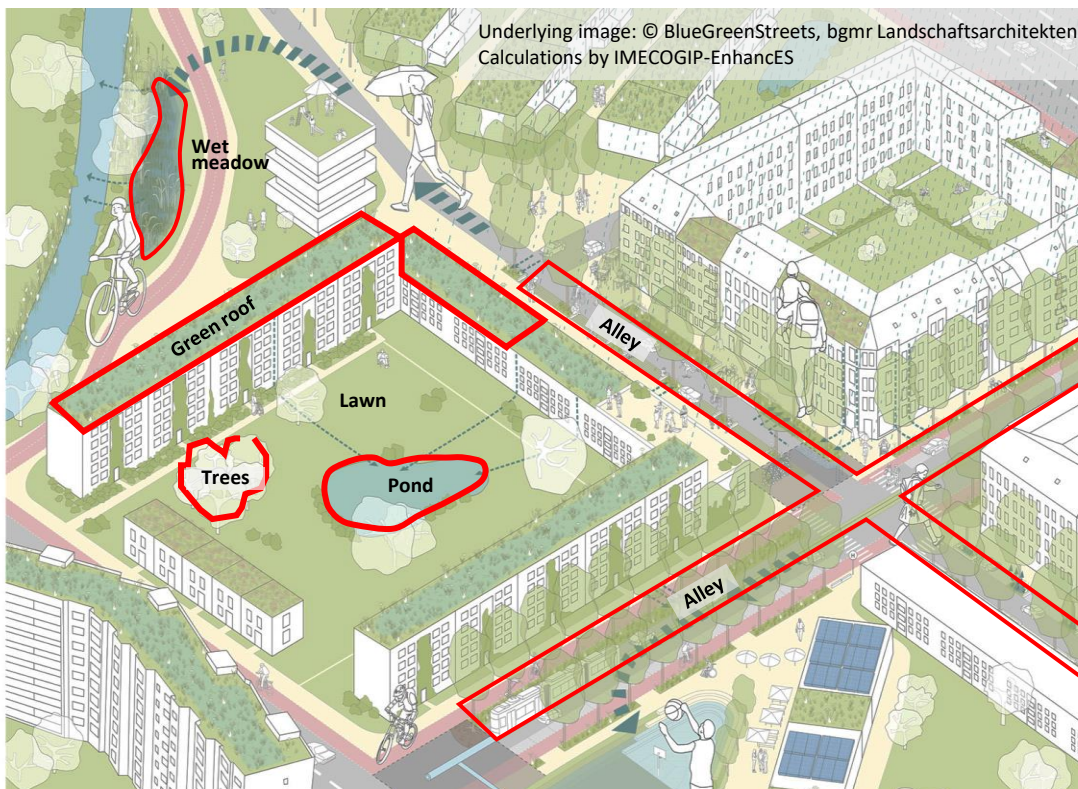




## Application 1:

### Improving Quality of life through green-blue infrastructure

What impact on ecosystem services can be expected?



From the vision ...

... to maps  
with coded  
biotope types



... to ecosystem  
services



Pollination



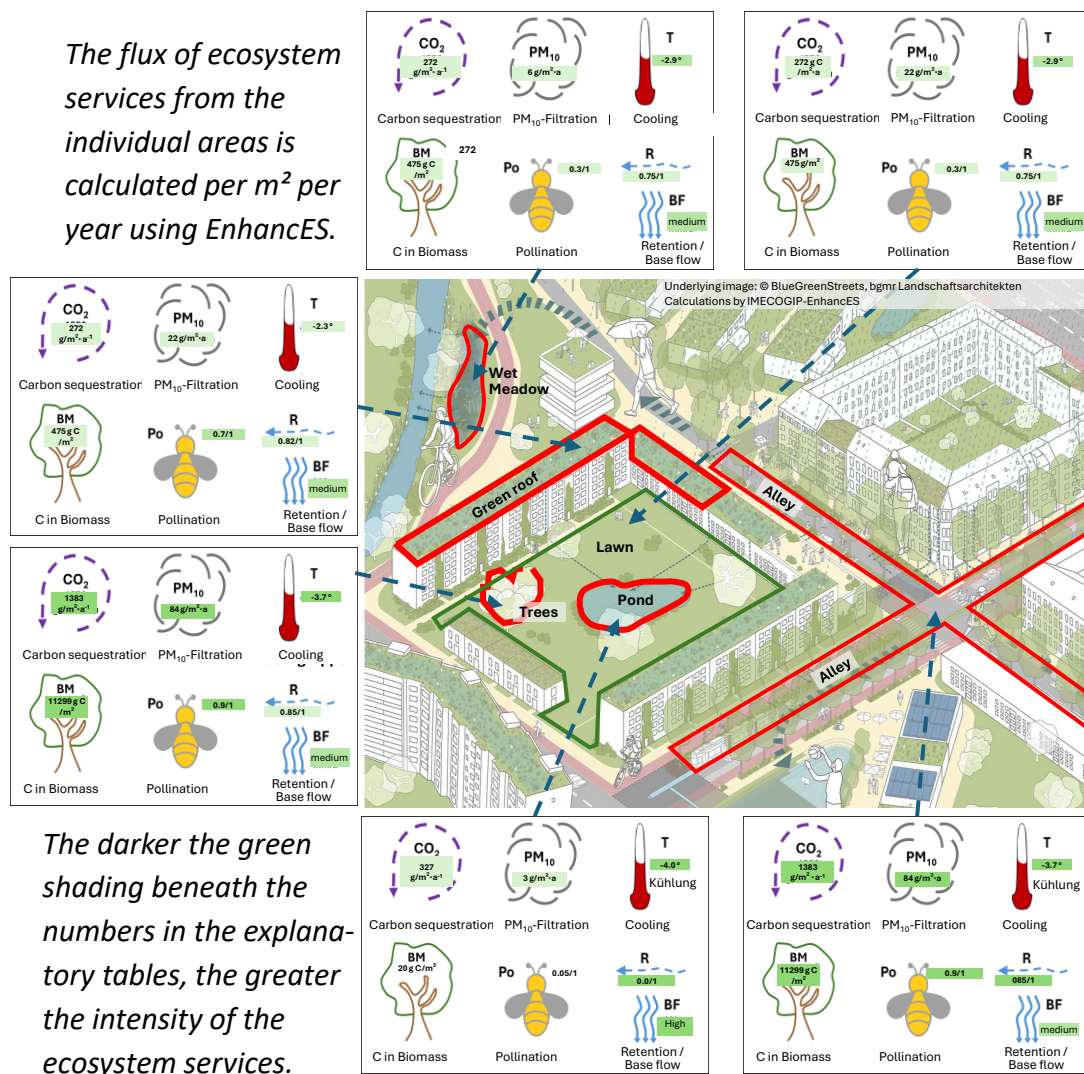
Carbon sequestration



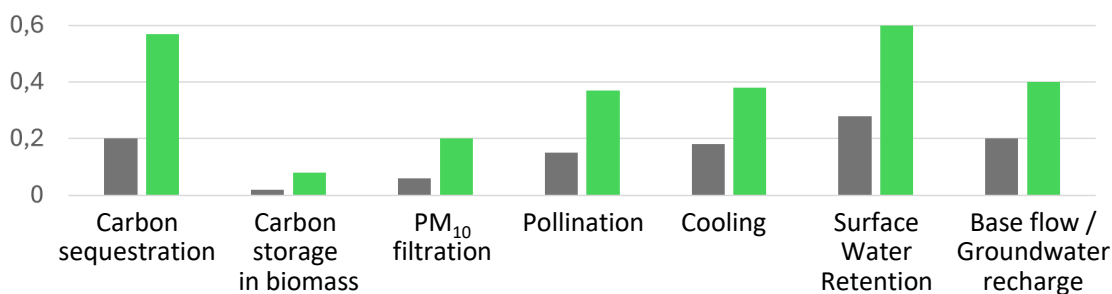
Surface water retention

## Visualization and Before-and-After Comparison

EnhancES calculates ecosystem services from each individual area in physical units (e.g., mm/year) or as ratios (e.g., 0.6/1). The figure below shows examples of some green-blue areas (outlined in red).



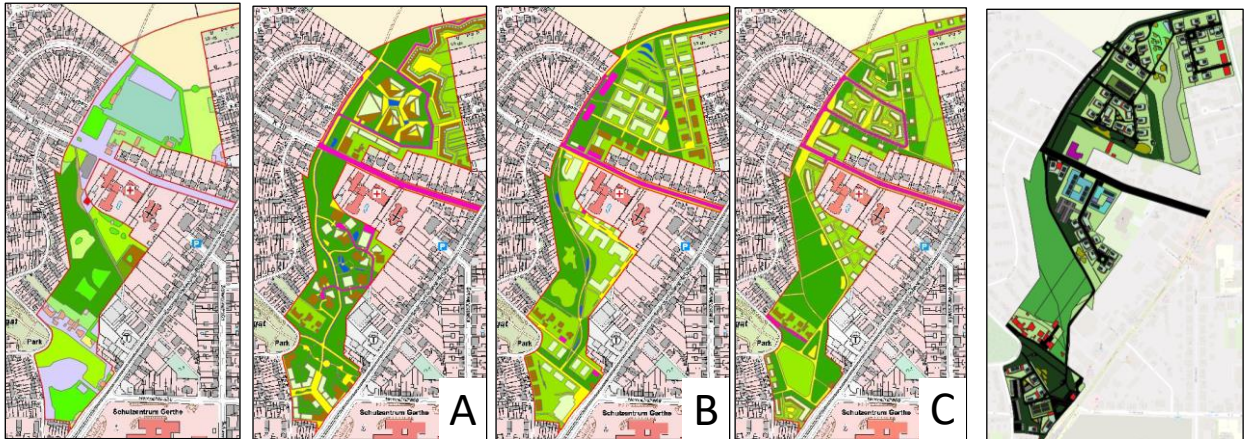
The standardized values for Carbon storage in biomass and six ecosystem services reveal the increases that are possible if all measures are implemented.





## Application 2:

### Land Use and Zoning Planning: A Comparison of Plan Options

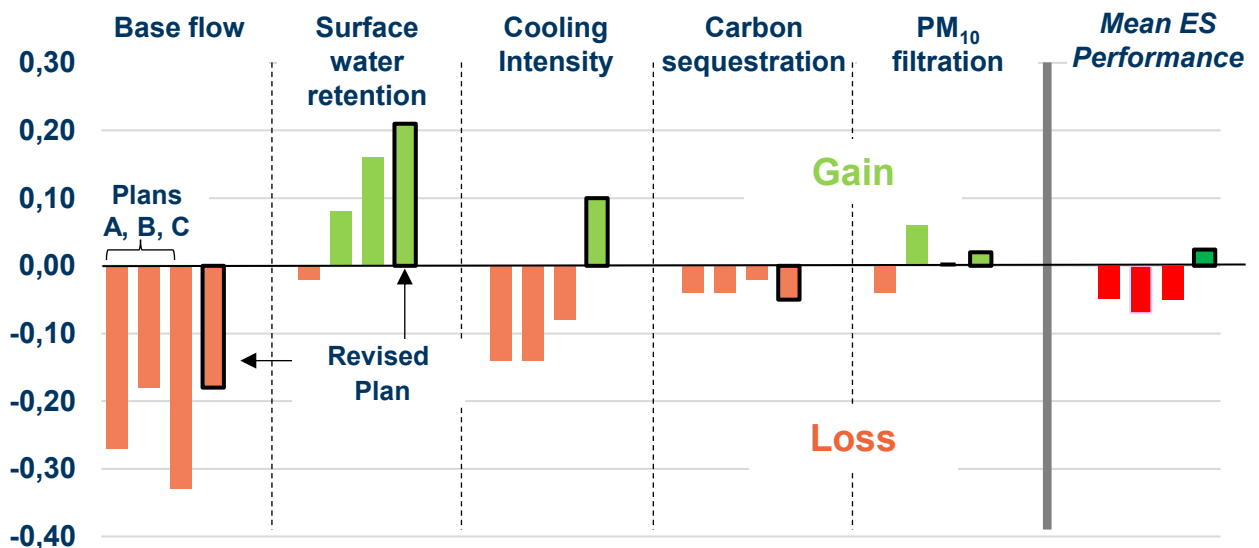


**Present**

**Plans A, B u. C**

**Revised  
plan**

A present mixed-use area (see figure on the left) is to be developed into a residential area. Following a multi-round design competition, three design proposals were submitted, along with a subsequently revised plan. Which plan promised the best ecosystem services compared to the site's initial condition?

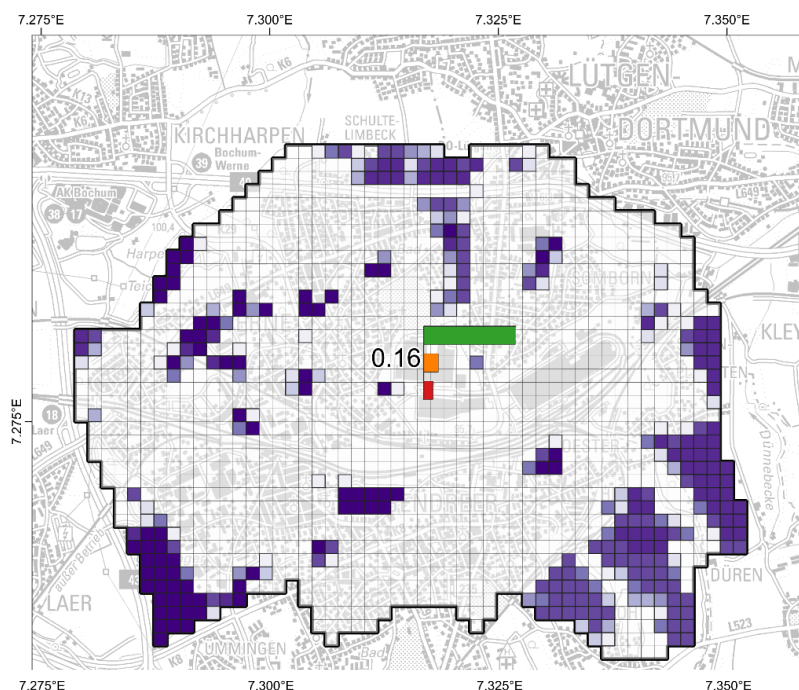


The bars show the standardized values (note: decimal commas) for five ecosystem services for each of the plans A – C as well as for the revised plan. Gains compared to the initial state are shown as green, upward-pointing bars, while losses are shown as red, downward-pointing bars. The expected impacts of the plans on ecosystem services vary greatly. Without weighting the ecosystem services, the revised plan would even promise an average gain in ecosystem services.



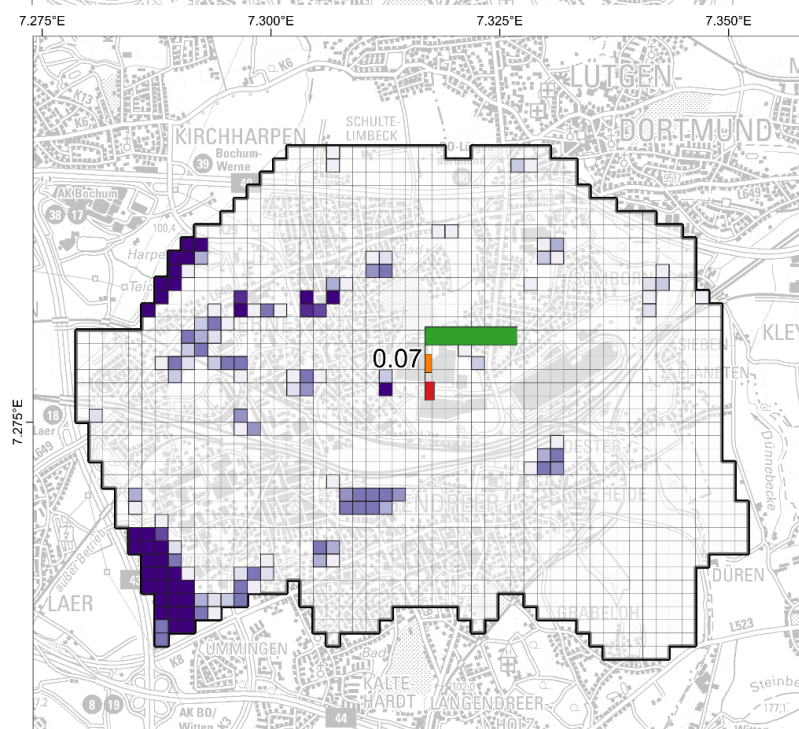
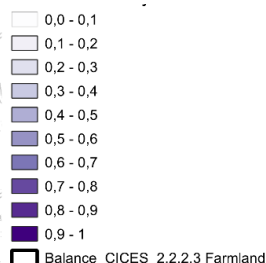
## Application 3: Supporting Biodiversity-Strategies

Biodiversity strategies are being developed and updated at all planning levels, from the EU down to the local level. In cities, habitats that are valuable for biodiversity and endangered species should be preserved, restored, or created. The EnhanceES tool ‘Maintaining nursery populations and habitats’ is based on ensemble species distribution models. It assesses suitability for five bird groups, known as guilds with specific habitat requirements: birds found on agricultural land, those dependent on open land, synanthropic species, aquatic species, and forest species. Synanthropic species are those that live in close association with humans in urban areas.



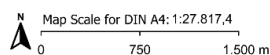
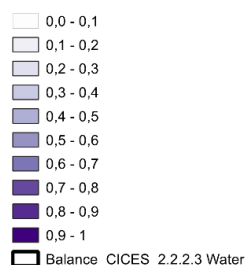
The map on the left shows the suitability for farmland guilds, while the map below shows suitability for the waterfowl guild.

### Birds on farmland

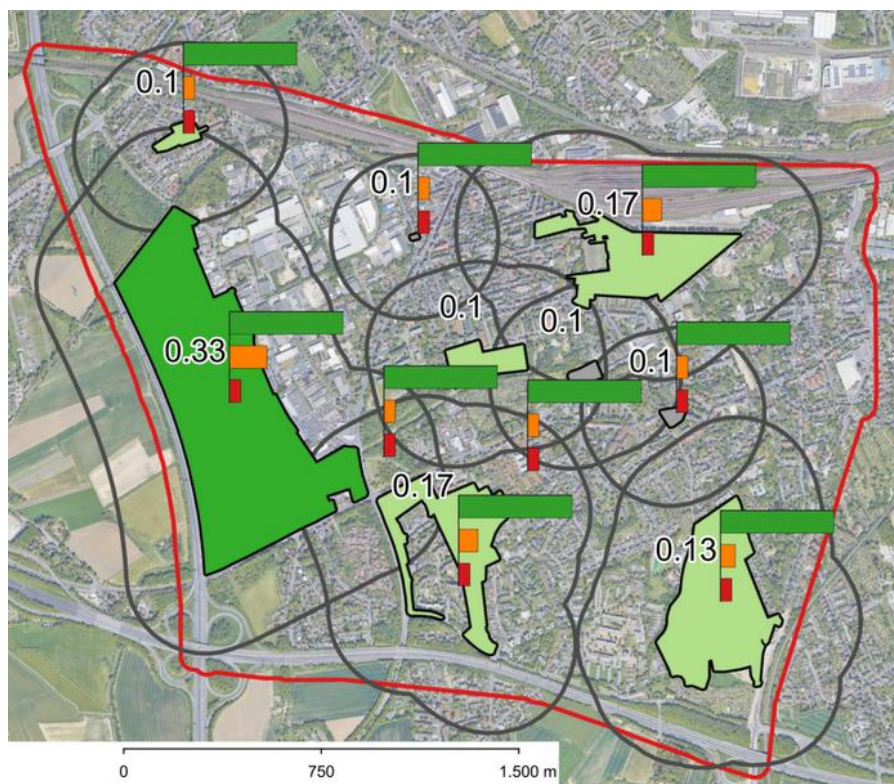


Each 100 x 100 m grid cell has a relative suitability value, which can be determined by referring to the colors in the legend.

### Waterfowl guild



## Application 4: Cultural ecosystem services in urban green spaces



Green spaces differ in terms of their biotope structures and technical infrastructure, as well as the number of potential users in their catchment area.

The map shows the relative suitability of urban green spaces to contribute to recreation through people's active interaction with nature. The orange bars and numbers represent the ratio of the respective green space to the park that achieved the highest score in the cities of Bochum and Gelsenkirchen.

## Application 5: PM<sub>10</sub> Filtration in a schoolyard



We assessed the impact of a schoolyard redesign on the provision of ecosystem services for a municipal government. The figure on the left shows particulate matter filtration under current conditions. The dark green areas generally represent shrub and tree vegetation. The future addition of extra vegetation shown in the figure on the right suggests an increase in PM<sub>10</sub> filtration from 108 kg/ha per year to 150 kg/ha per year. Furthermore, EnhancES enables quantitative assessments of changes in other ecosystem services. This allows the schoolyard to be optimized from an ecological perspective.



## Application 6:

### Strategic Urban Renewal Planning

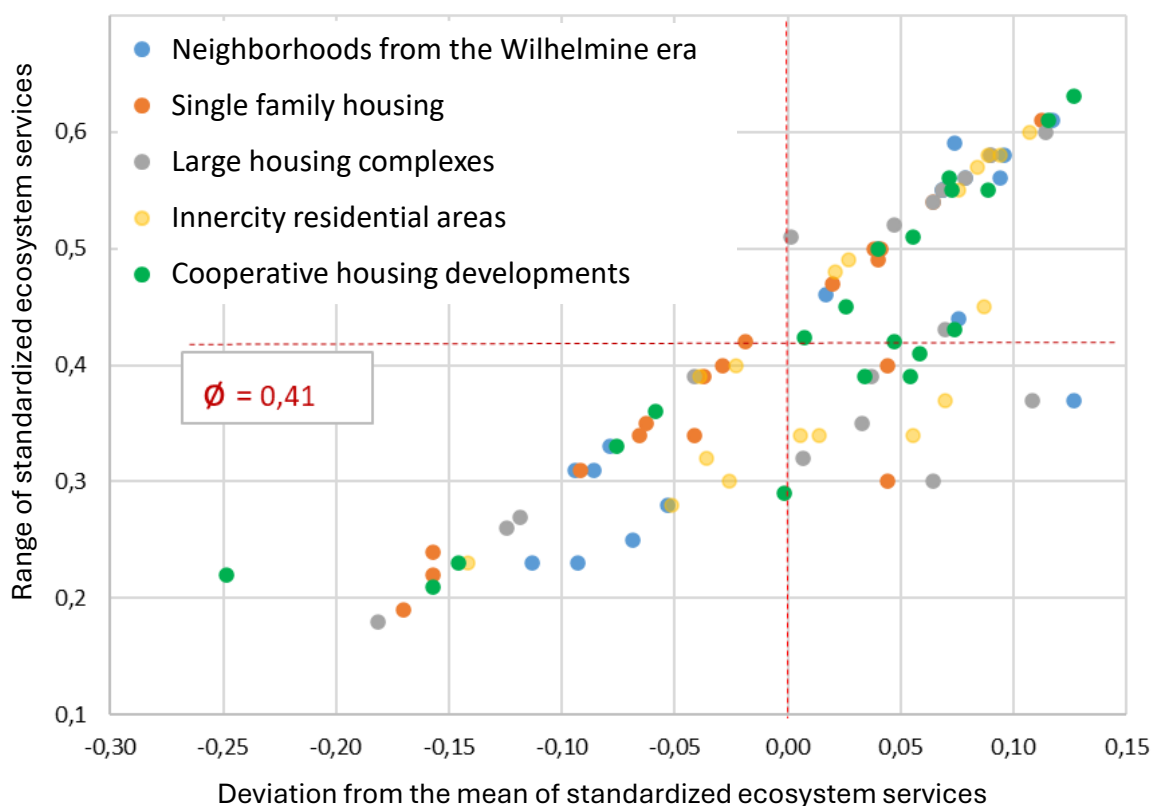
#### Where is action needed? Showcase achievements!



A livable city requires attractive residential areas. When applying for urban renewal grants, ecological improvements achieved through green infrastructure are important and must be demonstrated even before application of grants. Building blocks serve as ideal units of analysis for assessing strengths and weaknesses. An analysis of 115 building blocks with varying building structures in the central Ruhr region shows, for example, significant variations in average ecosystem services (x-axis) and differences between the highest and lowest ecosystem service values (contrasts) within the building blocks (y-axis). In only a few cases are clear distinctions discernible based on building structure types, which confirms the assessment based on the green infrastructure of the building blocks.

This type of visualization can serve the following purpose or answer the following questions:

- During the urban renewal planning process, the expected environmental improvements can be visualized and optimized through green infrastructure.
- In which building blocks is there a need for improvement?
- What changes have recently implemented renewal measures brought about?



The following regulating services were taken into account: particulate matter filtration (PM<sub>10</sub>), carbon sequestration and storage, heavy rain retention, baseflow discharge, habitat suitability for pollinating insects, and temperature regulation. (Note decimal commas)



## Typical application fields of EnhancES

- Analyze, identify, and assess the strengths and weaknesses of ecosystem services throughout the urban area. Evaluate spatial disparities.
- Analyze and clearly articulate how gains or losses of protected goods of nature and green infrastructure impact the provision of ecosystem services.
- Develop ecosystem service standards specific to your city or region.
- Supplement existing nature conservation requirements with additional sustainability indicators provided by the toolbox.
- Compare and optimize the ecosystem services of different planning options.
- Plan nature-based solutions based on ecosystem services.
- Improve and expand participatory processes by transparently presenting ecosystem services to informed citizens.
- Support grant applications for urban renewal and green infrastructure with quantitative statements of expected ecosystem services.



## The value of EnhancES

- All analyses are performed in an open-source QGIS environment.
- Input and output are handled seamlessly via geodata.
- Several tools model the ecological interactions of soil-water-vegetation complexes.
- Pre-installed land use/biotope (e.g. WorldCover, EU Urban Atlas, Urban Biotope Classification) and soil classifications for Germany, specifically North Rhine-Westphalia.
- EnhancES works with geodata available online (land use, biotopes, soils).
- EnhancES is open-source, allowing for custom modifications (land use, biotopes, soils).
- Scalable, i.e., adaptable to different spatial scales.
- User-friendly, quick tool runs.
- EnhancES is free.

## Software, Manual, Methodology, References & Literature, Explanatory Videos



<https://www.geographie.ruhr-uni-bochum.de/physik/imecogip.html.de>

imecogip@rub.de  
Prof. Dr. Harald Zepp



**We offer free training during IMECOGIP-EnhancES implementation phase.  
Please contact us.**