

**CLEARINGHOUSE**  
中欧城市森林应对方案

# A NOVEL TYPOLOGY FOR URBAN FORESTS AS NATURE-BASED SOLUTIONS



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°821242. Several Chinese CLEARINGHOUSE partners have also contributed to the funding.

该项目获得欧洲H2020**研究与创新计划**的资助（拨款协议号码：821242）。部分中国合作伙伴也为此提供了资金。



# Urban forests as nature-based solutions contribute to sustainable urban development.

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CLEARING HOUSE is a *Sino-European project* jointly coordinated by the European Forest Institute (EFI) and the Research Institute of Forestry at the Chinese Academy of Forestry (CAF-RIF). *Together with 10 cities and urban regions, the CLEARING HOUSE project will ...*

- ... **increase the evidence** about benefits from restored urban ecosystems by **mapping** how urban forests are used/managed as NBS, **surveying societal perceptions and demands** in Europe and China and by **preparing a comparative case study analysis** in 10 paired cities between China & Europe
- ... **analyse** the respective **policy frameworks in Europe and China**, e.g., to **make a business and investment case for urban forests as NBS**
- ... **establish a collaborative learning process** focusing on inner-city afforestation, air purification, heat-wave mitigation, outdoor recreation, river catchment restoration, mining site restoration, urban regeneration, socio-cultural integration and other services
- ... **develop** user-friendly UF-NBS tools such as **guidelines for cost-effective urban ecosystem restoration, a benchmarking tool and an online application**



48 MONTHS

26 PARTNERS

11 COUNTRIES

10 CITIES AND URBAN REGIONS

The European case studies are Barcelona, Brussels, Gelsenkirchen, Krakow and Leipzig-Halle. Their experiences will be shared and compared with those of Beijing, Hangzhou, Hong Kong - Guangzhou - Shenzhen, Huaibei, and Xiamen in China.

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# “Mission Statement”

- UF-NBS as subset of nature-based solutions generally comprising tree-based green infrastructure
- Important tools to build more resilient, more livable cities and facilitate sustainable urban development: Trees and forests as *proven* nature-based solutions to address environmental and societal challenges



# Objectives of the UF-NBS typology

- **Provide a standardised Sino-European UF-NBS typology:** Take inspiration from existing typologies, e.g., GREEN SURGE (Cvejić et al., 2015), Nature4Cities (Nature4Cities, 2018), Urban Nature Labs (Eisenberg & Polcher, 2019), ThinkNature (Nikolaidis et al., 2019), and consider findings from a literature review ([review.clearinghouseproject.eu](http://review.clearinghouseproject.eu))
- **Provide grounding knowledge**, e.g., for the tools to be developed in CLEARING HOUSE



# Nature-Based Solutions

- NBS represent solutions that are “inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.” (EC, 2015)
- NBS are “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.” (IUCN)



# Nature-Based Solutions

- NBS to **deliver a range of ecosystem services: Multifunctional solutions** to address challenges using nature and natural processes (Sgrigna, 2021)
- **Umbrella term** touching upon and/or evolving previous, neighboring concepts (Almenar et al., 2021; Somarakis et al., 2019)

**Ecological restoration**

**Ecosystem-based disaster risk reduction**

**Ecosystem Services**

**Green-Blue Infrastructure**

**Urban Forestry**



# Urban Forests as Nature-Based Solutions

## Conceptual definition of the Urban Forest

The urban forest is **defined to comprise all trees in the urban area** (Konijnendijk, 2003). **This includes city parks and urban forests, gardens with trees, trees on streets or in public squares, and any other green spaces with trees, such as riparian corridors, rooftops, and nurseries** (Endreny, 2018; Davies et al., 2017).

## Green-blue infrastructure (GBI)

In the context of an urbanized environment, green and blue infrastructure is to be **understood as all natural and semi-natural landscape elements that (could) form a green-blue network**. It can refer to landscape elements on various spatial scale levels: from individual rows of trees to complete valley systems (Green4Grey, Vlaamse Landmaatschappij).



# Urban Forests as Nature-Based Solutions

## Proposition I

UF-NBS present themselves as “**compositions of things**”<sup>2</sup>, hence, describing their composition as well as spatial context and/or institutional and management characteristics may result in distinct types of UF-NBS

<sup>2</sup> later here referred to as green, blue, and grey landscape elements

## Proposition II

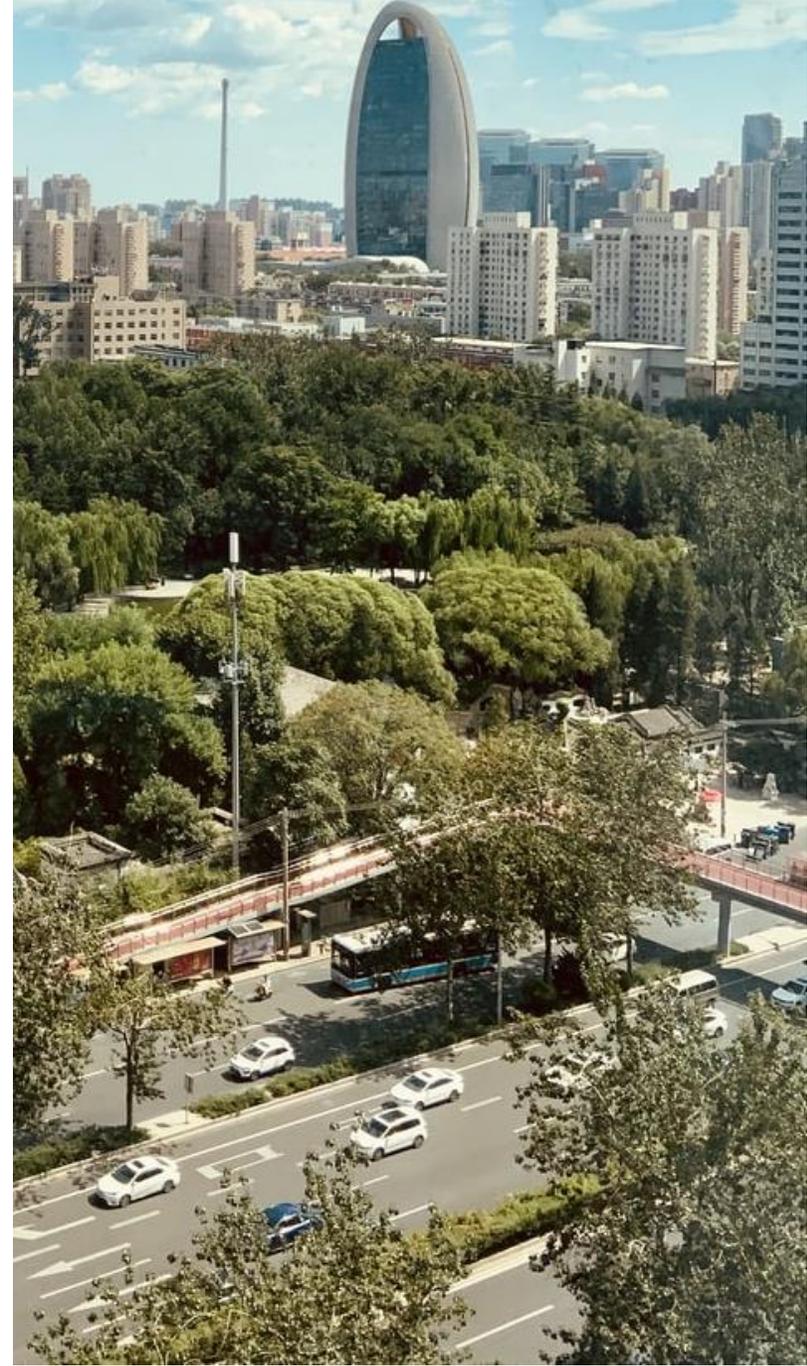
Previous research has emphasized that in urban systems, many different factors—particularly landscape and urban **patterns**, i.e., the urban morphology—**affect** conditions and thus **ecological functions and ecosystem service delivery** at multiple spatiotemporal scales

(e.g., Alberti, 2005; Alberti & Marzluff, 2004; Bierwagen, 2005; Holt et al., 2015; Koc et al., 2016; Pan & Du, 2020; Wang et al., 2019; Whitford et al., 2001)





Two realizations of a common type of green element (green verges) exemplifying that composition may be a key aspect. Whilst the example on the left cannot be considered an UF-NBS, the example on the right constitutes a part of the urban forest and may thus also be an UF-NBS.



## Concept and design

1,

Describe UF-NBS on the basis of characteristic traits, including, e.g.,

morphology (form, composition), spatial context and arrangement (topology), function, institutional characteristics etc.

2,

Consider the notion of UF-NBS as spatial entities of the GBI, as well as in terms of representing actions/types of interventions



## Concept and design

### Methodologically,

- **Semantic modelling:** process of organizing (unstructured) information to express relationships amongst entities (their semantics)
- **Ontology as knowledge management system** for the typology
- Ontology as **formal description of knowledge** (as a series of statements of facts, i.e., axioms) about entities relevant within a given domain (a subject). It thus provides a **vocabulary of terms** for use in a specific domain and **describes relationships between terms** (Baader et al., 2004).

### Technically,

- the proposed ontology is implemented using **Web Ontology Language (OWL)**
- We propose to use **Controlled Natural Language** to alleviate problems in readability of OWL declarative statements



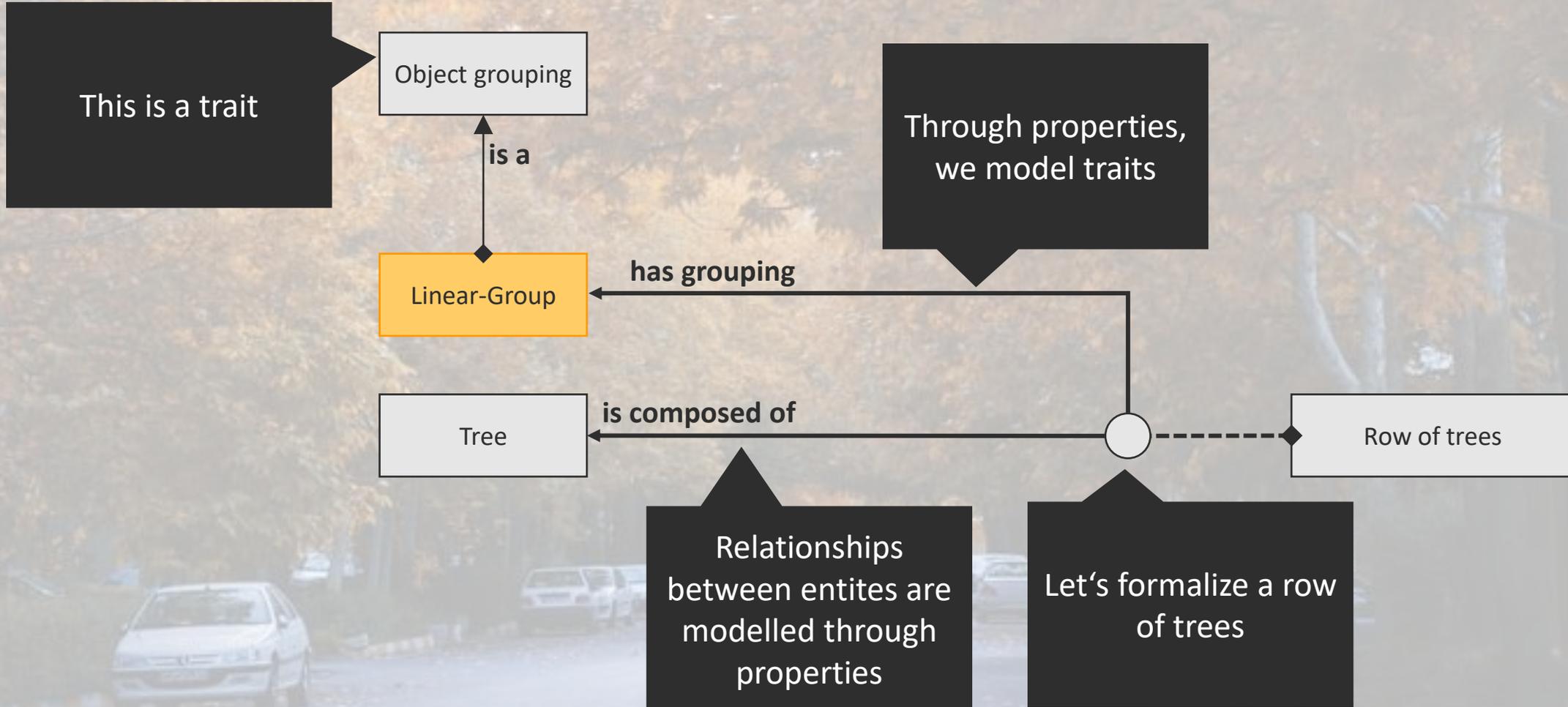


Identify relevant  
entities

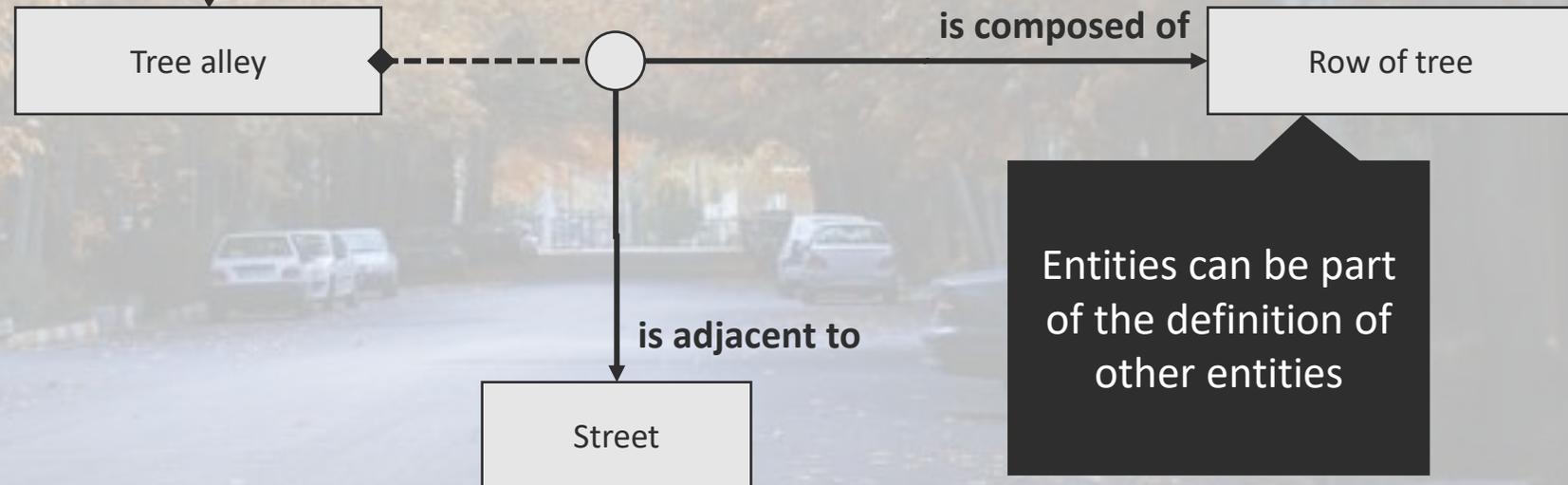
Tree

Street

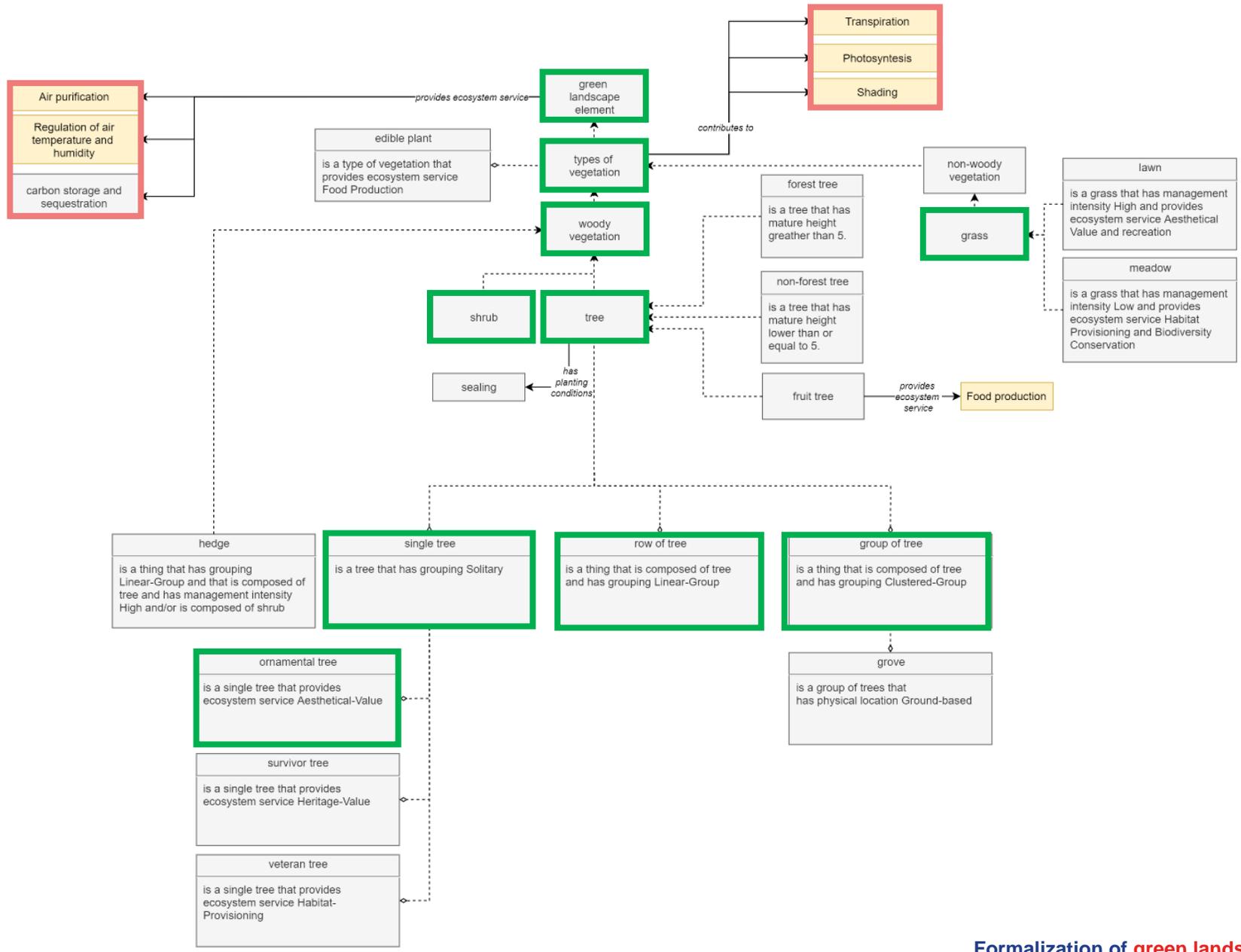
Row of trees



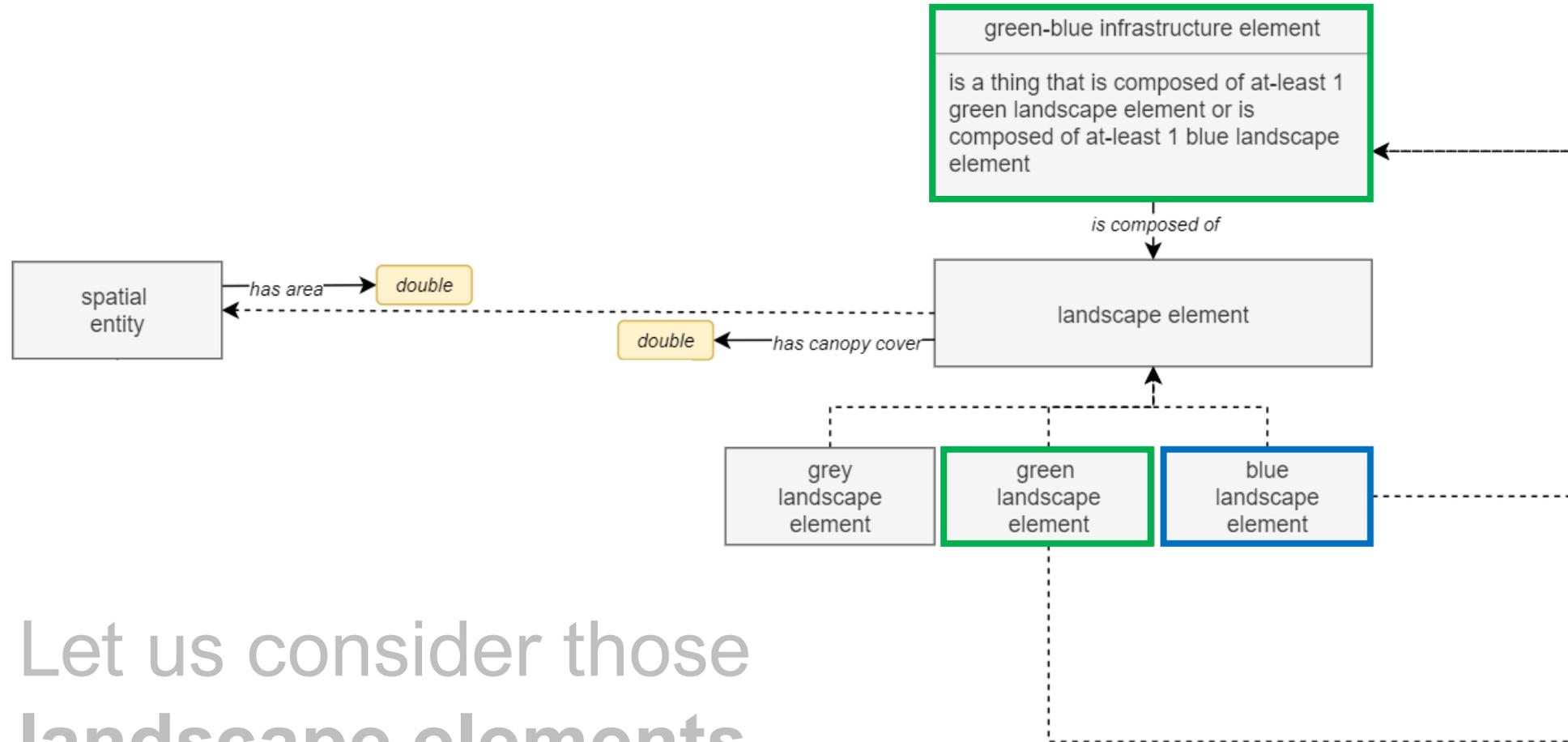
Through traits, we  
differentiate and  
define types of UF-  
NBS



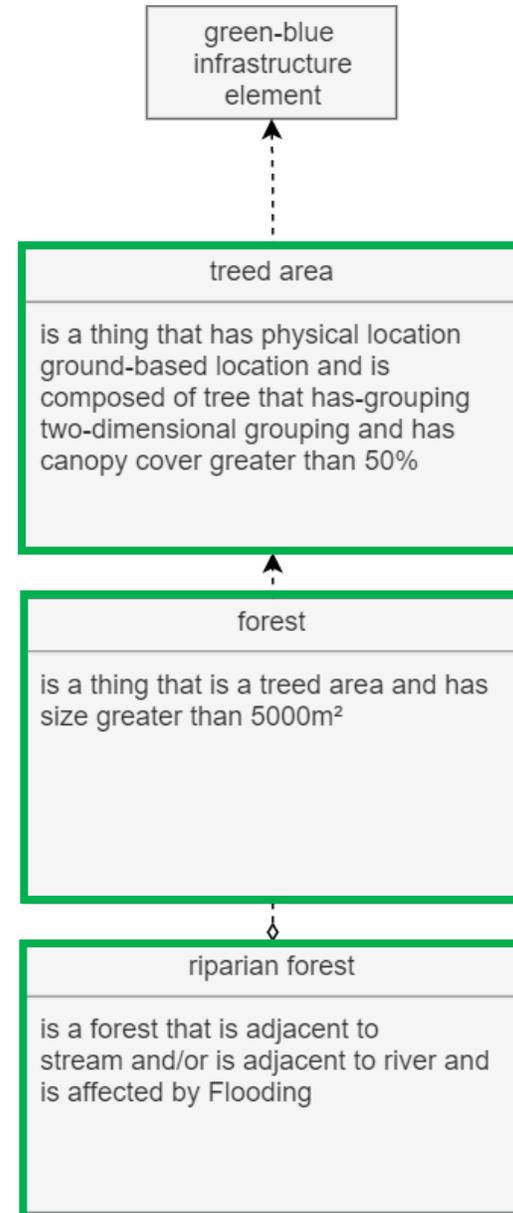
Entities can be part  
of the definition of  
other entities



Formalization of green landscape elements, including tree as a core entity, and proposing trees traits for subsequent linking to databases.



Let us consider those  
landscape elements  
as „building  
blocks“ ...



## ... and build a forest!

### How is a forest (stand) defined?

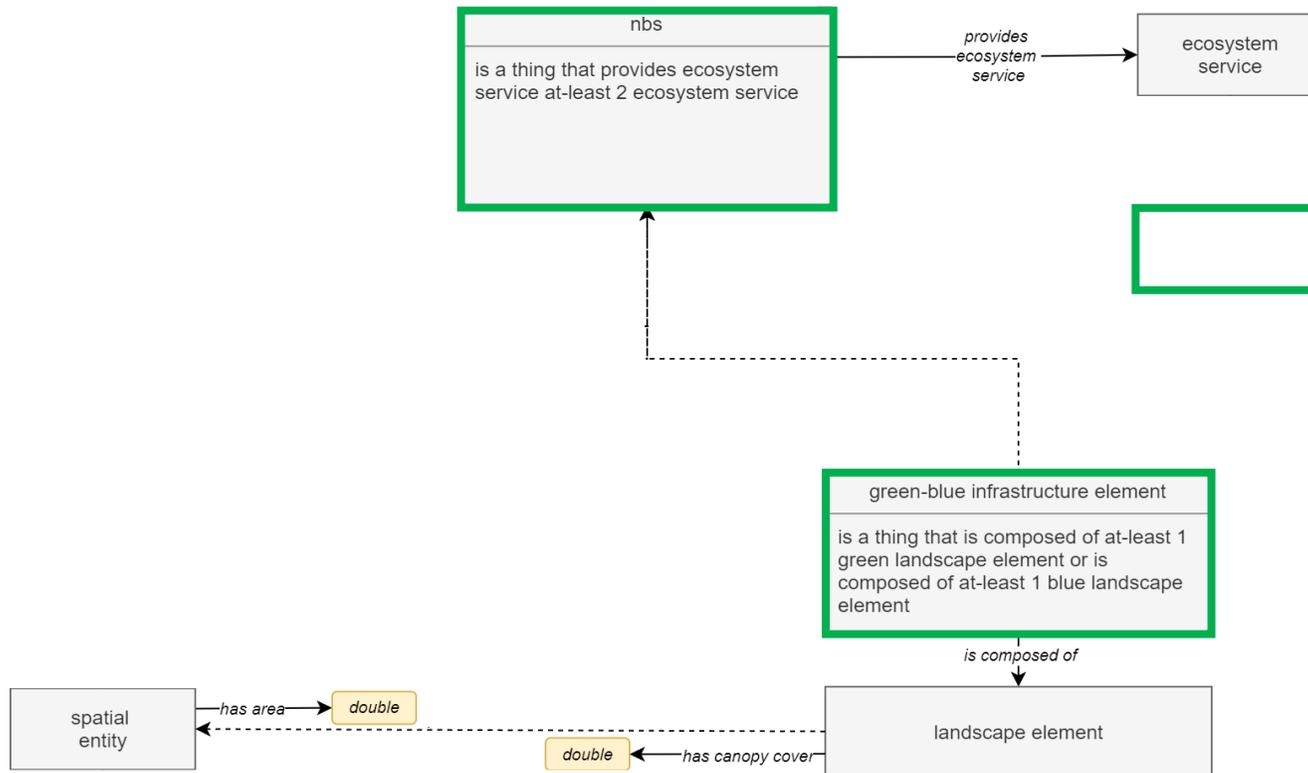
Generally, a forest can be understood as an **area dominated by trees**. Janssen & Rosu (2015) consider a tree-dominated area those areas with a canopy cover of at least 50%.

Moreover, following FAO (2018), a forest is **a portion of land bigger than 0.5ha** (5000m<sup>2</sup>), covered by forest trees.

Examples of **formalized types of green-blue infrastructure elements**, and by extension UF-NBS: **Treed area, forest, and riparian forest**. Formal declaration of **synonymous terms** wood and floodplain forest.

Overview of formalized types of (UF-)NBS, conceptualized as elements of the green-blue infrastructure.

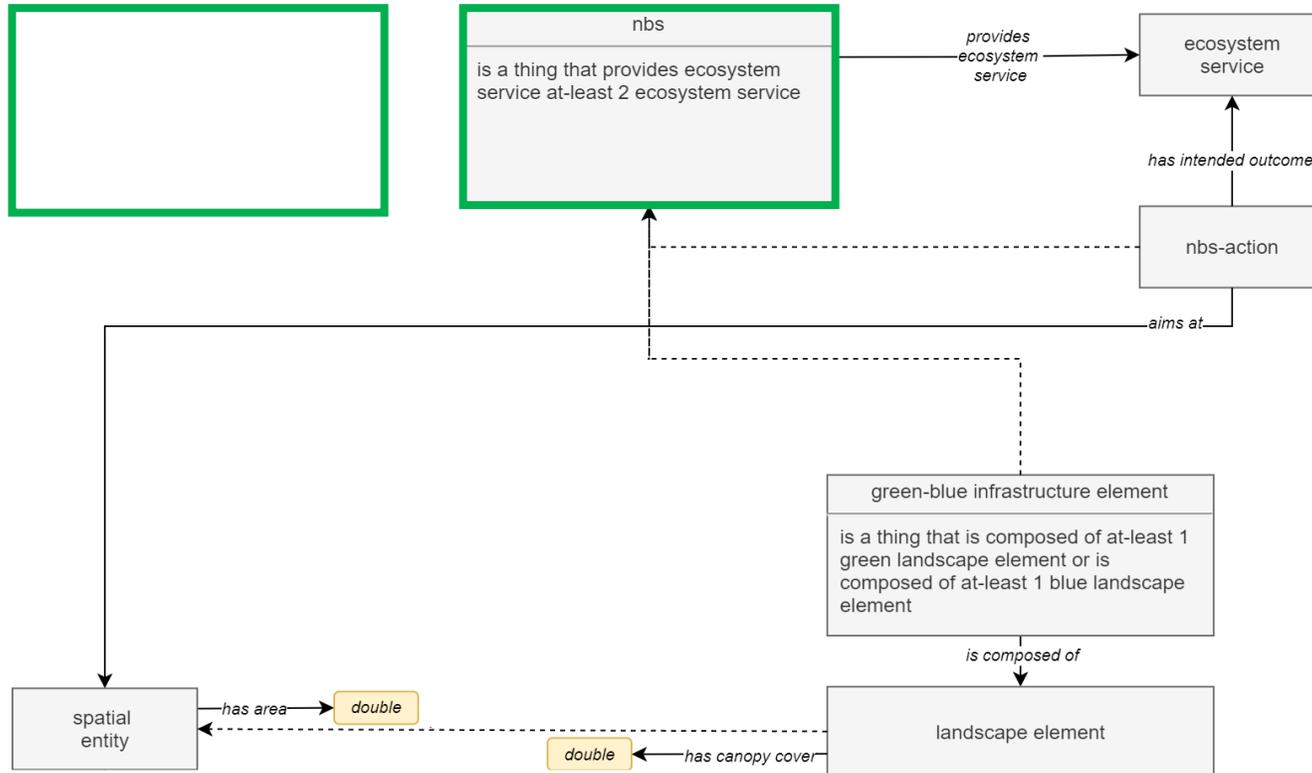
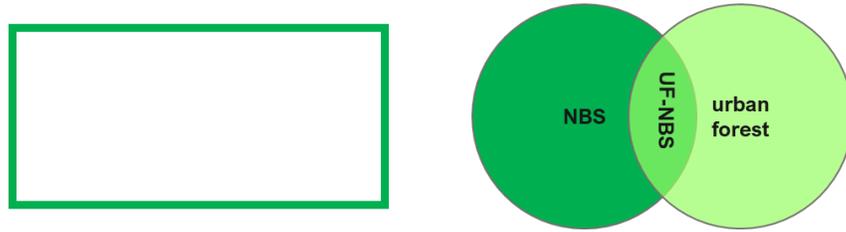
Group	Type	Remark
Forests as natural and semi-natural areas	<b>Treed area (wood), forest, riparian forest (floodplain forest)</b>	
Urban food forest, plantations	<b>Orchard, nursery, forest plantations</b>	
Urban green areas	<b>Riverbank green, urban park, botanical garden, historical park, allotment garden, community garden, neighbourhood green space, house garden, courtyard green</b>	Generalized as parks and gardens
Associated with urban networks	<b>Green verge, margin, railroad bank, single street tree, tree alley</b>	
Other	<b>Cemetery, arboretum</b>	
Associated with buildings and structures	<b>Green roof, green wall, balcony green, atrium, vegetated pergola</b>	



Now, how does a  
GBIE become a  
NBS?

Overview of formalized types of (UF-)NBS, conceptualized as actions.

Group	Characteristics	Type	Remark
Implementation action	Seek <i>provisioning of additional benefits/ecosystem services</i> through implementation of additional UF-NBS	<b>Afforestation, wetland construction</b>	Generalized as greening
Restoration action	Seek the <i>improvement of ecosystem services delivered</i> by a given UF-NBS	<b>Reforestation, wetland restoration, orchard restoration, enrichment planting (species diversification)</b>	Generalized as greening
Management action	Seek the <i>maintenance of current ecosystem service delivery</i>	<b>Tree monitoring, forest monitoring, tree pruning, tree watering, pest management, forest conservation</b>	



And so, when do we consider NBS to be an UF-NBS?

## Concept and design

### Methodologically,

- We propose to use an **ontology** as **knowledge management system** for the typology
- Implemented through **semantic modelling**: process of organizing (unstructured) information to express relationships amongst entities (their semantics)
- **Ontology** as **formal descriptions of knowledge** (as a series of statements of facts, i.e., axioms) about entities relevant within a given domain (a subject). It thus provides a **vocabulary of terms** for use in a specific domain and **describes relationships between terms** (Baader et al., 2004).

### Technically,

- Ontology implementation in the **Web Ontology Language (OWL)**
- Use **Controlled Natural Language** to alleviate problems in readability of OWL declarative statements



Comment: 'Define classes and their taxonomy:'.

Every tree is a woody-vegetation.

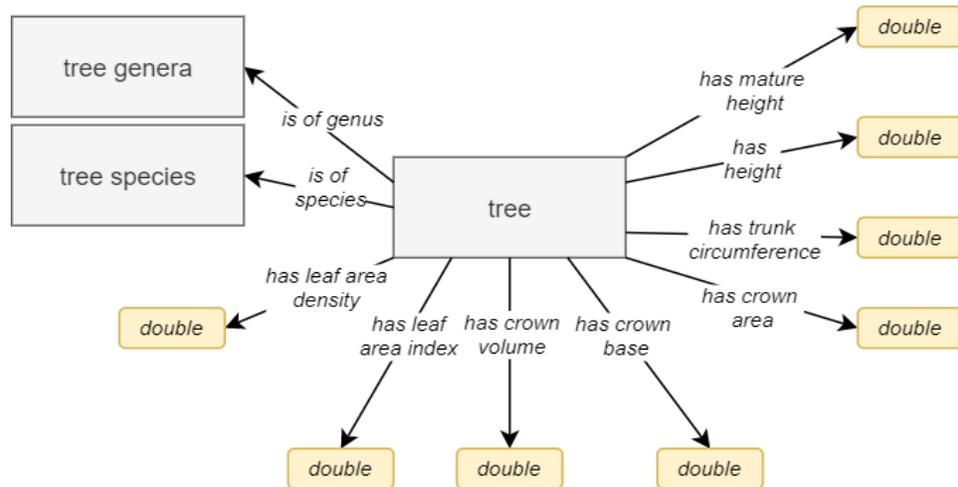
Every woody-vegetation is a type-of-vegetation.

Every type-of-vegetation is a green-landscape-element.

Comment: 'Relationships between concepts and ecosystem services:'.

Every type-of-vegetation contributes-to Transpiration .

Every-single-thing that contributes-to Transpiration provides-ecosystem-service Regulation-Of-Air-Temperature-And-Humidity .



## Machine-readable knowledge representation

- „Understood“ by software tools

## Support reasoning and inference

- Enable querying of knowledge
- Infer information from provided data

## Re-usable end extendible

- Include additional bodies of knowledge
- Link databases and models



CLEARINGHOUSE  
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## CLEARING HOUSE Typology on Urban Forests As Nature-Based Solutions

Authors: Sebastian Scheuer, Jessica Jache, Thilo Weilmann, Manuel Wolff, Dagmar Haase, and the CLEARING HOUSE project.

Download serialization:

Format: [RDF/XML](#) [Format: RDF/XML](#) [Format: N-Triples](#) [Format: TTL](#)

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Visualization:

[Visualize with WebViz](#)

Cite as: Scheuer, S., Jache, S., Weilmann, T., Wolff, M., & Haase, D. (2021). Outlining a semantics-based Sino-European UF-NBS typology (Deliverable 1.1). H2020 project CLEARING HOUSE, grant no. 821242.

### Abstract

This deliverable outlines the CLEARING HOUSE typology of urban forests as nature-based solutions (UF-NBS). The typology thus conceptualizes entities relevant to UF-NBS. To do so, elements of the green-blue infrastructure (GBI) are defined in the typology. Contrary to purely textual representations of knowledge, CLEARING HOUSE proposes a definition of GBI elements through traits, i.e., characteristic and defining morphological, physical, functional, and institutional attributes, including for example the composition, spatial grouping and topology of (UF-)NBS elements, and the ecosystem services and benefits provided them. CLEARING HOUSE proposes a semantic approach to express this knowledge, i.e., a formalization of knowledge as an ontology using the Web Ontology Language. Such ontologies are machine-interpretable series of statements of facts to define a taxonomy (a vocabulary). The definitions of GBI elements are embedded within a formalization of overarching concepts, particularly, of urban forest nature-based solutions (NBS), and of UF-NBS. Here, urban forest is conceptually understood as the entirety of trees within an urban-ecological system. NBS are perceived in CLEARING HOUSE as an overarching concept that embraces natural and semi-natural elements of the GBI such as forests, engineered solutions such as permeable pavements, as well as actions inspired by nature. UF-NBS are then conceptualized as the intersection of the two previous entities, i.e., as the intersection of urban forest and NBS, and thus include any tree-related NBS. The proposed typology will provide the grounding knowledge of the comparative case study analysis to be conducted by CLEARING HOUSE, and will serve as a basis for the development of the CLEARING HOUSE benchmarking tool.

### 1. Introduction

The purpose of the typology is: (i) to define distinct types of UF-NBS; (ii) to devise a systematic taxonomy of UF-NBS types; and (iii) to embed defined types and their taxonomical relationships within a definition of overarching concepts. These overarching concepts include the urban forest concept, the green-blue infrastructure concept, and the concepts of NBS and UF-NBS, respectively. The knowledge that will be formalized in this typology provides the grounding knowledge for the comparative case study analysis of CLEARING HOUSE and will provide one basis for the development of the CLEARING HOUSE UF-NBS benchmarking tool. Please see the [CLEARING HOUSE website](#) for more information.

#### 1.1. Namespace declarations

Table 1: Namespaces used in the document

[Ontology NS Prefix]	<http://clearinghouseproject.eu/typology/elements>
owl	<http://www.w3.org/2002/07/owl>
rdf	<http://www.w3.org/1999/02/22-rdf-syntax-ns>
terms	<http://purl.org/dc/terms>
xsd	<http://www.w3.org/2001/XMLSchema>
bibo	<http://purl.org/ontology/bibo>
rdfs	<http://www.w3.org/2000/01/rdf-schema>
default namespace	<http://clearinghouseproject.eu/typology/elements>
dc	<http://purl.org/dc/elements/1.1>

### 2. CLEARING HOUSE Typology on Urban Forests As Nature-Based Solutions: Overview

This ontology has the following classes and properties.

#### Classes

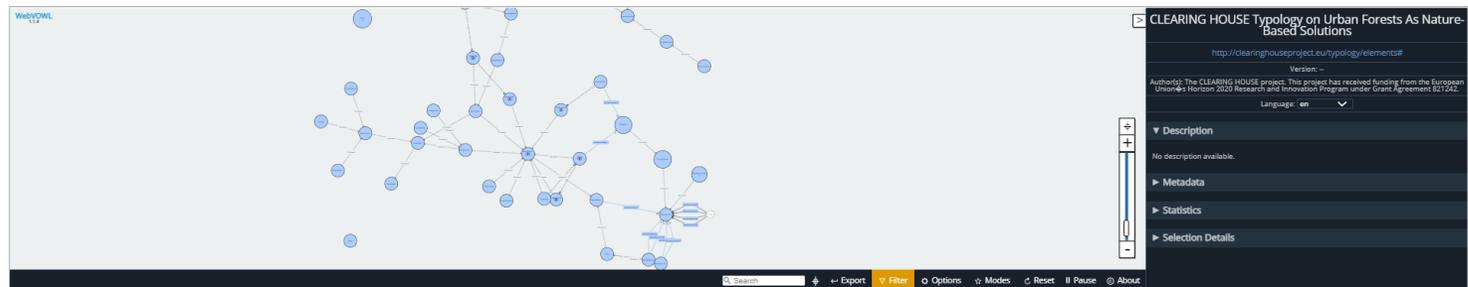
Action activity Afforestation Allotment Garden Arboretum Atrium Balcony Green bench blue landscape element Botanical Garden building Building-associated Green canal canoe cover Carbon Sequestration and Storage Cemetery Community Garden Courtyard Green Cultural Service Ecosystem Service advice class equipment element Entertainment Planning Entertainment fitness equipment Foodbank forest Forest Forest Conservation Forest Monitoring Forest Plantation Forest Tree Fruit Tree functional attribute Grass vine open landscape element Green Roof Green Verge green wall Green-Blue Infrastructure Element Greening grey landscape element ground based location Group of Trees grouping principle Grove hedge historical garden Historical Park House Garden Implementation Action institutional accessibility Institutional attribute Interaction with Nature lake landscape element Lawn location not associated with a support structure location on building location on support structure Management Action management intensity margin Meadow morphological attribute multistorey building Nature-Based Solution Neighbourhood Green Space network infrastructure element Network-associated Green non forest tree Non-wood vegetation Nurseries object feature object category One-Dimensional Grouping (1D) Orchard Orchard Restoration Ornamental Tree Parks and Gardens path permanent standing water permeable pavement pest control pest management physical attribute physical location physical access phenomenon plantation forest Planting Activity playground Pollution Removal pond private house process phenomenon Prunus Service Railroad Bank Recreation Reforestation regular patterns Restorable equipment rest control rest management physical attribute physical location Riverbank Green Row of Trees sealing shrub Single Street Tree Single Tree skate park spatial entity species diversification species diversity sports field square stream Street Trees Supporting Service Survivor Tree track Tree Tree alley Tree Monitoring tree opening tree watering Treated Area Two-Dimensional Grouping (2D) type of vegetation Urban Food Forest Urban Forest Urban Park Urban Forest as Nature-Based Solution Wapitiated Florida Veteran Tree Water Flow Regulation watercourse wetland Wetland Construction Wetland Restoration wood wood vegetation Two-Dimensional Grouping (2D)

#### Object Properties

aims at has entitlement has grouping has institutional accessibility has intended outcome has management intensity has part has physical location has species diversity is adjacent to is affected by is composed of is enclosed by is fully enclosed by is part of provides the ecosystem service (benefit) seeks implementation of seeks improvement of seeks maintenance of seeks provisioning of

#### Named Individuals

Active Recreational Use Aesthetical Value Air Purification application of pesticides average Biodiversity Conservation biological pest control Carbon Sequestration Carbon Storage cluttered open construction Education elevated evapotranspiration evapotranspiration flooding Food Production grass planting ground based Habitat Provisioning Heritage Value biob infiltration irregular pattern linear open low low or monoculture Mixed Recreational Use monitoring Non-Timber Forest Products not managed on balcony on building facade on building roof on carport Passive Recreational Use paved pest control photosynthesis Place Attachment Plant Propagation private opening public railroad track regular open regular pattern Regulation of Air Temperature and Humidity restoration restricted collective restricted private Runoff Regulation Scientific Value selective semi public shading shrub planting Social Cohesion solitary temporarily restricted access temporarily unrestricted access Timber Production tram tracks transportation Tree Planting unwaxed unrestricted public Water Purification waterway water control



### 3. CLEARING HOUSE Typology on Urban Forests As Nature-Based Solutions: Description

The following figure provides a draft visualization. A more detailed description for Version 1.0 as of March 2021 of this typology can be accessed under doi 10.5281/zenodo.4549951.

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# Discussion, conclusions, and outlook

- Started with identifying core entities, including the tree concept, to propose a traits-based approach to formalize UF-NBS entities
- With regard to both UF-NBS as spatial entities and as actions, and including overarching concepts
- In comparison to other typologies, limited expressiveness in regard to certain sub-taxonomies, e.g., parks and gardens: elements such as *pocket park*, *town park*, *precinct park*, *large urban park* not included, not found to be universally distinct
- Review and expand on defining traits, establish a common understanding: **Semantic modelling and ontology building as an interactive process**



# Discussion, conclusions, and outlook

- **Opportunities for re-use** include, e.g.,
  - Building of UF-NBS inventories
  - Classification and assessment tools
  - Knowledge-based applications
  - Implementation of decision-support systems

