

The rhythm of Urban Animal Design

TO WHAT EXTENT CAN NATURE-BASED SOLUTIONS (NBS) OR ANIMAL-AIDED DESIGN (AAD) CONTRIBUTE TO URBAN PLANNING IN AACHEN'S SUSTAINABLE DEVELOPMENT?

TO WHAT EXTENT CAN NATURE-BASED SOLUTIONS (NBS) OR ANIMAL-AIDED DESIGN (AAD) CONTRIBUTE TO URBAN PLANNING IN LARGE DENSE TOWN'S SUSTAINABLE DEVELOPMENT?

*Elies Horemans | Master thesis M. Sc. Transforming City Regions | Sommer Semester 2025
Examinators: Univ. Prof. Dr. Jakob Beetz & Prof. Dr. rer. nat. habil. Michael Leuchner
Supervisor: Dr.-Ing. Javier Ostos Prieto*

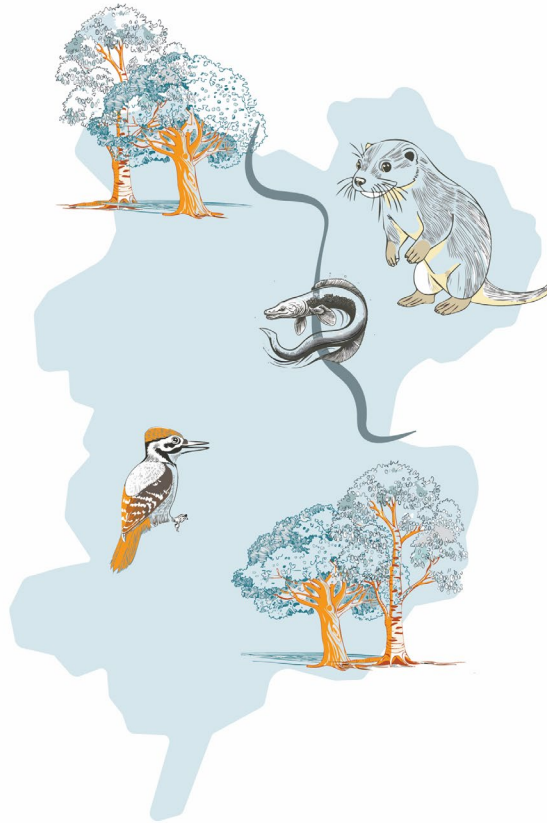


Figure 1: Illustration of a large dense town, made by author

1. Abstract

Amid growing urbanisation and an escalating climate crisis, how can Large dense towns not only sustain biodiversity but actively foster it? This thesis proposes an integrative design model that positions animals as key stakeholders in urban development. By combining Animal-Aided Design (AAD) with Nature-based Solutions (NbS), and embedding both into the frameworks of Urban Ecological Networks (UEN) and the Internet of Nature (IoN), the project introduces a novel approach to rewilding urban spaces.

Focusing on large dense towns, the Belgian municipality of Heist-op-den-Berg was the main topic of this research explores on how ecological resilience can be embedded in spatial planning across multiple density typologies ranging from dense cores to rural areas. Nine taxonomic groups of priority species were identified, and their habitat needs translated into spatial actions. Using GIS-based mapping, historical land-use analysis, water quality assessments, and ownership data, a layered masterplan was created across three zoom levels. Visual strategies such as puzzle-piece integration, section diagrams, and decision-making trees accompany a comprehensive design toolbox with cost estimations and phased implementation.

This thesis not only offers scientifically grounded strategies for biodiversity enhancement but also emphasizes public participation, policy relevance, and digital innovation. It provides a clear roadmap for municipalities, planners, and designers seeking to transform urban environments into thriving ecosystems where both people and wildlife flourish together.

Content table:

1.	Abstract.....	
2.	Introduction	1
3.	Problem statement.....	1
4.	Vision statement	2
5.	Initial hypothesis	2
6.	Methodology.....	3
7.	Literature review	5
	De natuur van onze steden by Nadine Galle	6
	The largest art: a measured manifesto for a plural urbanism by Brent D. ryan.....	7
	Animal-Aided Design in the living environment by Apffelbeck B., Hauck T. E., Jakoby C., Rogers R., Schröder A. and Weisser W. W.	7
	Interview with Prof. Dr. Thomas E. Hauck	8
	State of Art	11
	<i>Het kastanjebos in herent als voorbeeld van hoe elke euro voor de natuur veelvoud oplevert: "wordt nog te vaak over het hoofd gezien".....</i>	<i>11</i>
	<i>Building biospheres: belgië experimenteert met plantenintelligentie op de biënnale van venetië</i>	<i>11</i>
8.	Criteria of location.....	12
	Criteria of Large Dense Towns	12
	Criteria of Case Study Area	17
	<i>Buffer zone Heist-op-den-Berg.....</i>	<i>17</i>
9.	Theoretical framework.....	19
	Nature-based Solutions (NbS).....	21
	<i>Ecosystem Services.....</i>	<i>22</i>
	Animal Aided Design (AAD)	24
	Urban Ecological Networks (UEN).....	25
	Internet of Nature (IoN).....	26
	Previous Conclusion	26
10.	Conceptual framework.....	27
	Model	27
11.	Inventory of Information AAD	28
12.	Analysis.....	31
	Animal (Habitat) Analysis.....	31
	<i>Higher Plants: Juncus capitatus.....</i>	<i>31</i>
	<i>Amphibians And Reptiles: Triturus cristatus.....</i>	<i>32</i>
	<i>Fish: Anguilla anguilla.....</i>	<i>33</i>

<i>Breeding Birds: Leiopicus medius</i>	34
<i>Wintering Waterfowl: Aythya ferina</i>	35
<i>Mammals: Lutra lutra</i>	36
<i>Butterflies: Lycaena tityrus</i>	37
<i>Dragonflies: Leucorrhinia pectoralis</i>	38
<i>Grasshoppers And Crickets: Pseudochorthippus montanus</i>	39
Previous conclusion.....	40
Ecology Analysis	42
<i>Eco districts</i>	42
<i>Historical forest mapping</i>	43
Ferrariskaart 1777: forestation of 1775	43
Atlas of Neighbourhoods: forestation of 1850	44
Popp-mapping 1877: forestation 1940	45
Current urban configuration 2025: forestation 2021.....	46
Ownership Analysis.....	50
Analysis of water Quality.....	51
SWOT On Concepts	52
SWOT Analysis.....	52
<i>Regional SWOT</i>	52
<i>Large Dense Town SWOT</i>	53
13. Conceptual Integration	54
14. Structural plan.....	55
Regional	55
Large Dense Town.....	56
15. Masterplan.....	58
Large Dense Town	58
Zoom 1: Dense core.....	60
Zoom 2: Medium Dense Core.....	63
Zoom 3: Rural Periphery.....	64
16. Toolbox.....	65
Toolbox 1.1: Descision Tree And Toolbox CHART	66
Toolbox 1.2: Complete Network.....	67
Toolbox 1.3: Animal Urban Design Pieces.....	68
17. Conclusion: Urban Animal Network	72
Future Research Directions	73
18. Discussion	73
Acknowledgement	75

Resources	76
Table Of Figures:	79
List of Tables	80
Annex	81
SWOT On Concepts	81
<i>Animal Aided Design (AAD)</i>	81
<i>Urban Ecological Networks (UEN)</i>	82
<i>Nature-based Solutions (NbS)</i>	83
<i>Internet of Nature (IoN)</i>	84

2. Introduction

*"Leave them a flower, some grass and a hedgerow
A hill and a valley, a view to the sea
These things are not yours to destroy as you want to
A gift given once for eternity"
Wally Whyton - leave them a flower*

This quote, taken from an eco-protest song written in 1968 by Wally Whyton, encapsulates the way many cities are approached in terms of development, prioritizing short-term construction goals without a long-term vision for sustainability or post-development resilience. The thesis will highlight how this perception needs to be broadened.

Many large dense towns, such as Heist-op-den-Berg, have been the subject of studies assessing future heat loads and precipitation patterns, which are closely linked to human health. Additionally, the city has set a goal to decrease 40% of its CO₂ output before 2030 under the name of 'Kempen2030' (kempen 2030, n.d.). In this context, the role of urban planning becomes crucial. *To what extent can nature-based solutions (NbS) or animal-aided design (AAD) contribute to urban planning in large dense town's sustainable development?*

To answer this question a thorough research was made about the concepts of nature-based solutions who will be referred as NbS and animal aided design who will be referred as AAD.

This thesis examines the adaptability of nature-based solutions (NbS) and animal-aided design (AAD) in large dense towns, with a focus on their integration into a historical urban environment. The town Heist-op-den-Berg fits this description and will be examined in a more detailed way to create a case study. The German firm Animal Aided Design is recognized for incorporating AAD into buildings and has recently begun expanding its approach to urban planning. However, their work remains primarily focused on the architectural scale, and the transition to broader planning contexts is still in progress ('animal-aided design in the living environment', n.d.). As this is a new aspect in the approach of the field, this thesis could make a conclusion regarding this. (Prof. Dr. Baete et al., 2021)

As NbS has a broader research and has been achieved on urban planning scale (Ministry, 2022), the combination with animals could enlighten a new approach and showcase as an example for the inclusion of AAD in the making of resilient towns and cities.

3. Problem statement

Based on the growing interest in sustainable urban development, the combination of Animal-Aided Design (AAD) and Nature-Based Solutions (NbS) presents promising potential for contributing to climate neutrality in villages. However, this integrated approach remains underexplored in academic literature, and its positive effects on urban climate goals have not been frequently studied in a comprehensive or quantitative manner.

4. Vision statement

During the first semester of the master's program Transforming City Regions, the author was introduced to the concept of Animal-Aided Design (AAD) through an integrated project focused on Stolberg, Germany. In this context, animals such as a local castor fiber were employed as both ecological and design elements to address urban challenges like flooding and the need for floodplains (*Welcome to Stolberg, the Hidden Gem of the Nord-Eifel*, n.d.). Simultaneously, the concept of Nature-based Solutions (NbS) was applied to create multifunctional public spaces, including water retention ponds that served ecological purposes while integrating art and education.

This interdisciplinary combination of ecological thinking, spatial planning, and cultural engagement sparked a deep interest in the potential of AAD and NbS to contribute to more resilient urban environments. Despite the growing academic and policy attention toward both concepts individually, integrated approaches at the city-wide scale remain underexplored in the literature. This gap in research served as the foundation for the current thesis.

The underlying vision of this research is that reintegrating animal life into urban systems can foster a stronger human–nature relationship, enhance public understanding of ecological processes, and promote awareness of climate-related risks. Historically, animals have been forgotten from urban landscapes ('urbane tier-räume', n.d.). However, their return can play a pivotal role not only in ecological restoration but also in addressing key urban issues such as mental health, climate adaptation, and biodiversity loss (*Nature*, n.d.).

This thesis is grounded in the vision that urban planning must evolve into a model of shared habitat, one that integrates both human and non-human species. It embraces the belief that allocating space within cities for animals and ecological functions is not only a strategy for environmental sustainability, but also a socially transformative act.

By designing urban environments that promote coexistence, villages can become more resilient, adaptive, and inclusive. From enhanced ecosystem services and climate adaptation to improved public well-being and health.

5. Initial hypothesis

This thesis aims to demonstrate the potential of combining Nature-based Solutions (NbS) and Animal-Aided Design (AAD) within a large dense town-scale planning context. The objective is twofold: to assess the spatial and ecological impacts of such integration, and to provide a transferable guidance tool that supports urban practitioners in implementing these concepts effectively.

The analytical framework will be grounded in the ecosystem services cascade model (Joachim H; Spangenberg et al., 2014), enabling a semi-quantitative evaluation of both biophysical and socio-cultural ecosystem service flows. The assessment will prioritize achieving a subjectively measurable output based on spatial analysis.

Empirical data will be collected and analysed using Geographic Information Systems (QGIS) and relevant geospatial tools. Three key case studies will be examined to contextualize the application of NbS and AAD in diverse urban environments. Insights from these cases will inform the creation of a toolbox, a structured design and policy instrument, to guide future city-scale implementations of biodiversity-inclusive planning.

6. Methodology

This chapter outlines the six sequential research phases that structured the development of this thesis. Each phase builds on the outcomes of the previous one, forming a comprehensive and iterative research trajectory. While the phases are presented as distinct stages, ranging from conceptual exploration to the design of a practical planning toolbox, they are interlinked and overlapping rather than rigidly closed. Figure 2 provides a visual overview of the methodological flow, illustrating how theoretical insights, spatial data, and ecological analysis converge into actionable design strategies. Together, these phases support a cohesive framework to examine how Animal-Aided Design (AAD) and Nature-Based Solutions (NbS) can be applied across varying urban densities to foster biodiversity and climate resilience.

Phase 1: Research idea

- The initial phase involves an exploratory investigation into urban design strategies that contribute to climate neutrality at the city scale. This includes a theoretical examination of two emerging approaches: Animal-Aided Design (AAD) and Nature-based Solutions (NbS). In parallel, a typological analysis of urbanisation forms in Central Europe will be undertaken, focusing on the spatial, demographic, and ecological characteristics of cities, towns, and villages to inform the contextual framing of the case study area.

Phase 2: Literature review

- This phase includes a critical engagement with both theoretical and empirical literature. A key source is the book *De natuur van onze steden: Hoe we de natuur redden, zelf gezonder worden en onze wereld leefbaar houden* by Nadine Galle (2024), which explores the integration of ecological technologies through the concept of the Internet of Nature. Additionally, foundational papers on Animal-Aided Design—particularly *Animal-Aided Design: Planning for biodiversity in the built environment by embedding a species' life-cycle into landscape architectural and urban design processes* by Thomas E. Hauck and Wolfgang W. Weisser (2025)—will be analysed, along with other relevant publications by Studio Animal-Aided Design.

Phase 3: Collect data

- In this phase, quantitative and qualitative data will be collected to categorise various cities and villages based on criteria such as population density, total number of inhabitants, spatial footprint, and degree of urbanisation. This typological analysis aims to identify patterns and variations across urban forms in Central Europe. The outcome will support the selection of a representative urban context, whether city, town, or village, that aligns with the research objectives and offers potential for implementing Animal-Aided Design and Nature-based Solutions. The focus will be on identifying an urban typology that is both scalable and adaptable for integrative ecological planning strategies.

Building upon the selected urban typology and target area, this phase involves the systematic collection of ecological and spatial data:

- Biodiversity Inventory: Quantitative and qualitative data will be gathered on the presence, distribution, and abundance of key animal and plant species within the focus area. Special attention will be given to species with high ecological value or those that are indicator species for habitat quality.
- Biotope and Vegetation Mapping: Existing vegetation structures and biotopes will be identified using a combination of GIS analysis, satellite imagery, and local

environmental databases. This mapping will help determine the ecological integrity and potential for habitat enhancement through AAD and NbS.

- Urban Connectivity Assessment: Spatial data related to urban infrastructure, green corridors, and ecological networks will be collected to assess the degree of urban connectivity. This will help evaluate the feasibility of integrating ecological systems within the built environment and identifying fragmentation or barriers to species movement.

Phase 4: Analysis

This phase focuses on integrating ecological data with spatial analysis tools to identify ecological gaps and inform the application of Animal-Aided Design (AAD) and Nature-based Solutions (NbS):

- Species Presence and Gap Analysis: Key plant and animal species identified in the previous phase will be spatially analysed using GIS to determine their distribution patterns and identify zones with low or absent ecological presence. This helps highlight areas requiring targeted intervention.
- Conceptual Integration with Spatial Conditions: The core principles of AAD and NbS will be overlaid onto the spatial realities of the target area, with specific attention to regions of ecological deficiency.
- GIS-Based Spatial Mapping: QGIS will be used to map existing green spaces, habitat patches, and potential ecological corridors. Spatial relationships between fragmented ecosystems and built environments will be analysed to explore possibilities for urban ecological connectivity.
- Visualisation of Ecological Challenges: Illustrations and diagrammatic maps will be developed to communicate key spatial-ecological challenges, such as habitat fragmentation and disconnected green networks. These visual tools will support stakeholder engagement and design development.
- SWOT Analysis and Risk Assessment: A SWOT analysis will be conducted for the target zone to identify strengths, weaknesses, opportunities, and threats relevant to implementing AAD and NbS. Identified risks will be incorporated into a flexible design and planning framework to enhance resilience and adaptability.

Phase 5: Concept Development

Building upon the ecological-spatial analysis and SWOT assessment, this phase aims to formulate adaptable design strategies that integrate Animal-Aided Design (AAD) and Nature-based Solutions (NbS) within the target urban context:

- Translation of Analytical Insights into Design Concepts: Results from the previous phase—including ecological gaps, spatial constraints, and opportunities, will inform the development of site-specific concepts. These will address key deficiencies in the green fabric and propose ecologically supportive interventions for plants, animals, and human users.
- Establishment of a Transferable Conceptual Framework: A flexible framework will be created that synthesizes findings from the case study area and defines scalable criteria. This framework should be applicable across similar urban contexts, allowing for adaptation based on ecological and urban typologies.
- Formulation of Strategic Guidelines: The conceptual framework will be translated into actionable strategies. These may include typologies of urban interventions (e.g., habitat corridors, multifunctional green infrastructure, or biodiversity nodes) and design principles that align with the life-cycle needs of target species, urban densification levels, and spatial planning constraints.

Phase 6: Toolbox proposal

In this final phase, the research will be translated into a practical and scalable design instrument aimed at supporting urban planners and designers in implementing Animal-Aided Design (AAD) and Nature-based Solutions (NbS) within high-density large village context:

- **Toolbox Development for Multiple Urban Environments:** A comprehensive toolbox will be created that integrates NbS and AAD principles with a focus on their potential to reduce urban CO₂ emissions by 2030. This toolbox will be tailored to the spatial and ecological conditions identified in the focus area and will align with climate neutrality goals.
- **Contextual Adaptability and Site-Level Usability:** The toolbox will be elaborated in detail to ensure usability across sites with similar urban morphology and ecological challenges. It will include decision-making guidelines, design typologies, and species-specific interventions based on quantified ecological performance.
- **Scalability and Comparative Assessment:** The concluding section will reflect on the applicability of the toolbox across varying urban scales frameworks and strategies documented in literature, highlighting its contributions and limitations in addressing biodiversity integration and climate mitigation. (*Planning Process | Urban Learning*, n.d.)

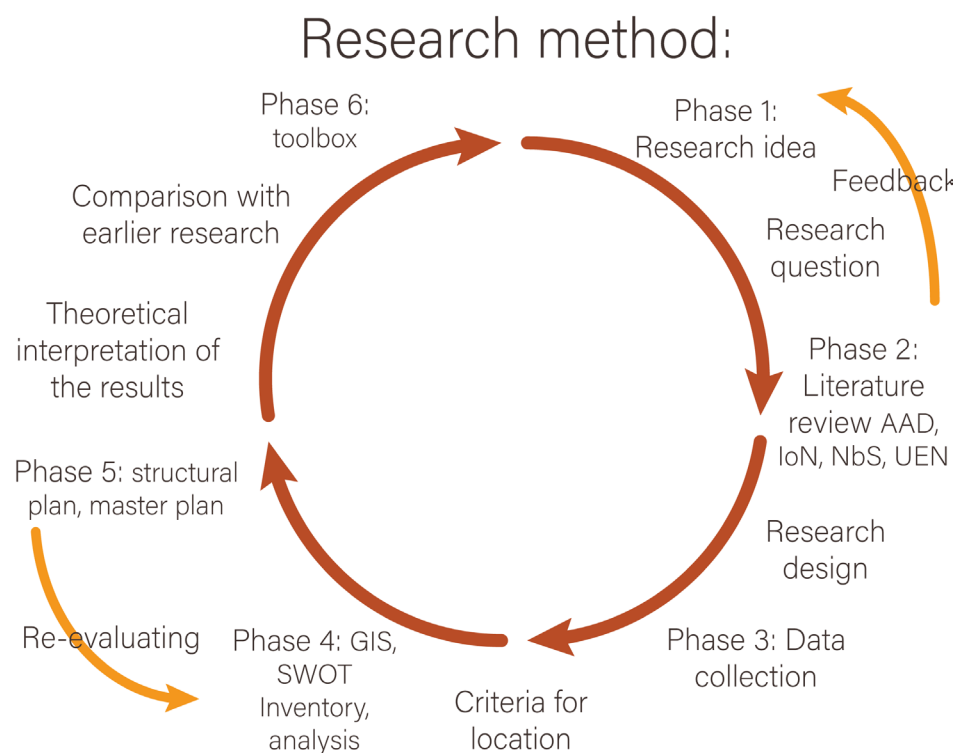


Figure 2: Research method, creation of author

7. Literature review

In the context of growing urbanization and accelerating climate change, urban planning is increasingly expected to address ecological resilience, environmental health, and social well-being simultaneously. Two emerging frameworks—Nature-based Solutions (NbS) and Animal-Aided Design (AAD)—offer promising approaches for achieving these integrated goals. While NbS has gained traction as a policy-driven, systems-based approach to climate adaptation and biodiversity enhancement (*IUCN Global Standard for Nature-Based Solutions*, 2020), AAD provides a more localized and species-specific design methodology aimed at reintegrating animals into the urban fabric (Weisser & Hauck, 2025)

This literature review focuses on the intersection of NbS and AAD, and critically investigates how their combined implementation may contribute to the reduction of localized CO₂ emissions in cities, while generating additional ecological and social co-benefits. Although both concepts are increasingly represented in urban design discourse, their combined application remains underexplored, especially at the scale of city planning.

The objective of this review is therefore twofold: (1) to assess the theoretical and empirical foundations of NbS and AAD within urban contexts, and (2) to evaluate the synergies and limitations of their integration, particularly in relation to climate mitigation, public health, and biodiversity outcomes.

Sources for this review were selected based on their scholarly contribution and relevance to the subject matter. Particular emphasis was placed on the works of leading researchers such as Thomas Hauck, a pioneer in AAD, and Nadine Galle, whose work on ecological urbanism and the "Internet of Nature" contributes to the discourse on digitally-enhanced NbS. Peer-reviewed journal articles, book chapters, and selected institutional reports form the core of the reviewed material, with an emphasis on publications from the last decade to ensure contemporary relevance.

DE NATUUR VAN ONZE STEDEN BY NADINE GALLE

Hoe we de natuur redden, zelf gezonder worden en onze wereld leefbaar houden.

"A society grows great when old men plant trees whose shade they know they shall never sit in,"
Greek proverb

Originally written in English and later translated into Dutch, *De Natuur van Onze Steden* is authored by Nadine Galle, a Dutch-born ecological engineer who emigrated to Canada during her youth. Drawing from her international perspective and frequent visits to the Netherlands, Galle provides a transdisciplinary narrative that integrates ecological awareness, urbanism, and digital innovation.

Galle is recognized as a pioneer in the field of urban ecological technology, most notably for her concept of the "Internet of Nature" (IoN). This framework explores how digital technologies—particularly sensors, remote sensing, and artificial intelligence—can be harnessed to monitor, evaluate, and manage urban green infrastructure in real time. Her book provides practical examples of how these technologies are applied in various cities to quantify ecosystem services, assess vegetation health, and track biodiversity. A significant contribution of Galle's work is her emphasis on the intersection between urban greenery and mental well-being. An 18th century saying: where it goes well with nature, it goes well with the people, is one of the arguments (Galle, 2024). She argues that access to nature is not merely an aesthetic or ecological concern but a public health imperative, particularly in the aftermath of natural disasters. The psychological restoration offered by urban green spaces is presented as essential for alleviating chronic stress and enhancing community resilience.

The book is structured around thematic chapters, each addressing a specific consequence of climate change, such as wildfires, flooding, and droughts. Within these chapters, Galle details both the challenges and technological solutions associated with urban ecological management. Her work aligns closely with the Nature-based Solutions (NbS) paradigm and offers an innovative lens through which to quantify green systems using digital tools. The main research question of Internet of Nature was: 'How do we repair the balance where our community once was remarkable for without losing all the progress that has been achieved?'

The core vision of this question is the aim to achieve a harmony between nature and technology.

The book highlights multiple empirical studies that underscore the ecological value of urban trees. For example, research conducted by the Toronto and Region Conservation Authority demonstrated that a single mature tree provides cooling equivalent to five air conditioning units operating for approximately 20 hours per day, thereby significantly reducing urban heat island effects and energy consumption (Wolf et al., 2020). In addition, a study by the U.S. Department of Agriculture (USDA) found that a single mature tree can absorb up to 4,000 liters of water annually, indicating the vital role of trees in managing stormwater and mitigating urban flooding risks (*Groundwater Publications*, 2018).

These findings support Galle's argument that green infrastructure, when supported by digital monitoring and planning systems, can deliver quantifiable ecosystem services. As such, her work contributes significantly to the emerging discourse on Nature-based Solutions (NbS), particularly in relation to the operationalization and measurement of ecological performance in urban contexts. (Galle, 2024)

THE LARGEST ART: A MEASURED MANIFESTO FOR A PLURAL URBANISM BY BRENT D. RYAN

This book presents a theoretical argument for embracing pluralism in urban design and planning. Central to his manifesto is the idea that cities of higher quality often emerge not through centralized uniformity but through the coexistence of multiple urban cores, each possessing a distinct identity while contributing to a broader collective narrative. Ryan challenges the dominance of singular, top-down planning approaches and instead advocates for a decentralized, multi-nodal urbanism where different scales, functions, and aesthetics coexist without requiring physical continuity.

Importantly, the book underscores that urban cohesion does not necessarily rely on visual or spatial connectivity, but can be constructed through experiential, cultural, or symbolic linkages. One illustrative example discussed is a notable example of plural urban design in Romania: the sculptural ensemble by Constantin Brâncuși in Târgu Jiu. This ensemble comprises three key elements—The Table of Silence, The Gate of the Kiss, and The Endless Column—which are aligned along an urban axis. Although these sculptures are not physically connected, they collectively create a cohesive urban narrative through their spatial arrangement and symbolic significance. Ryan uses this example to illustrate how plural urbanism can manifest through the integration of art and public space, contributing to a city's identity without relying on traditional architectural forms.

Ryan's plural urbanism offers a valuable lens for understanding how cities can integrate disparate elements—including nature, infrastructure, and cultural expression—into a layered and inclusive whole. This framework can inform discussions around Animal-Aided Design (AAD) and Nature-based Solutions (NbS) by validating approaches that do not rely on uniformity or strict functional zoning, but instead promote contextual integration and narrative layering as legitimate forms of urban coherence. (Brent D., 2017)

ANIMAL-AIDED DESIGN IN THE LIVING ENVIRONMENT BY APFFELBECK B., HAUCK T. E., JAKOBY C., ROGERS R., SCHRÖDER A. AND WEISSER W. W.

Integrating the needs of animal species into the planning and design of urban open spaces

This paper is an example of a growing body of literature emphasizes the need to integrate ecological considerations into urban planning through frameworks that prioritize not only green infrastructure, but also the inclusion of animal life as active agents in the urban ecosystem. The approach of this study extends across various urban typologies, including newly planned developments, retrofits, and adaptations of existing plots.

The study outlines how species-specific ecological requirements can be integrated early in the design process, enabling planners and architects to create environments that support biodiversity while simultaneously reducing maintenance needs over time. Importantly, the authors argue that enhancing urban ecological connectivity and enabling more direct interaction between residents and animal species can transform public perceptions of urban nature. This reconnection not only improves human–animal relations but also encourages stakeholders—such as private housing associations—to view AAD as a valuable investment in residential quality and property value.

The findings of Weisser & Hauck (2025) resonate with broader goals in Nature-based Solutions (NbS) and biophilic urbanism, particularly the emphasis on multifunctionality, ecosystem service delivery, and social co-benefits. Their work provides a foundational methodology for implementing AAD at various scales and offers a compelling case for its integration into climate-resilient urban strategies.

These case studies within the paper reveal that AAD is not only a species-centred design method, but also a vehicle for increasing social acceptance of urban biodiversity, enhancing ecosystem services, and supporting climate adaptation. However, implementation still faces challenges, including limited legal frameworks, interdisciplinary gaps, and lack of quantifiable data on long-term impacts. (Weisser & Hauck, 2025)

INTERVIEW WITH PROF. DR. THOMAS E. HAUCK

(Studio AAD, zoom meeting 5 of Mai 2025)

"When you bring nature closer to people in a meaningful way, it changes behaviour — suddenly, maintenance becomes care, and green space becomes identity."

Thomas E. Hauck

This interview was conducted as part of the research for a master's thesis focusing on the integration of Animal-Aided Design (AAD) and Nature-based Solutions (NbS) in urban planning. The aim of the interview was to gain expert insights into the practical challenges and opportunities related to the implementation and quantification of these approaches in real-world urban environments. The conversation was held via Zoom on Monday, May 5th, 2025, around midday, and lasted approximately 55 minutes. Prior to the start of the interview, permission was asked to record the session for academic use. The interviewee was selected based on their expertise in the field and their contributions to relevant literature and practice of Animal Aided Design.

Thomas E. Hauck is a German landscape architect and academic whose work is situated at the intersection of ecological design, biodiversity, and urban planning. As a co-developer of the concept Animal-Aided Design (AAD), Hauck has been instrumental in advocating for the integration of animal life cycles and habitat needs into the planning and design of urban spaces. He is affiliated with Studio Animal-Aided Design and has collaborated extensively with ecologist Wolfgang W. Weisser (*Animal-Aided Design: Planning for People and Animals* - TUM, n.d.) to promote cross-disciplinary approaches that bridge landscape architecture and conservation biology. His academic background includes studies in landscape architecture and urban planning, and his professional work reflects a commitment

to creating more inclusive, multispecies urban environments. Hauck's publications and projects emphasize the potential for design to serve both human and non-human inhabitants, positioning biodiversity not as a constraint but as a creative and functional asset within the urban fabric. ('About Us', n.d.)

- *In your experience, what data sources or methodologies are most effective for quantifying the ecological contributions of specific plant or animal species within urban environments?*

Effective methodologies for quantifying ecological contributions in urban environments often rely on species-specific ecosystem service (ES) valuation models, field-based biodiversity monitoring, and increasingly, remote sensing technologies. Notable tools include:

- iTree Eco (developed by the USDA), which quantifies ecosystem services like carbon sequestration and stormwater mitigation offered by urban trees.
- QGIS/Biodiversity Indicators such as the Urban Biodiversity Index (UBI), which can help spatially assess habitat quality.
- Citizen science platforms like GBIF, eBird, or iNaturalist, which offer occurrence data valuable for spatial and temporal analysis of species presence.

Quantifying animal contributions is more complex due to their mobility and indirect service provision (e.g., pollination, seed dispersal). Therefore, combining ecological modelling (e.g., habitat suitability, metapopulation models) with longitudinal field studies is often required for robust assessment.

- *Given the lack of standardized data, do you think developing a custom, weighted assessment system to evaluate species' impact is a valid approach? What criteria would you recommend prioritizing in such a model?*

Yes, a custom, weighted assessment system can be a scientifically valid and innovative solution, especially when adapted to the local urban context. Such systems can help bridge the gap between qualitative ecological value and quantifiable planning indicators.

- Recommended criteria to include in a weighted model might be:
- Ecological Functionality: e.g., pollination, pest control, soil aeration.
- Conservation Status: Red List category or endemism.
- Urban Adaptability: ability to survive and reproduce in built environments.
- Social and Cultural Value: species that evoke emotional or symbolic significance for urban residents.
- Synergy with NbS: how well the species' needs align with proposed green infrastructure.

This approach should be supported by expert elicitation, a multi-criteria decision analysis (MCDA) framework, and iterative feedback from ecologists, planners, and stakeholders.

- *What kind of policy changes or institutional support would help bring AAD into the mainstream of urban planning?*

Mainstreaming AAD requires a combination of top-down regulatory changes and bottom-up community initiatives. Key policy shifts could include:

- Mandating biodiversity-inclusive design in urban development codes (e.g., obligatory nesting provisions, green corridors).
- Establishing urban biodiversity targets within climate resilience plans.
- Providing incentives/subsidies for developers implementing AAD strategies.
- Requiring ecological impact assessments to account for animal habitat needs, not just green space surface area.

- Integrating AAD into public procurement guidelines for municipal landscaping and infrastructure.

Institutional support should focus on interdisciplinary collaboration, enabling knowledge transfer between ecologists, landscape architects, and urban planners through pilot projects, training, and research grants.

- *How do you see AAD evolving in the context of rapidly growing urban centres and the global biodiversity crisis?*

AAD is positioned to evolve from a niche practice to a mainstream ecological urbanism tool, especially as cities face mounting pressure to reconcile growth with biodiversity protection. Likely trends include:

- Integration of AAD with smart city technologies, enabling real-time monitoring of species interactions (as seen in Nadine Galle's "Internet of Nature").
- Expansion into policy frameworks such as the EU Biodiversity Strategy 2030 and Nature Restoration Law, which call for urban greening and species recovery.
- Increasing relevance in Global South megacities, where rapid urbanisation and biodiversity hotspots collide.
- Broader public support, as the mental health benefits of human-nature interaction become more recognised and supported by health policy.

Ultimately, AAD could shift the paradigm from "cities for people" to "cities for life," where human and non-human species cohabitate through thoughtful design.

- *"Do you believe there is an optimal balance between visual appeal and ecological functionality in urban design? And if so, to what extent could achieving this balance accelerate the acceptance and integration of concepts like Animal-Aided Design and Nature-based Solutions in mainstream planning practices?"*

The question was not directly asked but there was an answer given that suits to this question. "There is certainly a strong case for designing green infrastructure that serves both ecological and aesthetic purposes. When people perceive ecological elements—like habitats or species installations—as beautiful or artistically integrated, they are more likely to support them. This aesthetic engagement can act as a gateway to broader public acceptance, making it easier to introduce more functional, biodiversity-driven concepts like Animal-Aided Design or Nature-based Solutions into mainstream urban planning." (Hauck, 2025)

Conducted on May 5, 2025, with [Prof. Dr. Thomas E. Hauck, CEO Studio Animal Aided Design]

STATE OF ART

Het kastanjebos in herent als voorbeeld van hoe elke euro voor de natuur veelvoud oplevert: "wordt nog te vaak over het hoofd gezien"

– by Michaël Torfs, 14/05/2025

The VRT NWS article titled "Het Kastanjebos in Herent als voorbeeld van hoe elke euro voor de natuur veelvoud oplevert" highlights the significant societal and economic benefits of investing in nature restoration projects in Belgium.

The study, conducted by the Flemish Institute for Technological Research (VITO) and the University of Liège (ULiège) at the request of Natuurpunt and the World Wide Fund for Nature (WWF), analyzed three specific nature restoration projects: the Kastanjebos in Herent, the Demerbroeken near Diest, and the Plateau des Tailles in the Ardennes.

Key Findings:

- Kastanjebos in Herent: For every euro invested, the project yields €51 in societal benefits over a 100-year period, with a payback time of just 7 years.
- Demerbroeken near Diest: Each euro invested returns €8 in benefits over 100 years, with a payback period of 16 years.
- Plateau des Tailles in the Ardennes: The project delivers a 25% societal return, recouping investments within 12 years.

These returns stem from various ecosystem services, including flood mitigation, carbon sequestration, enhanced biodiversity, recreational opportunities, and improved public health. The study underscores that nature restoration is not only environmentally beneficial but also economically advantageous, providing substantial returns on investment through the diverse services ecosystems offer to society. (Torfs, 2025)

Building biospheres: België experimenteert met plantenintelligentie op de biënnale van venetië

– By Architectura, 09/05/2025

The article from Architectura discusses Belgium's innovative contribution to the 19th Venice Architecture Biennale through the exhibition "Building Biospheres," curated by landscape architect Bas Smets in collaboration with plant neurobiologist Stefano Mancuso. This project explores the integration of plant intelligence into architectural design, proposing buildings as dynamic environments where plants actively regulate climate conditions.

Central to the Belgian pavilion is a microclimate created by over 200 subtropical plants. These plants are equipped with a network of sensors monitoring sap flow, soil moisture, humidity, and photosynthesis in real-time. The system responds autonomously: if photosynthesis slows, lighting adjusts; if humidity drops, the installation initiates rainfall. This setup grants plants full autonomy in managing their environment, demonstrating a symbiotic relationship between flora and architecture.

The technology underpinning this ecosystem was developed in partnership with Ghent University and Plant AnalytiX. Experiments conducted in a greenhouse on Ghent's Campus Coupure focused on controlling light, ventilation, and irrigation based on plant behaviour. Measurements include changes in tree trunk diameter and soil temperature, allowing the building to respond to living organisms rather than preset controls. This approach illustrates how plants and digital technology can collaboratively create intelligent, energy-efficient indoor climates.

Smets describes the trees as "cyborgs," highlighting the fusion of organic life and technology. The pavilion serves not only as a botanical installation but also as a technological and philosophical experiment. Live displays show temperature variations between the biosphere, the external environment, and a plant-free control room, emphasizing the plants' role in climate regulation.

"Building Biospheres" challenges traditional architectural perspectives by positioning plant intelligence as a central design element. It advocates for a future where architecture and nature are intertwined, promoting sustainability and resilience in the built environment. (Architectura, 2025) (Heathcote, 2025) (Belgisch paviljoen op architectuurbiënnale Venetië 2025, n.d.)

8. Criteria of location

To determine an appropriate location for a case study integrating Animal-Aided Design (AAD), Nature-based Solutions (NbS), and the Internet of Nature (IoN), a cascade assessment was used. This method led to a broader investigation into the conceptual definitions and distinctions between urban typologies, specifically cities, towns, and villages. However the theme of this thesis contains biodiversity and on a finer grain level, an analysis will be made to highlight a region in need and suited for a case study.

CRITERIA OF LARGE DENSE TOWNS

The initial step in selecting an appropriate case study location involves a systematic classification of territorial units based on population density and spatial continuity. To ensure consistency with European spatial analysis standards, the methodology draws on the classification of 1 km² population grid cells, which are assessed in relation to their immediate neighbours. This typology allows for a standardized delineation of urban and rural environments, which is crucial for comparative and context-sensitive research.

Grid cells are grouped and classified into the following categories:

- **Rural Areas:** Defined as all grid cells that do not fall within urban clusters or urban centres. These are typically low-density, sparsely populated areas that remain outside the scope of concentrated settlement patterns.
- **Urban Clusters (Moderate-Density Clusters):** These consist of contiguous grid cells (either sharing sides or corners) with a population density of at least 300 inhabitants per km². A minimum total population of 5,000 inhabitants is required to form such a cluster. Urban clusters represent moderately dense settlements that often function as local service or commuter hubs.
- **Urban Centres (High-Density Clusters):** Composed of contiguous grid cells that share a border by side only (diagonal-only connections are excluded), these areas must exhibit a population density of at least 1,500 inhabitants per km². Additionally, the cluster must contain a total of at least 50,000 inhabitants, including through gap-filling methodologies where appropriate. Urban centres represent core metropolitan areas with high population concentration and infrastructural complexity. (*Territorial Typologies Manual - Degree of Urbanisation*, n.d.)

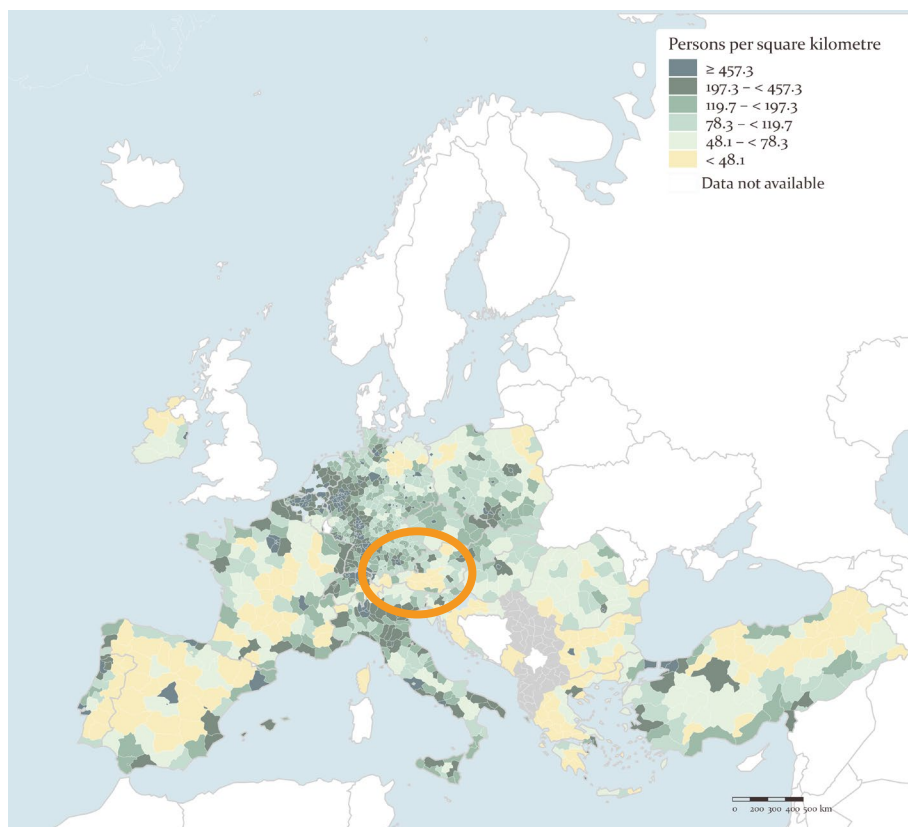


Figure 3: Population density, based on Geographical Information System of the Commission (GISCO) & EUROSTAT (2023)

Following the spatial classification of 1 km² population grid cells into rural areas, urban clusters, and urban centres, the second methodological step entails the integration of these spatial datasets with administrative boundaries. Specifically, this step overlays the previously defined grid cell typologies onto Local Administrative Units (LAUs) to systematically categorise administrative regions according to their degree of urbanisation. (*Local Administrative Units (LAU) - NUTS - Nomenclature of Territorial Units for Statistics - Eurostat, n.d.*)

The classification of LAUs is guided by the following criteria:

- Cities (Densely Populated Areas – Code 1): LAUs in which at least 50% of the population resides within one or more urban centres. These areas are characterised by high population densities, extensive infrastructure, and significant urban functions.
- Towns and Suburbs (Intermediate Density Areas – Code 2): LAUs where less than 50% of the population is located in an urban centre, but at least 50% is situated within an urban cluster. These zones typically represent peri-urban or semi-urban environments with mixed land uses and transitional density profiles.
- Rural Areas (Thinly Populated Areas – Code 3): LAUs in which more than 50% of the population lives in rural grid cells. These are predominantly non-urban areas, often associated with agricultural landscapes, dispersed settlements, and limited urban infrastructure. (*Local Administrative Units (LAU) - NUTS - Nomenclature of Territorial Units for Statistics - Eurostat, n.d.*)

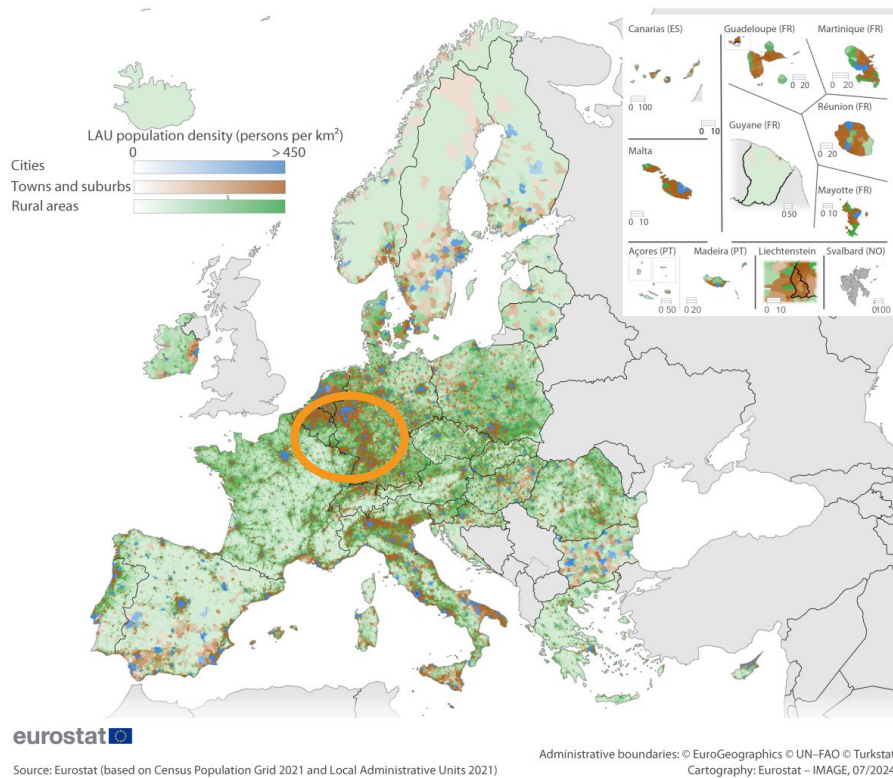


Figure 4: Degree of urbanisation typologies 2021, made by *Territorial Typologies Manual - Degree of Urbanisation*

When examining the identified region at a finer scale, a significant concentration of urbanised settlements becomes evident in the Rhine–Meuse–Scheldt delta, encompassing parts of Belgium, the Netherlands, and western Germany. This area demonstrates the highest levels of urban densification in the category of urbanised towns.

A notable concentration of large, densely populated towns is observed in this region. Subsequent research indicates that the Flanders region offers the most comprehensive and accessible data relevant to Animal-Aided Design (AAD) and Nature-based Solutions (NbS), making it a suitable focus area for further investigation.

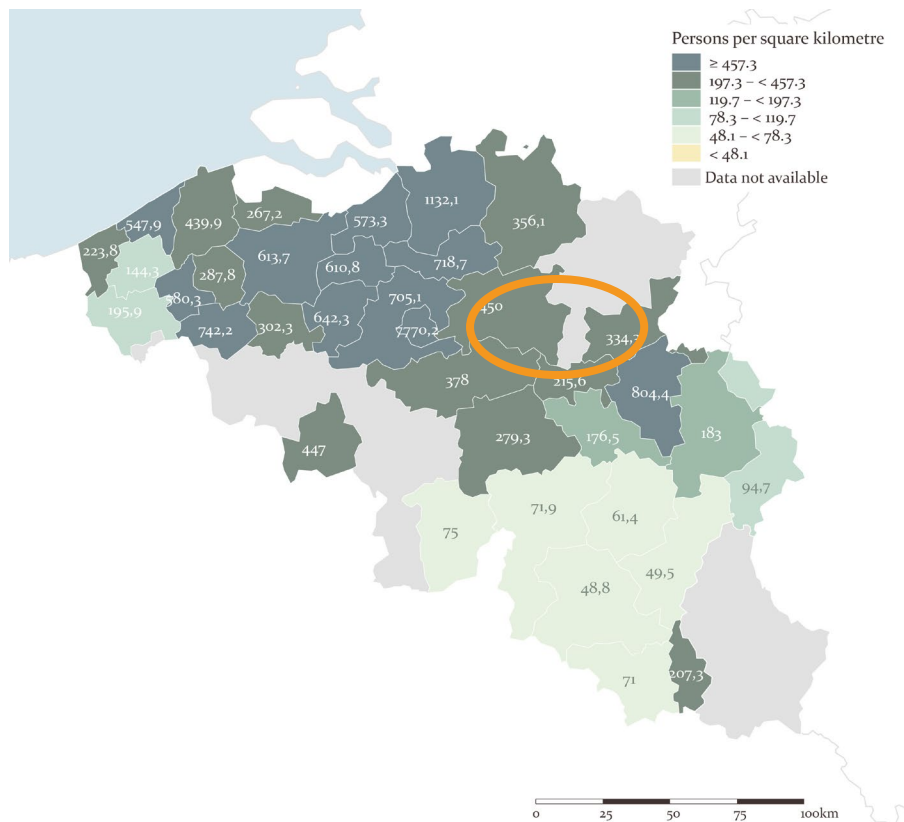


Figure 5: population density on regional level, based on Geographical Information System of the Commission (GISCO) & EUROSTAT (2023)

When the analysis is scaled down to the national level, regional disparities in population density become evident. Within Belgium, the Province of Antwerp consistently demonstrates the highest population density, making it a compelling candidate for further investigation. A more granular examination highlights the Mechelen region, characterised by a mosaic of varying density levels. Among the municipalities in this area, Heist-op-den-Berg emerges as a representative case of a "large, dense town" that aligns with the research criteria. According to official municipal records, the population of the urban core of Heist-op-den-Berg has increased from 6,439 inhabitants in 2011 to approximately 7,867 inhabitants in 2024. As a result, the population density has risen from approximately 2,146 inhabitants per square kilometre to an estimated 3,200 inhabitants per square kilometre.

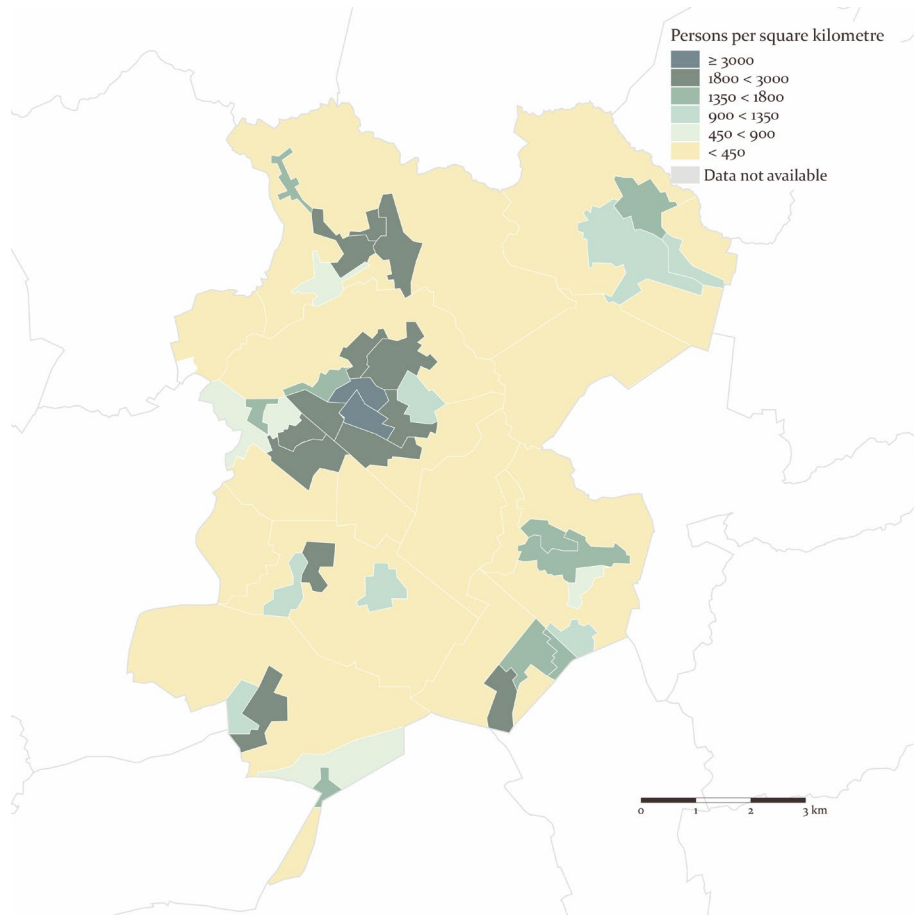


Figure 6: Densification of a local town within a large city with a high densification, made by Provincies.Incijfers.Be - Databank - Officiële Statistiek van Het Aantal Inwoners - 2024 - Gemeenten

The municipality of Heist-op-den-Berg demonstrates a diverse range of urbanization typologies, encompassing both high- and low-density developments. These spatial patterns are organized across a network of town centres, parishes, and sub-municipal units, each characterized by distinct morphological and demographic attributes. Owing to this heterogeneity, Heist-op-den-Berg offers a representative microcosm of multifunctional land use—including urbanized zones, agricultural landscapes, wetland ecosystems, and industrial areas—making it a suitable testing ground for the development and application of an integrated toolbox combining Nature-based Solutions (NbS) and Animal-Aided Design (AAD).

(Provincies.Incijfers.Be - Databank - Officiële Statistiek van Het Aantal Inwoners - 2024 - Gemeenten, n.d.)

CRITERIA OF CASE STUDY AREA

Given its geographic position on the border between the provinces of Antwerp and Flemish Brabant, the municipality of Heist-op-den-Berg occupies a strategic location within the broader ecological and administrative landscape. As ecological systems and species distributions are not constrained by political or administrative boundaries, a broader spatial delineation was established to more accurately reflect the continuity of ecological processes. To this statement, an expanded study area was defined, encompassing all municipalities directly bordering to Heist-op-den-Berg. This approach facilitates a comprehensive assessment of urban ecological connectivity by capturing the potential cross-boundary interactions of flora and fauna.

Each neighbouring village was systematically analysed in terms of its urban morphology, green infrastructure, and the presence of ecological corridors. This enabled a more robust understanding of the regional urban ecological networks, particularly in relation to biodiversity flows and habitat connectivity. In support of this analysis, two spatial mappings were generated to visualise the distribution and density of animal habitats across the extended area. These maps highlight regions with varying concentrations of natural habitats on a 1x1 km grid. Where darker green tones and larger symbology signify a higher presence and ecological value of habitat zones (Fig. 6). The data utilised for these visualisations was sourced from and used with permission of the Instituut voor Natuur- en Bosonderzoek (INBO), ensuring that the analysis is grounded in reliable and scientifically validated biodiversity data.

Buffer zone Heist-op-den-Berg

Within the delineated buffer zone, a distinct spatial pattern emerges, revealing a higher concentration of natural habitats in areas adjacent to the river systems. Most notably, the zones surrounding the river 'Grote Nete' exhibit increased ecological richness and biodiversity. This spatial configuration can be attributed to the region's hydro-geomorphological characteristics, as it was historically shaped by extensive wetland ecosystems. These riparian zones, subject to periodic flooding, have remained relatively undisturbed by intensive urban development and land use conversion. Consequently, they continue to function as critical ecological refugia, supporting diverse species and ecosystem services. In stark contrast, the urban cores—characterised by high population densities and intensive land use—demonstrate markedly lower habitat availability and ecological function (Fig. 7). This dichotomy underscores the fragmented nature of urban–natural interfaces in the study area. The Grote Nete River, which constitutes the primary ecological axis in the buffer zone, is of particular significance. Its name, derived from Celtic origins, translates to "the soft winding river," reflecting both its morphological character and its cultural-historical relevance (*Het Vlaams Woordenboek » Neet*, n.d.). The river system traces its origin to the Weichselian glaciation, which shaped much of the region's fluvial landscape. Today, it remains an essential structural element in the regional ecological network, offering connectivity for both aquatic and terrestrial species. (*Rapport*, n.d.)

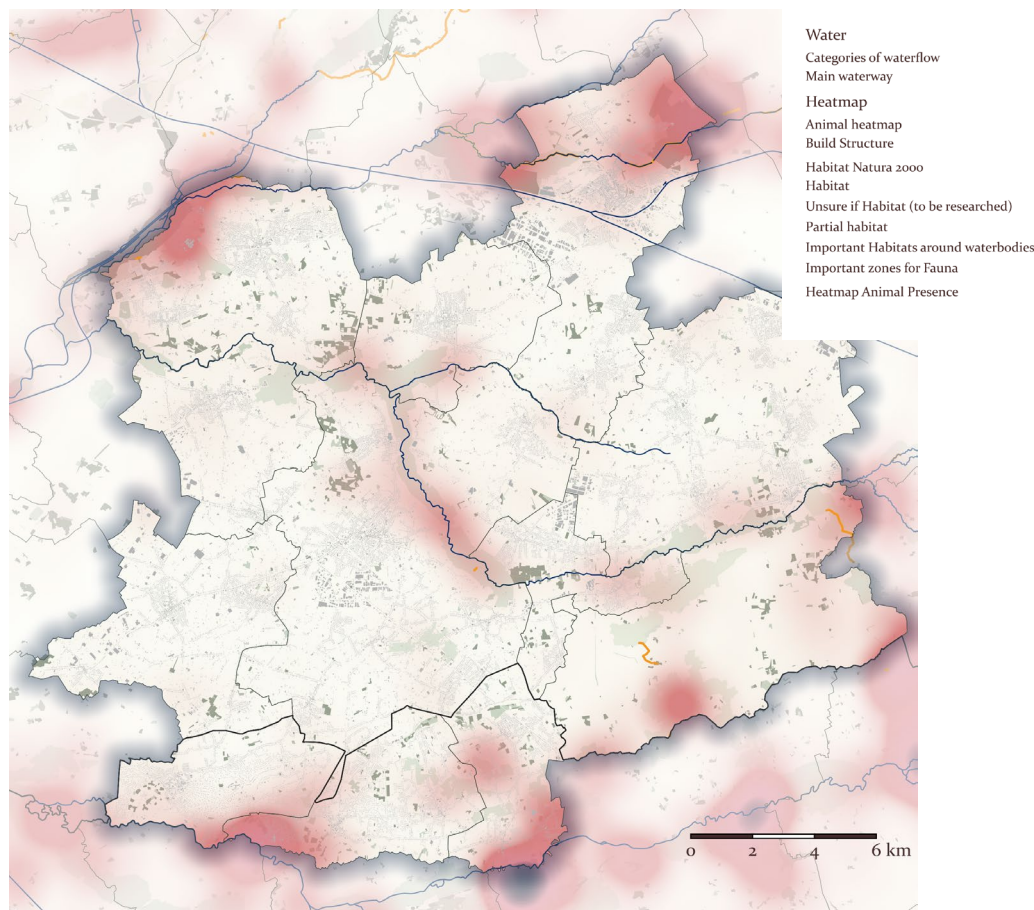


Figure 8: Habitat density per/km² in the region, based on INBO

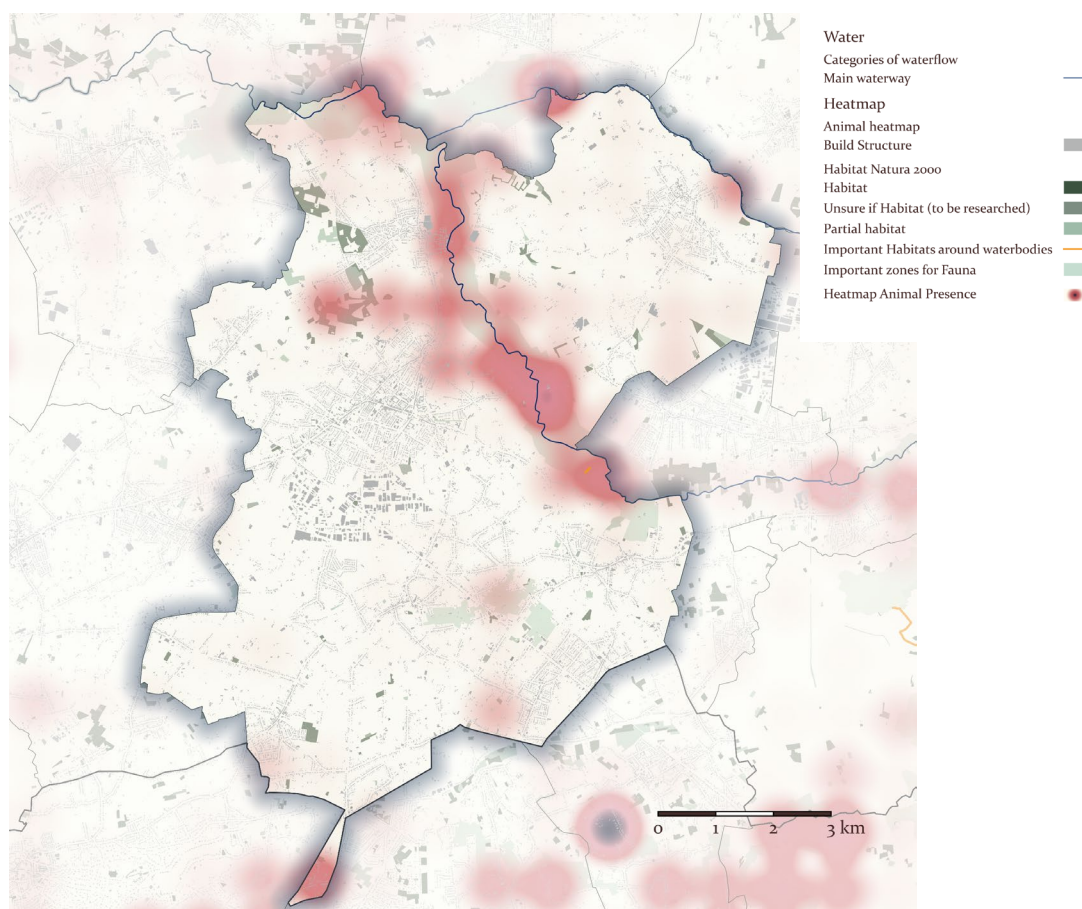


Figure 7: Habitat density per/km² in Heist-op-den-Berg, based on INBO

9. Theoretical framework

This research is grounded in a multidisciplinary theoretical framework that draws from the fields of urban ecology, ecosystem services, and design theory. The integration of Nature-based Solutions (NbS), Internet of Nature (IoN) and Animal-Aided Design (AAD) is examined through the lens of systems thinking and socio-ecological resilience, with a particular focus on how these approaches mediate interactions between urban environments, biodiversity, and human well-being.



Figure 9: Theoretical Framework, created by author

1. Nature-based Solutions (NbS)

NbS are defined by the IUCN (2020) as “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.” NbS are underpinned by the ecosystem services framework, which identifies the tangible and intangible benefits nature provides to humans (e.g., regulating climate, reducing urban heat, supporting mental health). The cascade model of ecosystem services (Müller et al., 2013) will serve as a foundational model in this thesis, helping to conceptualize the flows from ecological structures and functions to human values and benefits.

2. Animal-Aided Design (AAD)

AAD is an emerging design methodology that introduces the habitat requirements of specific animal species into early stages of urban planning and landscape design (Weisser & Hauck, 2025). Unlike traditional ecological planning, AAD is species-centred and proposes a paradigm shift by positioning animals as “clients” of the planning process. It operationalizes ecological design through species profiles and spatial needs, linking biodiversity conservation directly with everyday urban functions such as playgrounds, public squares, and parks. AAD aligns with theories of coexistence design and multispecies urbanism, which challenge anthropocentric planning models.

3. Urban Ecological Networks (UEN)

The concept of urban ecological networks (UEN) was indirectly referenced by Thomas E. Hauck during the interview, in which he emphasized the importance of linking fragmented green areas and highlighted this connectivity as a fundamental principle of urban planning. UENs support the integration of Nature-Based Solutions (NbS) and Animal-Aided Design (AAD) by promoting the structural and functional interconnectivity of green infrastructure within urban systems. These networks are designed not only to maintain ecological functions and biodiversity but also to preserve the spatial identity of urban landscapes. Within this framework, the inclusion of animal species and ecological processes in urban contexts transcends traditional conservation objectives, instead serving as a strategy for enhancing urban resilience and adaptability. Furthermore, this thesis builds upon the theory of urban coexistence, which is reinforced by the logic of UEN. This theory advocates for urban environments that are intentionally designed to accommodate both human and non-human species, thereby fostering mutually beneficial relationships and multifunctional shared spaces within the urban fabric. (Huang et al., 2021)

4. Internet of Nature (IoN)

Despite their individual strengths, NbS and AAD are not fully operationalized together. While NbS tends to focus on system-level functions and policy frameworks, AAD brings a fine-grained, behaviourally informed approach to urban biodiversity. This research aims to bridge this gap by evaluating how their combined application can be embedded into city-scale planning tools using spatial analysis (QGIS) and concepts of Internet of Nature (IoN). At the launch of the most recent Venice Architecture Biennale, the Belgian pavilion presented an innovative installation that integrated architecture with environmental sensors within a house setting. This project was developed by Building Biospheres, a company that challenges the conventional notion of the house as a sealed entity. Instead, it proposes a paradigm shift towards viewing the built environment as a porous system capable of integrating natural processes. As stated by Bas Smets, the installation encourages a reconsideration of spatial boundaries, advocating for architectural models where nature is not excluded but actively invited into the living environment. (Architectura, 2025)

NATURE-BASED SOLUTIONS (NBS)

Nature-Based Solutions (NbS) represent an integrated approach to addressing environmental, social, and economic challenges by leveraging natural processes and ecosystems. The concept, widely endorsed by the European Commission and the International Union for Conservation of Nature (IUCN), emphasizes the sustainable management and use of nature to tackle pressing global issues such as climate change, biodiversity loss, urbanization, and disaster risk. In the European context, countries such as Germany have committed to this approach and advises every appropriate project to use this concept (Ministry, 2022).

According to the *IUCN Global Standard for Nature-Based Solutions* (2020), Nature-Based Solutions are defined as "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." This definition underscores the multifunctionality of NbS, as they are designed to generate co-benefits improving ecological integrity while delivering tangible value to human societies. To fully grasp how these ecological interventions translate into tangible advantages for society, it is essential to introduce the framework of the ecosystem services cascade. This model conceptualizes the progression from ecosystem structures and functions to services, benefits, and ultimately their value to human well-being. By linking biophysical processes with societal outcomes, the cascade framework provides a systematic understanding of how nature-based interventions appear measurable and valuable contributions to sustainable development in an subjective way.

NbS interventions include a wide range of practices such as urban greening (e.g., green roofs, street trees, urban forests), wetland restoration, sustainable drainage systems, afforestation, and ecological corridors. These interventions can operate across multiple scales—from local to regional—and can be tailored to urban, peri-urban, or rural contexts. The effectiveness of NbS lies in their ability to enhance the ecosystem services upon which cities and communities depend. A fundamental attribute of NbS is their contribution to climate change mitigation and adaptation. For example, urban vegetation can reduce the urban heat island effect, improve air quality, capture carbon, and manage stormwater runoff through natural infiltration processes. Simultaneously, these solutions enhance biodiversity by creating or restoring habitats and promoting ecological connectivity in fragmented urban landscapes.

From a planning perspective, NbS offer a paradigm shift from conventional grey infrastructure towards more resilient and adaptive systems. They emphasize participatory governance, interdisciplinary collaboration, and long-term sustainability. Importantly, NbS must be evidence-based, inclusive, and context-specific to ensure effectiveness and equity. In recent years, the relevance of NbS has grown in alignment with international frameworks, including *The European Green Deal - European Commission* (2021), the UN Sustainable Development Goals (SDGs) (dpicampaigns), and the post-2020 Kunming-Montreal Global Biodiversity Framework (GBF) (Unit, 2024). Their integrative nature makes them particularly suitable for cities facing increasing environmental pressures, where they can serve as a bridge between ecological health and human well-being.

In summary, Nature-Based Solutions represent a scientifically grounded, operational approach to restoring the balance between human development and the natural environment. When properly implemented, they provide scalable and cost-effective alternatives to conventional infrastructure while fostering ecological and social resilience.

Ecosystem Services

Ecosystem services depend fundamentally on the structures and processes generated by living organisms and their interactions with, and processing of, abiotic materials.
(Haines-Young & Potschin, 2010)

An essential component of this concept is the framework of ecosystem services, particularly as structured by the ecosystem services cascade model. This model (figure 8) illustrates how natural systems provide multiple benefits to humans, by tracing the flow from ecological structures and processes to their tangible and intangible contributions to human well-being (Haines-Young & Potschin, 2010). Within this framework, ecosystem services are commonly categorized into four main groups: supporting, provisioning, regulating, and cultural services.

Supporting services, such as soil formation, nutrient cycling, and habitat provision, form the ecological foundation upon which the other categories rely. Provisioning services include tangible outputs like food, water, and raw materials. Regulating services refer to nature’s role in moderating environmental conditions, such as air quality, climate regulation, and flood control. Cultural services encompass the non-material benefits people obtain from ecosystems, including recreation, aesthetic enjoyment, and spiritual enrichment.

Ecosystem Service	Importance of Linkage to Well-being	Linked Well-being Targets
Provisioning	Strong	Basic materials for a good life (food, shelter, resources)
	Medium	Health (nutrition, clean water)
	Medium	Security (secure access to resources)
	Weak	Freedom of choice and action
Regulating	Strong	Security (climate, flood, and disease regulation)
	Strong	Health (clean air and water, reduced disease burden)
	Medium	Basic materials for a good life (stability of resources)
	Medium	Freedom of choice and action
Cultural	Strong	Good social relations (cohesion, shared spaces, identity)
	Strong	Freedom of choice and action (mental well-being, spiritual values)
	Medium	Health (emotional and psychological health through nature access)
	Weak	Basic materials for a good life (indirect cultural-economic impact)
Supporting	Foundational	All well-being categories indirectly via provisioning & regulating

Table 1: Own interpretation based on The links between ecosystem services and human well-being, from Haines-Young & Potschin (2010)

All four categories are interlinked with human health and well-being, reinforcing the idea that integrating nature into urban planning is not only ecologically beneficial but also essential for sustainable human development.

The next level of the cascade pertains to the benefits derived from these services, which are measurable in terms of improvements to human health, economic activity, and quality of life. Finally, these benefits are translated into societal values, which may be expressed through monetary valuation, policy priorities, or cultural significance. This final stage (figure 9) illustrates how ecosystems contribute to broader social goals such as public health, climate resilience, and sustainable development.

Main System Layer	Specific Element	Role / Definition	Upstream Inputs	Downstream Influence
Drivers (exogenous)	Economy, Technology, etc.	External societal factors influencing the system.	N/A	Pressures, States
Pressures (endogenous)	Climate change, Land use, etc.	Environmental stressors arising from drivers.	Drivers	States
States	ESBs, ESPs, Supporting System	Core of ecosystem service production & use.	Pressures	Service Provision
Service Units	SPUs	Measurable ecological units delivering services.	States	Impacts
Impacts	On services	Resulting changes in quantity/quality of services.	SPUs	Valuation, Responses
Responses	Policies, strategies	Decisions taken to mitigate pressures or adapt system states.	Impacts, Valuation	States, Pressures
Valuation/Trade-offs	Ecosystem valuation	Societal decisions and value judgments about services and priorities.	Impacts	Responses

Table 2: Own interpretation based on A framework for linking direct and indirect drivers, pressures and responses in a coupled socio-ecological system for assessment of the effects of environmental change drivers on ecosystem services, from Haines-Young & Potschin (2010)

The cascade model is particularly relevant for urban and regional planning, as it facilitates the integration of ecological knowledge into decision-making processes. It allows stakeholders to identify and quantify the contributions of nature to urban resilience and liveability, particularly when applying Nature-based Solutions (NbS) or Animal-Aided Design (AAD) frameworks. Furthermore, it highlights the dependency of societal well-being on healthy and functioning ecosystems, thereby supporting interdisciplinary approaches that combine environmental science, economics, and spatial planning.

In conclusion, the ecosystem services cascade model is a vital tool for understanding and operationalizing the value of ecosystems. It reinforces the importance of maintaining ecological integrity not only for environmental sustainability but also for enhancing the quality of urban life.

ANIMAL AIDED DESIGN (AAD)

Animal-Aided Design (AAD) is an emerging planning and design methodology that seeks to integrate the needs of specific animal species into the fabric of urban development. As defined by Hauck, Weisser, and colleagues (Weisser & Hauck, 2025), AAD involves embedding the complete life-cycle requirements of target species into landscape architectural and urban design processes from the earliest planning stages. Rather than treating animals as passive recipients of habitat remnants, AAD actively positions them as main stakeholders of urban environments. This approach redefines the role of biodiversity in cities, not only as a passive consequence of green infrastructure but as an intentional outcome of design. By integrating species-specific requirements into the planning and design of urban spaces, Animal-Aided Design (AAD) serves as a pioneering approach that bridges ecological and human needs. AAD is not merely about biodiversity inclusion—it reframes animals as active design parameters within urban development processes. According to Hauck and Weisser (as noted in the interview), this approach fosters a "co-species urbanism" where the built environment becomes a shared habitat, rather than a dominantly anthropocentric one.

SDG	Goal Title	Relevance to AAD	Examples of Contribution
3	Good Health and Well-being	Enhances mental and physical health by integrating nature and species encounters in urban life.	Access to biodiverse green spaces shown to reduce stress and improve psychological health.
11	Sustainable Cities and Communities	Promotes inclusive, biodiverse, and resilient urban environments.	Embeds habitats in public spaces, improves liveability in dense urban areas.
13	Climate Action	Supports climate mitigation and adaptation through urban biodiversity and ecological services.	Provides cooling through shading, evapotranspiration; enhances climate resilience.
15	Life on Land	Restores habitats and increases urban biodiversity by designing for species' full life cycles.	Habitat-specific urban design supports native flora/fauna; reconnects ecological networks.
16	Peace, Justice and Strong Institutions	Encourages participatory governance and community involvement in ecological planning.	Involves residents in species selection and habitat placement, fostering civic engagement.
17	Partnerships for the Goals	Requires interdisciplinary cooperation across sectors and institutions.	Collaboration between ecologists, planners, designers, and public authorities.

Table 3: SDG matrix for Animal Aided Design, created by author

In doing so, AAD contributes directly to several of the United Nations Sustainable Development Goals (SDGs). Specifically, it supports SDG 3 (Good Health and Well-being) by facilitating daily encounters with urban nature, which research increasingly associates with psychological well-being, reduced stress, and improved mental health. AAD also advances SDG 11 (Sustainable Cities and Communities) by creating inclusive, safe, and biodiverse public spaces that enhance liveability across urban densities. The design principles help address SDG 13 (Climate Action) through passive cooling strategies, microclimate regulation, and increased climate resilience made possible by strategic species integration and habitat provision. Moreover, SDG 15 (Life on Land) is core to the philosophy of AAD, as it directly supports the protection, restoration, and promotion of urban biodiversity. The method contributes to SDG 16 (Peace, Justice and Strong Institutions) by encouraging participatory planning models that include local stakeholders and community groups in defining species preferences and habitat placements, an idea also emphasized by Hauck during the interview as essential to long-term success. Finally, AAD aligns with SDG 17 (Partnerships for the Goals)

by necessitating interdisciplinary collaboration between ecologists, planners, architects, and citizens, as evidenced by the transdisciplinary partnerships promoted on the Studio Animal-Aided Design platform.

Through this integrative lens, AAD offers a scalable, context-sensitive framework for urban planning that not only contributes to ecological connectivity and climate adaptation but also nurtures a stronger cultural and emotional connection between people and the non-human species with whom they share urban space.

URBAN ECOLOGICAL NETWORKS (UEN)

Urban Ecological Networks (UEN) represent a theoretical and practical framework aimed at mitigating habitat fragmentation and ecological degradation caused by urbanization. Rooted in landscape ecology and green infrastructure planning, UEN focus on the spatial and functional connectivity between green spaces within cities (Benedict et al., 2006). These networks consist of interconnected habitat patches, ecological corridors, and buffer zones designed to support biodiversity, sustain ecosystem services, and enhance urban resilience. The concept of UEN is grounded in the understanding that isolated green spaces often fail to sustain viable populations of species over time due to edge effects, limited genetic exchange, and reduced ecosystem functionality, these become land mosaics (Marburger & Forman, 1997). As mentioned by Forman (1997) 'That one should aggregate lands uses, yet maintain corridors and small patches of nature throughout developed areas, as well as outliers of human activity spatially arranged along major boundaries'. By strategically connecting these spaces, UEN seek to restore ecological flows, enable species migration, and ensure the continuation of vital processes such as pollination, seed dispersal, and nutrient cycling. These networks also contribute to broader goals of sustainable urban development by improving air quality, regulating temperature, and providing recreational and cultural benefits to urban residents (Tzoulas et al., 2007). In the urban setting the aim is set for an urban connectivity.

Urban ecological networks have gained increasing relevance in contemporary urban planning discourses, particularly in light of the biodiversity and climate crises. Within this context, UEN are not merely conservation tools but are positioned as essential components of urban resilience strategies. They align closely with emerging nature-based approaches, such as Nature-Based Solutions (NbS) and Animal-Aided Design (AAD), by enabling the spatial framework through which these approaches can be effectively implemented. UEN facilitate the integration of species-specific habitat requirements and ecosystem services into urban fabric, thus transforming cities into multifunctional landscapes that serve both human and ecological needs. In a recorded interview conducted for this study, landscape architect Thomas E. Hauck implicitly referred to the principles of UEN by highlighting the importance of linking "isolated patches" of green space as a core planning strategy. While not directly using the term "urban ecological networks," Hauck emphasized that connectivity is a prerequisite for effective ecological integration within cities and a fundamental aspect of both AAD and NbS implementation.

In summary, Urban Ecological Networks provide a robust theoretical basis for reimagining cities as interconnected ecological systems. They support a shift from fragmented, human-centred urban development towards integrated, resilient, and biodiversity-inclusive urban landscapes. As such, UENs are essential for advancing interdisciplinary urban planning approaches that prioritize ecological function alongside human well-being.

INTERNET OF NATURE (ION)

The Internet of Nature (IoN), as introduced by Nadine Galle (2024), represents an emerging interdisciplinary framework that seeks to integrate digital technologies with ecological systems in urban environments. The core premise of IoN is the use of advanced sensing technologies, data analytics, and ecological monitoring tools to bridge the gap between the digital and natural worlds. By embedding sensors in urban green spaces, soil, water systems, and even vegetation, the IoN enables the continuous collection and interpretation of environmental data. This technological approach enhances the understanding of ecosystem dynamics and the real-time needs of habitats, facilitating more targeted and adaptive interventions. As such, it provides a mechanism to actively support ecological resilience, biodiversity, and human well-being. Through this digital-ecological integration, cities can reconstruct and maintain natural systems in ways that are more responsive and sustainable. Moreover, the IoN aligns with broader goals in urban planning that aim to promote environmental justice, health equity, and climate adaptation, making it a crucial complement to Nature-Based Solutions (NbS) and Animal-Aided Design (AAD).

Previous Conclusion

In summary, the Internet of Nature (IoN) holds significant potential as a bridging framework between Nature-based Solutions (NbS) and Animal-Aided Design (AAD). While NbS primarily functions within a policy-oriented and ecosystem service-driven paradigm, AAD focuses on species-specific, animal-centered integration into urban design. These two approaches occupy distinct yet complementary positions within the ecological urbanism spectrum. However, for their mutual reinforcement to be effective, a shared operational and monitoring infrastructure is required. IoN, through its use of sensor networks, environmental data collection, and adaptive management, provides the necessary technological tools to create this overlap. When deployed within the structure of Urban Ecological Networks (UEN), IoN elements can serve as nodes that spatially and functionally link NbS and AAD interventions. This not only fosters improved communication and feedback between ecological and species-specific needs, but also contributes to more resilient, inclusive, and intelligent urban ecosystems.

10. Conceptual framework

The conceptual framework is structured around the dynamic synergies between the various components of the theoretical framework. Each topic or domain within the theoretical foundation not only contributes individually to the understanding of the research problem but also reinforces and complements the others. This interdependence forms the backbone of the conceptual approach, ensuring that the framework functions as a cohesive and integrated system rather than as a set of isolated concepts. By acknowledging and leveraging these synergies, the framework enables a more holistic and interdisciplinary analysis, which is particularly crucial when addressing complex urban challenges. The strength of this conceptual model lies in its ability to bridge theoretical insight with practical applicability. Without these interconnections, the framework would lack the coherence and depth necessary to support comprehensive implementation or to scale effectively across diverse urban contexts.

In summary, it is precisely through the interaction between the theoretical components that the conceptual framework gains its full relevance and operational capacity, making these synergies essential for its validity and success. To understand the synergies of Urban ecological Networks a conceptual framework was made to understand the HOW, WHAT and WHERE.

MODEL

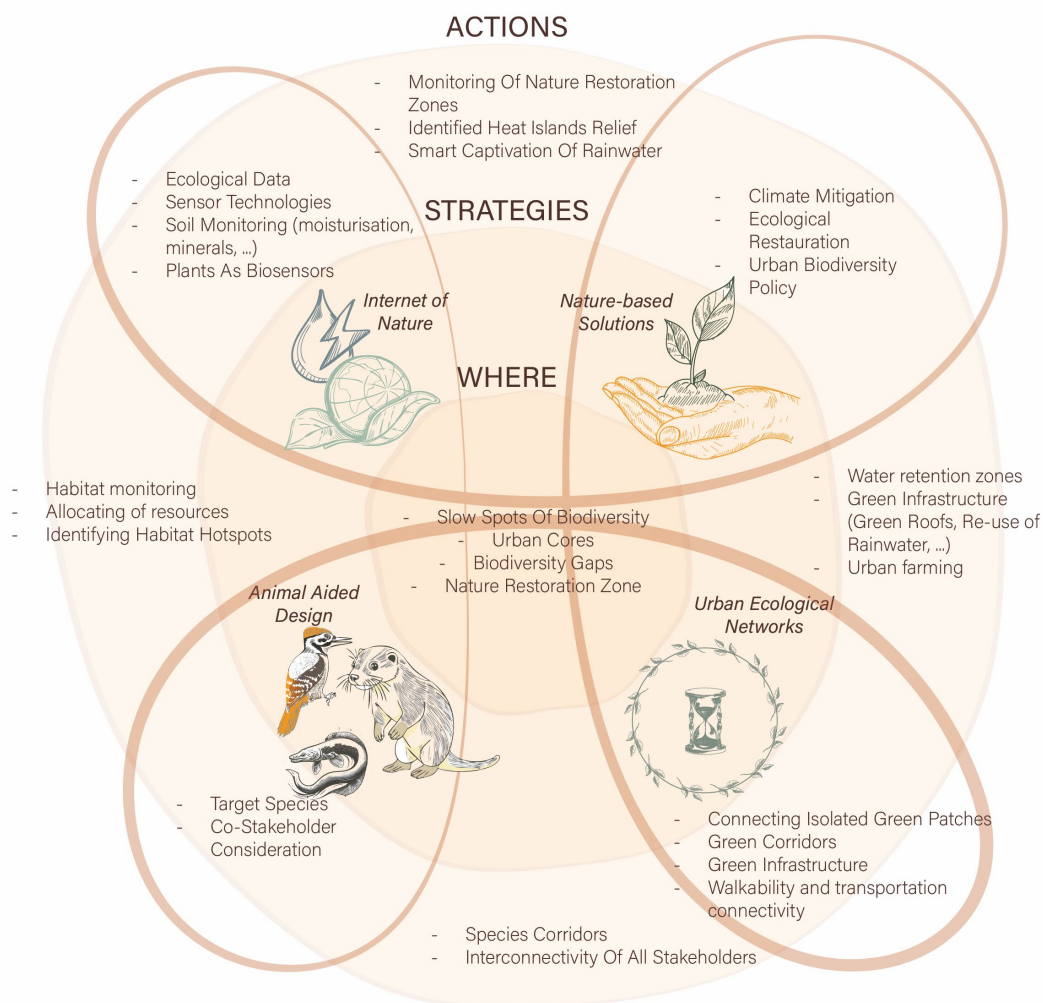


Figure 10: conceptual model, made by author

11. Inventory of Information AAD

Order of use	Main Information	Title Document	Organisation
1	 procedure for delineating Provincial Priority Species, but also other species that may be important for provincial nature conservation and/or policy.	Criteria for the Delineating of Provincial Priority Species Material and Method, 2021	Instituut voor Natuur- en Bosonderzoek 2021 (INBO) (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Thomaes, et al., 2021)
2	 list of species in nine taxonomic groups, provincial nature conservation, management and policy making	Provincial Priority Species in the province of Antwerp	Instituut voor Natuur- en Bosonderzoek 2021 (INBO) (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Van Den Berge, et al., 2021)
3	 list of species in nine taxonomic groups, provincial nature conservation, management and policy making	Provincial Priority Species in the province of Flemish Brabant	Instituut voor Natuur- en Bosonderzoek 2021 (INBO) (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Swinnen, et al., 2021)
4	 Biological Valuation Map (BVM) is a uniform field-driven survey of the land cover and vegetation in the Flemish Region.	Biological Valuation Map and Natura 2000 Habitat map, 2023	Instituut voor Natuur- en Bosonderzoek 2021 (INBO) (De Saeger et al., 2023)
5	 Autochthonous tree inventory or region adapted plants are, adapted to their current environment and can be an important source of resilient planting material.	Action plan for autochthonous and forestry planting stock	Instituut voor Natuur- en Bosonderzoek 2021 (INBO) (Wilms et al., 2024)

Table 4: Inventory of documents needed for analysis Animal Aided Design, made by author

Building upon the established conceptual framework, a structured review of key documents was undertaken to systematically guide the integration of animal species as co-stakeholders in urban design. The selection and analysis of these documents followed a deliberate

sequence, aimed at ensuring that relevant ecological, conservation, and spatial data were effectively synthesised to inform evidence-based design interventions.

The first document reviewed outlines the methodological criteria used to identify and prioritise species of conservation concern. It defines priority species as those classified as endangered on the European Red List or as defined by scientific experts. These species are selected based on their appearance in the province, if the endangered species are more present in a province. They will be highlighted as such, since their habitat is present. Furthermore, the document provides strategic guidance on conservation policy, highlighting necessary protection and restoration measures.

The second and third documents present the Provincial Priority Species Lists for two Flemish provinces. These lists classify species into nine taxonomic groups: (1) higher plants, (2) amphibians and reptiles, (3) fish, (4) breeding birds, (5) wintering waterfowl, (6) mammals, (7) butterflies, (8) dragonflies, and (9) grasshoppers and crickets. For each group, spatial distribution is visualised using heatmaps on a 1x1 km grid, developed from ecological atlases and databases maintained by scientific institutes. These maps are regularly updated with citizen-science observations via the platform waarnemingen.be, enhancing their accuracy and temporal relevance.

The fourth document focuses on protected ecological areas, incorporating spatial data from the Natura 2000 network and designated biologically valuable habitats. It maps zones of high ecological importance, offering critical insight into habitat connectivity and regional biodiversity hotspots.

Finally, the fifth document provides guidance on the selection of native flora to support the habitat needs of target fauna. It identifies tree and plant species that are underutilised in current landscaping practices but are ecologically significant for enhancing biodiversity.

Through this sequential document analysis, a comprehensive and site-specific ecological profile is constructed. This approach ensures that species inclusion within design processes is grounded in empirical evidence and aligned with regional conservation priorities.

12. Analysis

To start the analysis we follow the previous made inventory. This is the first step since it was mentioned by prof. Thomas E. Hauck before that AAD should be implemented from the start. This makes it convenient to start with location the main priority species in the region around the village of Heist-op-den-Berg, for each taxonomic group one specie is selected and taken to the next step.

ANIMAL (HABITAT) ANALYSIS

Higher Plants: *Juncus capitatus*

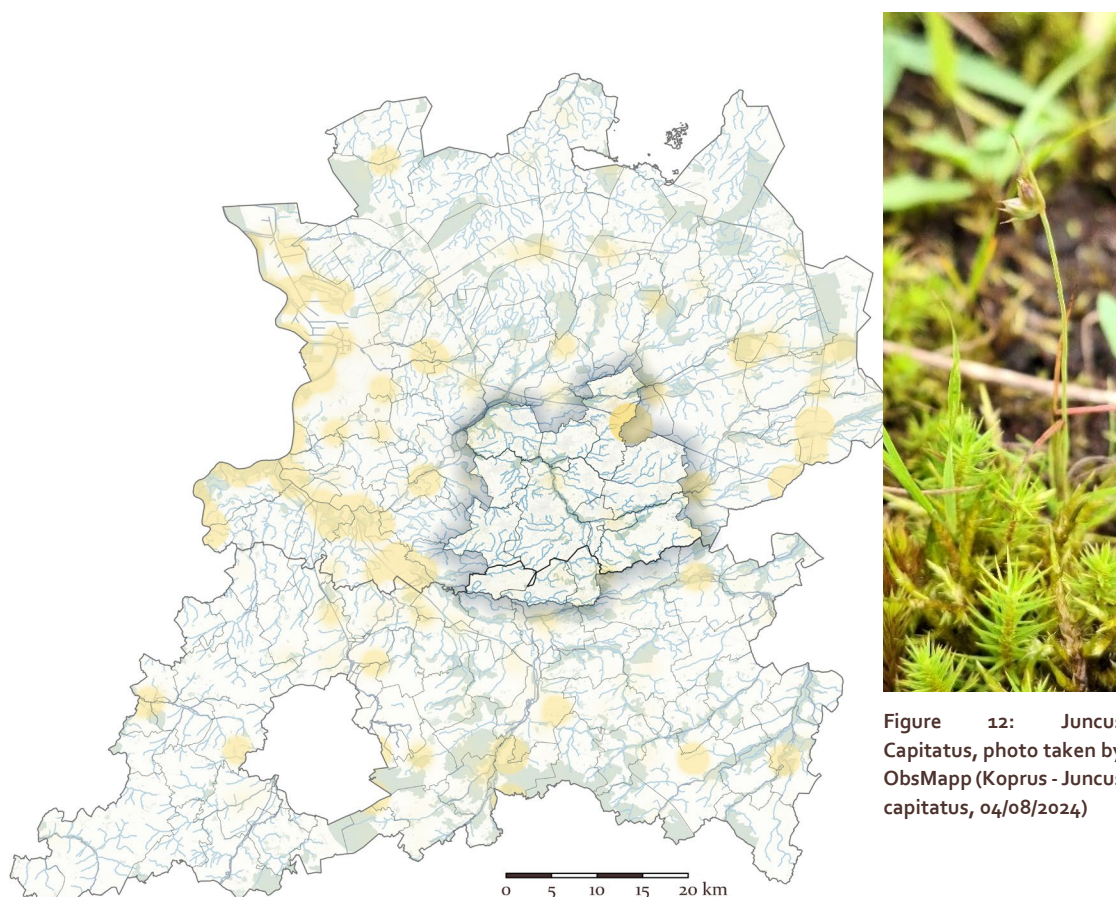


Figure 11: Heatmap Higher Plants with provincial priority specie *Juncus capitatus*, based on GBIF.org User (2025)

The species *Juncus capitatus*, also known as leafybract dwarf rush, was selected for this analysis due to its highly endangered status and the corresponding necessity for targeted conservation measures, including habitat protection and ecological restoration. As outlined in the priority species of Flemish Brabant report by Maes, et al. (2021), *J. capitatus* is currently considered endangered provincial priority species within the province of Flemish Brabant. Subsequent fine-scale spatial analysis revealed that the species is confined (fig. 12, heatmap), indicating a highly localized and fragmented distribution. This restricted presence suggests that the species is at heightened risk from habitat degradation and local extinction. However, the species is very much present within these two cells with around 1002 individuals present. Yet it also presents a unique opportunity for strategic range expansion through focused restoration and management interventions. Suitable habitats include riparian zones (such as ditches, seasonally dry shallow pools, and stagnant water channels in winter, as well as stream and riverbanks), heathlands (including cart tracks and wet heath), sod-cut areas, grasslands (particularly trampled zones created by livestock), forested areas (notably

clearings within wet woodland), coastal dunes (sod-cut patches within dune heath), and arable land (such as ditches between fields and compacted furrows in sandy agricultural soils). (NDFV Verspreidingsatlas | *Juncus Capitatus* - Koprus, n.d.) Furthermore, examination of the broader landscape context using the general distribution map highlights a pronounced lack of habitat connectivity in the targeted area, particularly concerning core areas for higher vascular plant species. This fragmentation of ecological networks is likely to further constrain the dispersal and long-term viability of *J. capitatus* populations. Therefore, the region presents both a conservation priority and a strategic opportunity: restoring ecological connectivity here could not only support the persistence of existing populations but also facilitate the species' natural spread into suitable adjacent habitats, contributing to its overall recovery at the regional scale.

Amphibians And Reptiles: *Triturus cristatus*

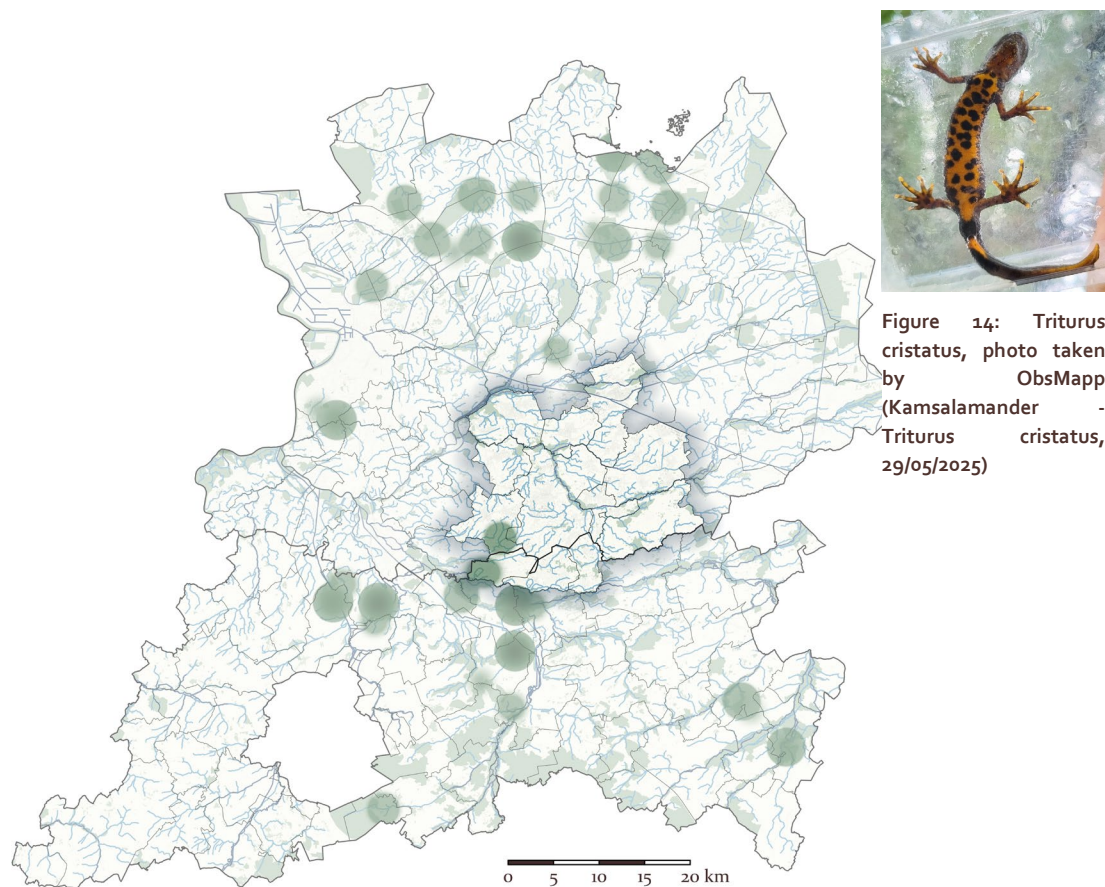


Figure 13: Heatmap of amphibians and reptiles with provincial priority species *Triturus cristatus*, based on GBIF.org User (2025b)

The salamander species *Triturus cristatus*, also known as Northern crested newt, was selected for this analysis due to its classification as vulnerable, which underscores the need for proactive conservation planning and habitat management. The species is known to occur in both provinces included in the study area, thereby aligning well with the criteria for transboundary or regional-scale conservation interventions (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Swinnen, et al., 2021; Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Thomaes, et al., 2021). Its presence supports the implementation of coordinated measures aimed at mitigating threats and enhancing population resilience across administrative boundaries. As demonstrated in the analysis (see Fig. 14), the species' distribution within the target area is characterized by a pronounced lack of ecological connectivity. This fragmentation of suitable habitat patches limits dispersal potential, and increases the species' vulnerability to local extirpation. Consequently, this

species serves as an appropriate case study for the application of AAD (Amphibian Area Design) principles, which emphasize habitat connectivity, population viability, and landscape-scale ecological coherence. Within the delineated area, approximately 51 individual salamanders have been recorded, providing a baseline for monitoring and potential expansion efforts (*Waarnemingen.be*, n.d.). Given these characteristics, the species not only fulfils the conservation prioritization criteria but also provides a practical example for the integration of AAD concepts into regional planning frameworks aimed at improving amphibian habitat connectivity and long-term persistence..

Fish: *Anguilla anguilla*

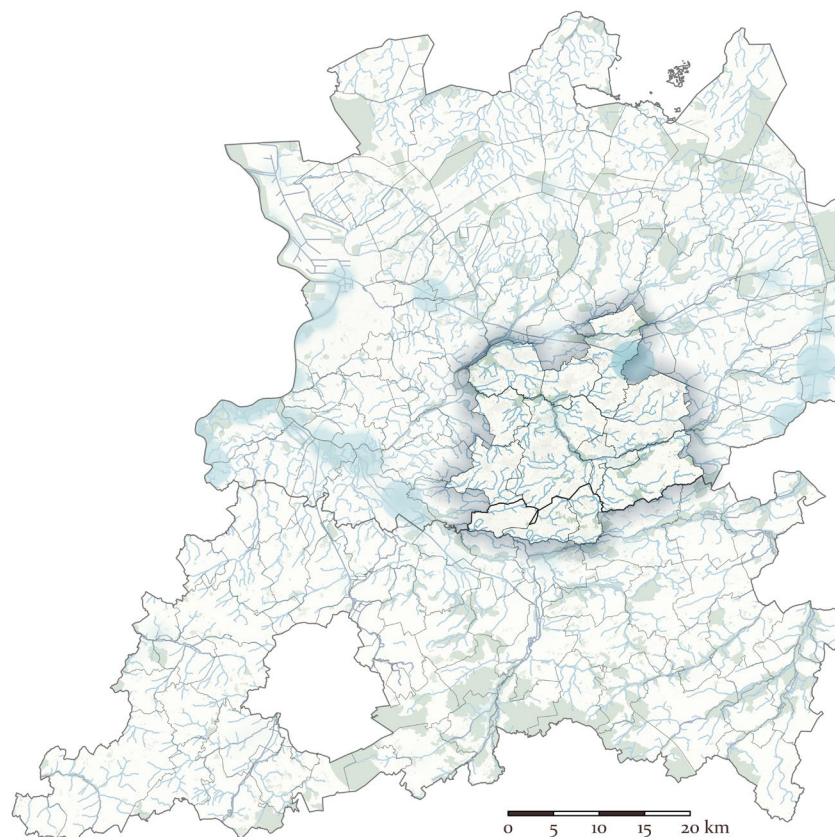


Figure 15: Heatmap of fish with provincial priority specie *Anguilla Anguilla*, based on GBIF.org User, (2025b)



Figure 16: *Anguilla anguilla*, photo taken by Rudi Segers (Aal - *Anguilla anguilla*, 01/06/2025)

The fish species under consideration, commonly known as the European eel (*Anguilla anguilla*), naturally inhabits inland freshwater systems, particularly rivers, but requires access to marine environments to complete its life cycle. As a catadromous species, the European eel migrates from freshwater habitats to the sea to reproduce, making the connectivity between riverine and marine systems essential for its survival (Klein Breteler & Emmerik, 2005). This species was selected for analysis due to its classification as highly endangered and its documented presence in both provinces within the study area, making it a suitable candidate for cross-regional conservation efforts. Although currently absent from the specific target area (fig. 17), the ecological conditions there, such as the presence of a flowing river and unimpeded access to saltwater environments, are favourable for reconnection using the river De Grote Nete. Given these characteristics, the European eel is a particularly relevant species for inclusion in the Animal Aided Design (AAD) framework, which emphasizes Urban Ecological Connectivity and the review of possible ecological barriers. Population data indicate the presence of approximately 52 individuals across the two provinces. Habitat modelling suggests that the expected population within the Flanders region could reach approximately 87 individuals. Thus, the species are native to the region

and are in need of local restoration of the living conditions. Moreover, this could suggest that the water quality of the river De Grote Nete is not as high as it is to be expected.

Breeding Birds: *Leiopicus medius*

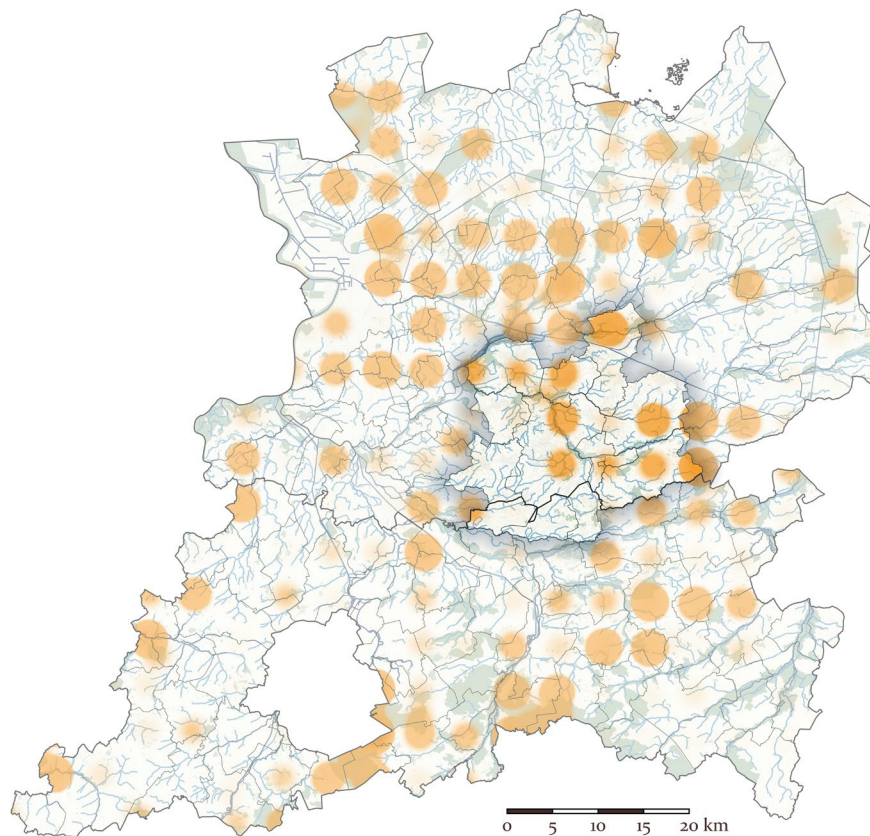


Figure 17: Heatmap of breeding birds with provincial priority species *Leiopicus medius*, based on GBIF.org User (2025b)



Figure 18: *Leiopicus medius*, photo by Claessens Ronald (Middelste Bonte Specht - *Dendrocoptes medius*, 14/05/2025)

Within the taxonomic group of birds, a distinction was made between resident breeding species and migratory species that visit the region during the winter months in search of warmer climates. In this section the focus was placed on breeding bird species, with particular attention given to *Leiopicus medius*, commonly known as the Middle Spotted Woodpecker. This species was selected due to its presence in both provinces and its conservation status as "Near Threatened". Given this status, conservation measures are necessary to support its persistence and promote population growth. To assess spatial distribution and identify conservation priorities, a species specific heatmap was employed to map the density of *L. medius* in and around the target area (fig. 18). In the delineated area 47 individuals were approximately recorded. This spatial analysis revealed zones of higher vulnerability where habitat quality and connectivity are limited, emphasizing the importance of ecological linkage restoration to support viable breeding populations. The assessment was confined to the immediate vicinity of the target area, providing a focused understanding of local conservation needs and opportunities for enhancing habitat continuity for this species.

Wintering Waterfowl: *Aythya ferina*

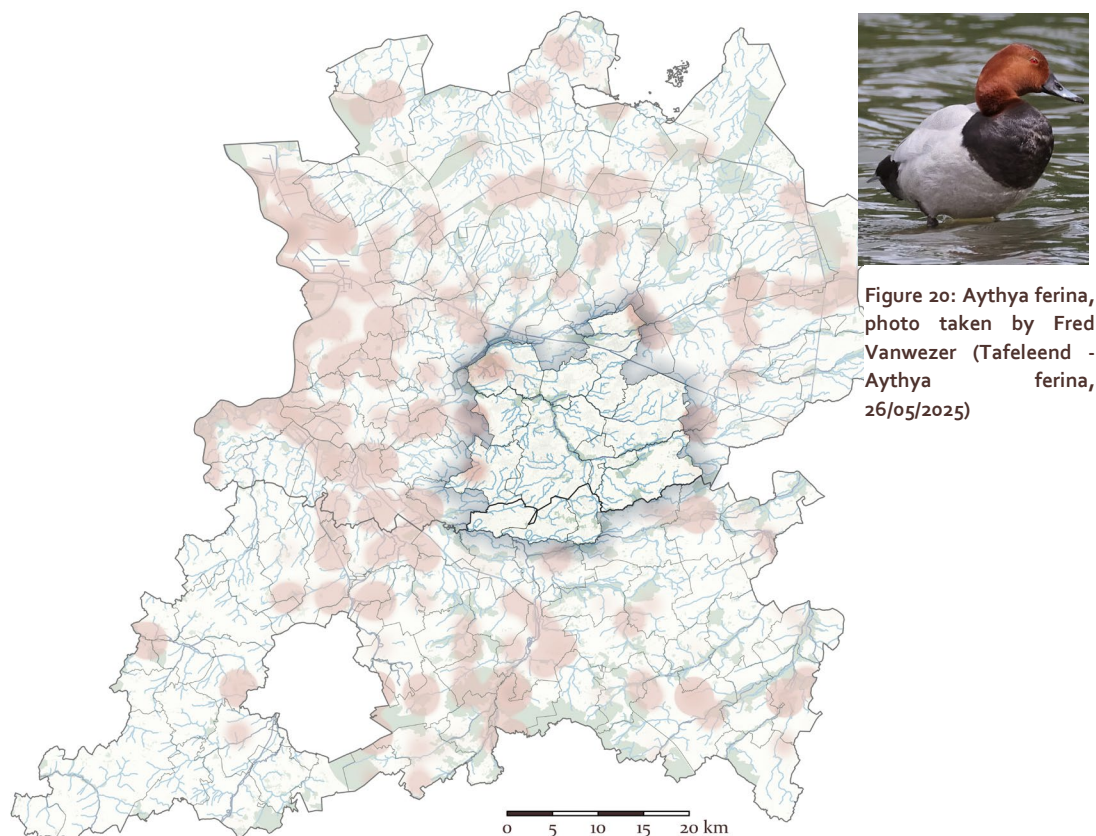


Figure 19: Heatmap of wintering waterfowl with provincial priority species *Aythya ferina*, based on GBIF.org User (2025b)

The second category within the birds analysis concerns wintering waterfowl species, which migrate to the region during the colder months in search of favourable foraging conditions. The focal species *Aythya ferina*, also known as a Common pochard, is in this group currently listed as "Vulnerable" on *The IUCN Red List of Threatened Species* (2025). Indicating a global concern for its long-term viability. As a migratory species, this bird exhibits a wide-ranging distribution, relocating seasonally to areas where food and suitable wetland habitats are available during winter or dry periods. However, while the IUCN recognizes its vulnerability, this status is not explicitly reflected in the provincial priority species lists, but is highlighted in both provinces as a local priority species. Notably, population records indicate that the province of Flemish Brabant supports significantly fewer individuals of wintering waterfowls compared to the average densities observed across the broader Flanders region. In the target area, approximately 84 individuals have been recorded. To assess the spatial distribution of the species, a species specific heatmap was applied (fig. 20). This analysis revealed that the species' distribution within the area is highly fragmented, suggesting that habitat connectivity is insufficient to support a stable overwintering population. Therefore, this zone would benefit from targeted ecological restoration efforts to reconnect fragmented wetland habitats and enhance the area's capacity to support wintering waterfowl populations in the long term.

Mammals: *Lutra lutra*

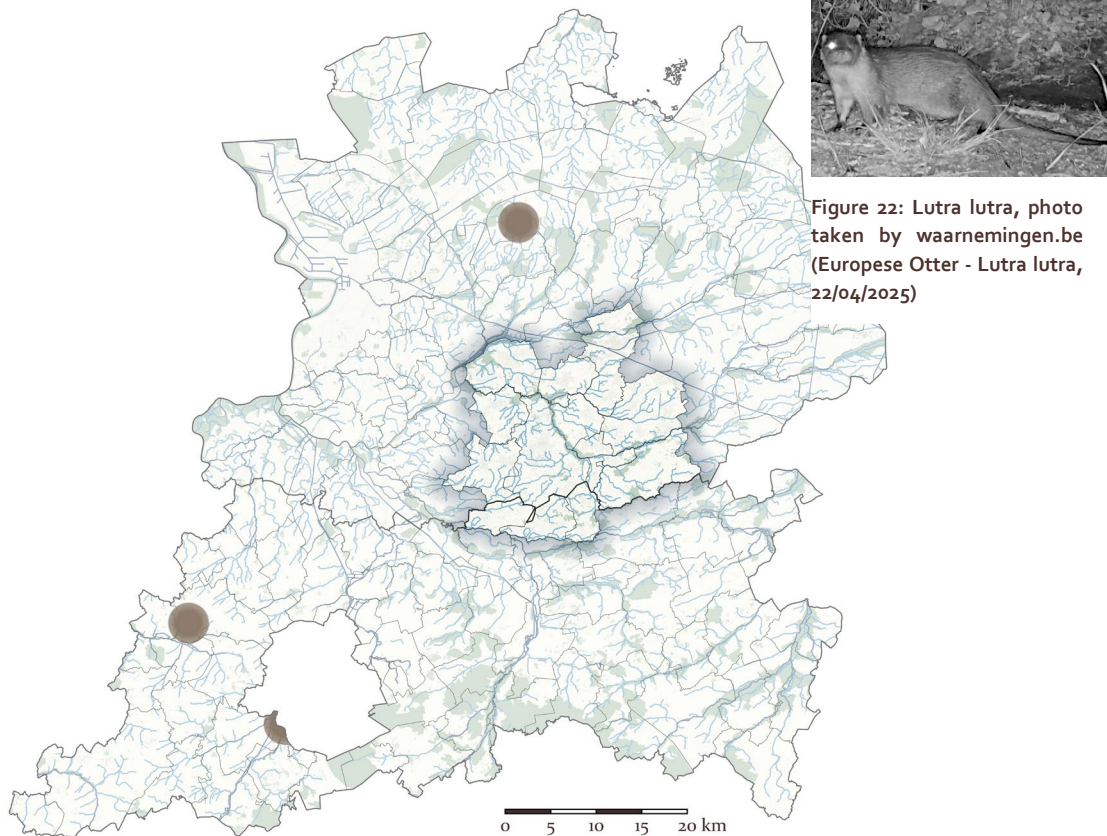


Figure 21: Heatmap of mammals with provincial priority species *Lutra lutra*, based on GBIF.org User (2025b)

This species was selected for analysis based on its classification as highly endangered in both provincial priority species documents (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Swinnen, et al., 2021; Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Thomaes, et al., 2021). *Lutra lutra*, commonly known as the European Otter, is a semi-aquatic mammal whose ecological requirements align well with the environmental characteristics of the target area. The species thrives in freshwater ecosystems, including rivers, tributaries, lakes, and canals, provided that water quality is high and food sources, such as fish and amphibians, are abundant. Additionally, suitable shoreline habitat is essential, requiring flat surfaces, dense vegetation or natural cover for concealment, and areas with minimal human disturbance.

Spatial analysis reveals a significant ecological network gap within the target area (Fig. 23: orange squares), indicating a lack of functional habitat connectivity for the species. Despite this, the area contains the essential ecological conditions necessary to support *L. lutra*, making it an optimal candidate for the implementation of the AAD approach, in combination with the UEN framework. These integrated strategies aim to restore landscape connectivity and improve habitat suitability for target species. Current records indicate that approximately 12 individuals (fig. 23) are present in these two provinces, based on observations reported in a species specific heatmap (*Waarnemingen.be*, 2025). This limited and fragmented distribution highlights the urgent need for habitat restoration and connectivity enhancement to support population recovery and regional expansion of this endangered species.

Butterflies: *Lycaena tityrus*

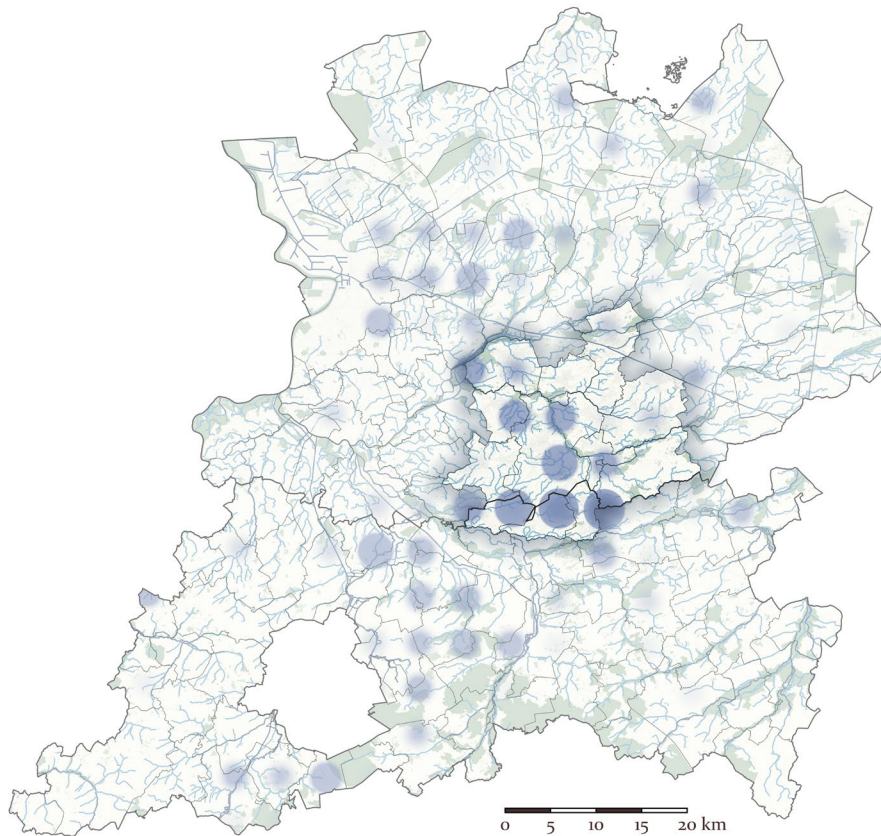


Figure 24: *Lycaena tityrus*, photo taken by waarnemingen.be (Bruine vuurvliender - *Lycaena tityrus*, 01/06/2025).

Figure 23: Heatmap of Butterflies with provincial priority specie *Lycaena tityrus*, based on GBIF.org User (2025b)

This species was selected due to its classification as highly endangered in both relevant provincial conservation documents. *Lycaena tityrus*, commonly known as the Sooty Copper, is a butterfly species of significant conservation concern owing to its limited and fragmented distribution. While its presence has been recorded within the designated target area, it is notably absent from the northern part of the province of Antwerp, underscoring its regional rarity and vulnerability. The species' preferred habitat includes herbaceous environments characterized by native vegetation such as bramble (*Rubus* spp.), scrub heather (*Calluna vulgaris*), common heather (*Erica tetralix*), and field thistle (*Cirsium arvense*). These native plant species are essential for the butterfly's life cycle, providing key resources such as nectar for adult feeding, foliage for oviposition, and sheltered microhabitats for larval development and pupation (Netherlands, n.d.). Herbaceous verges and ecotonal zones that incorporate these plant communities offer the appropriate combination of food availability, cover, and breeding opportunities necessary for the persistence of *L. tityrus*. However, due to its restricted occurrence and specialized habitat requirements, targeted conservation actions, particularly habitat management and connectivity enhancement are needed to support existing populations and promote regional recolonization. These considerations make the species a strong candidate for inclusion in integrative ecological restoration frameworks such as the AAD and UEN approaches. In the spatial analysis, a species specific heatmap was applied to assess the distribution of the species, within which only seven individuals were recorded (fig: 24, heatmap). This low density strongly indicates a population on the brink of regional extinction, highlighting the urgent need for targeted conservation interventions to prevent further decline.

Dragonflies: *Leucorrhinia pectoralis*

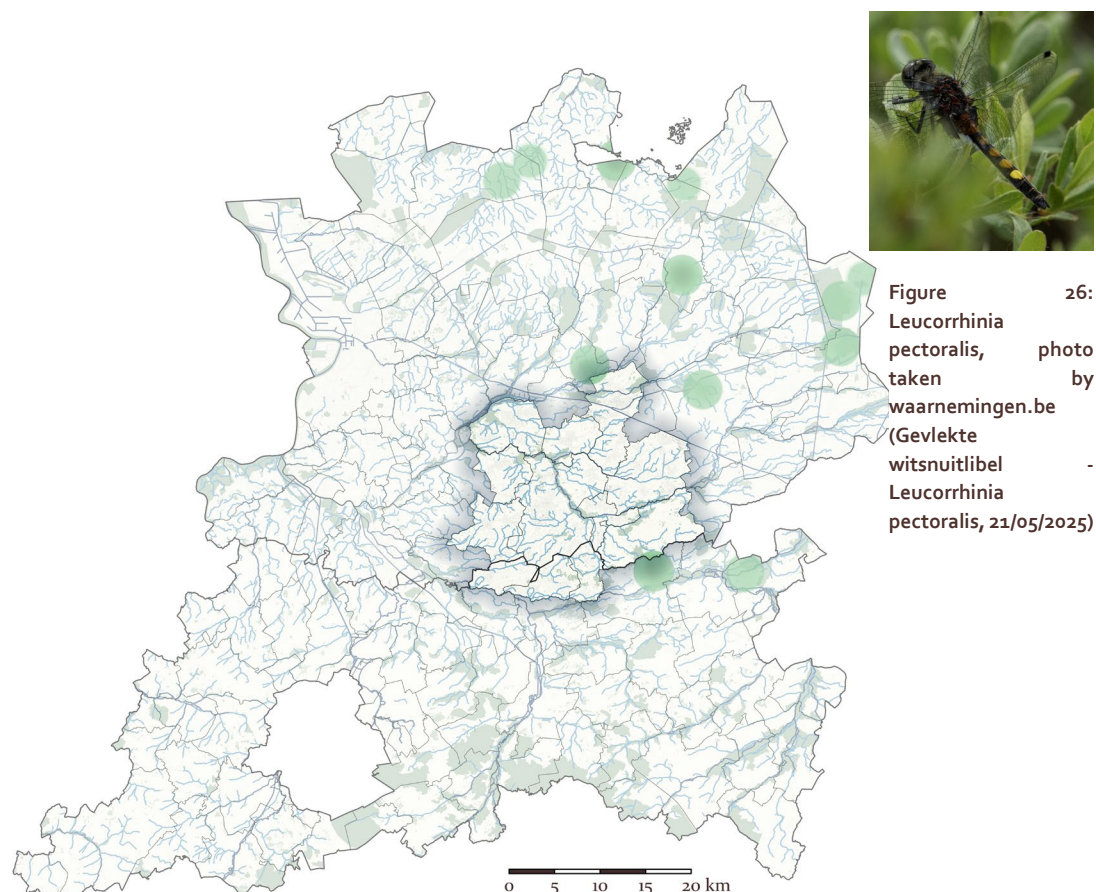


Figure 25: Heatmap of Dragonflies with provincial priority species *Leucorrhinia pectoralis*, based on GBIF.org User (2025b)

This species was selected based on its inclusion in both provincial priority species lists. *Leucorrhinia pectoralis*, commonly known as the Large White-faced Darter, is the only dragonfly designated as a priority species in the province of Flemish Brabant. It is classified as Vulnerable in the province of Antwerp and as Highly Endangered in Flemish Brabant, underscoring its conservation significance within the region.

The spatial distribution of *L. pectoralis* is uneven across the provincial areas, with higher population densities recorded in the northern part and markedly lower representation in the southern region. While the species is present within the designated target area, its distribution remains fragmented and does not cover the full extent of suitable habitat within this zone. In total, approximately 179 individuals have been recorded across the broader area, reflecting both the species' regional importance and its vulnerability to habitat degradation (Waarnemingen.be, n.d.).

The species' ecological requirements are relatively specific, favouring habitats with clear water and a balance of nutrient availability. It typically occupies moderately nutrient-rich sections of lowland moors as well as moderately nutrient-poor fens. These habitat types must maintain good water quality and low levels of disturbance to support viable populations. Given these constraints, the species is highly sensitive to hydrological alterations and eutrophication, emphasizing the need for targeted habitat protection and restoration measures in both provinces.

Grasshoppers And Crickets: *Pseudochorthippus montanus*

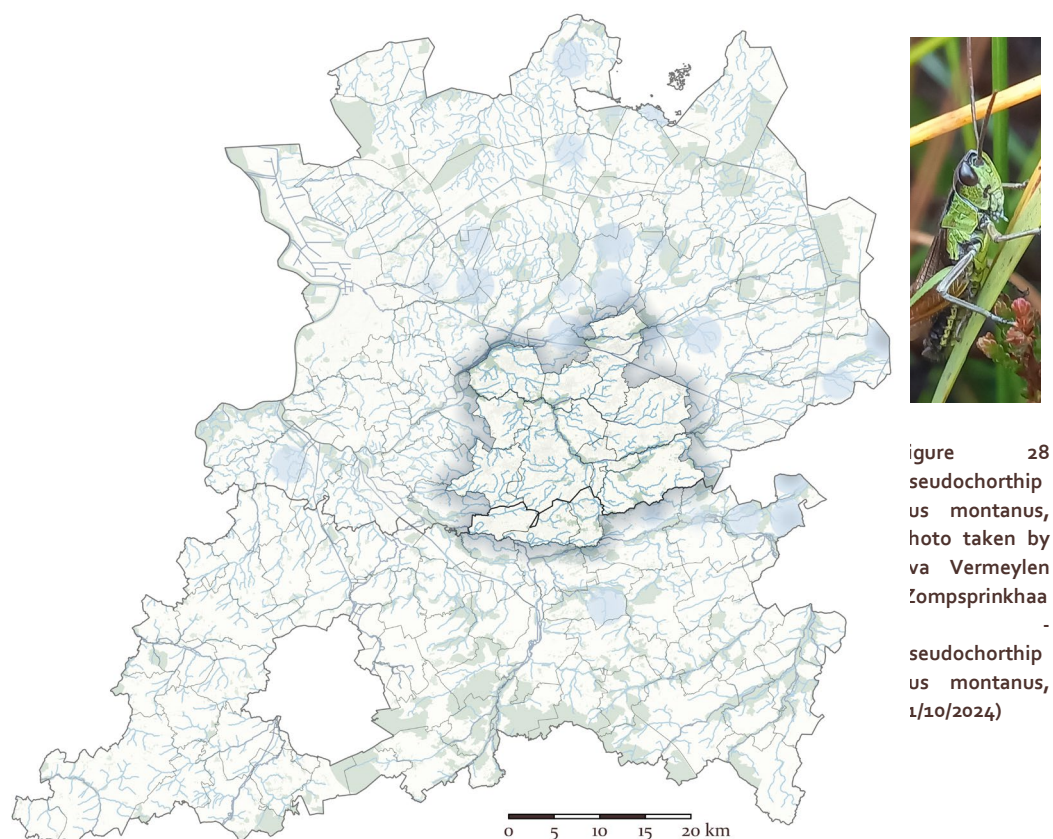


Figure 27: Heatmap of Grasshoppers and Crickets with provincial priority species *Pseudochorthippus montanus*, based on GBIF.org User (2025b)

This species is identified as a provincial priority species in both conservation documents and is classified as endangered. Commonly known as the Water-meadow Grasshopper, its distribution within the provinces is limited due to its highly specialized habitat requirements. The species depends primarily on moist environments, such as fens and low moorlands, which are scarce within the region. Although suitable habitats are few, the species can exhibit high local population densities at these sites. Current population estimates indicate approximately 522 individuals present across the region. The restricted distribution and specialized habitat preferences highlight the importance of conserving and managing remaining wetland areas to ensure the species' long-term viability.

Previous conclusion

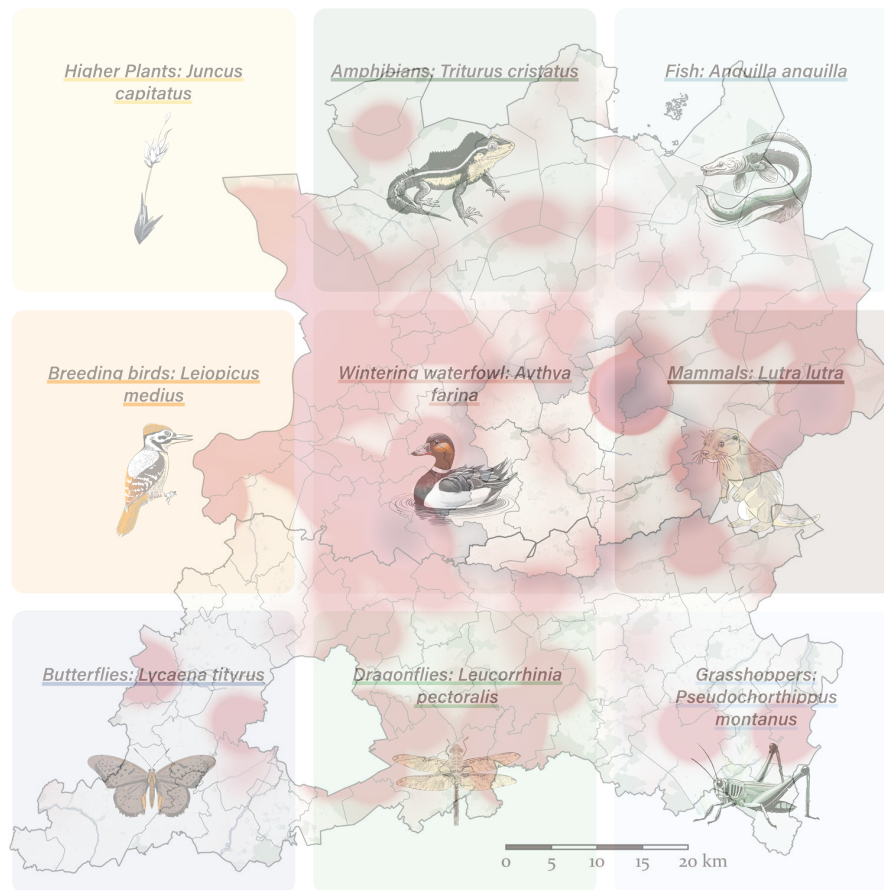


Figure 29: Provincial important habitat types with a grid system based on previous analysis, made by author (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Swinnen, et al., 2021; Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Thomaes, et al., 2021)

This analysis follows a prior inventory and applies the AAD (Animal-Aided Design) approach from the outset (Hauck, 2025), focusing on priority species around Heist-op-den-Berg. For each taxonomic group, one key species was selected for detailed study based on conservation status and regional relevance.

Collectively, Table 3 highlights the fragmented and vulnerable state of biodiversity within the region, underscoring the urgent need for habitat restoration, the enhancement of ecological connectivity, and the implementation of coordinated conservation strategies of the priority species. These measures should be guided by the principles of Animal-Aided Design (AAD) and Urban Ecological Networks (UEN) to ensure integrative and resilient ecological planning.

Taxonomic Group	Species Name	Conservation Status	Distribution & Population	Habitat Requirements & Notes	Conservation Implications
Higher Plants	<i>Juncus capitatus</i>	Highly Endangered	Localized in two 10 × 10 km grid cells; ~1002 individuals	Fragmented distribution; requires habitat connectivity for dispersal	Priority for habitat restoration and connectivity
Amphibians	<i>Triturus cristatus</i>	Vulnerable	Present in both provinces; ~51 individuals	Fragmented habitat limits dispersal; suitable for AAD implementation	Enhance habitat connectivity and population viability
Fish	<i>Anguilla anguilla</i>	Highly Endangered	Present in provinces; ~52 individuals; absent in target area	Requires freshwater habitat with access to sea for reproduction; flowing river present in target area	Restore river-sea connectivity and improve water quality
Breeding Birds	<i>Leipopicus medius</i>	Near Threatened	Present in both provinces; ~47 individuals (5×5 km grid)	Requires habitat connectivity; vulnerable zones identified	Focus on ecological linkage restoration
Wintering Waterfowl	<i>Aythya farina</i>	Vulnerable (IUCN 2025)	Broad but fragmented; ~84 individuals in target area	Migratory species needing connected wetlands for overwintering	Restore fragmented wetlands to enhance connectivity
Mammals	<i>Lutra lutra</i>	Highly Endangered	~12 individuals in provinces (10×10 km grid)	Requires high water quality, shoreline cover; network gap present (Fig. 23)	Urgent habitat restoration with AAD and UEN frameworks
Butterflies	<i>Lycaena tityrus</i>	Highly Endangered	Fragmented; only 7 individuals in 10×10 km grid	Dependent on native herbaceous plants for food, breeding, and shelter	Targeted habitat management and connectivity enhancement
Dragonflies	<i>Leucorrhinia pectoralis</i>	Vulnerable (Antwerp), Highly Endangered (Flemish Brabant)	~179 individuals; uneven distribution	Prefers clear, nutrient-moderate wetlands; sensitive to eutrophication	Protect and restore wetland habitats
Grasshoppers	<i>Pseudochorthippus montanus</i>	Endangered	Limited but locally abundant; ~522 individuals	Moist habitats like fens and low moorlands; specialized and scarce	Conservation and management of wetland habitats

Table 5: Summary of priority species, based on the provincial priority species of Antwerp and Flemish Brabant INBO

ECOLOGY ANALYSIS

Eco districts

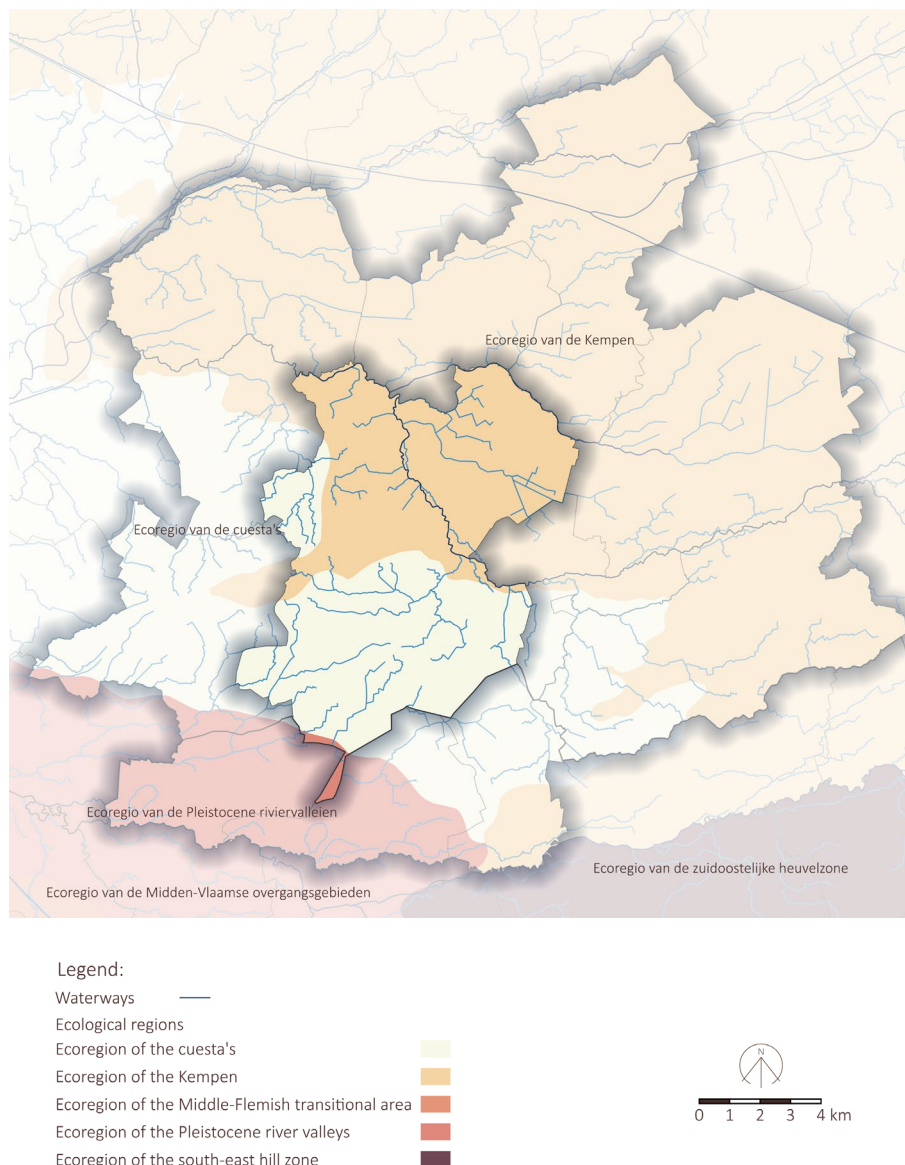


Figure 30: Ecoregion analysis of target area and region, based on INBO

To accurately assess the ecological characteristics and restoration potential of the target region, it is essential to delineate the specific ecoregions encompassed within the study area. Ecoregional classification serves as a fundamental tool in landscape ecology, as it reflects long-term geological, hydrological, and climatic influences that shape local biodiversity, habitat structure, and ecosystem functioning. Understanding the composition and interaction of these ecoregions provides a foundational context for identifying relevant abiotic and biotic factors that must be considered when designing conservation strategies, such as habitat restoration, species connectivity, and ecological resilience. The study zone encompasses three distinct ecoregions (fig. 31):

- the Kempen ecoregion (light orange), characterized by sandy soils, numerous waterways, and the presence of inland dunes;
- the Cuesta ecoregion (pastel green), which exhibits a mixed substrate of sand and clay;
- the Pleistocene River Valley ecoregion (dark red), defined by its sandy substratum and substantial subsurface phreatic groundwater reserves.

(Sevenant et al., 2002)

Together, these three ecoregions form a complex ecological landscape in which transitions between soil types, hydrological conditions, and habitat structures can occur over relatively short spatial scales. Recognizing and integrating these regional distinctions is vital for informed ecological planning, particularly in the context of applying frameworks such as Animal Aided Design (AAD) and the Urban Ecological Network (UEN), which aim to strengthen habitat continuity and species viability within fragmented landscapes.

Historical forest mapping

Ferrariskaart 1777: forestation of 1775

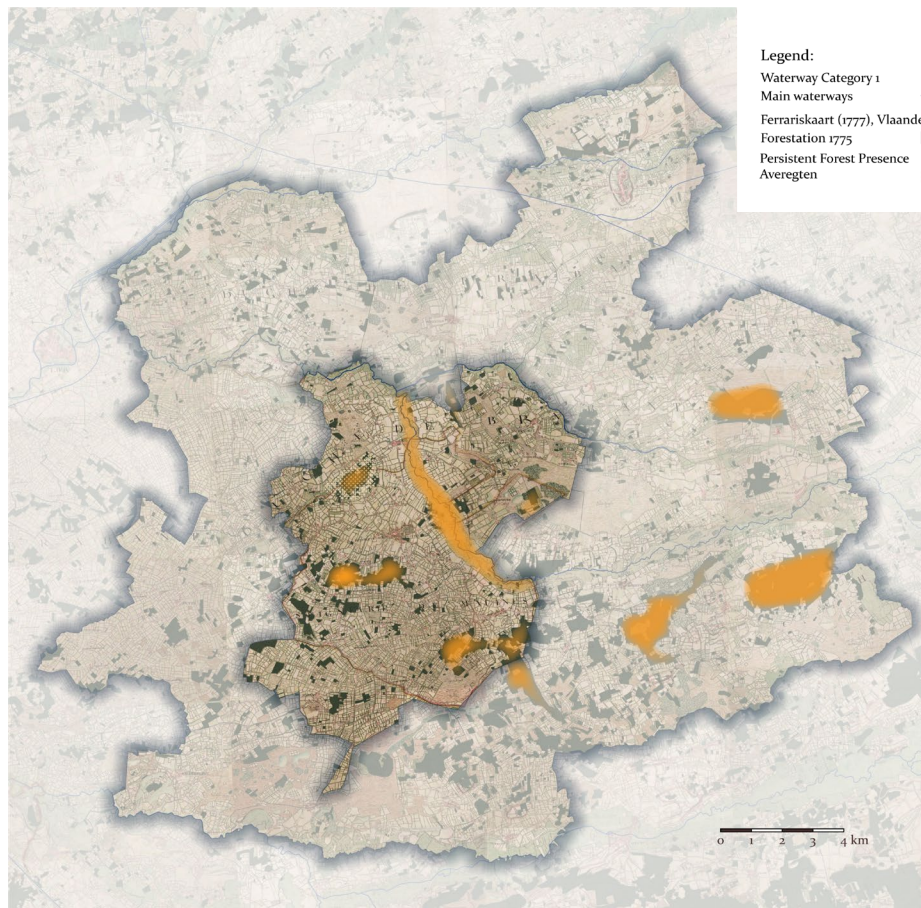


Figure 31: Historical forestation 1775, based on the Ferrariskaart & INBO

To understand the growth and distribution of ecological systems to integrate restoration of biodiversity, an analysis needs to be made of the historical forestations. The oldest available mapping is the Ferrariskaart from 1777, on the basis of this mapping the Institute For Nature And Forest (INBO: Instituut voor Natuur en Bos) made a historical underlining of the forest existing in 1777. This will be used as a starting base for further analysis.

Atlas of Neighbourhoods: forestation of 1850

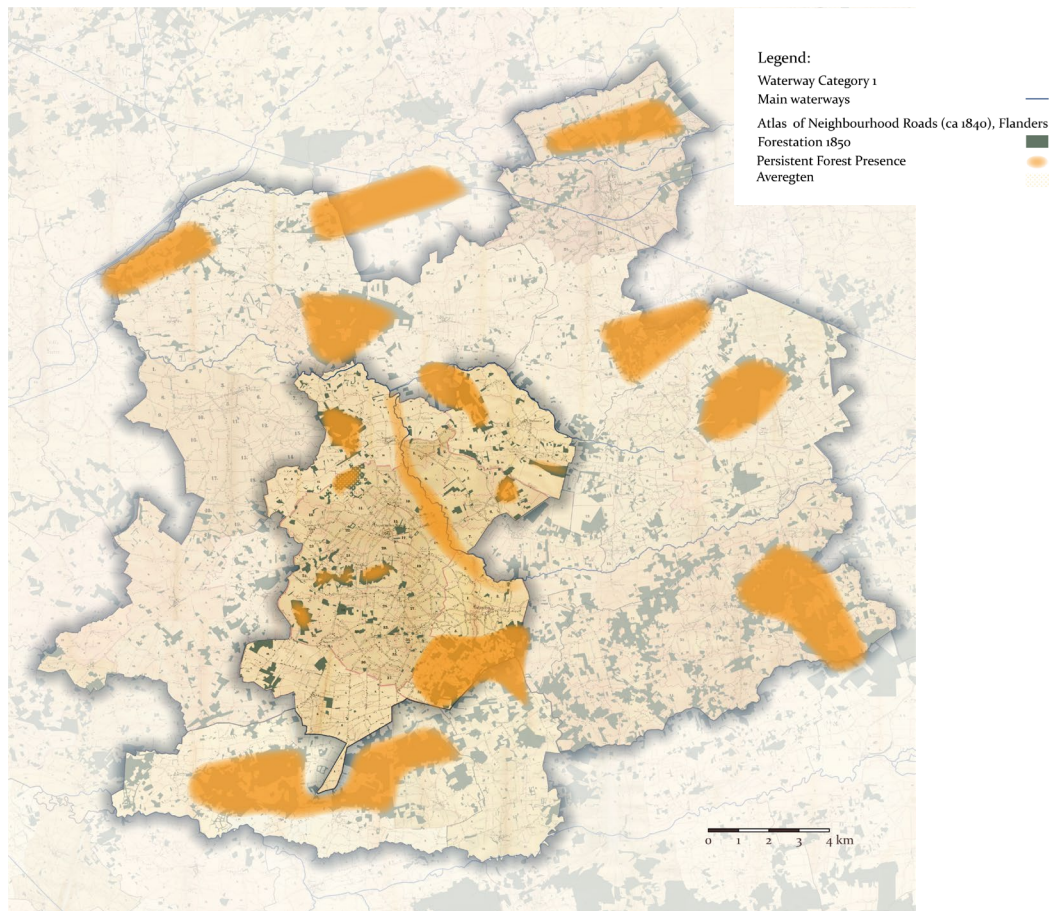


Figure 32: Historical forestation 1850, based on the Atlas of Neighbourhoods 1840 & INBO

The spatial mapping reveals a trend of increasing fragmentation and distribution of green spaces across the landscape. This pattern is most likely attributable to the expansion of agricultural activities and the systematic conversion of forested areas into cultivated land. Such land-use changes contribute significantly to habitat loss and landscape fragmentation, which can negatively impact ecological connectivity and biodiversity. Within the northern sector of the target region, a prominent contiguous green area is observed. This patch corresponds to the provincially protected zone, since 1994, known as "De Averegten", which serves as a critical ecological refuge amid a predominantly anthropogenic landscape. Established in the 18th century, De Averegten has maintained its ecological significance over time, functioning as a stable forested habitat that supports native flora and fauna. Its long-standing presence enhances the region's conservation value and offers an important anchor point for ecological network planning and biodiversity conservation strategies.

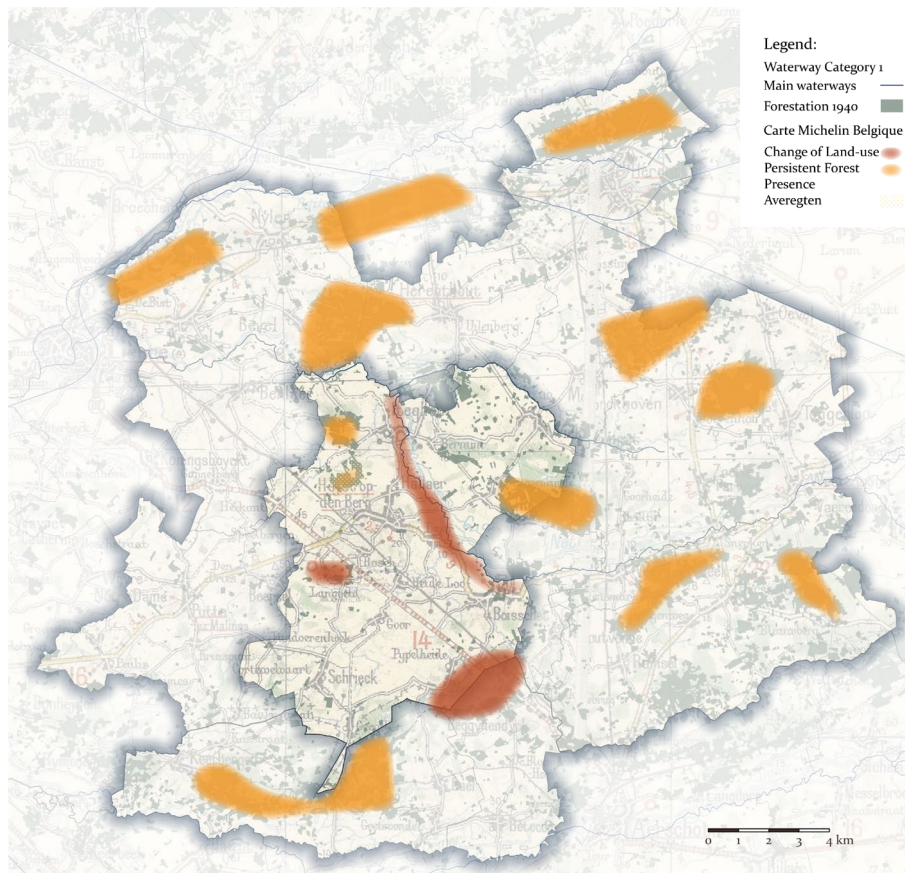


Figure 33: Historical forestation 1940, based on the Michelin-mapping (1920) & INBO (GmbH (<https://www.klokantech.com/>)), n.d.)

An analysis of spatial mappings from the interbellum reveals a progressive fragmentation of green spaces across the landscape. This trend is largely attributable to the absence of structured land-use planning with regard to ecological assets, as green spaces were not recognized as a significant priority during that time. Consequently, formerly extensive and continuous vegetated areas began to diminish in both size and integrity. While several historically prominent green zones have persisted, they too have experienced gradual reduction and internal fragmentation. Conversely, certain areas, particularly along river corridors, have witnessed new forestation efforts during the same period. These interventions were not primarily driven by ecological concerns but rather by utilitarian land management practices. However, recent reassessments of these historical land-use decisions have brought attention to their unintended environmental consequences—most notably, an increased incidence of regional flooding. Hydrological analysis and historical land cover patterns suggest that these areas originally functioned as wetlands, naturally adapted to buffer excess water. Their conversion to other land uses has disrupted the landscape's natural water retention capacity. Consequently, current land management discussions increasingly advocate for the restoration of these areas to their historical wetland state in order to mitigate flood risks and enhance ecological resilience.

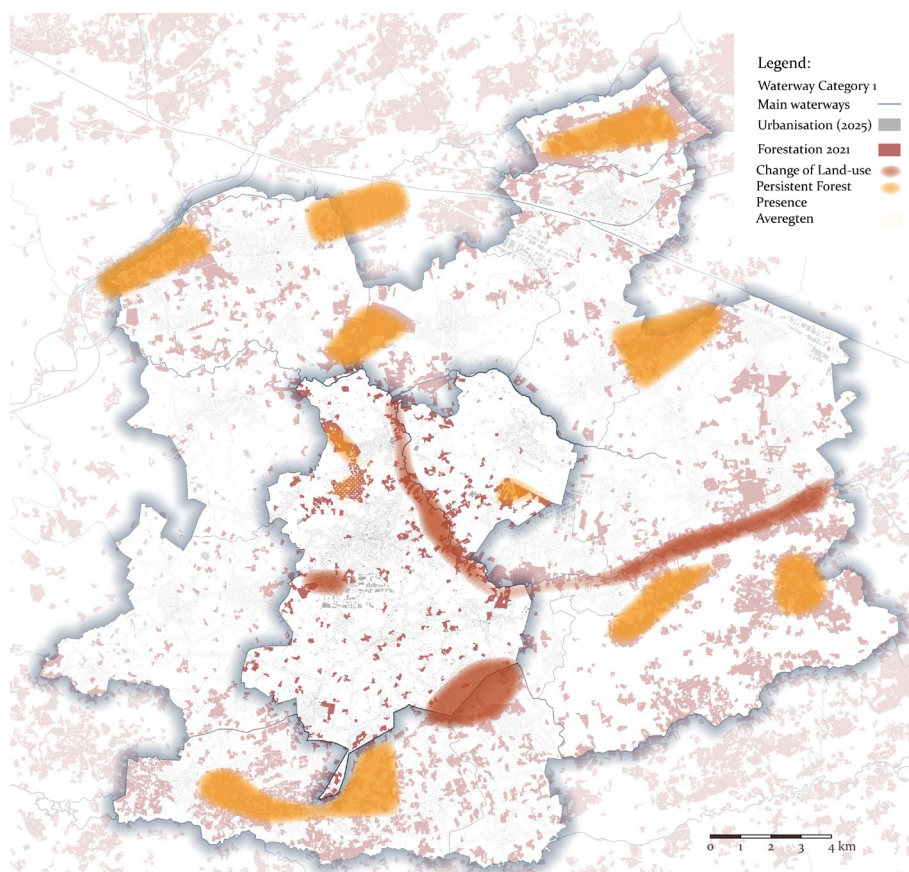


Figure 34: Forestation 2021, based on the current urban configuration (2025) & INBO

This forestation map of 2021 showcases the most recent allocations of forestation. The year 2021 was marked by several extreme weather events, including unprecedented flooding events within the province. These occurrences served as a critical warning signal, prompting provincial authorities to initiate the Vlaams Ecologisch Netwerk (VEN) programme. As part of this initiative, it was determined that areas adjacent to the river should be returned to their historical land use as wetlands. The objective of this program is to improve flood resilience, enhance ecological connectivity, and restore natural hydrological functions. As this restoration project is still in progress, no updated forestation plan has yet been developed.

In addition, the 2021 mapping indicates continued fragmentation of forested areas in the southern part of the target zone. This reflects an ongoing pattern of alternating loss and gain in forest patches, further highlighting the dynamic and transitional nature of land use in the region.

Previous conclusion

When these land cover transformations are juxtaposed with species distribution data, a clear correlation emerges: recent changes in forest structure and spatial configuration have had a direct impact on local fauna populations. The fragmentation and restoration patterns observed appear to influence habitat availability and ecological connectivity, with implications for species viability and movement corridors. To ensure comprehensive interpretation, the concluding synthesis map was constructed at the provincial scale. This allows for a multi-scalar understanding of landscape dynamics and integrates ecological, historical, and spatial planning perspectives necessary for guiding future conservation and restoration efforts.

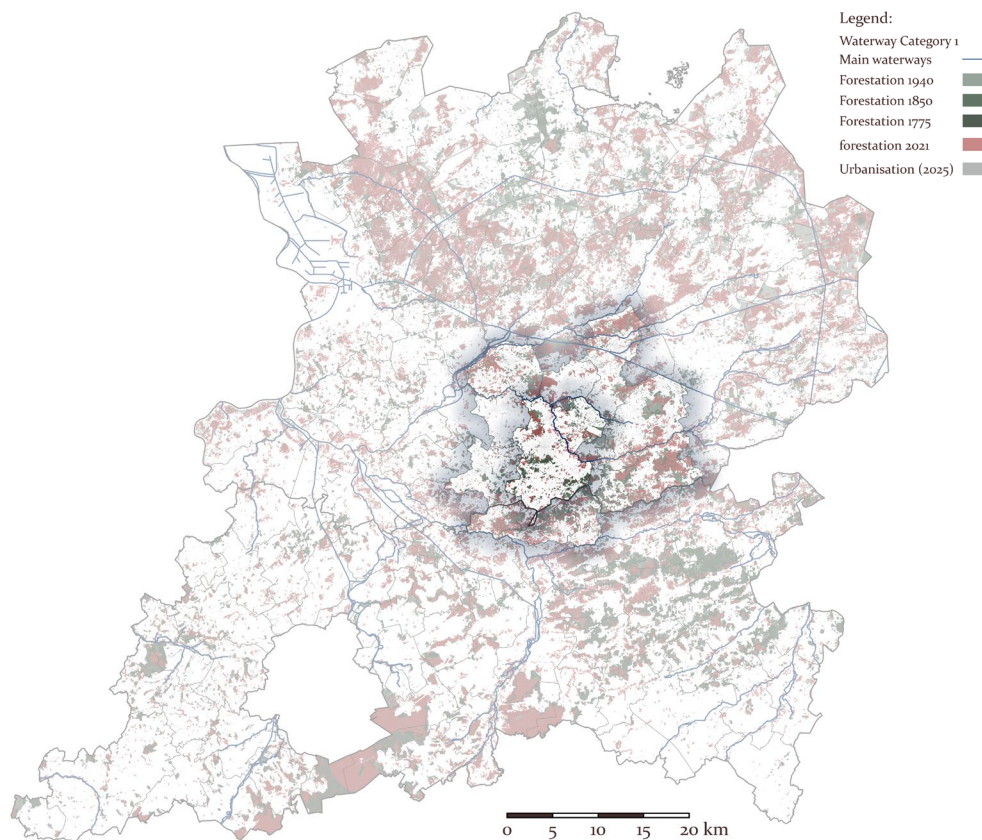


Figure 35: conclusion map of forestation evolution between 1775-1940 provincial level, made by author

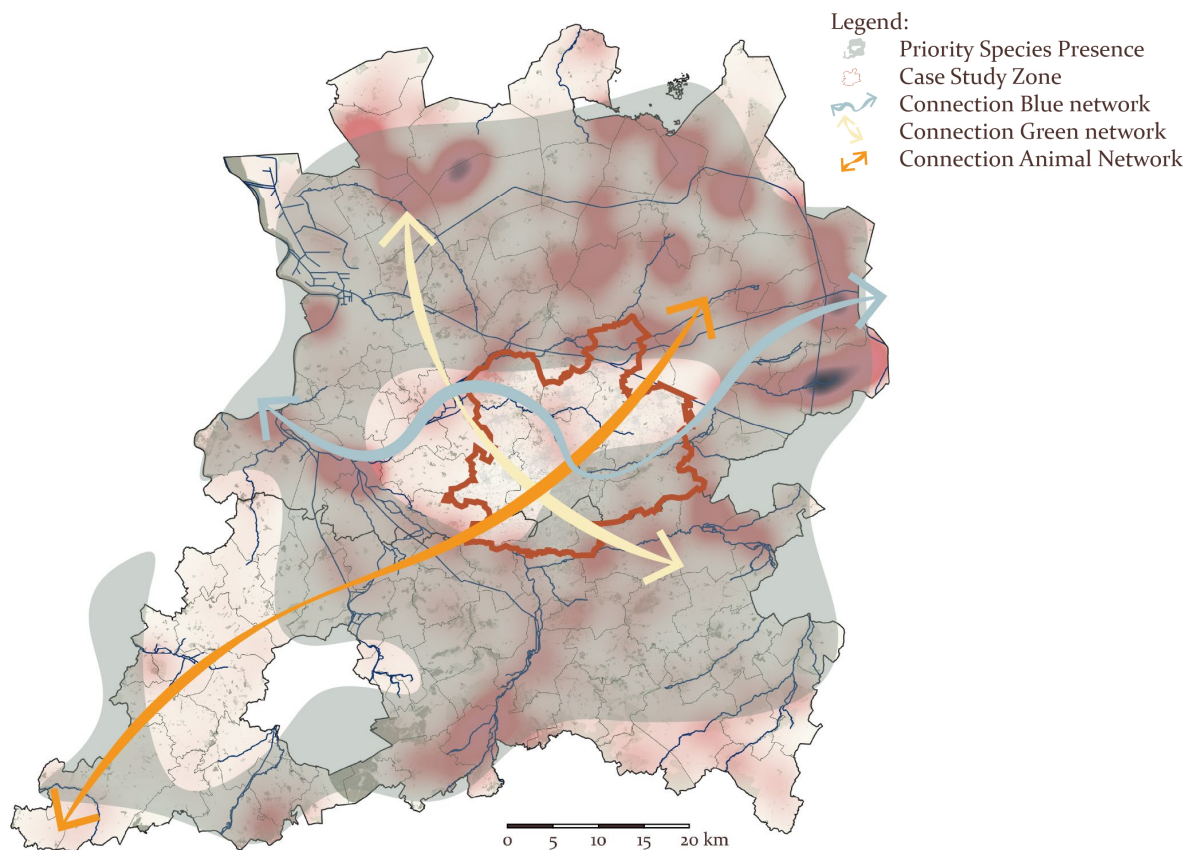


Figure 36: Synthesised analyse of the combination of Habitats of provincial priority species and forestation, made by Author

In this regional analysis, a clear gap is visualised around the target area. A lack of green distribution, good quality of the river water system in the dense areas is the ground of this. To restore these gaps, improvement in Urban ecological networks should be made, by reconnecting the green patches and improving the blue network quality together with a right aim to include priority species.

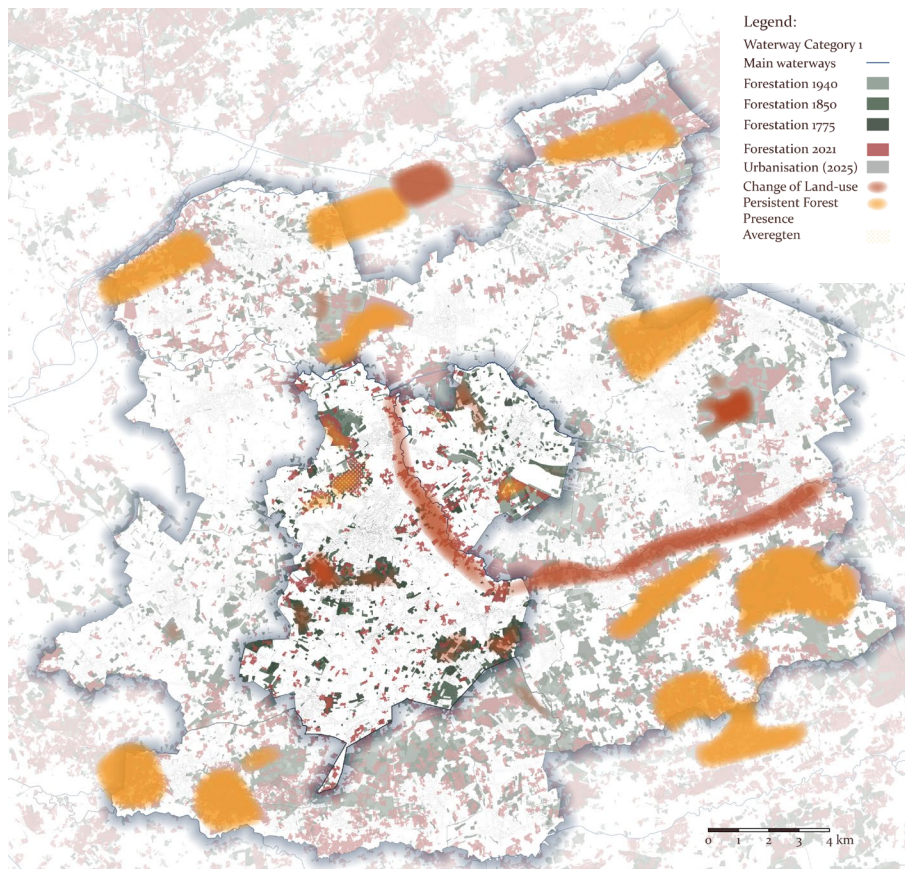


Figure 37: conclusion map of forestation evolution between 1775-1940 regional level, made by author

The spatiotemporal analysis of the landscape surrounding the provincially protected area “De Averegten” (Fig. 35: orange highlighted zone with light crosses within the target area) reveals a dynamic pattern of both forest loss and gain over time. Closer to the urban core, particularly in the central-western section of the target zone (Fig. 35: dark green zone), substantial deforestation has occurred, reflecting pressures from urban expansion and land-use change. In the southern part of the target area, historical forest coverage has largely disappeared, indicating long-term land conversion trends. In contrast, the northeastern section of the target zone demonstrates notable reforestation, with a significant increase in vegetative cover.

(*Catalogus*, n.d.)

OWNERSHIP ANALYSIS

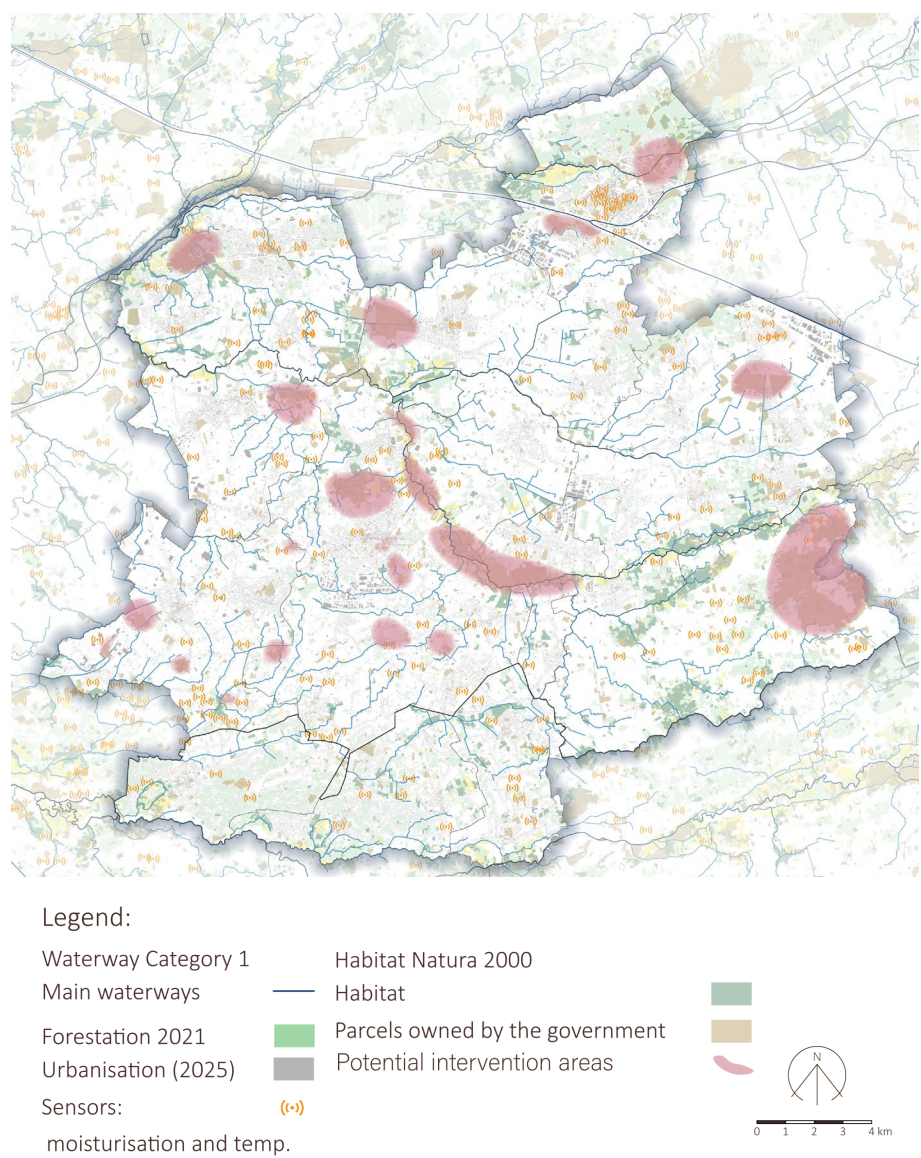


Figure 38: State ownership analyse, based on geopunt.be

Based on spatial data available through the Belgian geospatial platform Geopunt.be, it is evident that the government possesses a substantial number of strategically located land parcels within densely built urban areas. Many of these plots are currently used for low-intensity functions such as parking lots for public events. Additionally, a significant proportion of publicly owned land is situated adjacent to the regional river systems, presenting a valuable opportunity for the ecological restoration of wetland areas. These river-adjacent zones are particularly suitable for the development of continuous green and blue infrastructure, potentially forming a natural ecological corridor. Such a corridor could serve as a multifunctional landscape element, supporting biodiversity, water retention, and recreational use. Furthermore, it offers a promising framework for intermunicipal cooperation, enabling ecological planning and climate adaptation strategies to be implemented at a broader, regional scale.

ANALYSIS OF WATER QUALITY

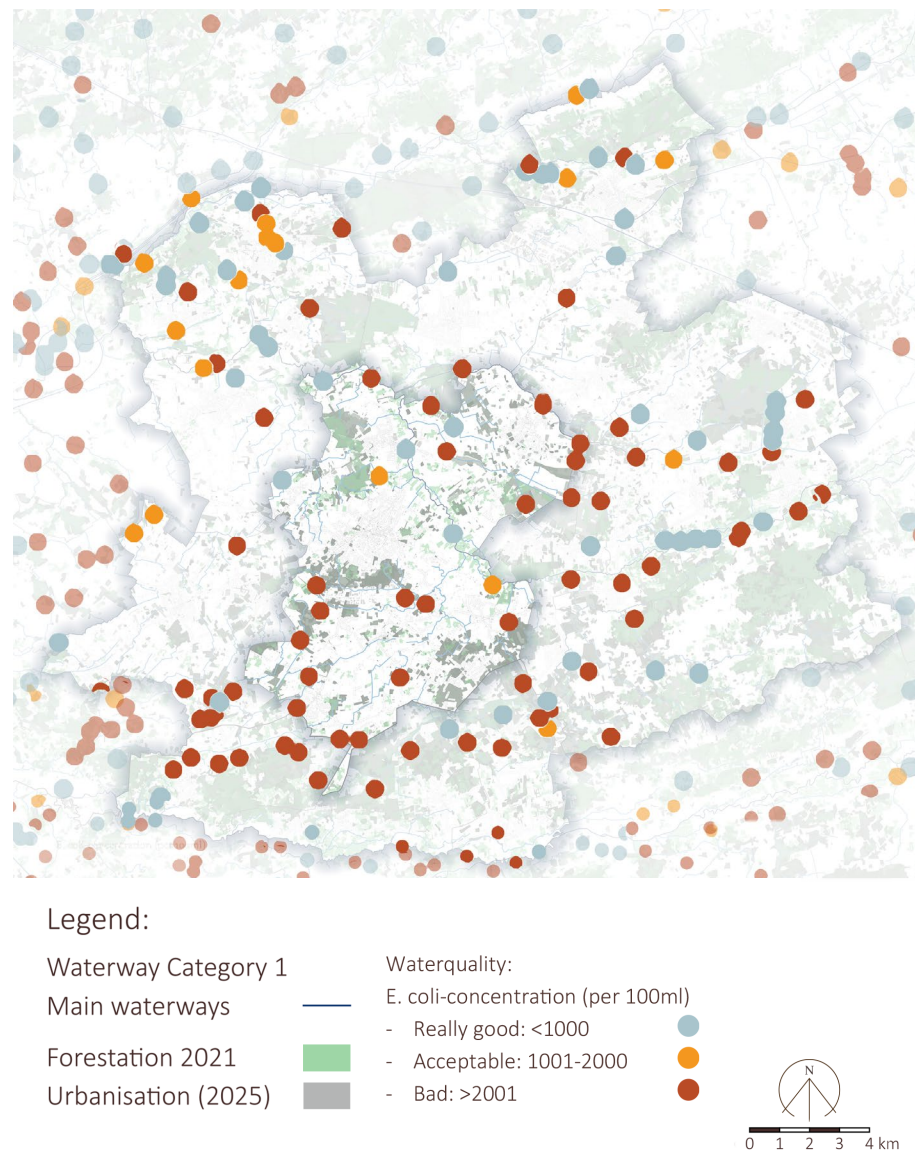


Figure 39: water quality analysis, based on Hoe proper is het water in uw buurt?, 2025

This study was conducted through a collaboration between the Belgian newspaper De Standaard, the Catholic University of Leuven (KU Leuven), and several institutional sponsors. The methodology relied on participatory citizen science, wherein members of the public were mobilized to collect water samples across various locations. In total, approximately 5,000 civilians, 110 schools, and 180 environmental organizations participated in the campaign. At each designated site, five individual samples were collected to ensure reliability and reduce variability. The primary parameter assessed was the concentration of *Escherichia coli* (*E. coli*), a well-established microbiological indicator of fecal contamination and water pollution. Specific threshold values and procedural guidelines were established to standardize the sampling process and ensure the scientific validity of the results. (*'Watermonsters' is gestart*, 2025)

SWOT ON CONCEPTS

In the annex, a SWOT analysis was conducted for each of the four key concepts in tabular form. Due to space limitations within the main body of the thesis, a more detailed and comprehensive investigation is presented in this section.

In conclusion, Heist-op-den-Berg's intermediate urban density, ecological value, and socio-political setting result it both a challenging and promising context for applying integrated nature-based frameworks. The SWOT results indicate that with coordinated governance, community engagement, and technological support, nature-inclusive strategies such as AAD and NbS not only become viable but exemplary, setting a precedent for similar towns across Belgium and the Eurodelta region.

SWOT ANALYSIS

Regional SWOT

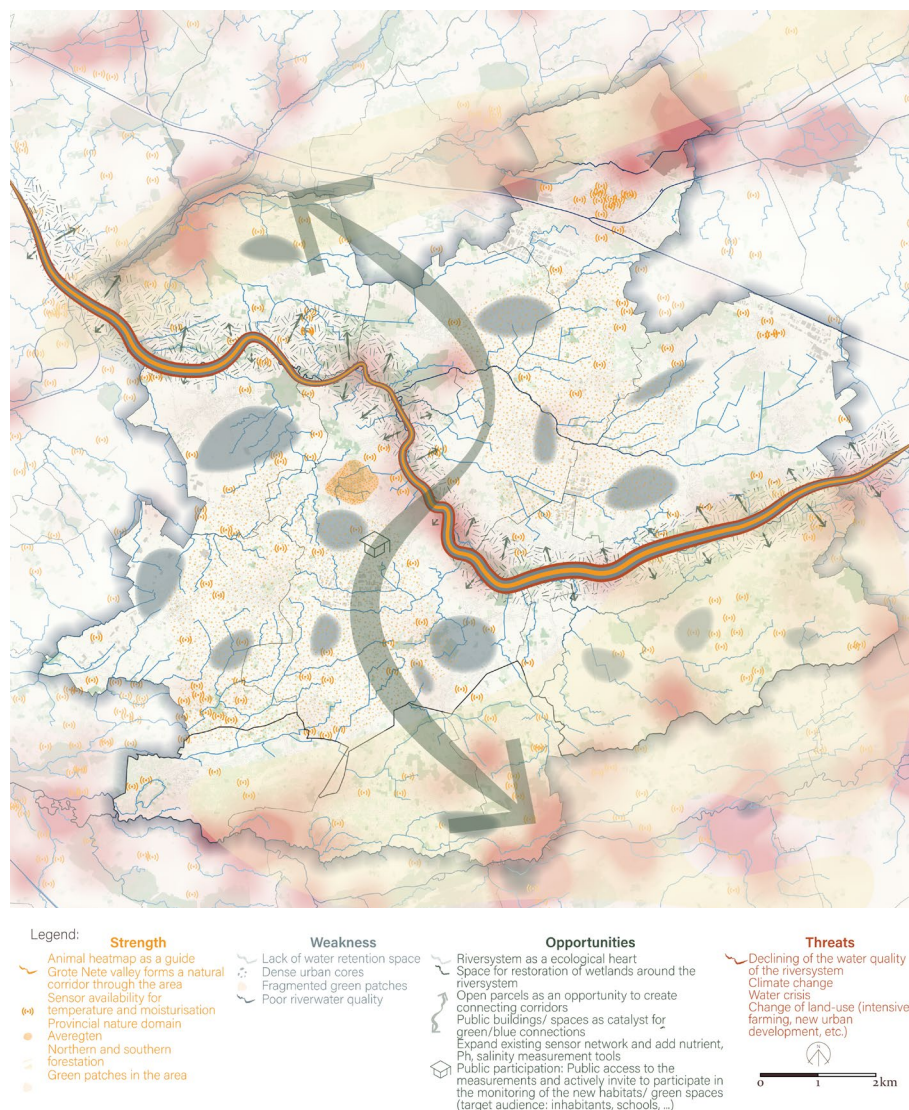


Figure 40: Regional SWOT analysis, made by author

The regional SWOT analysis makes the base for the inclusion of the conceptual model on a bigger scale. Surrounding these analysis a checklist can be made to follow as a toolbox.

Large Dense Town SWOT

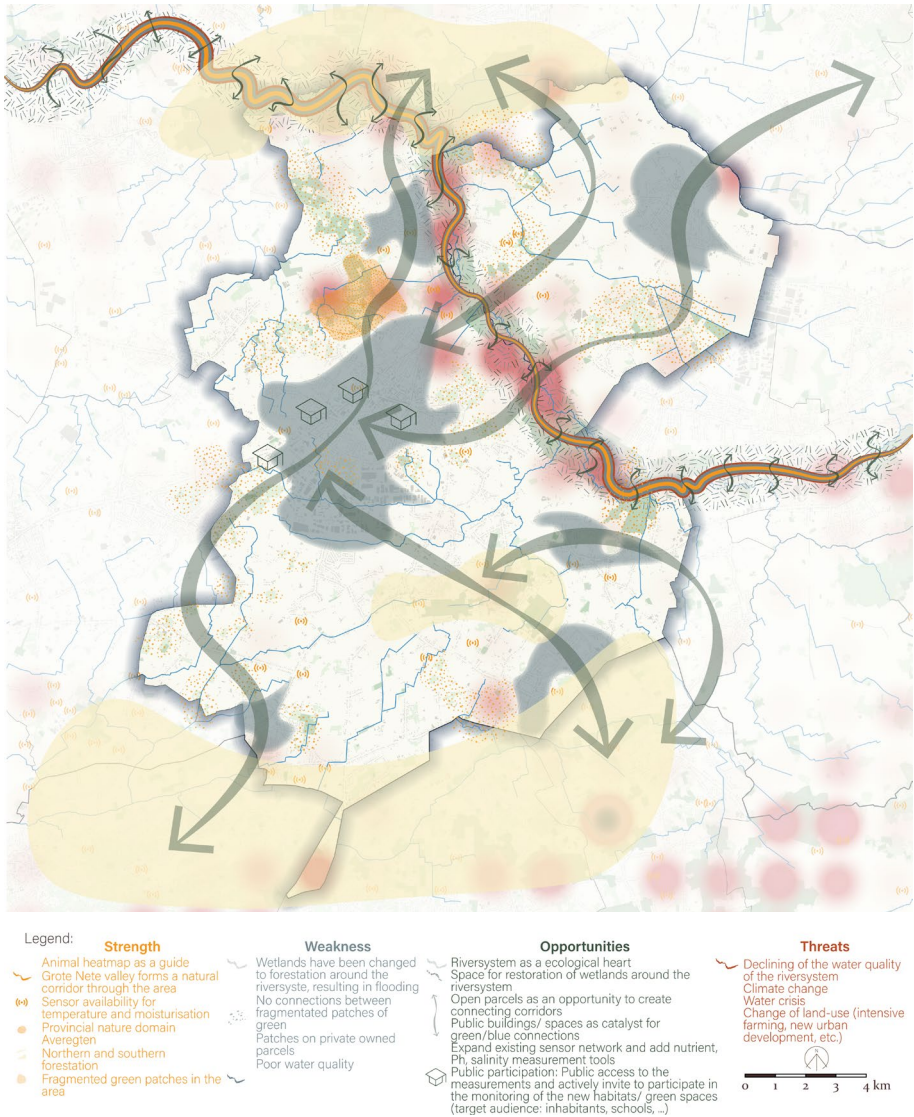


Figure 41: Local SWOT analysis, made by Author

13. Conceptual Integration

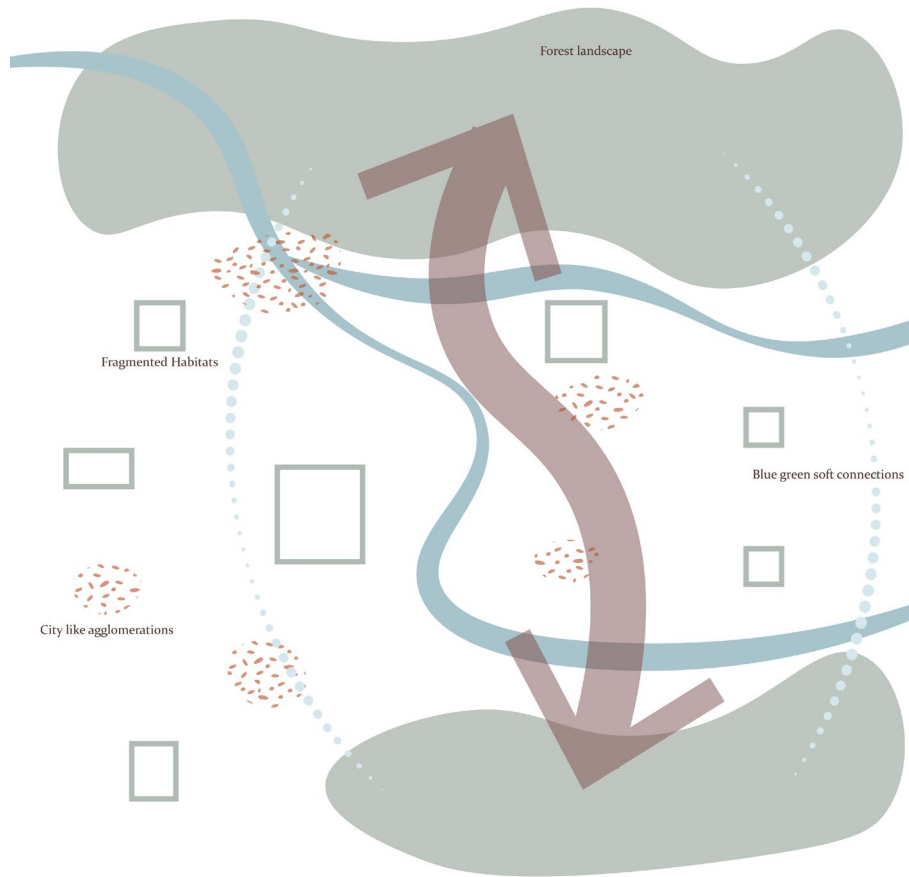


Figure 42: Conceptual model presenting the integration of AAD, NbS, EUN and IoN, made by author

This integrated model highlights the issues of many large dense towns. Fragmented green spaces with little to no connections with bigger forestation. With the soft blue green connections extensive natural zones would be interconnected via the fragmented habitat pieces. By creating these corridors, habitats can expand their territory. This can create a thriving environment and improve biodiversity on a small scale. With the main red arrow the greater connection is sought via the river system, as it functions as a main artery and strengthen the backbone of a area. The connections are existing of the principles of Animal Aided Design, Nature-based Solutions, Urban Ecological Networks and Internet of Nature.

14. Structural plan

REGIONAL

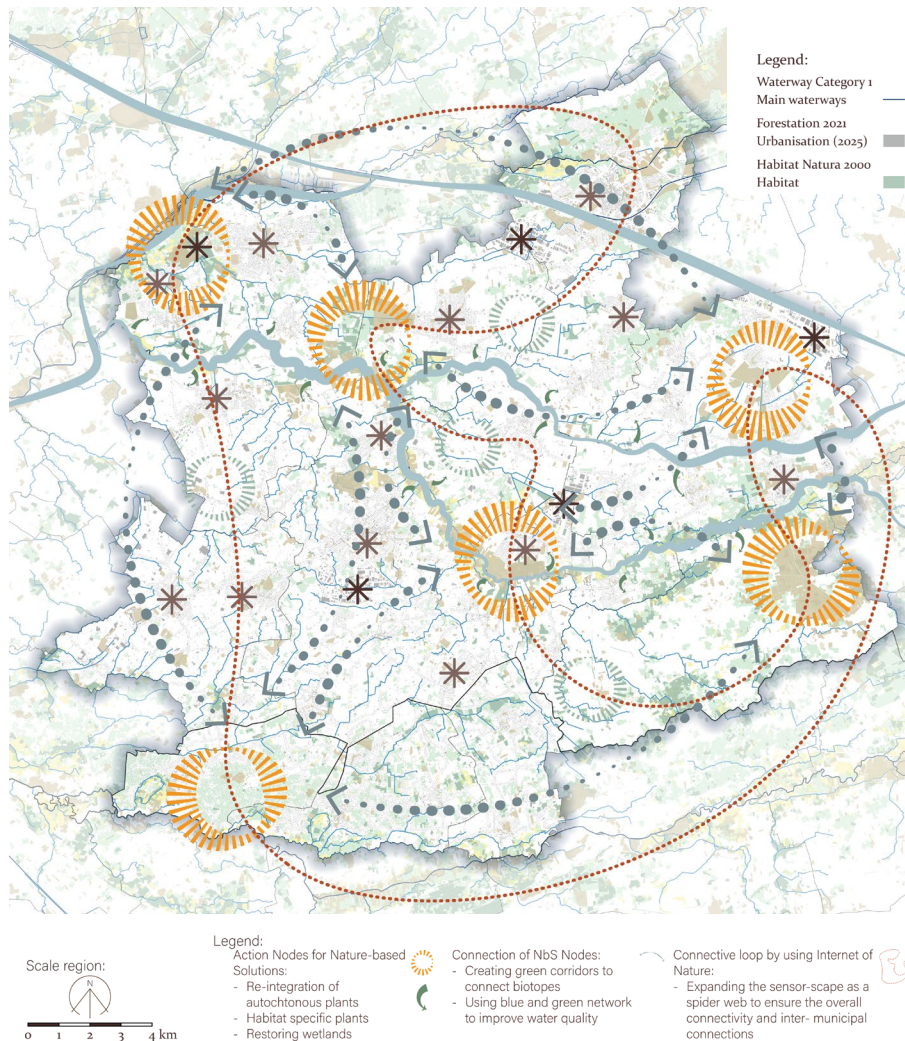


Figure 43: Structural plan of the region, with different attention nodes and actions zones, created by author

This structural plan outlines the structural plan and potential application zones for integrated ecological and technological interventions. Central to this framework is the river system, conceptualized as a principal ecological artery that serves as the backbone for regional connectivity. The expansion of wetland areas along these river corridors exemplifies the deployment of Nature-Based Solutions (NbS), aimed at enhancing flood resilience, biodiversity, and climate regulation. In parallel, the framework incorporates the Internet of Nature (IoN) paradigm through the expansion of sensor-based environmental monitoring infrastructure. This sensor-scape allows for the identification of priority intervention zones, thereby supporting data-driven decision-making and the development of adaptive, tactical maintenance regimes.

Green nodes, characterized by underutilized plots, vacant parcels, and grasslands, are identified as zones requiring extra attention. These areas are strategically positioned to act as ecological catalysts within the urban fabric, facilitating the development of green corridors and contributing to the expansion of viable habitat zones.

Pastel dark red nodes indicate urban cores affected by the urban heat island effect, often due to their high-density, built-up morphology. These areas are prioritized for NbS interventions in conjunction with Animal-Aided Design (AAD) strategies, which not only promote

biodiversity but also create green oases that improve mental well-being and urban liveability. The integration based on the inventory of autochthonous plant species, in alignment with provincial priority species needs, supports the establishment of thriving, context-specific ecosystems. The addition of sensor technologies in these zones further enables efficient, need-based maintenance while potentially reducing long-term public health and infrastructure costs. Dark red nodes, representing industrial zones, are designated for intensified environmental monitoring. Here, the use of advanced sensor systems enables real-time detection of industrial pollutants, which informs both the selection of water/ soil purifying vegetation and the potential for implementing stricter effluent regulations. This ensures that these areas can contribute to ecological restoration while remaining functional within the broader urban economy.

To ensure coherence and connectivity across the region, the plan proposes the establishment of Urban Ecological Networks (UENs). These networks facilitate the physical and ecological linkage between fragmented habitats, thereby enhancing biodiversity conservation, improving ecosystem services, and fostering intercommunal collaboration. Moreover, these corridors act as educational and experiential landscapes, encouraging public engagement and biodiversity awareness by allowing residents to encounter and interact with local species.

LARGE DENSE TOWN

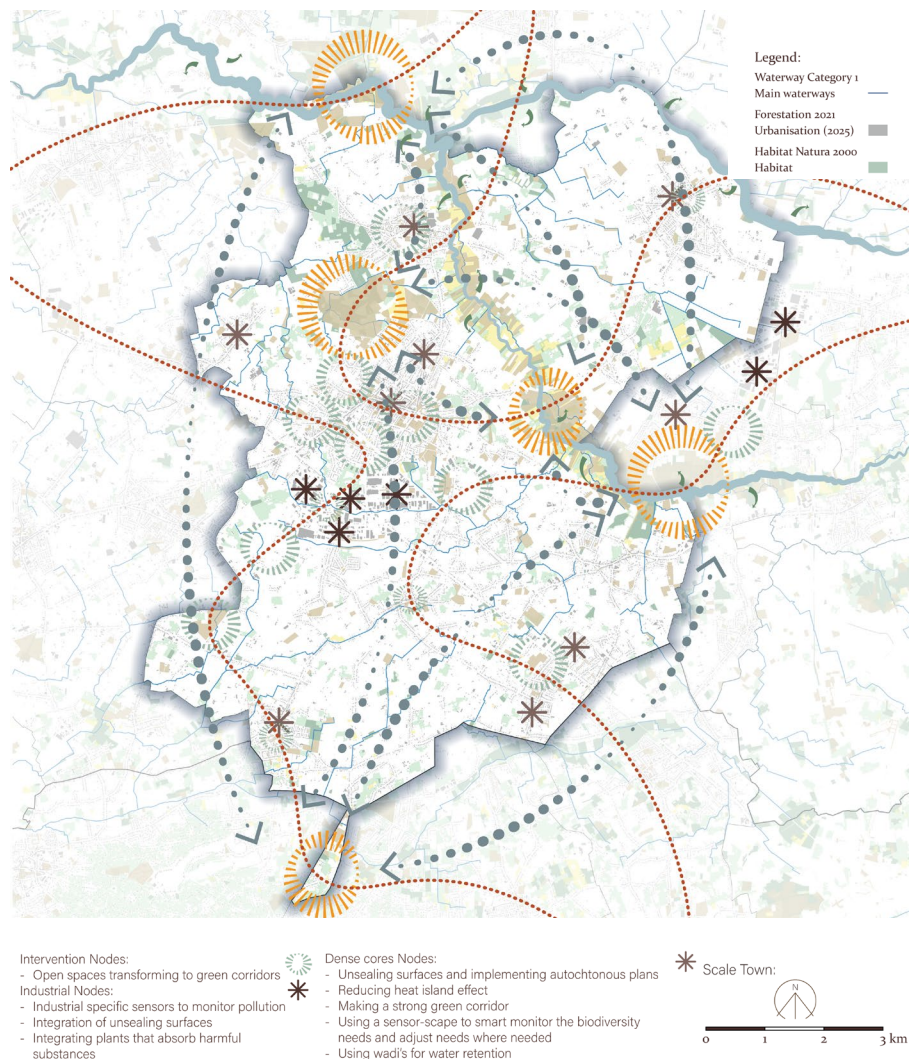


Figure 44: Structural plan of a large dense town, with different attention nodes and actions zones, created by author

This structural plan mirrors the framework established at the regional scale; however, the local scale allows for a more detailed and context-specific decision-making process. At this scale, urban and industrial cores become more distinctly visible, and the identification of state-owned plots (depicted in beige) enables a strategic selection of potential action zones based on land ownership and feasibility of intervention. The plan delineates two primary categories of intervention nodes. The orange nodes indicate areas where forested zones and existing habitats are present but require a more ecologically resilient management approach. These strategies may include the introduction of autochthonous (native) species or the re-establishment of wetland ecosystems to support regional biodiversity objectives.

In contrast, the light green nodes highlight either (1) underutilized parcels that could serve as critical ecological stepping stones (drip links) for connecting fragmented habitats and forested patches, or (2) densely built-up urban cores where biodiversity enhancement is essential for mitigating urban heat island effects and promoting soil unsealing. In these nodes, Nature-Based Solutions (NbS) and Animal-Aided Design (AAD) approaches are proposed as means to foster ecological restoration and improve human well-being within the urban context. The prioritization of publicly owned land for pilot interventions is emphasized, as this allows for swift implementation while serving as demonstration projects to enhance civic engagement and awareness. Initiatives such as community-managed fruit-picking gardens exemplify strategies that encourage coexistence between human and non-human species, while fostering social cohesion and promoting ecological literacy. Notably, in the southern section of the municipality, a historically evolved village is observed to have developed in close interaction with green oases. This settlement is presented as a model of nature-integrated urbanism, providing an example of how future neighbourhood developments—particularly in peri-urban zones—could be designed to prioritise green space integration from the outset. While such spatial opportunities are limited in high-density cores, their principles can inform future urban expansion, ensuring alignment with climate resilience and biodiversity goals.

15. Masterplan

LARGE DENSE TOWN

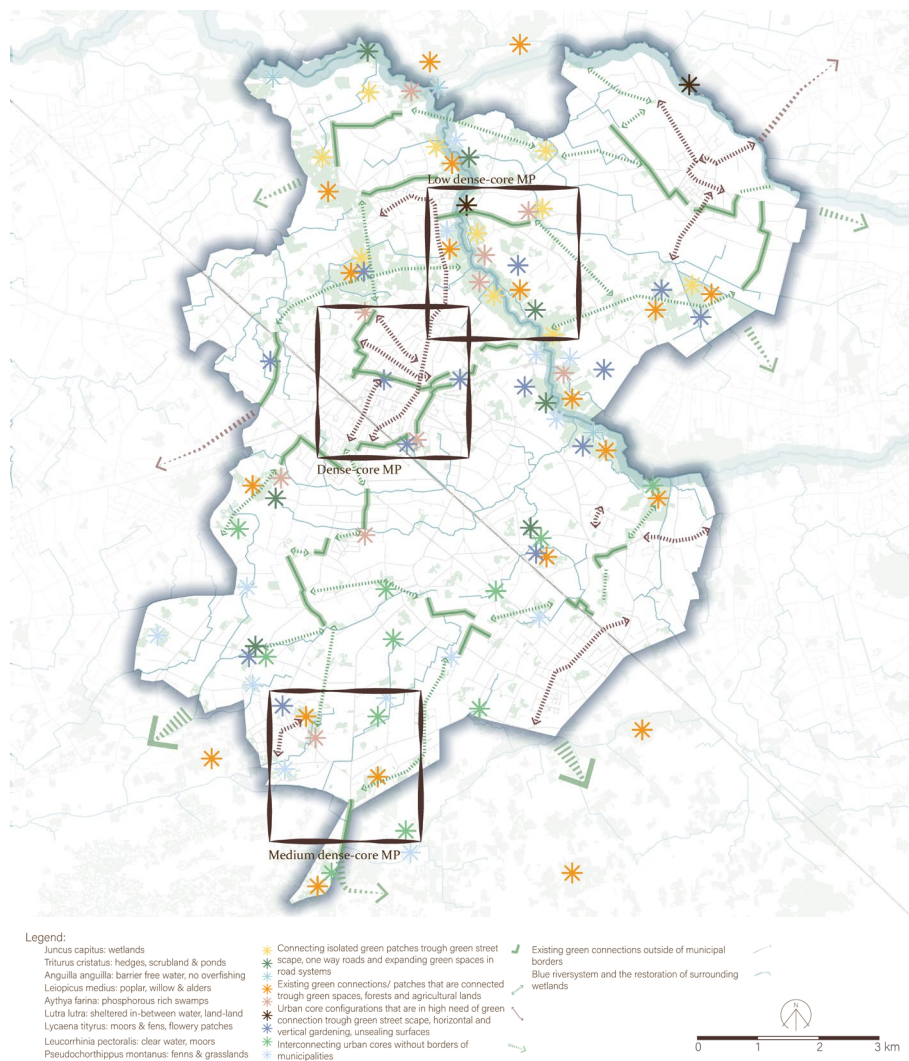


Figure 45: Masterplan large dense town, 1/50 000 scale, created by author

In order to develop a masterplan in which animal species are considered as essential stakeholders, a system of species-specific flashcards was devised. These flashcards were based on the selected priority species outlined in Chapter 11 and serve to communicate the ecological requirements and spatial needs of each species. The priority species are grouped into nine distinct taxonomic categories, each of which has been allocated a target habitat zone where it can potentially thrive, contingent upon the implementation of targeted ecological interventions. The identified interventions play a pivotal role in the formulation of a sustainable development strategy for large, densely populated towns. These strategies focus on the integration of Nature-based Solutions (NbS), including the introduction of native (autochthonous) plant species in combination with Animal-Aided Design (AAD) principles. Such an approach is anticipated to yield co-benefits including improved water quality, enhanced soil stability, and a measurable reduction in the urban heat island effect. To facilitate a coherent and scalable implementation, a strategic masterplan was developed at a scale of 1/50 000. At this scale, macro-level ecological corridors and intervention zones are identified; however, finer spatial resolutions are required to operationalize these strategies. Consequently, three detailed zoom-in areas were selected to illustrate potential interventions across varying urban densities within the broader region. The colours of the masterplan correspondents with the colour of underlining on the flashcards.

Higher Plants: *Juncus capitatus*

Needs: Riparian zones (stagnant water bodies)
Soil: Sand & loam, moist (Eco-region Kempen)
Sunlight: Sunny to light shadow
Triggers: Drainage of soils, increased fertilisation concentration (base rich & phosphorus poor)



Amphibians: *Triturus cristatus*

Needs: Surface water (small waters), forest, hedges, scrubland, submerged vegetation
Food: Invertebrates, larvae, insects
Enemies: Heron (bird)
Life-cycle: February till September above ground, hibernates in soil, needs high quality of water to lay eggs in (May - April), after 10-20 days out of egg, after 3-4 months out of water



Fish: *Anquilla anquilla*

Needs: Sweet inland water bodies with mud soils, migratory, sheltered spaces
Food: Invertebrates (aquatic woodlouse, bait shrimp)
Enemies: Great cormorant (bird)
Life-cycle: 0 to 2-3 Y: salt water, 3-12 Y: sweet water, 5-... Y: migration to the Caribbean to reproduce, hibernates in mud from November till March
Triggers: Habitat loss, barriers on migration path, water pollution, fishing & consumption



Breeding birds: *Leiopicus medius*

Needs: Middle to top layer of deciduous trees, tree cavities (resident bird)
Food: Insects, larvae & spiders, drinks tree sap, wintertime: nuts, acorns, seeds
Enemies: Sparrow hawk & weasel (bird & mammal)
Life-cycle: Out of hibernation February- March, nest-cavity in poplar, willows or alders
Eggs: April- May, 11-14 days breeding, flying after 20-26 days, reproducing after 1 year



Wintering waterfowl: *Aythya farina*

Needs: Well vegetated swamps (>phosphor), marshes, lakes, slow flowing rivers, fringing vegetation (riparian plants filtering water)
Food: Omnivorous (seeds, roots, aquatic plants & insects, larvae, crustaceans, worms, amphibians, small fish)
Enemies: Mink, red fox
Life-cycle: Hibernation: September- March, ground & water plants as base for nest build with reeds & leaves
Eggs: April- May, +-3 weeks breeding, +-8 weeks flying
Triggers: Salinity increase, <carp, correlation with Black headed Gull, agriculture



Mammals: *Lutra lutra*

Needs: Space (10-20 km, 1 male & +females) between water & land; rivers, tributaries, channels, ponds, lakes & high quality water & shelter riparian vegetation, home between roots of tree in water
Food: Carnivorous staple food: fish (eel), amphibians, water birds & eggs
Life-cycle: 61-63 days: gestation, 3+- months: dive, +1 Y: interdependent, +2 Y: fertile, breeding = inland
Triggers: Pollution, humans & dogs



Butterflies: *Lycaena tityrus*

Needs: Grasslands, moors & fens, flowery patches, overwinters on sheep's sorrel & common sorrel
Food: 1: blackberry flower, 2: heather, cross-leaved heather, creeping thistle, thyme (nectar)
Life-cycle: 2 generations: May-june and July-August, larvae: herbivore (sorrel, verge sorrel), chrysalis: 2-4 weeks
Triggers: Loss of biodiversity, fertilisation



Dragonflies: *Leucorrhinia pectoralis*

Needs: Clear water: moderate nutrient rich fens, low moors & moderate nutrient-poor fens
Food: Insects (mosquito (larvae), flies (larvae), moths)
Life-cycle: Larvae in riparian zones & overwinters 2x, May-June: exit riparian zone, flying to sheltered area, eggs: water plants and lay off under water surface, flies until July
Triggers: Drying sandy grounds, fertilisation



Grasshoppers: *Pseudochorthippus montanus*

Needs: Fens, moist, half-open areas with wet grasslands, low vegetation (swamps)
Food: Herbivorous arrow root, reeds, rushes & sedges
Life-cycle: July - October
Eggs: at ground level or roots of the grass, next spring nymphs hatch & peels +-4 times, species doesn't fly
Triggers: Droughts (eggs die off)



Figure 46: Flash cards of 9 taxonomic priority species, created by author (based on information on waarnemingen.be)

One of the primary insights derived from the spatial analysis is the significance of establishing a north-south ecological corridor aligned with the existing blue (hydrological) network. This corridor functions as a backbone for enhancing biodiversity and contributes to the establishment of an Urban Ecological Network (UEN). The overarching objective of the masterplan is to maximize ecological connectivity, both for species dispersal and for the perceptual continuity of green infrastructure, thereby fostering integrated, multifunctional landscapes that support both human and non-human life.

ZOOM 1: DENSE CORE

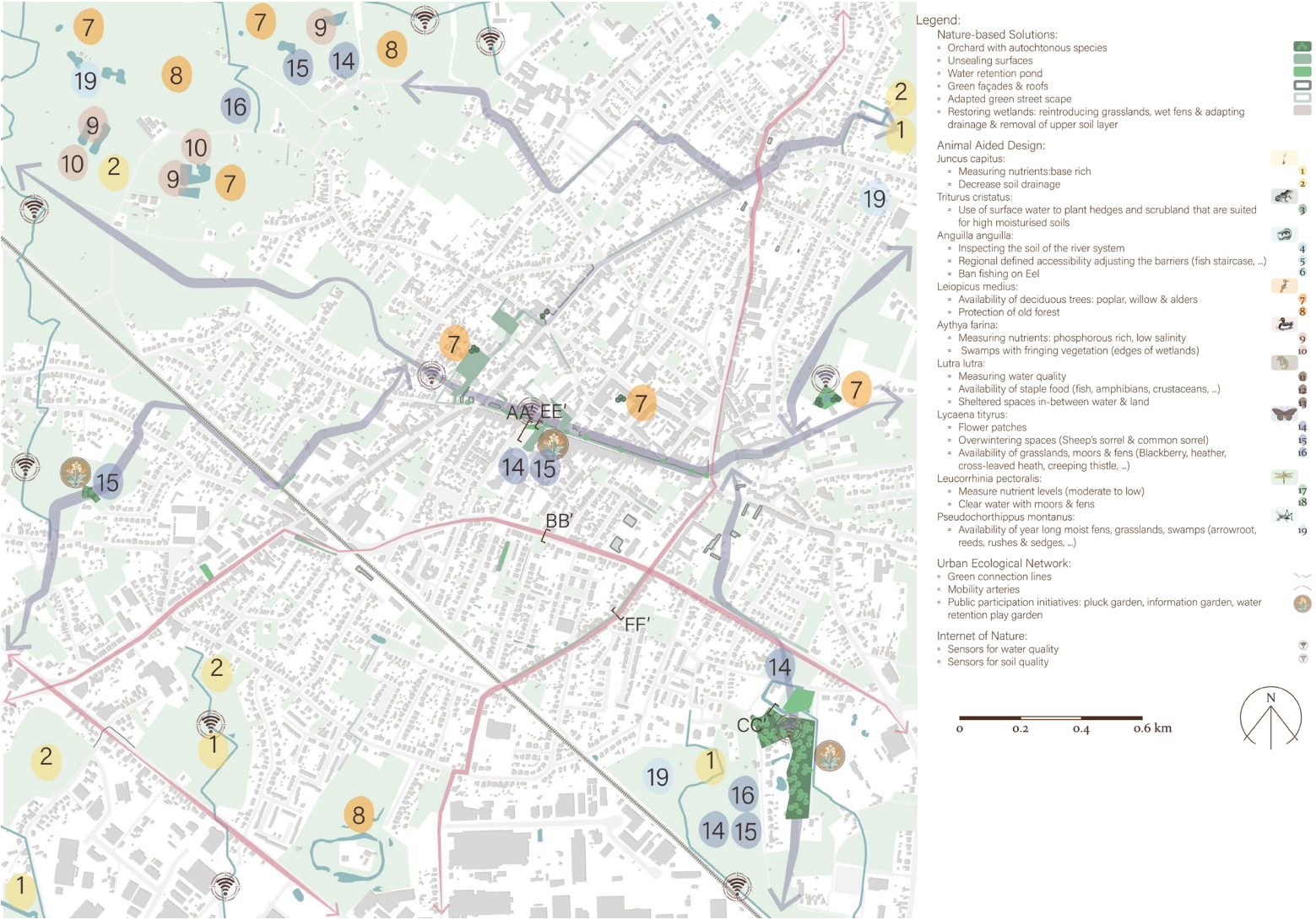


Figure 47: Zoom 1 dense core, made by author

In this first zoom-in, the focus is directed toward the spatial implementation of the urban ecological network delineated in the overarching masterplan in the most dense part of the town. The Density in this area is measured between 1896-3997 pers./ km². Drawing upon the species-specific habitat requirements identified in the priority species cards, this detailed view highlights ecological needs that are spatially translated into targeted design interventions. These requirements are reflected both in the cartographic legend and in the action-based spatial representations within the zoomed-in area. To more effectively communicate species needs and design responses at the urban scale, a series of schematic cross-sections have been developed. These illustrate the spatial experience from a public perspective and are intended to foster community engagement and participatory awareness.

The principal insights derived from this first zoom-in emphasize the multi-scalar integration of biodiversity. This includes both horizontal layering - such as green roofs, rain gardens, water retention ponds, and riverine systems - and vertical strategies involving vegetated façades, climbing plants, and green gutters. Together, these spatial interventions contribute to an ecologically resilient urban fabric and support the broader objective of enhancing biodiversity through integrative, multispecies urban design.

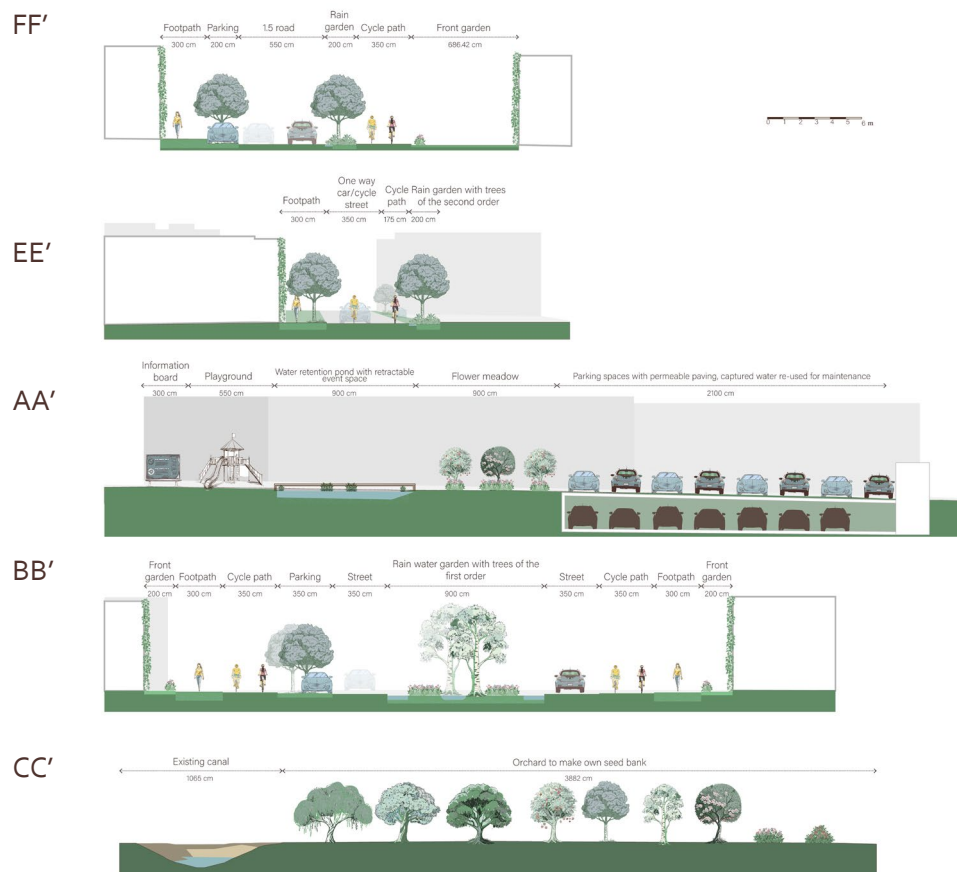


Figure 48: Sections from zoom 1, made by author

The cross-sectional illustrations serve as spatial narratives that articulate the core interventions proposed for enhancing urban ecological integration and addressing multifunctional needs within urban infrastructure. Each section highlights a targeted strategy for improving biodiversity, water management, and public well-being, tailored to specific urban contexts and street typologies.

Section AA' illustrates the adaptive reuse of a conventional parking area into a multifunctional biodiversity hub. This transformation includes the implementation of a water retention pond, a native flower meadow, and an educational interpretive panel. By situating such interventions within the urban core, this strategy fosters public awareness and encourages participatory engagement with ecological functions embedded in everyday environments.

Section BB' depicts the redesign of a dual-lane traffic artery into a more ecologically functional urban street. Here, one lane is repurposed into a green stormwater infiltration zone, effectively contributing to climate resilience. The system is designed to accommodate variable widths depending on spatial constraints and provides delayed runoff absorption as well as enhanced stormwater conveyance during heavy rains.

Section CC' focuses on the strategic ecological enhancement of underutilized green spaces, often maintained as generic grass fields. These spaces are converted into ecological seedbanks through the planting of autochthonous tree species and habitat-specific flowering plants. This robust intervention serves long-term biodiversity objectives by addressing the life-cycle needs of selected priority species, thereby enhancing ecological integrity and resilience.

Section EE' introduces a traffic-calming and biodiversity strategy in contexts where traffic intensity permits. Conventional two-way streets are converted into one-way systems, with the reclaimed lane allocated for the extension of bicycle infrastructure and biodiversity strips. This dual intervention improves urban mobility, promotes active transportation, and integrates ecological functions within high-density urban areas. In synergy with local mobility hubs, this strategy is anticipated to enhance well-being and promote environmentally sustainable transit behaviour.

Section FF' proposes the design of a one-and-a-half-lane street configuration in traffic-calmed zones. The reduction of vehicular lanes enables the expansion of cycling infrastructure and the introduction of rain gardens in buffer zones between parking pockets and bus crossing areas. The spatial arrangement includes physical separation between bicycle paths and vehicular lanes to improve user safety while simultaneously contributing to water infiltration and biodiversity enhancement.

Together, these sections exemplify a comprehensive, scalable approach to urban ecological design that aligns ecological infrastructure with mobility, safety, well-being, and community engagement. The proposed interventions support the overarching goal of embedding biodiversity as a structural element in urban planning, contributing to long-term ecological resilience and improved quality of urban life.

ZOOM 2: MEDIUM DENSE CORE

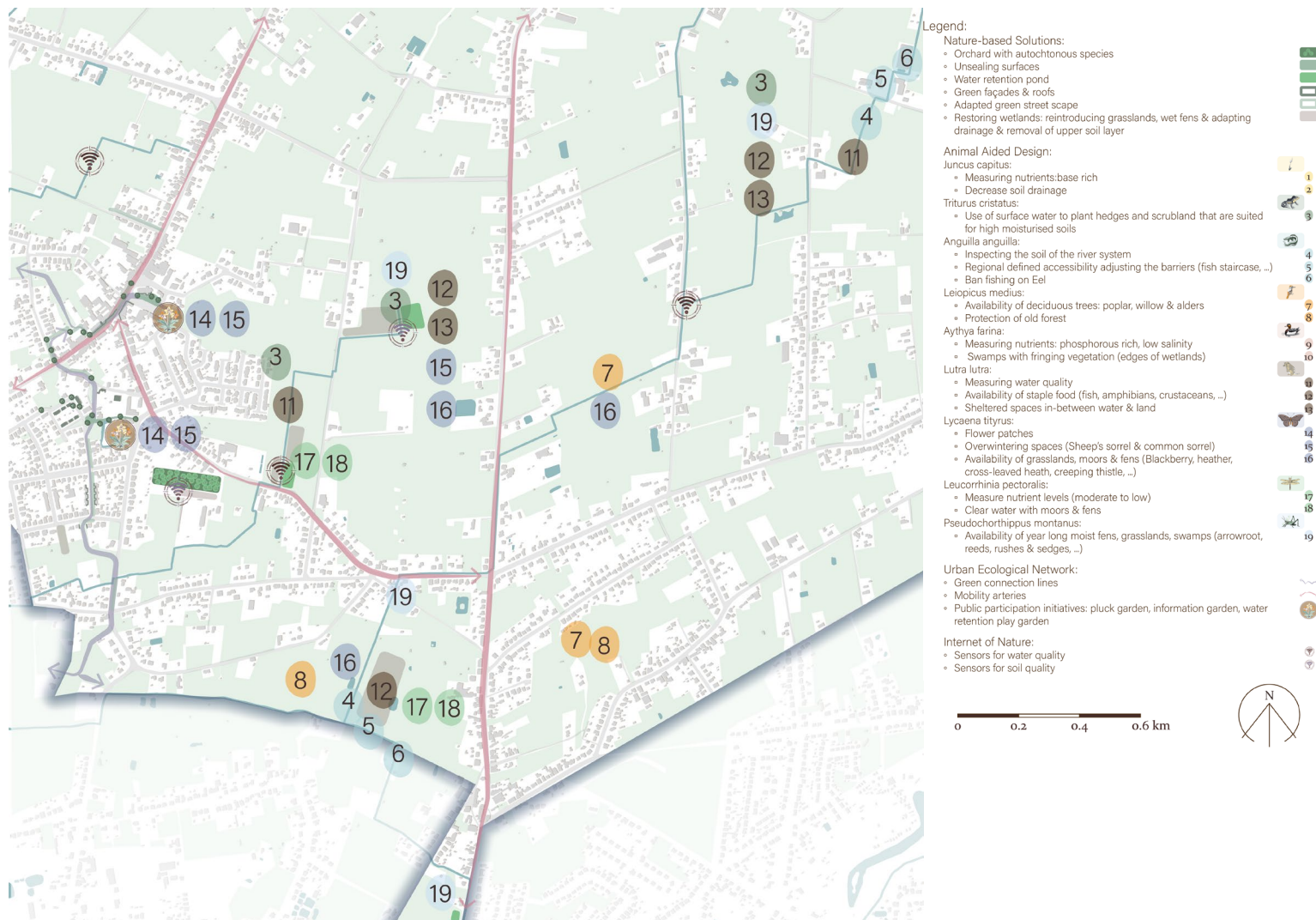


Figure 49: zoom 2 medium dense core, made by author

This zoom-in analysis focuses on the spatial configuration of existing green areas and their current fragmentation within the parish core and its surroundings. In the local centre, population densities range between 1,332 and 2,222 inhabitants per square kilometre, indicating the presence of underutilised open spaces within the urban fabric. This spatial condition offers opportunities for the implementation of green infrastructure interventions such as vegetated streetscapes and native flower meadows, directly within the central areas.

In the northern section of the study area, the landscape is characterised by a higher concentration of forested zones and an increased presence of watercourses. These environmental features provide the foundational ecological conditions suitable for the habitat restoration of semi-aquatic species such as the Eurasian otter (*Lutra lutra*), by enhancing habitat connectivity and water quality.

The broader peri-urban and rural zones in this area are predominantly shaped by agricultural activity. These zones present a strategic opportunity to engage local farmers in transitioning towards more biodiversity-oriented and climate-resilient farming practices. By integrating biodiversity-enhancing measures - such as the installation of flowering field margins, hedgerows, different crops in a rotation on one site and agroecological buffer strips - pollination services can be improved and natural pest control can be stimulated. Such actions not only support habitat development for key species but also contribute to improved soil quality and increased agricultural productivity on smaller plots of land.

ZOOM 3: RURAL PERIPHERY

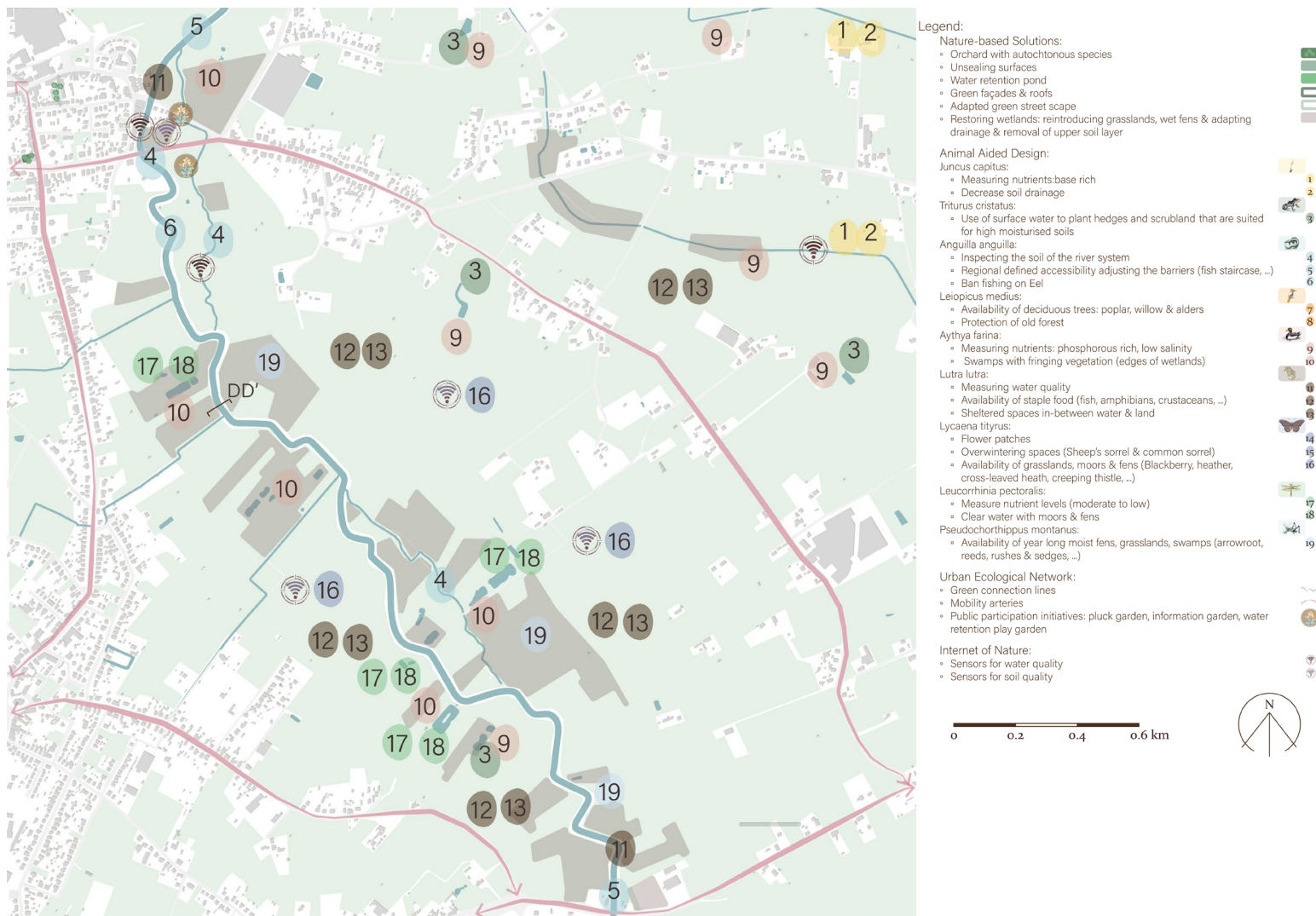


Figure 50: Zoom 3 Rural Periphery, made by author

Zoom 3 focuses on the area with the lowest population density, situated centrally within the municipality, with approximately 92 inhabitants per square kilometre. The primary objective in this zone is the ecological restoration of the former wetland system, which has been gradually converted into forested land. The adjacent river system is notably polluted, thereby necessitating the integration of phytoremediation strategies through the use of water-purifying plant species. These plantings also align with the habitat requirements of *Aythya ferina* (common pochard), which relies on such aquatic vegetation for both reproduction and diet.

Importantly, this river corridor borders a more densely populated parish, illustrating the mutual benefits that can arise from the spatial interplay between low- and higher-density urban zones. The reintroduction of autochthonous plant species—propagated in the experimental plots detailed in Zoom 1—forms the ecological foundation of this intervention. The implementation of a sensor-scape enables real-time environmental monitoring, facilitating adaptive maintenance regimes and proactive flood management through automated wetland overflow systems. Furthermore, the restored river corridor may serve a secondary function as a climate-adaptive cooling pathway, helping to mitigate the urban heat island effect in surrounding built-up areas.

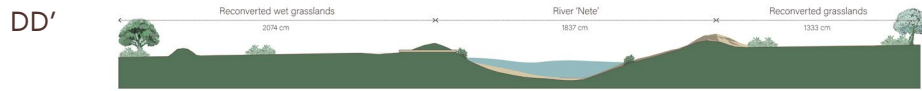


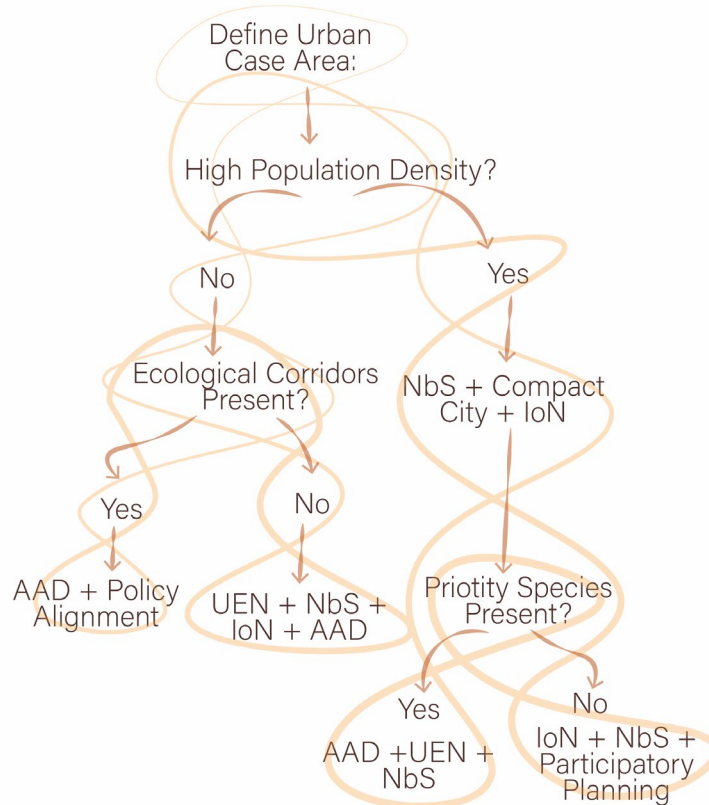
Figure 51: Section DD', showing the riversystem with native plant species

This section illustrates the strategic use of restored wetland systems and overflow infrastructure designed to support dynamic hydrological conditions. The surrounding vegetation is selected for its capacity to tolerate prolonged soil moisture while also exhibiting resilience during drought periods. These riparian plant species not only serve as ecological indicators for overall biodiversity health, but also contribute to habitat improvement for *Anguilla anguilla* (European eel), a species of high conservation concern. The re-establishment of muddy substrates created by the hydrological dynamics provides essential cover and shelter for the eel, supporting both its foraging behaviour and juvenile development.

16. Toolbox

The proposed toolbox serves as a critical instrument for synthesising the research findings and supporting the practical implementation of biodiversity-oriented urban planning. It is composed of three integrated components. The first component is a comprehensive action table and decision tree, which details specific interventions each accompanied by cost estimations and tailored to various urban densities and ecological conditions. The second component presents a visual assembly of nine interlocking "puzzle pieces" that collectively form a coherent Urban Ecological Network (UEN). These represent the core spatial elements required to establish ecological connectivity and multifunctional green infrastructure in urban environments. The third component deconstructs each puzzle piece, linking it to relevant planning strategies, target species from the provincial priority list, and functional typologies derived from spatial section analysis. This modular approach facilitates flexible application while ensuring alignment with both Animal-Aided Design (AAD) and Nature-based Solutions (NbS) principles.

TOOLBOX 1.1: DECISION TREE AND TOOLBOX CHART



	City:	Town or suburb:	Rural area:	Subsidies:
Animal Aided Design: 	1 Façade-integrated nesting modules (€150-€500 per unit) 2 Micro-habitat planters on vertical structures (€500-€2,000 per unit (modular system)) 3 Species-centric courtyard design (€20,000-€40,000 per courtyard (500-1,000 m²))	4 Linear habitat edges along bicycle and walking paths (€200-€500/ linear meter) 5 Community park biodiversity zones (€15,000-€30,000/ zone (ca. 500-1,000 m²)) 6 Biodiversity stormwater ponds (€35,000-€80,000/ pond (depending on size and soil work))	7 Farmstead wildlife shelters & nesting posts (€200-€600 per unit) 8 Edge habitat planting & hedgerows (€3-€5/m linear hedge planting) 9 Pond brink microhabitats (€5,000-€15,000 per pond area (500-1,500 m²))	Province of Flemish Brabant: for Provincial Priority Species -> min 10 000€ and max 75 000€ per project and minimal 25% of own equity
Nature-based Solutions: 	1 Rain gardens in sidewalk bulb-outs (€500-€1,500 per m²) 2 Retrofitted green roofs with native plant layers (€150-€300 per m²) 3 Tree pit biodiversity enhancements (€1,000-€3,000 per pit (upgrade))	4 Linear bioswales along residential streets (€150-€350/ linear meter) 5 Pocket park transformation with native plants (€30,000-€60,000/ 1,000 m²) 6 Tree rows with cooling canopy (€2,000-€4,000/ tree (incl. ground prep and maintenance))	7 Constructed farm ponds & wetlands (€10,000-€40,000/ wetland) 8 Riparian forest buffer planting (€3,300 per hectare to afforest, annual maintenance ~ €500/ha) 9 Swale & infiltration trench systems (€300-€400 per 30m length for swales; ~€1,000 for infiltration trench of equivalent)	Agency Nature and Forest: for NbS -> max 100 000€ and minimal 20 000€ project -> max 15 000€ and minimal 4000€ project
Internet of Nature: 	1 Compact smart soil & water sensors (€800-€1,500 per sensor unit) 2 Urban tree health sensors with wireless sync (€500-€1,200 per tree unit) 3 AI-Enabled Biodiversity Cameras & Sound Devices (€1,000-€3,000 per device)	4 Distributed Sensor Grid in Green Spaces (€8,000-€12,000 for 10-15 sensors) 5 Tree Canopy Health Mapping with Drones or LIDAR (€3,000-€6,000 per survey) 6 Community-Connected Wildlife Monitoring Apps + Devices (€500-€1,500/ device + free / low-cost platform)	7 Soil moisture & nutrient probe nodes (€800-€1,500 per unit) 8 River health sensor stations (€800-€2,000 per station) 9 Acoustic wildlife monitoring units (€1,000-€2,500 per unit)	/
Urban Ecological Networks: 	1 Ecological façade corridors (€250-€400/m²) 2 Stepping-stone plazas with microclimates (€30,000-€75,000 per site (200-400 m²)) 3 Green alley or passage retrofit (€500-€1,000/m²)	4 Green street loops (€100,000-€250,000 per loop (depending on length & interventions)) 5 Interconnected courtyard habitats (€15,000-€25,000 per courtyard upgrade) 6 Riparian buffer zones (€100,000-€500,000 depending on hydrology & engineering)	7 Hedgerow & field margin networks (€3-€5/m linear planting) 8 Village green link trails (€25,000-€50,000 per km trail (depends on width and planting density)) 9 Interconnected countryside corridors (€10,000-€40,000 each, scaled by size and hydrological complexity)	Flemish Department Urban Planning: for agro-ecologie -> max 20 000€ and minimal 25% own equity

Figure 52: Toolbox chart, made by author

The decision tree was developed as a strategic tool to facilitate the initial selection of context-specific planning strategies. It serves as a preliminary filter to determine which of the four key frameworks Animal-Aided Design (AAD), Nature-Based Solutions (NbS), Internet of Nature (IoN), and Urban Ecological Networks (UEN) should be prioritised for implementation based on urban density typologies. The x-axis categorises three urban density types city cores, medium-dense towns, and rural villages while the y-axis lists the four conceptual strategies. For each intersection of concept and urban density, three representative actions were identified and assessed. The visual opacity of the action cells corresponds to their implementation phase within a proposed multi-step strategy: Phase I (Quick Wins & Visibility: 2025-2026), Phase II (Connectivity & Monitoring: 2026-2028), and Phase III (Systemic Impact & Policy Integration: 2028-2030). Furthermore, each action includes a cost estimate derived from recent European urban greening projects and current market pricing. An additional column estimates potential subsidy levels. These values are currently limited, as Belgium is undergoing a governmental transition, and official budgetary allocations for environmental subsidies remain pending. Despite this uncertainty, the decision tree provides a systematic foundation for guiding municipalities, designers, and policy-makers in selecting viable interventions tailored to their ecological and spatial context.

TOOLBOX 1.2: COMPLETE NETWORK

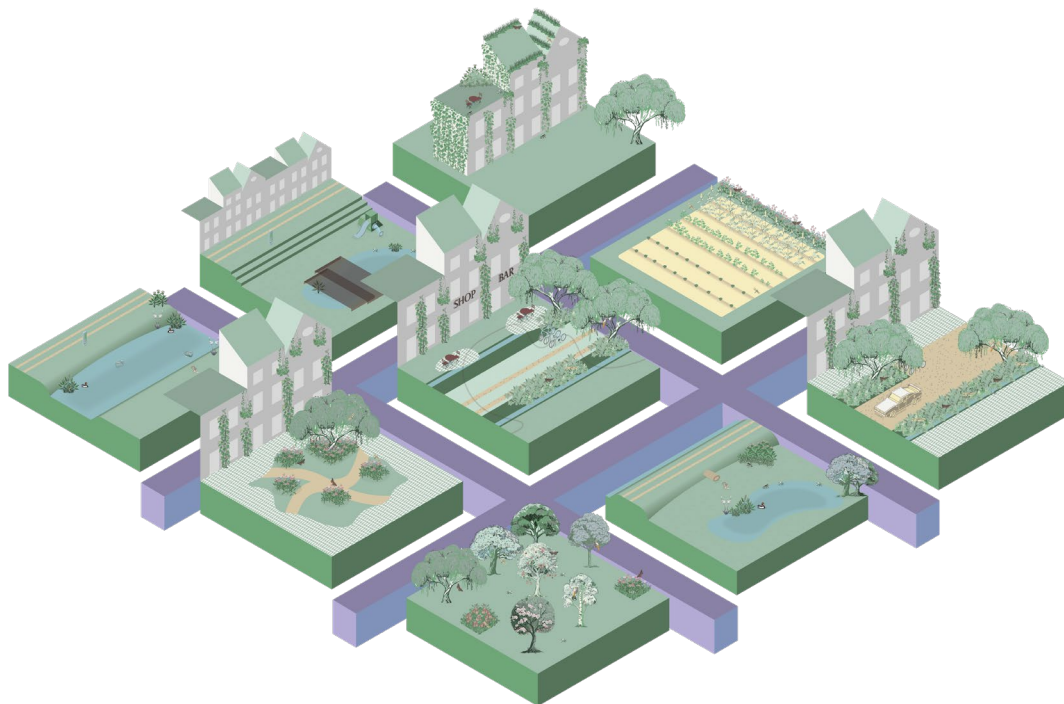
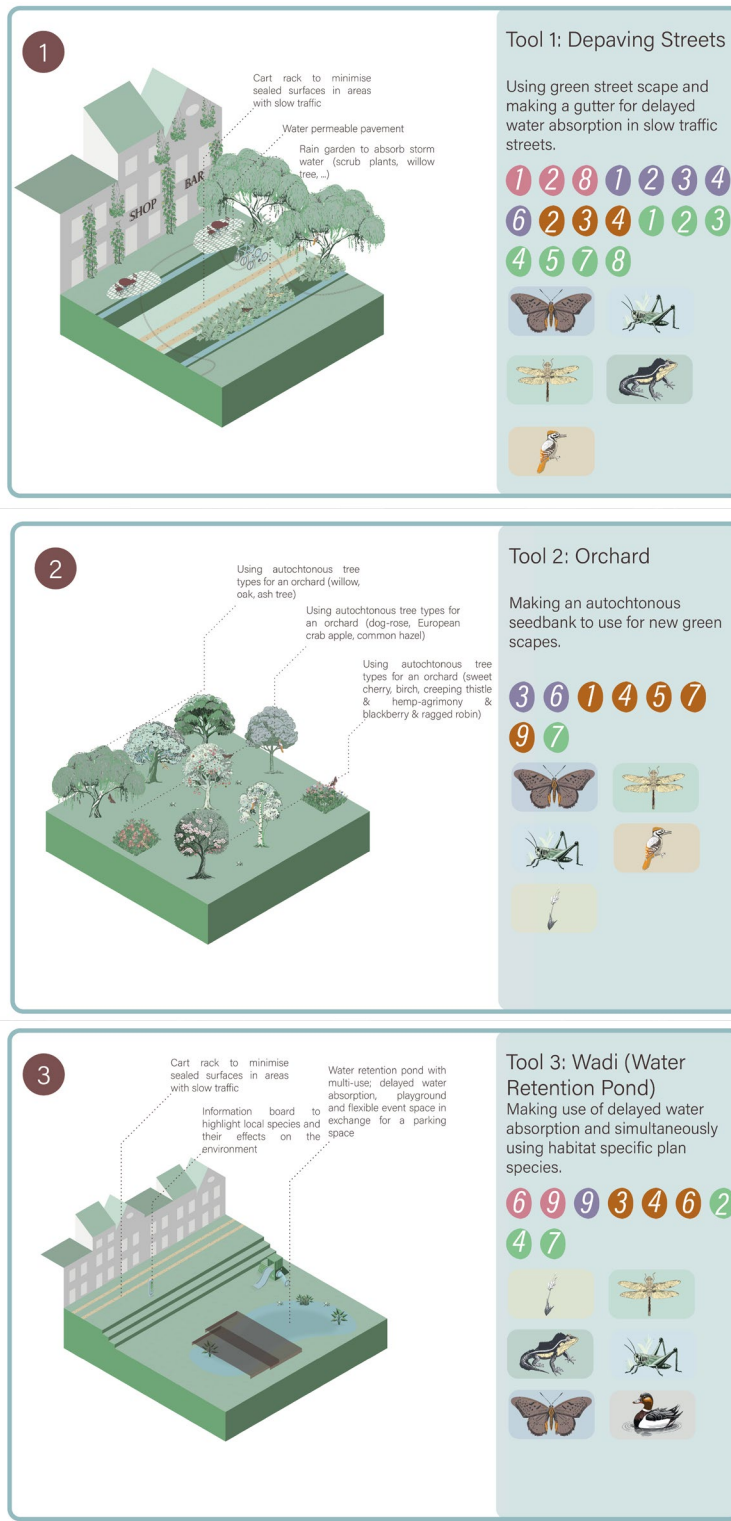


Figure 54: 9 puzzle piece that form a complete urban ecological network, made by author

These nine elements collectively form a cohesive and integrative urban ecological network, designed to ensure that each identified priority species is adequately represented within the spatial strategy. The framework accounts for the full spectrum of urban densities from high-density urban cores to low-density rural areas and thereby promoting inclusivity, ecological connectivity, and functional biodiversity across all territorial contexts.

TOOLBOX 1.3: ANIMAL URBAN DESIGN PIECES



One of the key findings of this research is the significant potential for integrating priority species, even within densely urbanised environments. While many of these species tend to be smaller organisms such as insects, the data also suggest that certain bird species, traditionally associated with less disturbed habitats, are capable of inhabiting urban contexts under the right conditions. Notably, species such as the Common Pochard (*Aythya ferina*), which typically require open water bodies and expansive habitats, can be encouraged to enter and remain in urban public spaces, provided that adequate ecological structures such as sheltered nesting areas, feeding resources, and minimal disturbance zones are implemented. This highlights the adaptability of certain species and reinforces the feasibility of urban biodiversity enhancement through targeted design interventions.

Figure 55: First part of the animal urban design pieces, made by author

Establishing interconnected ecological networks across multiple spatial dimensions horizontal, vertical, and stratified by elevation is essential for fostering resilient urban ecosystems. Horizontal linkages, such as green corridors and continuous vegetation strips, enable species movement and habitat continuity, while vertical structures such as green roofs, façades, and multi-layered planting systems enhance ecological functionality within limited urban space. Simultaneously, the restoration of wetlands along river systems provides critical habitat expansion for priority species that require larger, undisturbed territories. Furthermore, integrating interpretive signage and informational panels along pedestrian routes in green zones has been shown to significantly enhance public engagement. These educational interventions not only raise awareness of local biodiversity but also positively influence citizens' behaviour and decision-making towards more ecologically supportive practices.

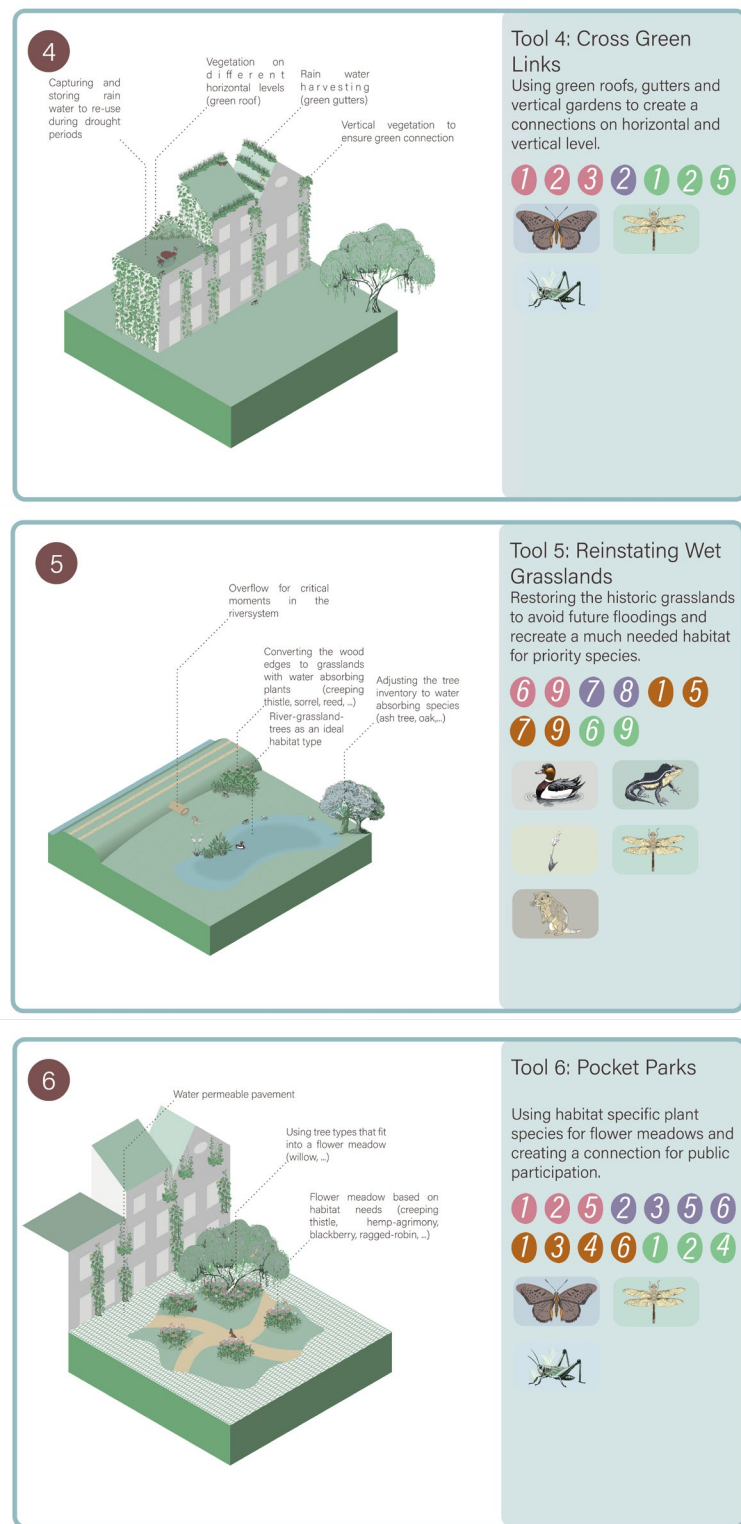


Figure 56: Seconds part of the animal urban design pieces, made by author

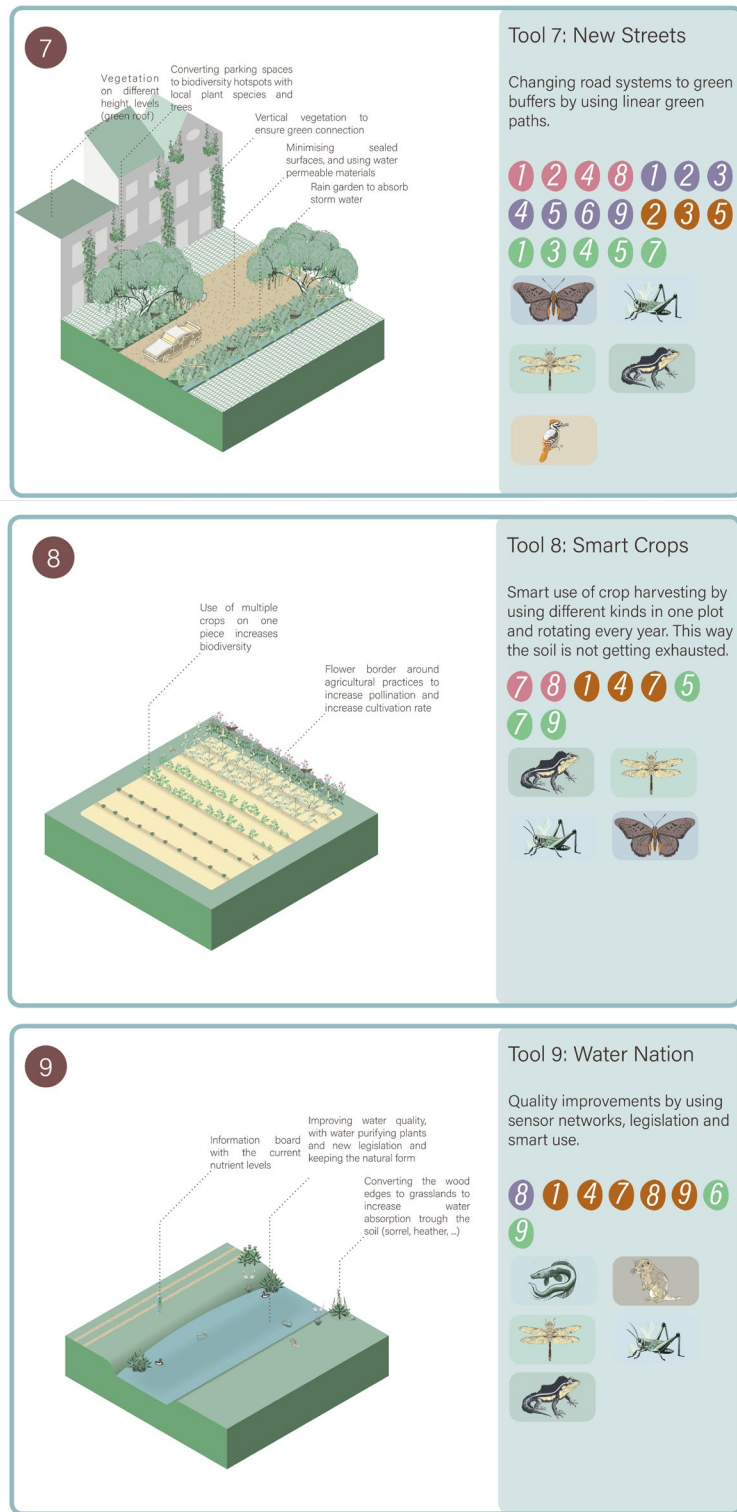


Figure 57: Third part of the animal urban design pieces, made by author

Certain urban configurations within the densest spatial typologies require comprehensive interventions to enhance ecological resilience and biodiversity. In these contexts, implementing strategies that mitigate the urban heat island effect is particularly critical. Measures that increase the perception and presence of urban greenery not only contribute to improved microclimates but also shelters demonstrable benefits for mental health and well-being. Additionally, the “Smart Crops” puzzle piece plays a pivotal role in semi-rural and village settings, where agricultural land remains prevalent. These areas present significant opportunities for biodiversity enhancement through relatively accessible interventions. By informing and engaging local farmers in climate-smart agricultural practices such as crop rotation, cover cropping, and the use of biodiversity buffer zones these agricultural spaces can be transformed into ecological catalysts. Such practices support pollinator activity, improve soil health, and align with broader objectives for nature-inclusive urban development.

Tool No.	Tool Name	Main Intervention	Unit	Estimated CO ₂ Reduction	Source
Tool 1	Depaving Streets	Rain gardens + street trees	1 tree + 1m ² rain garden	22 kg (tree) + 1.5 kg = 23.5 kg/year	(<i>A Bio-Infiltration Raingarden at the University of Villanova in Pennsylvania, US</i> LSHTM Evidence Bank, n.d.)
Tool 2	Orchard	Autochthonous fruit trees	1 tree	22 kg/year	(<i>See Tree Benefits - Maps - i-Tree Landscape</i> , n.d.)
Tool 3	Water Retention Pond (Wadi)	Retention pond & wetland plants	1m ²	6–8 kg/year (indirect via water mgmt)	(Peng et al., 2024)
Tool 4	Cross Green Links	Green façades and roofs	1m ² vertical surface	1.8 kg/year	(<i>Green Roof Basics</i> EFB, n.d.)
Tool 5	Reinstating Wet Grasslands	Meadow & seasonal floodplain	1m ² meadow	1.0 kg/year	(<i>Resource Room - Alberta NAWMP Partnership</i> , n.d.)
Tool 6	Pocket Parks	Native flowering meadows	1m ² meadow	1.0 kg/year	(<i>The Value of Green Infrastructure</i> , 2011)
Tool 7	New Streets	Linear tree lines + permeable soil	1 tree	22 kg/year	(<i>The Value of Green Infrastructure</i> , 2011)
Tool 8	Smart Crops	Border plant strips + crop rotation	1m ² buffer / 10m ² crops	0.5–0.7 kg/year	(Biffi et al., 2022; <i>Terra – I</i> , n.d.)
Tool 9	Water Nation	Sensor-based flood control + wetlands	1m ² wetland edge	6–8 kg/year (indirect/avoided CO ₂)	(<i>See Tree Benefits - Maps - i-Tree Landscape</i> , n.d.)

The CO₂ values provided should be considered baseline scientific approximations with a margin of variability:

- Trees: ±20%
- Green roofs/façades: ±30%
- Wetlands/ponds: ±50% (highly variable depending on methane emissions)
- Smart crops: ±25% depending on species and soil type

(Guo et al., 2024; Nowak et al., 2013)

17. Conclusion: Urban Animal Network

This thesis set out to explore to what extent Animal-Aided Design (AAD) and Nature-based Solutions (NbS) can meaningfully contribute to the sustainable development of large, dense towns. By focusing on the Belgian municipality of Heist-op-den-Berg, the research demonstrated that ecological resilience and biodiversity support can be embedded into urban planning through an integrative spatial framework. Combining AAD and NbS with Urban Ecological Networks (UEN) and the Internet of Nature (IoN), the study introduced a design approach where animals are positioned not as passive recipients of urban change, but as key stakeholders.

The research objectives were threefold:

1. Identify suitable priority species across different urban densities;
2. Translate their ecological needs into spatial planning strategies;
3. Create an applicable and scalable design toolbox to support municipalities in decision-making.

Through a structured six-phase methodology, the thesis effectively aligned theoretical frameworks with empirical spatial data. The methodology, based on layered GIS analysis, typological urban classification, ecological and biotope mapping, species-specific planning, and strategic visualisation, was appropriate and proved instrumental in achieving the set objectives. A key contribution of this work lies in the translation of ecological knowledge into urban design strategies, addressing both spatial fragmentation and species-specific needs. Nine taxonomic groups of priority species were identified, ranging from the European eel (*Anguilla anguilla*) to the Common pochard (*Aythya ferina*) and Sooty Copper butterfly (*Lycaena tityrus*). The integration of spatial and ecological data led to targeted design proposals contextualised for high-, medium-, and low-density urban typologies.

The GIS-based ecological gap analysis and historical landscape mapping revealed significant opportunities for reconnection through green corridors, water retention zones, and habitat-specific planting. These were translated into nine "toolbox" interventions, such as Smart Crops, Green One-Ways, and Biodiversity Hubs, each accompanied by cost estimations, CO₂-reduction potential, and suitability per density. The result is a flexible design and decision-making framework that municipalities can adapt to their context and available resources.

Importantly, the research has shown that even in highly urbanised environments, meaningful contributions to biodiversity conservation are not only possible, they are necessary. While smaller species such as pollinators benefit most directly from micro-scale interventions like green façades and rain gardens, the restoration of larger ecological systems, particularly wetlands, can support more space-demanding species and mitigate climate effects such as the urban heat island.

This thesis contributes not only a theoretical framework but a proof of concept that urban biodiversity integration is a designable, measurable, and scalable strategy. However, to fully realise its potential, further research is needed to validate long-term ecological impacts, quantify CO₂ performance more precisely, and assess human well-being outcomes. The proposed strategies aim to fill a policy and implementation gap at the municipal level, offering tools that can support biodiversity objectives and climate neutrality targets at both local and regional scales.

Ultimately, the Urban Animal Network presented here reframes urbanisation as an opportunity—not a threat—for nature. It invites planners, policymakers, and designers to imagine cities not as separate from ecology, but as habitats where humans and wildlife can thrive in parallel rhythms.

FUTURE RESEARCH DIRECTIONS

While this thesis provides a robust foundation for integrating Animal-Aided Design (AAD), Nature-based Solutions (NbS), Urban Ecological Networks (UEN), and the Internet of Nature (IoN) into spatial planning, several areas merit further investigation to refine and expand these strategies.

First, future research should assess the ecological effectiveness of the proposed interventions—particularly their impact on the long-term survival and reproduction of priority species. Empirical studies and longitudinal monitoring are needed to validate the assumed biodiversity gains and ensure that spatial actions lead to measurable ecological benefits. Second, the CO₂ absorption potential of the toolbox strategies should be quantified more precisely. While this thesis offered literature-based estimations, site-specific measurements of carbon sequestration through vegetation, soil improvement, and water systems could strengthen the case for integrating these approaches into climate policy frameworks. Third, the well-being impacts of ecological interventions deserve further exploration. Although this thesis highlights promising links between biodiversity, green space, and mental health, interdisciplinary studies combining environmental science, psychology, and urban sociology could provide the evidence needed to operationalize these benefits in planning practices. Lastly, future work should examine the institutional and regulatory feasibility of implementing these strategies at scale. This includes exploring policy alignment, funding mechanisms, and participatory processes that support long-term ecological urbanism across different governance levels.

In sum, this thesis offers a starting point for applied ecological design in dense urban settings, but its full potential will only be realised through continued research that grounds its innovations in data, policy, and lived experience.

18. Discussion

The integration of Animal-Aided Design (AAD) and Nature-based Solutions (NbS) within spatial planning presents a novel yet necessary reorientation of urban design in the face of escalating ecological and climatic challenges. This thesis sought to embed biodiversity and ecological functioning into the core of urban and peri-urban transformation strategies, using Heist-op-den-Berg as a representative model of large dense towns in Central Europe. The resulting masterplan, toolbox, and decision-making frameworks illustrate the feasibility of this approach. However, several critical reflections emerge when evaluating both the effectiveness and limitations of the adopted methodologies and their implications.

1. Bridging Disciplines: Ecological Design in Urban Planning

One of the key contributions of this thesis lies in its interdisciplinary synthesis—merging urban planning, landscape ecology, environmental data science, and digital innovation. While Animal-Aided Design offers a species-specific lens, Nature-based Solutions provide systemic, multifunctional infrastructure. When embedded within Urban Ecological Networks (UEN) and complemented by the Internet of Nature (IoN) technologies, these approaches produce a layered and holistic framework. However, this interdisciplinarity also introduces complexity: planners and policymakers are often not trained in ecological principles or biodiversity indicators, just as ecologists may lack experience in regulatory urban development. Thus, while the conceptual framework is strong, successful implementation will require cross-sectoral education, institutional cooperation, and a translation of ecological terminology into actionable urban policy.

2. Methodological Strengths and Challenges

The applied methodology—spanning GIS-based mapping, typological density analysis, species card development, ecological sectioning, and toolbox creation—was robust in translating theoretical frameworks into visual and spatially grounded actions. However, certain methodological challenges were also encountered. For example, habitat suitability was assessed using static land-use data, yet species behaviour is dynamic and influenced by noise pollution, human activity, and microclimatic shifts. Additionally, CO₂ absorption rates were estimated using literature-based proxies rather than empirical measurements. While sufficient for design exploration, future application of the model would benefit from site-specific environmental monitoring, soil testing, and biodiversity surveys to ground proposals in measurable outcomes.

3. The Role of Priority Species: Representative or Reductive?

The inclusion of nine taxonomic groups of priority species enabled a structured design process that aligns green infrastructure with ecological needs. This species-driven method is effective in embedding biodiversity into spatial planning. Nonetheless, one could argue that it risks oversimplifying complex ecological networks. Ecosystems are interdependent and evolve over time; designing for one species does not guarantee long-term success unless broader ecosystem dynamics are considered. In addition, the social acceptability of certain species (e.g. invertebrates or rodents) in public space is culturally dependent and may hinder implementation unless paired with awareness campaigns or participatory design processes.

4. Digital Infrastructure: The Internet of Nature as a Monitoring Tool

The integration of IoN sensors and digital tracking systems in this thesis is both innovative and increasingly necessary. These tools offer a means to track soil moisture, water quality, species presence, and plant health—key metrics for evaluating the long-term success of interventions. However, the technological readiness level of these tools in local municipalities is uneven. Many towns lack the digital infrastructure or expertise to manage sensor networks, let alone interpret ecological data. Thus, while IoN opens up exciting possibilities, future development should include accessible interfaces, community science strategies, and partnerships with tech providers to ensure equitable and scalable implementation.

5. Public Participation and Policy Translation

Another dimension of the thesis involved stimulating public engagement through spatial design. Elements such as educational signage, urban biodiversity hubs, and participatory corridors aim to foster behavioural change and stewardship. Still, their success depends on early inclusion of local communities and integration into broader policy frameworks. In Belgium, spatial planning remains a jurisdictional patchwork between federal, regional, and local authorities. Embedding this ecological model into practice will thus require lobbying, municipal capacity-building, and alignment with planning instruments such as regional structure plans or climate action plans.

6. From Concept to Replication: Scaling the Toolbox

The toolbox developed in this thesis provides a practical resource for planners and designers, with cost estimations, phasing, species-specific strategies, and subsidy insights. Its modularity allows adaptation across urban typologies—from dense cores to rural edges. However, its future impact depends on empirical validation through pilot projects, cost-benefit analysis, and post-occupancy evaluation. Additionally, as climate conditions change, adaptive management will be crucial—requiring that the toolbox remain a living instrument rather than a static manual.

Acknowledgement

This thesis would not have been possible without the invaluable support, guidance, and encouragement of many individuals to whom I am deeply grateful.

First and foremost, I would like to express my sincere appreciation to my supervisor, **Professor Jakob Beetz**, for his critical insights, academic mentorship, and patient guidance throughout this process. His constructive feedback and interdisciplinary vision have helped shape this research into a grounded and coherent contribution to the field.

I would also like to thank **Professor Leuchner** and the examination committee for their thoughtful evaluation and valuable input. Their expertise and perspectives have greatly enriched the quality and clarity of this work.

A special word of gratitude goes to **Professor Thomas E. Hauck**, whose work has been foundational to this thesis. I am especially thankful for the opportunity to interview him, and for his openness in sharing his knowledge and reflections on Animal-Aided Design. His contributions were intellectually inspiring and deeply appreciated.

I would also like to thank **Javier Ostos Prieto** for his valuable feedback, academic advice, and the opportunity to engage in insightful discussions that contributed meaningfully to the direction and refinement of this research.

I am equally grateful to my peers, fellow students and friends, who supported me with helpful discussions, shared resources, and motivating conversations along the way. Their collaboration and encouragement created a truly inspiring academic environment.

Lastly, I extend my thanks to all interview participants, local contacts, and professionals who contributed their time and expertise to support the development of this research.

To everyone who played a role in this academic journey - thank you.

*A city that listens to the rhythms of its animals does not just adapt, it blossoms with purpose,
growing greener with every wingbeat and footprint.*

Horemans E.

Resources

A bio-infiltration raingarden at the University of Villanova in Pennsylvania, US | LSHTM Evidence Bank. (n.d.). Retrieved 5 August 2025, from https://climatehealthevidence.org/case-studies/bio-infiltration-raingarden-university-villanova-pennsylvania-us?utm_source=chatgpt.com

About us. (n.d.). AAD. Retrieved 13 May 2025, from <https://animal-aided-design.de/en/about-us/>

ANIMAL-AIDED DESIGN IN THE LIVING ENVIRONMENT: A PROJECT FROM MUNICH. (n.d.). AAD. Retrieved 11 February 2025, from <https://animal-aided-design.de/en/portfolio-items/animal-aided-design-in-the-living-environment-a-project-from-munich/>

Animal-Aided Design: Planning for people and animals—TUM. (n.d.). Retrieved 13 May 2025, from <https://www.tum.de/en/news-and-events/all-news/press-releases/details/32309>

Architectura. (2025, May 9). *Building Biospheres: België experimenteert met plantenintelligentie op de Biënnale van Venetië*. <https://architectura.be/nl/nieuws/building-biospheres-belgie-experimenteert-met-plantenintelligentie-op-de-biennale-van-venetie/>

Benedict, M., McMahon, E., Fund, T., & Bergen, L. (2006). Green Infrastructure: Linking Landscapes and Communities. *Bibliovault OAI Repository, the University of Chicago Press*, 22.

Biffi, S., Chapman, P. J., Grayson, R. P., & Ziv, G. (2022). Soil carbon sequestration potential of planting hedgerows in agricultural landscapes. *Journal of Environmental Management*, 307, 114484. <https://doi.org/10.1016/j.jenvman.2022.114484>

Brent D., R. (2017). *The largest art: A measured manifesto for a plural urbanism*. The MIT Press.

Catalogus. (n.d.). Vlaanderen.be. Retrieved 8 August 2025, from <https://www.vlaanderen.be/datavindplaats/catalogus>

De Saeger, S., Dhaluin, P., Erens, R., Guelinckx, R., Hennebel, D., Jacobs, I., Kumpen, M., Van Oost, F., Spanhove, T., Leyssen, A., Oosterlynck, P., Van Dam, G., Van Hove, M., & Wils, C. (2023). *Biologische Waarderingskaart en Natura 2000 Habitatkaart, uitgave 2023*. Instituut voor Natuur- en Bosonderzoek. <https://doi.org/10.21436/inbor.96375305>

dpicampaigns. (n.d.). Take Action for the Sustainable Development Goals. *United Nations Sustainable Development*. Retrieved 16 May 2025, from <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

Galle, N. (2024). *De natuur van onze steden, Hoe we de natuur redden, zelf gezonder worden en onze wereld leefbaar houden*. Lannoo.

Green Roof Basics | EFB. (n.d.). Retrieved 5 August 2025, from <https://efb-greenroof.eu/green-roof-basics/>

Groundwater Publications. (2018, January 24). US Forest Service. <https://www.fs.usda.gov/managing-land/natural-resources/geology/groundwater/publications>

Guo, Y., Ren, Z., Wang, C., Zhang, P., Ma, Z., Hong, S., Hong, W., & He, X. (2024). Spatiotemporal patterns of urban forest carbon sequestration capacity: Implications for urban CO₂ emission mitigation during China's rapid urbanization. *Science of The Total Environment*, 912, 168781. <https://doi.org/10.1016/j.scitotenv.2023.168781>

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In D. G. Raffaelli & C. L. J. Frid (Eds.), *Ecosystem Ecology* (1st ed., pp. 110–139). Cambridge University Press. <https://doi.org/10.1017/CBO9780511750458.007>

Hauck, T. E. (2025, May 5). *Interview Studio Animal Aided Design* [Audio recording].

Het Vlaams woordenboek » Neet. (n.d.). Retrieved 26 May 2025, from <https://www.vlaamswoordenboek.be/definities/21930/geschiedenis>

Huang, X., Wang, H., Shan, L., & Xiao, F. (2021). Constructing and optimizing urban ecological network in the context of rapid urbanization for improving landscape connectivity. *Ecological Indicators*, 132, 108319. <https://doi.org/10.1016/j.ecolind.2021.108319>

IUCN Global Standard for Nature-based Solutions: First edition. (2020). IUCN. <https://doi.org/10.2305/IUCN.CH.2020.08.en>

Joachim H; Spangenberg, Haaren, C. von, & Settele, J. (2014). *The ecosystem service cascade: Further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy.*

Kempen 2030. (n.d.). Heist-op-den-Berg. Retrieved 28 April 2025, from <https://www.heist-op-den-berg.be/kempen2030>

Klein Breteler, J. G. P., & Emmerik, W. A. M. van. (2005). *Kennisdocument Europese aal of paling, Anguilla anguilla (Linnaeus, 1758)* (Vol. 1–1 online resource (83 p.)). Sportvisserij Nederland. <http://edepot.wur.nl/117714>

Local administrative units (LAU)—NUTS - Nomenclature of territorial units for statistics—Eurostat. (n.d.). Retrieved 26 May 2025, from <https://ec.europa.eu/eurostat/web/nuts/local-administrative-units>

Maes, D., De Knijf, G., Devos, K., Gouwy, J., Gyselings, R., Packet, J., Speybroeck, J., Swinnen, K., Vermeersch, G., Thomaes, A., Van Den Berge, K., & Van Thuyne, G. (2021). *Provinciaal Prioritaire Soorten in de provincie Vlaams-Brabant: Versie 2021*. Instituut voor Natuur- en Bosonderzoek. <https://doi.org/10.21436/inbor.54729665>

Maes, D., De Knijf, G., Devos, K., Gouwy, J., Gyselings, R., Packet, J., Speybroeck, J., Thomaes, A., Van Den Berge, K., Van Landuyt, W., Van Thuyne, G., & Vermeersch, G. (2021). *Provinciaal Prioritaire Soorten in de provincie Antwerpen: Versie 2021*. Instituut voor Natuur- en Bosonderzoek. <https://doi.org/10.21436/inbor.54726564>

Maes, D., De Knijf, G., Devos, K., Gouwy, J., Gyselings, R., Packet, J., Speybroeck, J., Van Den Berge, K., Van Landuyt, W., Vermeersch, G., & Piesschaert, F. (2021). *Criteria voor het aanduiden van Provinciaal Prioritaire Soorten: Materiaal en methode Versie 2021*. Instituut voor Natuur- en Bosonderzoek. <https://doi.org/10.21436/inbor.54722626>

Marburger, J. E., & Forman, R. T. T. (1997). Land Mosaics. *Ecology*, 78(2), 642. <https://doi.org/10.2307/2266037>

Ministry, F. E. (2022, March 29). *Drafts: Federal Action Plan on Nature-based Solutions for Climate and Biodiversity- BMUV - Download*. Bmuv.De. <https://www.bmuv.de/DL2872-1>

Müller, N., Ignatieva, M., Nilon, C. H., Werner, P., & Zipperer, W. C. (2013). Patterns and Trends in Urban Biodiversity and Landscape Design. In T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. McDonald, S. Parnell, M. Schewenius, M. Sendstad, K. C. Seto, & C. Wilkinson (Eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities* (pp. 123–174). Springer Netherlands. https://doi.org/10.1007/978-94-007-7088-1_10

Nature: How connecting with nature benefits our mental health. (n.d.). Retrieved 30 April 2025, from <https://www.mentalhealth.org.uk/our-work/research/nature-how-connecting-nature-benefits-our-mental-health>

NDDFF Verspreidingsatlas | *Juncus capitatus*—Koprus. (n.d.). Retrieved 6 July 2025, from <https://www.verspreidingsatlas.nl/o677#>

Netherlands, e-V. nl, The. (n.d.). *De Vlinderstichting | Vlinder: Bruine vuurvlinder / Lycaena tityrus*. Retrieved 7 June 2025, from <https://www.vlinderstichting.nl/vlinders/overzicht-vlinders/details-vlinder/bruine-vuurvlinder>

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*, 178, 229–236. <https://doi.org/10.1016/j.envpol.2013.03.019>

Peng, Y., Wang, Y., Chen, H., Wang, L., Luo, B., Tong, H., Zou, Y., Lei, Z., & Chen, S. (2024). Carbon reduction potential of a rain garden: A cradle-to-grave life cycle carbon footprint assessment. *Journal of Cleaner Production*, 434, 139806. <https://doi.org/10.1016/j.jclepro.2023.139806>

Planning Process | Urban Learning. (n.d.). Retrieved 28 April 2025, from <http://www.urbanlearning.eu/toolbox/planning-process/>

Prof. Dr. Baete, J., Hauck, T. E., Jakoby, C., Piecha, J., Rogers, R., Schröder, A., & Weisser, W. W. (2021). ANIMAL-AIDED DESIGN IN THE LIVING ENVIRONMENT Integrating the needs of animal species into the planning and design of urban open spaces. *German Federal Agency for Nature Conservation & Animal-Aided Design*©.

Provincies.incijfers.be—Databank—Officiële statistiek van het aantal inwoners—2024—Gemeenten. (n.d.). Retrieved 26 May 2025, from <https://provincies.incijfers.be/databank>

Rapport: Valleicursus landschapsbiografie van de Kleine Nete tussen Geel en Herentals. (n.d.). Regionale Landschappen. Retrieved 26 May 2025, from <https://www.regionalelandschappen.be/landschapsacademie/rapport-valleicursus-landschapsbiografie-van-de-kleine-nete-tussen-geel-en-herentals>

Resource Room—Alberta NAWMP Partnership. (n.d.). Retrieved 5 August 2025, from https://abnawmp.ca/resource_room/

See Tree Benefits—Maps—I-Tree Landscape. (n.d.). Retrieved 5 August 2025, from <https://landscape.itreetools.org/maps/benefits/>

Sevenant, M., Menschaert, J., Couvreur, M., Ronse, A., Antrop, M., Geypens, M., Hermey, M., & De Blust, G. (2002). *Ecodistricten. Ruimtelijke eenheden voor gebiedsgericht milieubeleid in Vlaanderen. Deel II: Afbakening van ecodistricten en ecoregio's - verklarende teksten*. <https://marineinfo.org/doc/publication/288076>, <https://www.vliz.be/nl/imis>

Terra – I. (n.d.). Alliance Bioversity International - CIAT. Retrieved 5 August 2025, from <https://alliancebioversityciat.org/tools-innovations/terra-i>

Territorial typologies manual—Degree of urbanisation. (n.d.). Retrieved 25 May 2025, from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual_-_degree_of_urbanisation

The European Green Deal—European Commission. (2021, July 14). https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

The IUCN Red List of Threatened Species. (n.d.). IUCN Red List of Threatened Species. Retrieved 4 June 2025, from <https://www.iucnredlist.org/en>

The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. (2011, January 21). Center for Neighborhood Technology. <https://cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and-social-benefits/>

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), 167–178. <https://doi.org/10.1016/j.landurbplan.2007.02.001>

Unit, B. (2024, October 1). *Kunming-Montreal Global Biodiversity Framework*. Secretariat of the Convention on Biological Diversity. <https://www.cbd.int/gbf>

URBANE TIER-RÄUME. (n.d.). AAD. Retrieved 30 April 2025, from <https://animal-aided-design.de/en/portfolio-items/urbane-tier-raeume/>

Waarnemingen.be. (n.d.). Waarnemingen.be. Retrieved 3 June 2025, from https://waarnemingen.be/species/447/maps/?start_date=2020-06-04&interval=157680000&end_date=2025-06-03&map_type=grid10k

'Watermonsters' is gestart: Bekijk hier waar in uw buurt de waterkwaliteit wordt gemeten. (2025, April 23). De Standaard. <https://www.standaard.be/binnenland/watermonsters-is-gestart-bekijk-hier-waar-in-uw-buurt-de-waterkwaliteit-wordt-gemeten/60787099.html>

Weisser, W. W., & Hauck, T. E. (2025). Animal-Aided Design – planning for biodiversity in the built environment by embedding a species' life-cycle into landscape architectural and urban design processes. *Landscape Research*, 50(1), 146–167. <https://doi.org/10.1080/01426397.2024.2383482>

Welcome to Stolberg, the hidden gem of the Nord-Eifel. (n.d.). Gesellschaft Für Stadtmarketing STOLBERG e.V. Retrieved 30 April 2025, from <https://sms-stolberg.de/en/willkommen-english/>

Wilms, H., De Ro, A., De Cuyper, B., Vander Mijnsbrugge, K., & Vanden Broeck, A. (2024). *Actieplan uitgangsmateriaal voor autochtoon en bosbouwkundig plantgoed*. Instituut voor Natuur- en Bosonderzoek. <https://doi.org/10.21436/inbor.116158845>

Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R. A., Van Den Bosch, M., & Bardekjian, A. C. (2020). Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health*, 17(12), 4371. <https://doi.org/10.3390/ijerph17124371>

Table Of Figures:

Figure 1: Illustration of a large dense town, made by author	3
Figure 2: Research method, creation of author	5
Figure 3: Population density, based on Geographical Information System of the Commission (GISCO) & EUROSTAT (2023)	13
Figure 4: Degree of urbanisation typologies 2021, made by <i>Territorial Typologies Manual - Degree of Urbanisation</i>	14
Figure 5: population density on regional level, based on Geographical Information System of the Commission (GISCO) & EUROSTAT (2023)	15
Figure 6: Densification of a local town within a large city with a high densification, made by Provincies.Incijfers.Be - Databank - Officiële Statistiek van Het Aantal Inwoners - 2024 – Gemeenten	16
Figure 7: Habitat density per/km ² in Heist-op-den-Berg, based on INBO	18
Figure 8: Habitat density per/km ² in the region, based on INBO	18
Figure 9: Theoretical Framework, created by author	19
Figure 10: conceptual model, made by author	27
Figure 11: Heatmap Higher Plants with provincial priority specie <i>Juncus capitatus</i> , based on GBIF.org User (2025)	31
Figure 12: <i>Juncus Capitatus</i> , photo taken by ObsMapp (Koprus - <i>Juncus capitatus</i> , 04/08/2024)	31
Figure 13: Heatmap of amphibians and reptiles with provincial priority specie <i>Triturus cristatus</i> , based on GBIF.org User (2025b)	32
Figure 14: <i>Triturus cristatus</i> , photo taken by ObsMapp (Kamsalamander - <i>Triturus cristatus</i> , 29/05/2025)	32
Figure 15: Heatmap of fish with provincial priority specie <i>Anguilla Anguilla</i> , based on GBIF.org User, (2025b)	33
Figure 16: <i>Anguilla anguilla</i> , photo taken by Rudi Segers (Aal - <i>Anguilla anguilla</i> , 01/06/2025)	33
Figure 17: Heatmap of breeding birds with provincial priority specie <i>Leiopicus medius</i> , based on GBIF.org User (2025b)	34
Figure 18: <i>Leiopicus medius</i> , photo by Claessens Ronald (Middelste Bonte Specht - <i>Dendrocoptes medius</i> , 14/05/2025)	34
Figure 19: Heatmap of wintering waterfowl with provincial priority specie <i>Aythya farina</i> , based on GBIF.org User (2025b)	35
Figure 20: <i>Aythya ferina</i> , photo taken by Fred Vanwezer (Tafeleend - <i>Aythya ferina</i> , 26/05/2025)	35
Figure 21: Heatmap of mammals with provincial priority specie <i>Lutra lutra</i> , based on GBIF.org User (2025b)	36
Figure 22: <i>Lutra lutra</i> , photo taken by waarnemingen.be (Europese Otter - <i>Lutra lutra</i> , 22/04/2025)	36
Figure 23: Heatmap of Butterflies with provincial priority specie <i>Lycaena tityrus</i> , based on GBIF.org User (2025b)	37
Figure 24: <i>Lycaena tityrus</i> , photo taken by waarnemingen.be (Bruine vuurvinder - <i>Lycaena tityrus</i> , 01/06/2025).	37
Figure 25: Heatmap of Dragonflies with provincial priority specie <i>Leucorrhinia pectoralis</i> , based on GBIF.org User (2025b)	38
Figure 26: <i>Leucorrhinia pectoralis</i> , photo taken by waarnemingen.be (Gevlekte witsnuitlibel - <i>Leucorrhinia pectoralis</i> , 21/05/2025)	38
Figure 27: Heatmap of Grasshoppers and Crickets with provincial priority specie <i>Pseudochorthippus montanus</i> , based on GBIF.org User (2025b)	39
Figure 28 <i>Pseudochorthippus montanus</i> , photo taken by Eva Vermeylen (Zompsprinkhaan - <i>Pseudochorthippus montanus</i> , 11/10/2024)	39
Figure 29: Provincial important habitat types with a grid system based on previous analysis, made by author (Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Swinnen, et al., 2021; Maes, De Knijf, Devos, Gouwy, Gyselings, Packet, Speybroeck, Thomaes, et al., 2021)	40
Figure 30: Ecoregion analysis of target area and region, based on INBO	42
Figure 31: Historical forestation 1775, based on the Ferrariskaart & INBO	43

Figure 32: Historical forestation 1850, based on the Atlas of Neighbourhoods 1840 & INBO	44
Figure 33: Historical forestation 1940, based on the Michelin-mapping (1920) & INBO (GmbH (https://www.klokantech.com/)), n.d.)	45
Figure 34: Forestation 2021, based on the current urban configuration (2025) & INBO	46
Figure 35: conclusion map of forestation evolution between 1775-1940 provincial level, made by author	47
Figure 36: Synthesised analyse of the combination of Habitats of provincial priority species and forestation, made by Author	48
Figure 37: conclusion map of forestation evolution between 1775-1940 regional level, made by author	49
Figure 38: State ownership analyse, based on geopunt.be	50
Figure 39: water quality analysis, based on Hoe proper is het water in uw buurt?, 2025	51
Figure 40: Regional SWOT analysis, made by author	52
Figure 41: Local SWOT analysis, made by Author	53
Figure 42: Conceptual model presenting the integration of AAD, NbS, EUN and IoN, made by author	54
Figure 43: Structural plan of the region, with different attention nodes and actions zones, created by author	55
Figure 44: Structural plan of a large dense town, with different attention nodes and actions zones, created by author	56
Figure 45: Masterplan large dense town, 1/50 000 scale, created by author	58
Figure 46: Flash cards of 9 taxonomic priority species, created by author (based on information on waarnemingen.be)	59
Figure 47: Zoom 1 dense core, made by author	60
Figure 48: Sections from zoom 1, made by author	61
Figure 49: zoom 2 medium dense core, made by author	63
Figure 50: Zoom 3 Rural Periphery, made by author	64
Figure 51: Section DD', showing the riversystem with native plant species	65
Figure 52: Toolbox chart, made by author	66
Figure 53: Decision Tree Toolbox Integration, made by author	66
Figure 54: 9 puzzle piece that form a complete urban ecological network, made by author	67
Figure 55: First part of the animal urban design pieces, made by author	68
Figure 56: Seconds part of the animal urban design pieces, made by author	69
Figure 57: Third part of the animal urban design pieces, made by author	70

List of Tables

Table 1: Own interpretation based on The links between ecosystem services and human well-being, from Haines-Young & Potschin (2010)	22
Table 2: Own interpretation based on A framework for linking direct and indirect drivers, pressures and responses in a coupled socio-ecological system for assessment of the effects of environmental change drivers on ecosystem services, from Haines-Young & Potschin (2010)	23
Table 3: SDG matrix for Animal Aided Design, created by author.....	24
Table 4: Inventory of documents needed for analysis Animal Aided Design, made by author.....	28
Table 5: Summary of priority species, based on the provincial priority species of Antwerp and Flemish Brabant INBO.....	41
Table 6: SWOT Animal Aided Design, made by author	81
Table 7: SWOT based on Urban Ecological Networks, made by author.....	82
Table 8: SWOT based on Nature-based Solutions, made by author.....	83
Table 9: SWOT based on Internet of Nature, made by author	84

Annex

SWOT ON CONCEPTS

Animal Aided Design (AAD)

Focus: Integration of animal needs as co-design parameters in urban development.



Strengths

- ✓ Growing interest in human-nature integration in Flemish urban design
- ✓ AAD methodology offers a structured approach to include species in public space
- ✓ Use of INBO's provincial priority species maps allows precise targeting
- ✓ Supports SDGs: 3 (Good Health and Well-being) 11 (Sustainable Cities and Communities) 13 (Climate Action) 15 (Life on Land) 16 (Peace, Justice and Strong Institutions) 17 (Partnerships for the Goals)

Weaknesses

- ✗ Lacks a formal regulatory framework in Belgian planning law
- ✗ Underrepresentation in local and regional spatial strategies
- ✗ Interdisciplinary implementation (ecologist-designer-policy) is still rare

Opportunities

- ✚ Partner with local schools and citizens for animal observation & design
- ✚ Embed AAD into redevelopment zones or schoolyard redesigns
- ✚ Test design in peri-urban edges for endangered species (e.g. amphibians)

Threats

- ⚠ Risk of tokenistic application without functional habitats
- ⚠ Public fear or rejection of urban wildlife (e.g. insects, bats)
- ⚠ Development pressure may reduce space for animal needs

Table 6: SWOT Animal Aided Design, made by author

Urban Ecological Networks (UEN)

Focus: Connectivity between urban and peri-urban biodiversity patches and corridors.



Urban Ecological
Networks

Strengths

- ✓ Framework is grounded in European ecological policy and planning theory
- ✓ Grote Nete valley forms a natural corridor through the area
- ✓ Heist's location enables inter-municipal ecological integration

Weaknesses

- ✗ High fragmentation due to infrastructure (roads, housing sprawl)
- ✗ Lack of corridor zoning or land acquisition tools
- ✗ Difficult for municipalities to monitor ecological connectivity

Opportunities

- ✚ Implement corridor restoration via Blue Deal and spatial structure plans
- ✚ Add green infrastructure links between Heist and bordering villages
- ✚ Use UEN as lens to coordinate inter-municipal nature strategy

Threats

- ⚠ Weak enforcement or political support for corridor protection
- ⚠ Conflict with intensive land use (e.g. agriculture, real estate)
- ⚠ Climate change may shift species distribution, fragmenting new connections

Table 7: SWOT based on Urban Ecological Networks, made by author

Nature-based Solutions (NbS)

Focus: Use of ecological systems to solve urban challenges like heat, flooding, and biodiversity loss.



Nature-based Solutions

Strengths

- ✓ NbS aligns with EU Green Deal, Flemish Blue Deal, and SDG agendas
- ✓ Demonstrated cost-efficiency for water and temperature regulation
- ✓ Widely accepted by public and government bodies

Weaknesses

- ✗ Tendency to oversimplify or 'greenwash' with superficial greenery
- ✗ Requires integrative governance — often missing in smaller towns
- ✗ Maintenance often neglected after project delivery

Opportunities

- ✚ Use wetlands and floodplains around Grote Nete for NbS pilot projects
- ✚ Position Heist as a model for semi-urban NbS integration
- ✚ Combine NbS with school grounds, parking areas, or health infrastructure

Threats

- ⚠ Urban development may take precedence over ecological function
- ⚠ Lack of local resources for long-term maintenance
- ⚠ Climate extremes may exceed NbS design thresholds

Table 8: SWOT based on Nature-based Solutions, made by author

Internet of Nature (IoN)

Focus: Use of digital tools, sensors, and data networks to monitor, manage, and understand nature in cities.



Strengths

- ✓ Belgium supports open data (e.g. Geopunt, waarnemingen.be, INBO)
- ✓ IoT costs are decreasing, and citizen science is growing
- ✓ IoN provides real-time monitoring and can guide AAD/NbS planning

Weaknesses

- ✗ Municipalities lack technical capacity or digital infrastructure
- ✗ Interpreting complex ecological data remains a challenge
- ✗ IoN not yet integrated in urban policy or planning tools

Opportunities

- ✚ Create citizen sensing networks for bats, birds, and water quality
- ✚ Build partnerships with universities (e.g. UAntwerp, KU Leuven)
- ✚ Use apps/sensors in schools to monitor local habitats and trees

Threats

- ⚠ Overreliance on sensors without ecological context
- ⚠ Data privacy concerns in public spaces
- ⚠ Funding instability for smart infrastructure and tech support

Table 9: SWOT based on Internet of Nature, made by author

Previous Conclusion

The conducted SWOT analysis provides a strategic overview of the potential and challenges related to implementing a biodiversity-integrated urban planning framework in Heist-op-den-Berg, with specific reference to the ecological and socio-spatial conditions of the Antwerp province. By examining the internal and external factors that shape the applicability of AAD, NbS, UEN, and IoN, this evaluation supports a multidimensional understanding of nature-inclusive planning in a dense village context.

Strengths identified in the analysis include the presence of biologically valuable landscapes—such as the riparian zones along the Grote Nete—which offer natural corridors for biodiversity, and the availability of provincial data on priority species through institutions like INBO. Furthermore, the growing recognition of NbS in European environmental policy, as seen in regional strategies aligned with the EU Green Deal and Biodiversity Strategy 2030, strengthens the institutional readiness for such interventions on a local level. The strong cultural interest in sustainability, combined with the presence of Natura 2000 areas in its proximity, further reinforces local engagement and ecological relevance.

However, weaknesses persist. The fragmentation of habitat patches due to infrastructure development, low integration of species needs in standard urban planning restrict implementation capacity. Additionally, awareness of AAD remains low in Flemish municipalities, and its integration into planning legislation is nascent. These gaps pose risks of underperformance unless addressed through targeted education, policy reform, and stakeholder alignment.

Opportunities arise from multiple levels. The potential for Heist-op-den-Berg to serve as a demonstrative pilot for nature-inclusive design is substantial. Programs such as the VEN (Flemish Ecological Network) Strategy create enabling policy environments. There is increasing availability of open-source data (e.g., waarnemingen.be, governmental publications, geopunt.be), which can be leveraged for informed decision-making. Furthermore, the convergence of smart city agendas and IoT infrastructure provides a fertile ground to implement the Internet of Nature, enabling real-time biodiversity monitoring and environmental health assessments. For example, expanding urban sensors near the Grote Nete could provide both flood forecasting and habitat health metrics with inclusion of Ph, salinity sensors.

Threats include potential conflicts between urban expansion demands and conservation goals, particularly as Heist-op-den-Berg experiences population growth. The lack of an integrated legal framework supporting multifunctional land use may hinder cross-disciplinary implementation. Additionally, reliance on external funding for innovative ecological projects creates financial uncertainty. Climate-related threats, such as droughts or invasive species, could also disrupt the fragile biodiversity targeted by AAD strategies.

Importantly, the SWOT analysis reveals that the synergies between AAD and NbS—supported by UEN as a spatial strategy and IoN as a technological enabler—can be fully leveraged only when a cross-sectoral governance model is adopted. For instance, embedding biodiversity considerations within municipal zoning laws, aligning educational campaigns with local planning departments, and involving citizens in data collection (citizen science) can collectively mitigate threats and activate dormant strengths.