Overview of the status & trends of biodiversity loss in Belgium

Pre-analysis of literature on the risks to Belgium associated with the loss of biodiversity

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Key preliminary remarks

This report provides an overview of the challenges facing Belgium in relation to the loss of its biodiversity, considering regional, national, and international contexts. The underlying work falls within the framework of the first Belgian Climate Risk Assessment developed by Cerac in close collaboration with a consortium of experts.

Due to the broad scope of the topic and the large amount of existing information, as well as the limited resources available, **this report is not meant to be all-encompassing**. **It should not be regarded as a comprehensive analysis of the topic**.

Additionally, it is not the intention of the authors and/or their parent institutions to assign blame to any individuals, services, or institutions. Any such impression is unintended and should be disregarded. Rather, this report aims to foster awareness, dialogue, and collaboration in addressing the shared challenges ahead.

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Summary

Overview of the Status & Trends of Biodiversity Loss in Belgium

Pre-analysis of literature on the risks to Belgium associated with the loss of biodiversity

1. Purpose and scope

This explanatory report provides a pre-analysis of the current status and trends of biodiversity loss in Belgium as described by the Regions, focusing on risks and implications for society, economy, and environment. Its goal is to synthesise scientific and technical literature, identify gaps, and offer insights for the reader. This work, carried out under the supervision of the Climate Risk Assessment Center (Cerac), was modestly intended to contribute to Belgium's first Climate Risk Assessment (BCRA). It is part of a collaboration agreement between Cerac and the National Geographic Institute (NGI), aiming to inform policy and future risk-mapping initiatives.

2. Background

Biodiversity underpins ecosystem health and resilience, delivering essential services such as food, clean water, climate regulation, and public health. Yet, Belgium, like much of the world, is experiencing an unprecedented decline in biodiversity mainly due to habitat fragmentation and loss, pollution, climate change, overexploitation, and invasive alien species. As a densely populated and highly industrialised country, Belgium faces significant challenges in balancing conservation with economic and societal needs. International and European frameworks, such as the Kunming-Montreal Global Biodiversity Framework and the EU Biodiversity Strategy for 2030, provide targets and guidance for reversing these trends.

3. Key Findings

3.1. State and trends of biodiversity loss

- Declining biodiversity is a top global risk: biodiversity loss and ecosystem collapse are among the top three risks globally for the next decade (World Economic Forum, 2024).
- Monitoring challenges: no single metric captures the full complexity of biodiversity. The report reviews ground-sourced (species abundance, occurrence, richness) and remote-sensing methods, highlighting strengths and gaps for Belgium.
- Regional disparities: Belgium’s biodiversity is monitored through regional initiatives and citizen science platforms, but data are fragmented and, in some cases, biased toward certain taxa and habitats.
- Trends by habitat: (*i*) species in agricultural areas show the steepest decline; (*ii*) species in wetlands and open habitats are increasing or decreasing slightly, depending on the species considered; (*iii*) forest birds and long-distance migrants face moderate to strong declines; (*iv*) Marine mammals and certain fish species show mixed trends in the Belgian Part of the North Sea.
- Ordinary biodiversity is overlooked, inducing potential biases: common species and belowground biodiversity (soil microorganisms) receive less attention than rare or protected taxa, though they are crucial for ecosystem services.

3.2. Principal threats

- Habitat loss and fragmentation from urbanisation and agriculture are the most significant drivers in Belgium.
- Pollution, especially nitrogen deposition, impacts sensitive ecosystems such as heathlands and grasslands; for instance, over 75% of biodiversity in Flemish grasslands is at risk.
- Climate change is altering species distributions, phenology, and ecosystem functions, with wetlands, forests, and marine environments especially vulnerable.
- Overexploitation and invasive alien species further destabilise ecosystems, with Belgium's role as a transport hub increasing introduction risks.
- Although wildfires are not currently a top risk for Belgium, they are already causing localised damage to biodiversity in protected areas; this risk to biodiversity is increasing as wildfires are expected to become more intense and occur more frequently and simultaneously.

3.3. Data and methodological challenges

- Comprehensive assessment of future risks posed by biodiversity loss is hindered by fragmented governance and limited data integration.
- Spatial and taxonomic gaps remain, *e.g.*, invertebrates and soil biodiversity are underrepresented.
- Remote sensing offers promise, particularly for forests and land-use change, but needs further development for key biodiversity metrics.
- Where relevant, integration and harmonisation of federal/regional datasets (Belgian Part of the North Sea, Brussels, Flanders, Wallonia) are needed for national-scale analysis.

3.4. Policy and management implications

- Belgium aligns with the EU Biodiversity Strategy for 2030 and participates in global initiatives (*e.g.*, KM-GBF, IPBES, GEO BON).
- Protected areas, *i.e.* Natura 2000 network, cover 15% of territory, but connectivity and effective management are ongoing challenges.
- Innovative tools (Eco-Accounts, river contracts, citizen science) and restoration efforts (*e.g.*, Zwin Nature Park, oyster reef projects) illustrate progress but require scaling and coordination.

3.5. Societal risks and opportunities

- Biodiversity loss mainly threatens food security, water supply, climate resilience, public health, and social equity.
- Declines in pollinators and soil health jeopardise agricultural productivity and economic stability.
- Ecosystem services approach (assessing supply/demand) provides a pragmatic framework for evaluating risks to Belgian society.

4. Synthesis of the recommended next steps

- Develop integrated, spatially explicit biodiversity databases across all regions, and support existing ones.
- Harmonise metrics and indicators for national and global reporting.
- Prioritise research on underrepresented groups (invertebrates, micro-organisms, *etc*.), with soil biodiversity as a priority.

- Support predictive modelling and mapping of biodiversity loss risks, especially in urban and agricultural areas, taking into account threats such as pollution.
- Assess and mitigate the impacts of wildfires and invasive alien species on biodiversity and key infrastructure.
- Strengthen inter-regional and cross-sectoral coordination to meet international biodiversity targets and efficiently reverse its decline.
- Embed biodiversity considerations in urban planning, construction, and economic development, leveraging both large-scale strategies and everyday actions.

5. Conclusion

Biodiversity loss in Belgium poses significant risks to ecosystems, the economy, and societal wellbeing. While considerable data and promising initiatives exist, essentially at regional level, challenges persist in harmonising efforts, filling knowledge gaps, and translating policy objectives into impactful actions. Coordinated, science-based strategies (grounded in robust data and inter-regional collaboration) are essential for reversing biodiversity decline and ensuring a resilient future for Belgium's people and nature.

Main recommendations

In no specific order:

- Because invasive alien species (IAS) are a growing threat, **we recommend carrying out an IAS-specific risk assessment, including its impact on the key Belgian infrastructures**;
- While the past evolutionary trends of certain aspects of biodiversity are known, predictive mathematical and statistical models are generally lacking. This compromises risk assessments, so a trial using the PREDICTS model (or another one designed for similar biogeographical conditions) could be carried out in Belgium and **full priority and support should be given to the development of such predictive models**, taking into account threats such as pollution, and land use and climate change;
- Belgium's situation as a highly industrialised, artificialised, and densely populated country makes supporting initiatives to assess, monitor, or increase biodiversity and associated ecosystem services in urban environments particularly important. **The risk to Belgian society due to the loss of urban biodiversity should also be assessed, paying particular attention to the repercussions on the role of ecosystems as nature-based solutions for public health** (*e.g.*, potential improvement for thermal comfort, mental health and air quality);
- Given the increasing risk of wildfires in Belgium, **it is recommended that the impacts of wildfires on biodiversity and the impacts of biodiversity loss on wildfire risks be further investigated**;
- **Additional technical research should be supported on some specific topics**, such as:

  (*i*) the relevance of using regional forest inventories as a model for setting up biodiversity monitoring systems for other ecosystems, such as grasslands, rivers, and soil,

  (*ii*) in woody areas, specifically forest environments, research could assess whether changes in average total height (*i.e.* a measure of the vertical structure of this ecosystem) could be used as a good proxy for possible changes in ecosystem services, using remote sensing-based monitoring;

- The **climate-security nexus deserves to be fully investigated in the Belgian context**, considering potential cascading effects on biodiversity and/or ecosystem services and subsequent collateral damage on our security;
- It is important to at least partially compensate for the bias associated with studying some taxa while neglecting others. The largest and least known group is that of invertebrates, which, according to Stevens et al. (2015), represent more than 60% of all species present in Flanders. **Soil biodiversity, most of the time overlooked, is another key example that deserves priority attention, with an urgent call to improve soil monitoring**.

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- Instituut Natuur-en Bosonderzoek (INBO)
- Agentschap voor Natuur en Bos (ANB)
- Koninklijk Belgisch Instituut voor Natuurwetenschappen/Institut royal des Sciences naturelles de Belgique (RBINS)
- Belgian Biodiversity Platform
- The Marine Environment Department of the Federal Public Service Health, Food Chain Safety and Environment
- France – Ministère de la transition écologique, de la biodiversité, de la forêt, de la mer et de la pêche/ Direction générale de l'énergie et du climat (FR-DGEC)

We would also like to thank all the institutions and individuals who contributed to this work, even if only in a small way, and who are not included in the above list.

"Climate change, land change, agriculture and wildlife use – the major threats to biodiversity – are also driving a global rise in infectious diseases. Biodiversity loss is generally harmful to human health." (Carlson et al., 2025).

1. Introduction

Biodiversity is the foundation of ecosystem health and resilience, supporting the life systems that sustain human, animal, and plant life alike. Biodiversity underpins life on Earth, and its decline inherently threatens humanity's ability to survive. Encompassing the diversity of life forms at genetic, species, and ecosystem levels, biodiversity enables ecosystems *e.g.* to produce food, clean water, and provide medicine and climate regulation. Defined by the Convention on Biological Diversity (CBD) as "*the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*", biodiversity is vital for maintaining the flow of essential ecosystem services that sustain society as emphasised by the WWF Biodiversity Risk Filter. However, despite its importance, biodiversity is currently experiencing an unprecedented rate of decline, with a significant proportion of species facing extinction within the next few decades due to human activities and climate change. The 20th century witnessed a global decline of biodiversity between 2 and 11% as shown by several indicators (Pereira et al., 2024). This trend not only disrupts the proper functioning of ecosystems but also threatens economic stability and human health, among other things. According to the global risks perception survey conducted by the World Economic Forum, biodiversity loss and ecosystem collapse is seen as one of the top 3 global risks over the next 10 years (Figure 1)(World Economic Forum, 2024). For too long, ecosystem services have been regarded as boundless and free, yet the loss of biodiversity threatens to reveal their irreplaceable value.

Globally, biodiversity loss has been driven by multiple interrelated factors, including habitat destruction, pollution, invasive alien species, and overexploitation of natural resources. In recent years, climate change has compounded these pressures, altering ecosystems and intensifying species migrations, habitat fragmentation, and shifts in species distributions. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) estimates that nearly one million species face extinction if these human-driven impacts are not curbed (IPBES, 2019). Recognising this crisis, international frameworks such as the Aichi Biodiversity Targets and the more recent Kunming-Montreal Global Biodiversity Framework (KM-GBF) have been established to halt and reverse biodiversity loss by promoting conservation and sustainable practices worldwide (United Nations, 2022).

Within the European Union (EU), biodiversity loss is acknowledged as a significant threat to both environmental and societal stability. As part of the European Green Deal, the EU's Biodiversity Strategy for 2030 is both an agenda and an invitation for the European Commission itself, for the Member States (gathered in the Council) and for the European Parliament to restore or contribute to the restoration of degraded ecosystems, protect biodiversity-rich areas, and implement sustainable agricultural practices. The European Commission proposes that biodiversity conservation is critical not only for preserving natural habitats but also for achieving climate resilience and meeting carbon reduction goals (European Commission, 2020). Despite these commitments, biodiversity decline within Europe remains a major concern, as urbanisation, industrial activities, and agricultural pressures continue to strain ecosystems, particularly in densely populated regions.

Figure 1: Global risks ranked by severity over the short and long term; participants were asked to estimate the likely impact (severity) of the following risks over a 2-year and 10-year period (World Economic Forum, 2024).

BIODIVERSITY LOSS IN BELGIUM: CHALLENGES AND NEEDS

Belgium, with its dense population and urban-industrial landscape, faces specific challenges in conserving biodiversity. The country's ecosystems, ranging from marine and coastal ecosystems to forests and urban green spaces[1], are consistently under pressure from land-use changes, pollution, and climate-related impacts. While Belgium has made efforts to address biodiversity loss through national and regional policies, habitat fragmentation and ecosystem degradation continue to pose significant threats. Given Belgium's highly modified landscapes and the need for both conservation and sustainable economic development, efforts in support of biodiversity must be carefully balanced with societal demands and economic constraints.

The implications of biodiversity loss in Belgium extend beyond the concept of ecological health (*sensu* Mallee, 2017), as this loss threatens the ecosystem services essential for public health, agriculture, and climate adaptation – among others. Belgium's natural resources, already limited by intensive land use and industrialisation, risk further depletion without effective intervention. As Belgium works to advance its conservation and sustainability objectives, comprehensive and reliable biodiversity data is essential. Where this is not already the case, effective conservation strategies must be based on an accurate assessment of direct and indirect biodiversity indicators, as well as current and projected trends.

([1]) Our country is home to a wide variety of ecosystems, some of which are particularly important to our society, further information on this subject is provided throughout the report. *Cf.* subsection 3.4 of this report for more information about these consultations.

2. Purpose and scope of the literature review

This literature review is conducted as part of a collaborative effort with the Climate Risk Assessment Center (Cerac) and the National Geographic Institute (NGI) to investigate the risks posed by biodiversity loss in Belgium[2]. The review aims at collecting and analysing scientific literature but also grey literature as well as institutional publications related to biodiversity loss relevant to Belgium[3]. In addition, an overview of the existing biodiversity data in Belgium already available via public agencies and other research institutions is presented. The review addresses two core objectives:

1. Understanding the state of biodiversity loss and its evolution

   This objective involves gathering and evaluating various methodologies for measuring biodiversity loss and assessing the associated risks. By examining both ground-sourced and remotely sensed biodiversity metrics, the review aims to discuss indicators relevant to Belgium's specific context, particularly those that can support spatial analysis. Various biodiversity measurements, such as species abundance, ecosystem diversity, and functional indicators, are analysed for their applicability in assessing biodiversity loss within Belgian ecosystems. In addition, other themes such as ecosystem services, spatial analysis, and conservation/mitigation strategies are tackled.

2. Identifying relevant data sources

   The second objective of the review is to identify and evaluate existing datasets on Belgian biodiversity, with an emphasis on geospatial data. Given that the NGI collaboration involves creating a "biodiversity loss risk map" at a further stage, the review prioritises resources that contain spatial components, facilitating integration into future risk mapping. Finally, the review identifies data gaps, particularly in spatially explicit data, that could hinder effective biodiversity assessment and inform future data collection efforts.

At a later stage, which is not covered by this report, the geographical information identified will be used to verify the feasibility of producing a national-scale biodiversity loss risk map, showing areas most prone to biodiversity loss and where there is a higher risk to societal functioning. In that view, spatially explicit data are seen as the most relevant in assessing the risks posed by the decline of biodiversity, although the absence of spatial component must also be recorded as it will allow to highlight the gaps in the current knowledge. As part of this work, a database of over 150 scientific articles, policy reports, and technical studies was compiled. These sources were categorised into thematic areas, including biodiversity metrics, ecosystem services, spatial analysis, and conservation strategies. This database serves as a critical resource for Cerac and NGI, offering quick access to scientific insights and methodologies relevant to biodiversity risk management. Additionally, recognising the complex interplay between biodiversity loss and climate risks, a separate report has been prepared on the topic of wildfires (Kruk et al., 2025). This complementary analysis explores the ecological and social impacts of wildfires in Belgium and beyond, providing a broader context for understanding the cascading risks associated with environmental change.

([2]) More information on the cooperation agreement behind this project can be found in Annex.9.3.
([3]) In the context of biodiversity, we recognise that the issue of biological invasions is highly significant and pertinent. However, due to limited resource, this topic fell beyond the scope of this work.

WHERE WE START

Before embarking on this review, the baseline was marked by:

1. Fragmented Governance: A patchwork of regional and federal initiatives that were not always harmonised or aligned with international standards;
2. Limited Data Integration: While regional datasets existed, such as Wallonia's vulnerability mapping and Flanders' green infrastructure programs, they lacked coordination and cross-regional compatibility;
3. Taxonomic and Methodological Gaps: Certain species groups and ecosystems were underrepresented in monitoring efforts, and methodologies often varied widely in scope, scale, and resolution;
4. Emerging Global Frameworks: Tools like the KM-GBF highlighted the need for standardised indicators but had yet to be fully operationalised in Belgium[4].

CHALLENGES AND MITIGATION

The vastness of the biodiversity theme and Belgium's institutional context posed significant challenges:

- Thematic Complexity: Biodiversity is inherently multifaceted, requiring integration of genetic, species, and ecosystem-level data. To address this, the review adopted a structured approach, categorising studies into methodologies for measuring biodiversity, ground-sourced or remotely sensed measurements, ecosystem services and modelling;
- Data Gaps: Where spatial or temporal data were missing, supplementary resources were identified, such as citizen-science platforms like Observations.be;
- Methodological Diversity: Divergent approaches were reconciled by organising findings into thematic areas and emphasising studies that employed standardised methods;
- Governance Fragmentation: The review prioritised insights that could be applied across regions, facilitating alignment with national and international frameworks.

This starting point provided the foundation for a systematic and rigorous review process, designed to overcome these challenges and produce actionable insights into biodiversity loss in Belgium.

The following sections detail the resources, methodologies, and frameworks employed in this review.

CURRENT STATUS OF THE REVIEW

A total of 154 documents (including scientific articles, reports, press articles, book chapters, *etc.*) have been selected according to their relevance to the subject (relevant results on biodiversity in Belgium or similar/neighbouring environment, relevant methodologies for assessing biodiversity and its risks). Further reading of articles may provide additional insights and will surely continue feeding the reflexion on the assessment of biodiversity loss related risks in Belgium. The first Belgian Climate Risk Assessment (BCRA) for Belgium carried out by the second half of 2025 by Cerac and a consortium of experts is to be fed by the present report.

Because of the limited resources allocated to this project, several choices were made in order to select relevant literature, and some topics were prioritised over others. For example, restricted focus was given to the drivers of biodiversity loss (among which the issue of invasive species), although a subsection of this report is dedicated to

(4) At the time of writing this report, work is underway to enable this operationalisation step in Belgium.

briefly present the main threats to biodiversity. In other cases, arbitrary choices[5] have been made to select which articles to read.

Note that this work is a pre-analysis of the literature identified as relevant for addressing the issue of biodiversity loss in Belgium and the associated risks. It is not a full academic literature review.

STRUCTURE OF THE REPORT

To achieve these objectives, the report is organised to guide readers through a systematic exploration of the literature on biodiversity loss and its implications for Belgium. Following this introduction, Section 3 defines the methodology used in the literature review, detailing the objectives and resources consulted, including data from Google Scholar, Cerac, and other key databases. This comprehensive approach ensures a broad yet precise examination of the literature, capturing both widely recognised and specialised data relevant to Belgium.

The core of the report is presented in Section 4, which provides an extensive analysis of key themes in biodiversity loss, organised by measurement types and methodological approaches. This section covers direct ground-sourced biodiversity measurements, such as species counts, and indirect assessments from remotely sensed measurements or using aggregated indicators that reveal biodiversity trends. Findings on the role of biodiversity in the delivery of ecosystems services are uncovered. Section 4 includes a subsection on the state of biodiversity measurements in Belgium and how are the different types of measures are used. Section 4 also exposes the different threats to biodiversity loss, mapping the risks posed by biodiversity loss and predictive models are also discussed, each offering unique insights into the current state and future trajectory of biodiversity. The review presents both a synthesis of findings and extracts from key studies, illustrating the depth and breadth of current knowledge and its limitations.

Building on this analysis, the following sections examine conservation efforts at national, regional, and global levels. Subsection 4.6 details Belgium's initiatives to address biodiversity loss, including specific policies, projects, and partnerships. This includes an overview of initiatives in neighbouring countries and across Europe, providing a comparative perspective on strategies in Belgium. The global context, highlighting the role of international organisations and frameworks that support Belgium's biodiversity efforts is also examined.

Belgian forests cover around a quarter of the country's land area, making them one of its most widespread ecosystems. These forests also provide a wide range of vital ecosystem services. Data on these ecosystems is collected annually in the field through regional inventories. These inventories are fantastic tools for describing and tracking changes in a number of biodiversity-specific parameters over time. Therefore, before the conclusion, a case study on biodiversity monitoring[6] through those forest inventories is elaborated. The report concludes with an appendix, including a detailed – but not exhaustive - collection of data on Belgian biodiversity, sourced from public agencies and research institutions (subsection 9.1) and followed by a list of several initiatives regarding biodiversity assessment (subsection 9.2). These resources provide additional context and firsthand insights that complement the main findings of the literature review.

This report provides an initial examination of the scientific and grey literature on biodiversity (loss) in Belgium, outlining existing knowledge, identifying data gaps, and highlighting key methodological challenges. By addressing these issues, the review aims to support the development of a more robust framework where appropriate, and, in any case, to bolster existing initiatives for assessing and mitigating the risks posed by biodiversity loss in Belgium.

([5]) To mitigate as much as possible the risks of bias posed by this arbitrary approach, consultations with experts were usefully incorporated into the process of selecting relevant complementary documents for analysis.
([6]) For more information on the concept of "biodiversity monitoring" and its underlying types and timescale, please refer to *e.g.* the analysis carried out by Bresadola & Bjärhall(2025), which is available online here.

3. Methodological framework

3.1. Literature screening and selection

This report is based on a review of relevant scientific and grey literature. Given our limited manpower and resources, it is designed to provide the most rigorous possible analysis of biodiversity and its loss in Belgium. Because of the breadth and complexity of the topic, a multi-source approach was employed to capture a wide spectrum of knowledge. Key sources included peer-reviewed articles retrieved through 1) Google Scholar, 2) a curated collection of documentation provided by Cerac (*e.g.*, scientific articles, reports, and related studies), and 3) additional trusted resources identified from biodiversity organisations and expert consultations.

Even though this analysis is not intended to be exhaustive, the screening and selection of literature aimed to guarantee high-quality, contextually relevant insights, with a particular focus on studies applicable to Belgium. Several challenges were encountered, including variations in the definition and scope of biodiversity, methodological inconsistencies, and, last but not least, gaps in geospatially explicit data (subsection 3.2). These limitations were mitigated by employing the most systematic methodology possible for selecting the literature and by integrating expert consultations to fill critical knowledge gaps (section 3.3).

For each source, a tailored screening and selection process was applied, ensuring consistency, relevance, and alignment with the objectives of this review. A series of guidelines were initially formulated to approach the subject (*i.e.*, integration of georeferenced info, correlation analysis between ecological requirements and what exists, satellite data for biodiversity loss and biodiversity loss risk map feasibility analysis). Those guidelines have been constantly redefined during the course of weekly consultations between the two parties (NGI and Cerac), in the light of revealed literature findings. As a result, the initial guidelines do no longer represent the current focus of this work.

3.1.1. Google Scholar

To identify scientific literature, Google Scholar was employed as a primary search tool, utilising Boolean operators (AND, OR, "-") to refine searches and exclude irrelevant content. Search terms targeted the intersection of biodiversity loss and its spatial dimensions within the context of Belgium. The methodology was designed to capture a broad dataset while prioritising studies relevant to the thematic (including the concept of risk) and geographical focus of the report.

The search terms were applied to the full text rather than limited to titles, as restricting searches to titles alone resulted in fewer relevant outputs. Articles published between 2018 and 2024 were prioritised, reflecting recent advancements and trends in biodiversity research. The most relevant search, yielding 187 articles, combined the following terms (in English[7]):

- "biodiversity loss" OR "nature loss" OR "biological diversity loss" OR "species richness loss";
- "biodiversity decline" OR "species richness decline";

([7]) The authors' decision to focus the bibliographic research on articles published in international peer-reviewed journals made it possible to narrow down the search. Where possible, documents available only in national languages, such as certain technical reports, were retrieved through the experts consulted. For more information, please refer to paragraphs 3.1.2 and 3.1.3 of this report.

- "mapping" OR "GIS" OR "spatial";
- "Belgium" OR "Benelux";
- Excluded terms: -global -humanity -invasive[8].

The search results were extracted using the software Publish or Perish and compiled into an MS Excel database. Articles were systematically and chronologically screened as follows:

1) assess relevance based on title (criteria: does it address one of the investigated topics? Is it applicable to the context of Belgium?);
2) assess relevance based on abstract;
3) for the selected articles only, read the full article and take notes on any relevant information.

3.1.2. Documents provided by Cerac

Climate Risk Assessment Center compiled an initial comprehensive collection of biodiversity-related documents, encompassing scientific articles, technical reports, and policy analyses mainly in English, Dutch and French. The documents were initially categorised into “Forestry”, “Ecosystem services”, “Climate-induced forest dieback” and the rest of the articles were not assigned to any specific category so those were assigned the “Biodiversity” tag.

For those articles, the selection was based on reading both the title and abstract. As with articles selected through the Google Scholar search (*cf.* § 3.1.1.), the selected articles were then read, and relevant insights/findings were collected in this report. The following steps were chronologically followed:

1) assess relevance based on title and abstract;
2) for the selected articles only, read the full article and take notes on any relevant information.

3.1.3. Other source material

Additional documents, including those in national languages, were identified by cross-referencing with the reviewed literature, or via recommendations from trusted biodiversity organisations and experts (see section 3.3). These sources were pre-screened for relevance by their origin, ensuring a high likelihood of alignment with the review’s objectives.

For classification, a similar two-step approach was chronologically applied:

1) Go through the abstract;
2) read the full article and take notes on any relevant information.

([8]) The issue of invasive species is a highly significant and pertinent topic in the context of biodiversity. However, mainly due to the limited resources available, it felt beyond the scope of this work.

3.2. Identified challenges and applied solutions

Several challenges emerged during the literature screening process:

- Thematic breadth: the vast scope of biodiversity necessitated categorisation into measurable subcomponents (*e.g.*, genetic diversity, species richness, ecosystem services);
- Data Gaps: spatial and taxonomic biases were mitigated by integrating regional datasets and citizen-science platforms like Observations.be;
- Methodological Inconsistencies: divergent methods were reconciled by focusing on studies with standardised approaches or robust metadata.

This multi-pronged methodology ensured that the literature review was both comprehensive and as scientifically rigorous as possible, forming a strong basis for the subsequent analysis. However, it is important to note that this analysis was not intended as a comprehensive academic literature review. Due to limited time and human resources, not all relevant information could be identified or encapsulated, and certain choices had to be made regarding priorities and the scale of depth. Therefore, the correct term for this work is "pre-analysis". Because we cannot guarantee that we captured all relevant information, certain limitations may apply to the use of our findings. For example, they may not always be applicable to very local contexts. Nevertheless, it is important to note that the content of this report has been significantly improved thanks to the expert consultation phase, and the main trends we arrive at (*cf*. sections 6 and 7 of this report) are all the more reinforced.

3.3. Experts' consultation

In addition to the selected literature (including scientific articles, reports, press articles, book chapters, *etc.*), the following biodiversity experts have been consulted, some of whom have given feedback on this report (by chronological order):

- Scientific support to Inventaire Permanent des Ressources Forestières de Wallonie (IPRFW) at Université de Liège (ULg)/Gembloux Agro-Bio Tech (GxABT): Jérôme Perrin, Nicolas Latte, Prof. Philippe Lejeune (September 2024);
- France - Ministère de la transition écologique, de la biodiversité, de la forêt, de la mer et de la pêche/ direction générale de l'énergie et du climat (FR-DGEC): Adeline Favrel (September 2024);
- Belgian Biodiversity Platform: Sonia Vanderhoeven, Sébastien Ronveaux (October 2024);
- Etude de diagnostic des vulnérabilités commandité par l'Agence wallonne de l'air et du climat (AwAC) (ULg/GxABT): Aurore Fanal (November 2024);
- Federal Public Service (FPS) Health, Food Chain Safety and Environment: Christelle Sponck, Jens Warrie (May 2025), Loes Rutten (September 2025);
- Instituut Natuur-en Bosonderzoek (INBO): Hilde Eggermont and team (June 2025);
- Agentschap voor Natuur en Bos (ANB): Carl De Schepper, Rene Meeuwis, Jeroen Panis, Caroline Thys (Jully 2025);
- Koninklijk Belgisch Instituut voor Natuurwetenschappen/Institut royale des Sciences naturelles de Belgique (RBINS): Jan Vanaverbeke (July 2025).

4. Understanding the state of biodiversity loss in Belgium and its evolution

Biodiversity or biological diversity represents the variety of living organisms on Earth. Biodiversity is also commonly used to refer to living organisms as a whole, so that the decline in abundance of even a single species can be considered as a loss of biodiversity. According to Article 2 of the CBD:

"Biodiversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Given the complexity of the interactions between the species and the environment in which they grow, biodiversity can be assessed from various perspectives. But its complexity, by nature, makes it difficult to (i) measure (*e.g.*, with one single aggregated parameter/variable) and (ii) model its dynamics over time and space. However, some studies have looked at past trends in biodiversity on a global scale.

4.1. Fostering a deeper understanding of biodiversity change through adequate indicators

There is a consensus that biodiversity is declining globally (Isbell et al., 2023; Boonman et al., 2024; Damiani et al., 2023), yet there is currently no method that grasps the complexity of biodiversity in all its dimensions (Damiani et al., 2023; McElderry et al., 2024, Preprint). As stressed by Leroy et al. (2023): "*empirical quantification of biodiversity change remains a challenge*" due to the existence of numerous metrics for the various and complex aspects of biodiversity. McElderry et al. (2024, Preprint) also highlights the lack of standardised and integrated assessment method for the multidimensional complexity of biodiversity and summarises it with the following words: *"Currently, there is still no single measure of biodiversity that incorporates available information across spatial scales to fully evaluate the state of nature."*

So far, numerous biodiversity metrics have been developed to support biodiversity monitoring and the datasets used to determine these metrics can be divided into two categories: 1) ground-sourced data and 2) remotely sensed data (McElderry et al., 2024, Preprint)([9]). In this section, we will present the results of the literature review regarding these two types of data and how these are applicable in Belgium.

([9]) Recently the biodiversity metrics subject is in the spotlight due to the growing demand for assessing biodiversity targets set by governmental policies and informing decision-making processes (*cf. e.g.*, Burgess et al., 2024; Marshall et al., 2024).

4.1.1. Ground-sourced biodiversity measurements

Ground-sourced data can provide detailed insights of biodiversity at local levels, in a specific area. A common ecological quantity used to analyse species population is species abundance. Abundance refers to the population size of species, it gives the number of individuals of a specific species in a specific area. Although it is not a measure of diversity *per se*, it may provide an understanding of populations dynamics.

Although costly, monitoring species abundance can be of great importance to prevent the loss of biodiversity. This is the case when monitoring the abundance of keystone species[10], whose impact on an ecosystem is large relative to their population size. Because these species are usually at the top of the food chain, their decline may cause other species to explode in number and cause the ecosystem to cascade down into a degraded condition (Dasgupta & Levin, 2023). On the other hand, the state of an ecosystem can be assessed by looking at the abundance monitoring of indicator species, whose presence reflects specific environmental conditions.

Another advantage of studying the abundance of species is to keep an eye on genetic diversity. Genetic diversity is an equally important aspect of biodiversity, and it can be maintained if populations size is large enough. The Ne 500 indicator is based on the idea that retaining an effective population size of 500 individuals is the minimum to warrant species resilience and evolutionary potential; DNA-based methods can also be used to study genetic diversity of species (Mastretta-Yanes, da Silva, et al., 2024; Mastretta-Yanes, Suárez, et al., 2024).

However, as stressed by Yin & He (2014), abundance data is often costly to collect and for that reason, are usually not available. Occurrence data are, on the other hand, much more widely available. Occurrence refers to the absence or presence of a species at a specific location and time. It allows for mapping the geographic range of species. As an example, occurrence data, the platform Observations.org gathers species data uploaded by citizens all around the world, where data quality is checked by species experts working with smart technology and artificial intelligence. Based on the assumption that species' abundance and spatial distribution are positively correlated, Yin & He (2014) have developed a method based on occurrence data as surrogate for abundance.

Species richness[11] is another common ground-sourced metrics in biodiversity assessment. It gives the number of different species present in a specific area (habitat or ecosystem) and does not take abundance into account. Species richness do not always correlate with abundance of species, because rare species are often replaced by more invasive species or because the declining species was the most abundant (Valdez et al., 2023).

Rosa et al. (2025) argue that "classical" metrics such as abundance and species richness may sometimes hide complex ecological interactions; their study fills the gap by comparing functional diversity to traditional metrics for vascular plants in different bioregions in Europe.

IN BELGIUM

LifeWatch Belgium[12] is a platform on which the Flanders Marine Institute (VLIZ) and INBO, among others, publish the results of a collection of sensor networks for monitoring biodiversity. LifeWatch tracks migration behaviour and habitats selection for mammals, medium to large-sized birds, marine and freshwater fishes, bats, plankton, shells and molluscs. Bats, plankton, shells and molluscs are examples of indicator species: their occurrence and abundance

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([10]) See *e.g.*, Projects - Meetnetten.be

([11]) Basically, there are two main types of indices used to describe diversity: dominance indices and information statistic indices. The two most common examples are the Simpson (Simpson's Diversity Index) and Shannon (or Shannon Diversity Index, Shannon-Wiener Index) indices, respectively. While the first one gives more weight to common or dominant species, the second one assumes all species are represented in a sample and are randomly sampled. Although these indices are simple to calculate, the underlying assumptions limit their use and can lead to biased results.

(12) LifeWatch Belgium is one of the eight national nodes composing LifeWatch ERIC, the e-Science European Infrastructure consortium providing data resources, web services and Virtual Research Environments (VRE) to biodiversity and ecosystem research. LifeWatch Belgium combines the regional and federal contributions to LifeWatch.

reflect an alteration in biodiversity. Plankton, for instance, are used as early warning systems of change in marine ecosystems. The data from these sensor/monitoring networks are published as open data.

LifeWatch combines ground-sourced species observations with advanced modelling methods to model species abundance. Modelling methods provide tools to extrapolate local observations to larger scales. The maps presenting the results of the models currently represent abundance of 80 bird species, 20 butterfly species and 35 plants species and focus only on the Walloon Region (Figure 2).

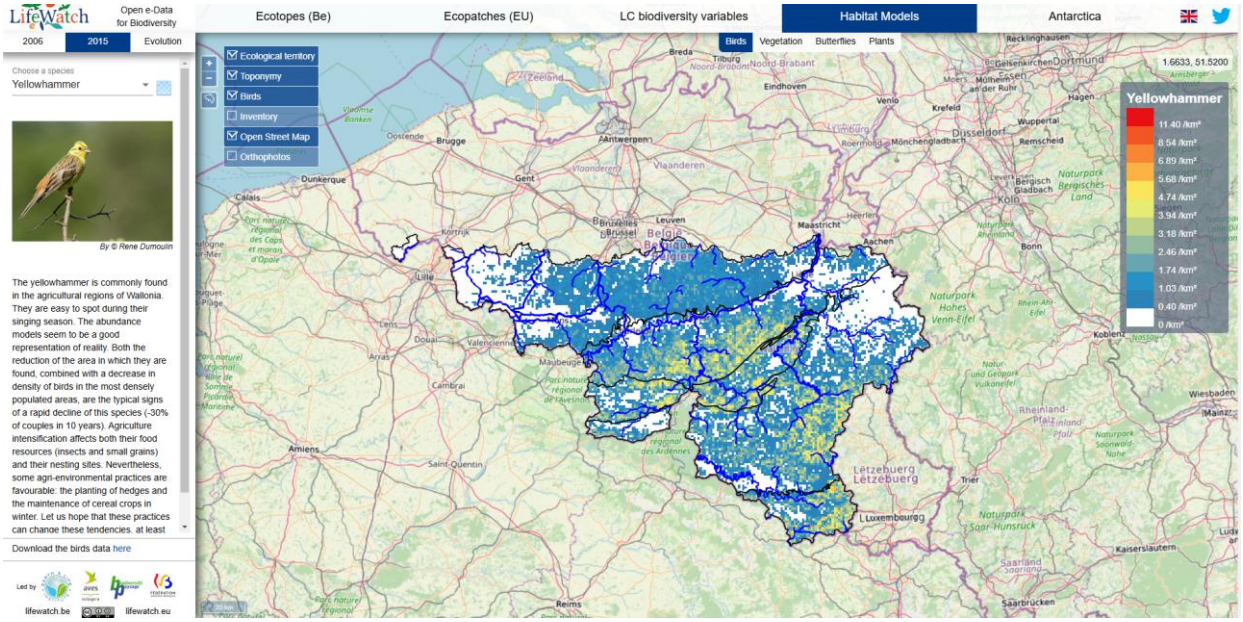

Figure 2: Example of the abundance of the yellowhammer (Emberiza citrinella, Linnaeus, 1758; passerine bird) in the Walloon Region (LifeWatch.be, 2024).

Waarnemingen.be / Observations.be are the two Belgian subsites of the global Observations.org[13], they gather observation data from all over Belgium, namely occurrence data. Waarnemingen.be is managed by Natuurpunt and observations.be is managed by Natagora. The data is actively being used for tracking species distribution and climate change, early warning for invasive alien species and monitoring disease vectors.

Observations validated by experts are regularly uploaded to the Global Biodiversity Information Facility (GBIF), where data is made available for download in multiple formats. Data uploaded on Waarnemingen.be/ Observations.be are published, respectively, by Natuurpunt and by Natagora. The platform gathers occurrence data from multiple publishers. Note that occurrence data give presence/absence information at a specific place and time for a specific specie and differ from abundance data, which accounts for the number of specimens in a defined area and requires much more field work and modelling. Nonetheless occurrence data can be used as a proxy for abundance, as shown by Yin & He (2014).

Taking the example of the presence of the yellowhammer in Belgium, one can find the observation data on GBIF. For the yellowhammer, there are a total of 56 444 records for Belgium from 26 datasets on GBIF, from which there

(13) Observation.org is a global biodiversity platform for citizen science and monitoring, established in 2004. Observation.org is organised as a non-profit foundation under Dutch law, with a team of 15 employees and an unpaid board of 3 members. Observation.org works with local partners (for Belgium: Natuurpunt & Natagora) to increase adoption and localisation of the platform, and to invite local species experts to join the validation process. Partners advise the board through delegates in the Global Team.

are 49 077 records published by Natuurpunt and no records published by Natagora. The rest of the records are published by other organisations such as INBO or Cornell Lab of Ornithology.

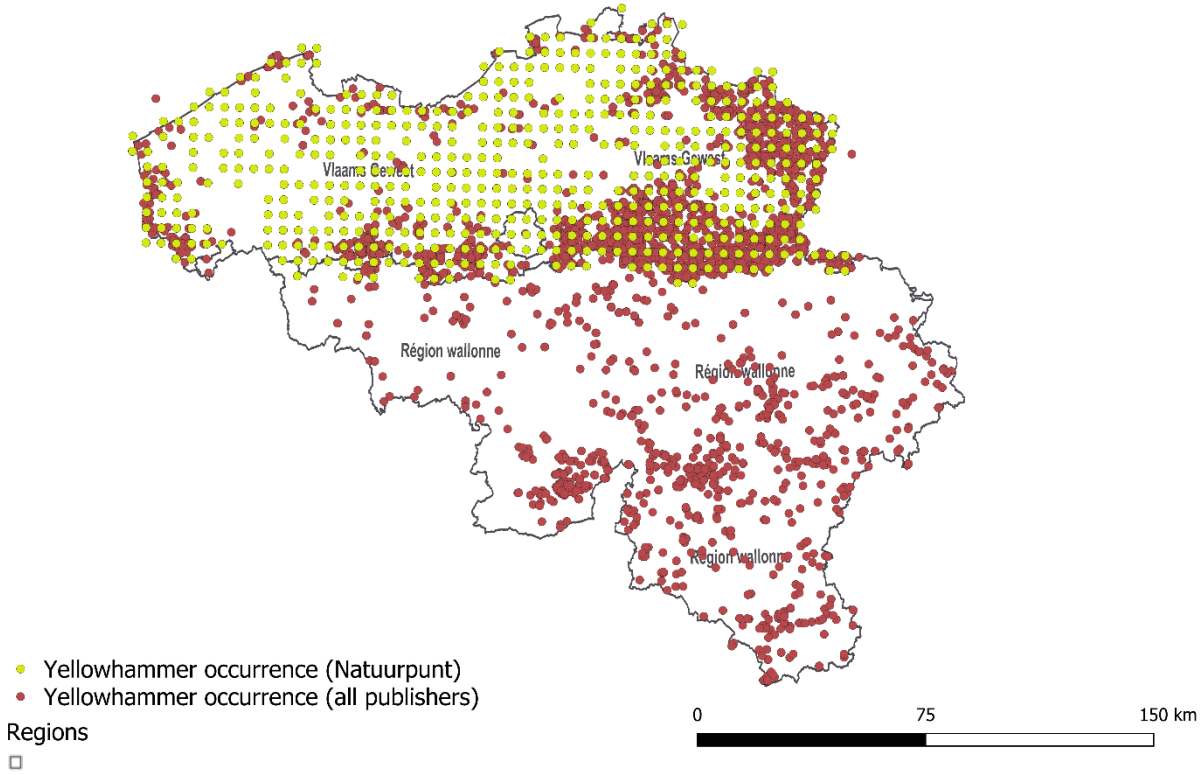

Figure 3: GBIF yellowhammer (E. citrinella) occurrence download published by Natuurpunt dataset in light green (GBIF.org, 2025a) *and in red, the total 26 datasets* (GBIF.org, 2025b).

The Marine Strategy Framework Directive (MSFD) is the European policy to protect the ocean, seas and coasts. By targeting a good environmental status by 2020, the Directive imposed Member States to first assess the initial state of specific ecosystem elements and monitor the progress towards a set of specific objectives. The Commission is currently reviewing the directive.

Marine genetic diversity is monitored using standardised methods via the European Marine Omics Biodiversity Observation Network (EMO BON), an EU-wide initiative created by the European Marine Biological Resource Centre (EMBRC) and coordinated with the European Research Infrastructure Consortium (ERIC). The initiative is implemented at the Belgian level by the VLIZ.

KEY POINTS

- Species abundance is costly to collect;
- Efforts to monitor changes in abundance over time can be focused on keystone species, provided the consequences of their increase/decrease in abundance are assessed at the level of the entire ecosystem;
- Occurrence data can be used as a proxy for abundance;
- As stated *e.g.* in the Living Planet Report for Belgium, species in agricultural zones experience the greatest decline in biodiversity in our country;
- The ordinary biodiversity (*i.e.*, more common species) is not well monitored in Belgium.

4.1.2. Remotely sensed biodiversity measurements

Remote-sensing techniques have the potential to provide standardised biodiversity-related data at global scales and with robust temporal coverage. When it comes to biodiversity, it is so far mostly used for applications regarding forests monitoring and ecosystems characterisation via the land cover variable.

Skidmore et al. (2015) argues that remote sensing data could be (and should be) used to provide consistent datasets on biodiversity across the globe; several parameters such as vegetation productivity can be measured from space and transposed into biodiversity metrics. McElderry et al. (2024, Preprint) stresses that remotely sensed biodiversity data have usually coarse spatial resolution and are limited to spectral information about ecosystem characteristics such as forests structure and connectivity.

For species-level distinction, satellites with moderate spectral resolution such as Sentinel-2 or Landsat have limited potential. Hyperspectral satellites such as NASA's EO-1 allow for distinguishing plant species (Michaels, 2022). LiDAR or SAR, both radar sensing systems, provide indirect measurements of species by supporting the identification of structural traits of certain plants. Finally, high-resolution optical imagery such as WorldView-3 also supports species identification. Combining these images sourced from distinct remote sensing techniques can help identifying certain species. But because of the technological limitations and costs, species are most often studied indirectly by gathering information about their habitats or other environmental variables.

Spectral imagery, such as MODIS, is used to assess changes in tree cover, phenological changes (*e.g.*, leaf green-up), vegetation productivity using proxies, and the health of forests and other types of vegetation over time. For example, Shen et al. (2024) used MODIS data to track phenological shifts due to climate change in forest inventory plots across the Northern Hemisphere. Li et al. (2023) combined meteorological data with NDVI data from the MODIS satellite-based sensor and canopy height data from LiDAR sensor on board of the ICESat-2 satellite and part of the NASA Carbon Monitoring System programme to estimate the impact of droughts of tree's radial growth.

This spaceborne LiDAR offers promising perspectives with regard to the monitoring of forests ecosystems via canopy height measurements (Besic et al., 2025). Indeed, such dendrometric variable (*e.g.*, the mean canopy height of a given forest stand) could be usefully employed as a proxy for assessing the health of a forest/woody ecosystem. The underlying assumption is that a weakened ecosystem will see its canopy suffer degradation/damage that can be assessed over time through the value taken by this height (see *e.g.*, Češljar et al., 2025). Rai et al. (2024) compared the performance of the spaceborne LiDAR ICESat-2 to airborne laser scanning in measuring canopy height and found good agreements, especially for evergreen forests[14] with high canopy cover. ICESat-2 satellite helps understanding forest structure on a large scale; and should be combined to finer resolution datasets (like Sentinel-2 or airborne laser scanning) for a finer forest structure monitoring (Rai et al., 2024). Because of best performance on evergreen forests, the ICESAT-2 satellite has good potential for most Belgian coniferous stands.

Skidmore et al. (2015) highlighted the need of agreeing on remotely sensed biodiversity metrics to support biodiversity monitoring. A few years later, initiatives to track biodiversity from space have emerged. Norton et al. (2018) combines satellite data with field data to produce natural capital metrics at the national level. From land cover data and spatially representative field data, Norton et al. (2018) evaluated three natural capital metrics linked to ecosystem services: top soil carbon headwater stream quality and nectar species plant richness. The study uses land cover data sourced and combined from Landsat, IRS and SPOT images to define habitats, whose outline is later refined from field survey. The Group on Earth Observations Biodiversity Observation Network **(**GEO BON) developed a framework for monitoring trends in ecosystem services globally using both ground-sourced and remote-sensed data (McElderry et al., 2024, Preprint; Norton et al., 2018).

(14) Similar conclusions could potentially be drawn for deciduous forests, which cover a significant proportion of Flanders' forests.

As part of the European programme Copernicus, remote sensing is being used routinely as a monitoring tool for Earth observations, from time to time in combination with data collected in the field. For example, the Copernicus Marine Service combines satellite imagery with *in-situ* data to monitor the ocean – through variables that can be divided into three categories: the Blue, the Green and the White ocean. The blue ocean monitors the physical state of the ocean (temperature, salinity, currents, pressure and density); the green ocean describes the biogeochemical processes in the ocean (variations of chlorophyll-a concentrations, ocean nutrients, phytoplankton, micronekton, acidification and oxygen levels); and finally, the white ocean monitors sea ice (cover and volume).

Sentinel-2 images are being used to detect damages caused by wind and bark beetle in forests. Candotti et al. (2022) developed vegetation indices to monitor spectral changes and supervised image classification to monitor forest health and forest cover change on a large scale.

IN BELGIUM

LifeWatch Belgium provides a platform to visualise land cover biodiversity variables observed from space. The variables include greenness (NDVI[15], phenology and anomalies)(Figure 4), snow periods, fire occurrences and sunshine fraction.

Unberath et al. (2019) used remote sensing data to map the gradual change in plants species composition (type and abundance) in the coastal nature reserve "Zwin" in Belgium. Haest et al. (2017) presents a multi-step approach to map Natura 2000 heathland habitats and assess their conservation status using airborne imaging. The study area was centred on the Kalmthoutse Heide, north of Belgium. Although this study shows promising application of remote sensing data to habitat mapping and monitoring, Vanden Borre et al. (2017) still argues that there is a lack of transferability of remote sensing methods to nature conservation requirements. For these reasons, remote sensing scientists and nature monitoring experts should stimulate the adoption of remote sensing techniques through specific actions such as demonstrating method transferability, limit ground reference data dependence, and make publicly available the programming codes.

TerraScope[16] leverages remote sensing techniques to support biodiversity monitoring by providing a platform showing high-resolution satellite imagery and time series data that help track changes in land cover, vegetation, and habitats. These tools enable the identification of critical biodiversity hotspots, detection of habitat loss or fragmentation, and assessment of ecosystem health over time. By integrating data from the Copernicus programme, such as Sentinel-2 imagery (Figure 5), TerraScope facilitates the mapping of biodiversity indicators, helping researchers and policymakers make informed decisions to protect and restore ecosystems. This approach enhances understanding and management of biodiversity at local, regional, and national scales.

The LiDAR on board of the ICESat-2 satellite has shown reliable results for monitoring forests canopy height, especially in the case of evergreen forests (Rai et al., 2024). The applicability to Belgian deciduous forests could be studied to leverage this data source.

([15]) NDVI stands for Normalised Difference Vegetation Index, and is a very common index sourced from satellite optical imagery used to monitor vegetation health, biomass and density.

([16]) TerraScope is Belgium's collaborative ground segment for the European Commission's Copernicus programme, providing free and open access to satellite imagery and Earth observation data. Managed by VITO (Flemish Institute for Technological Research) and funded by the Belgian Science Policy Office (BELSPO). TerraScope offers data from various satellite missions, including Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, PROBA-V, and SPOT-VEGETATION.

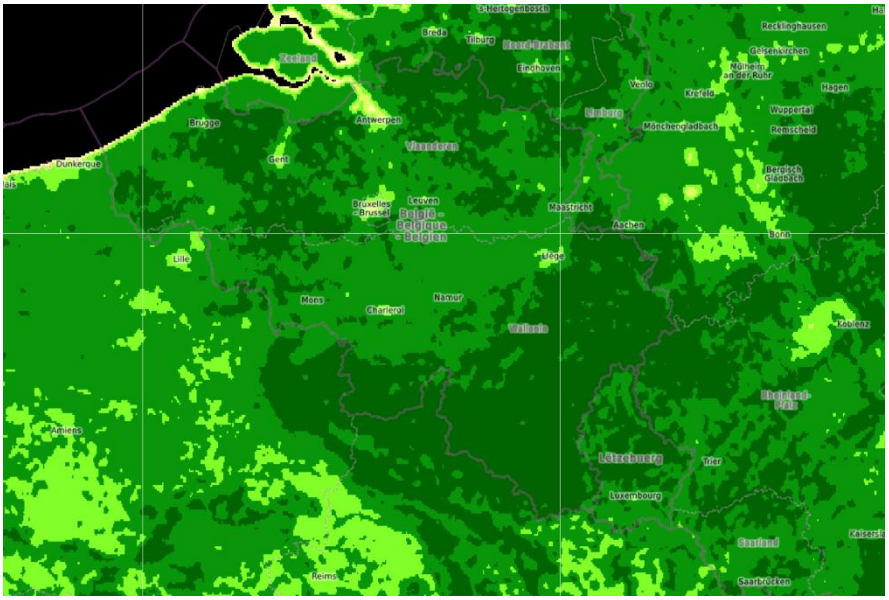

Figure 4: Long term average (1999-2021) of NDVI data for mid-July period (retrieved from LifeWatch viewer - LC biodiversity variables LifeWatch-FWB: UCL - Geomatics in December 2024).

Figure 5: Sentinel 2 NDVI data (vegetation greenness) on 28/07/2024 (retrieved from viewer TerraScope in December 2024). This is a cloud-free image, meaning that clouds have been automatically removed, leaving black spots on the image.

KEY POINTS

- Remote sensing provides a tool for large-scale standardised data and robust temporal coverage;
- Satellites images are still currently mostly used for land use change and forest monitoring, or characterisation purposes;
- Having said that, satellite measurements could reduce the need for resource- and time-intensive *in-situ* measurements;
- There should be more work done on how to transpose remote sensing measurements into biodiversity metrics;
- There is a potential to combine satellite with field data (*e.g.*, via LiDAR sensors) to evaluate natural capital metrics linked to ecosystem services;

- Remote sensing is also used in the context of the marine ecosystems, for the Belgian part of the North Sea specifically[17] or at a broader scale[18].

4.1.3. Aggregating biodiversity metrics into indicators

Although bringing together data is an essential first step, a presentation of data, proxies or model results does not yet make an indicator (Jacobs et al., 2014). Developing indicators, defined as the "*meaningful and purposeful collection and organisation of data*" (Innes, 1990), depends on both policy and scientific requirements. Developing effective indicators therefore requires more than just collecting and developing datasets and processing data; it also requires bringing together other relevant policy domains and data (Jacobs et al., 2014).

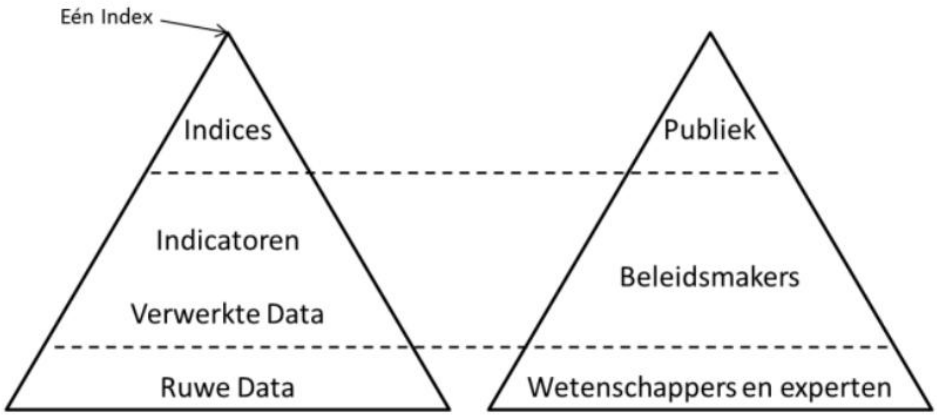

Figure 6: The Information Pyramid (adapted by Jacobs et al., 2014, from Pires, 2011).

Recent international agreements such as the KM-GBF and European directives on biodiversity[19] have accentuated the need of finding common ways of measuring/monitoring biodiversity, assess the progress towards the objectives and evaluate the effectiveness of restauration over time and space. Global standardised ways of quantifying nature are crucial for reporting and assessment under the KM-GBF[20] and support biodiversity-related tools (Fournier de Lauriere et al., 2023, preprint; McElderry et al., 2024, Preprint).

One of the indicators from the KM-GBF follows the System of Environmental-Economic Accounting (SEEA) for Ecosystem Accounting[21]. This is the internationally adopted statistical standard for organising data about ecosystems, measuring ecosystem services, tracking changes in ecosystem assets, and linking this information to economic and other human activities. It provides the conceptual framework and methodology for compiling this indicator. SEEA Ecosystem Accounting requires the extent of ecosystems to be accounted for in biophysical terms as one of the five core ecosystem accounts. The extent account provides the basis for the other four core accounts. Accounting tables have a standard structure based on standard definitions and classifications. This allows them to be compared across time periods and between countries. This makes the accounting approach a powerful foundation for developing national and global indicators. Another strength of this accounting approach is that

(17) See *e.g.*, the "eDNA and remote sensing data to determine marine biodiversity" project lead by the Instituut voor Landbouw-, Visserij- en Voedingsonderzoek (ILVO). More precisely, the goal of this Belspo-funded initiative is to develop reliable methods to monitor the biodiversity of microscopic animals in the seabed of the Belgian Part of the North Sea and elsewhere in North Sea, Balthic Sea and Mediterranean Sea.
(18) See *e.g.*, ESA - Protecting ocean biodiversity with satellite data
(19) See *e.g.*, The EU #NatureRestoration Law, The Habitats Directive and The Birds Directive.
(20) Indicators for the Kunming – Montreal Global Biodiversity Framework | Indicator Repository
(21) In Flanders, INBO is for instance working on the Flanders Ecosystem Accounting (FLEA) indicator.

accounts provide granular information useful *e.g.* for local application and fine-grained policy decisions, as well as aggregate information for national and global reporting.

In Europe, Moersberger et al. (2024) collected experts' insights over policy questions that need to be addressed in the coming decades regarding biodiversity monitoring. The interviewed experts pinpointed challenges related to biodiversity monitoring. The four main ones being 1) the lack of integrated data, 2) insufficient data (limited spatial coverage, low monitoring frequency, *etc.*), 3) Insufficient human or technical resources and 4) biased data (some taxonomic groups are more studied than others). *"Monitoring efforts in Europe, however, suffer from gaps and biases in taxonomy, spatial coverage, and temporal resolution, resulting in fragmented and disconnected data"* (Moersberger et al., 2024).

The International Union for Conservation of Nature (IUCN) developed a Red List of Ecosystems to assess their conservation status by combining their health condition with the level of threat it is facing. This Red List of Ecosystems is also one of the KM-GBF indicators.

Tackling the lack of global standardised biodiversity measures and because of the fact that no real definition of the "state of nature" nor suitable measures of the state of nature are given in the KM-GBF guidelines, McElderry et al. (2024, Preprint) introduced the Sustainable Ecology and Economic Development (SEED) framework which consolidates the multiple dimensions of biodiversity (genetic, species and ecosystems) across various taxa (plants, animals and microbial) into a single measure of biocomplexity at every location, the SEED biocomplexity index. By addressing the limitations of single-dimensional metrics like species richness, the framework emphasises ecosystem intactness and functional diversity, comparing current states to minimally disturbed reference ecosystems (McElderry et al., 2024, Preprint).

The SEED framework evaluates biodiversity across nine axes, nested within three hierarchical levels: genetic diversity, species diversity (including phylogenetic and functional traits), and ecosystem diversity (structure, function, and connectivity). The SEED biocomplexity index is calculated by taking the mean similarity between current and native state for all nine axes. Designed to be dynamic, it integrates new datasets and technologies, ensuring adaptability to evolving scientific and conservation needs. This multidimensional approach enables policymakers to track biodiversity change and assess restoration progress, aligning with global conservation goals.

Complementary to SEED, the Essential Biodiversity Variables (EBVs), identified by GEO BON, have been highlighted as a critical tool for aligning biodiversity monitoring across scales. The EBVs integrate ground-sourced and remotely sensed data, facilitating standardised biodiversity assessments and cross-country comparisons (Dasgupta & Levin, 2023). However, challenges such as gaps in data coverage, particularly for microbial and genetic diversity, and the coarse spatial resolution of current global datasets highlight the need for continued advancements in biodiversity monitoring.

CASE STUDY – GLOBAL SPECIES EXTINCTIONS PROCESS (STEVENSON ET AL., 2021)

Stevenson et al. (2021) used concepts from models in economics to categorise biodiversity indicators according to their role in decision-making and figured that *"some biodiversity indicators are best suited to prediction for preventative actions and others to retrospection and evaluating past actions.".* This approach enhances interpretability of biodiversity indicators and decision-making processes. The role of indicators in the decision-making process can be seen as:

1. Leading: indicators that measure aspects of the system that change before the coincident indicator, thus informing preventative measures;
2. Coincident: indicators considered to best measure change in the target variable in real time;
3. Lagging: indicators that measure aspects of the system that only change after the coincident indicator, it signals change after and is used to evaluate past actions.

The process of global species extinction unfolds in three phases (Stevenson et al., 2021):

1. State 1 – change to species abundance. Decline of abundance occurs when mortality exceeds births. Abundance and distribution are highly correlated, and a decline of abundance, usually occurring locally, will affect the species distribution, with a certain time lag;
2. State 2 – changes to species distribution. Distribution change occurs when abundance decline locally and results to local species extinction;
3. State 3 – changes to global extinction numbers. Global extinction occurs when both abundance and distribution of local populations reach zero.

The role of indicators for each of the three states in the process of global species extinction is described in Table 1 and Table 2 gives examples of existing global indicators, classified into the three states. For example, the Living Planet Index (LPI), which accounts for change in vertebrate population abundance (Collen et al., 2009), is coincident in relation to the abundance variable and has a leading role when it comes to monitor distribution and extinction.

Table 1: Classification of indicators for each of the three changing states in the process for global species extinction (modified from Stevenson et al., 2021).

Indicator	**Type of variation measured**	**Indicator relationship to**		
		Abundance	Distribution	Extinction
Indicators of state 1	Change to species abundance	Coincident	Leading	Leading
Indicators of state 2	Changes to species distribution	Lagging	Coincident	Leading
Indicators of state 3	Global extinction	Lagging	Lagging	Coincident

Table 2: Global indicators of biodiversity for each of the states in the process for global species extinction (modified from Stevenson et al., 2021). Some of these indicators also form part of the KM-GBF.

Indicator	**Type of variation measured**
Indicators of State 1: Change in species abundance	
Living Planet Index	Change in relative abundance of vertebrate populations (Collen et al., 2009)
Biodiversity Intactness Index (abundance)	Change in proportion of original species abundance remaining in a location in comparison to pre-industrial era (Newbold et al., 2015)

Indicator	Type of variation measured
Mean Species Abundance	Change in proportion of native species in an ecosystem compared to their abundance in an undisturbed ecosystem (Schipper et al., 2020).
Red List Index (past abundance)	Change in species' Red List status under abundance criterion (hypothetical disaggregation of the abundance and distribution criteria, Bubb et al., 2009)
Wild Bird Index	Change in relative abundance of a group of bird species (Sheehan et al., 2010)
Climatic Impact Index for birds	Change in abundance of birds affected by climate change (Gregory et al., 2009)
Indicators of State 2: Change in species distribution	
Biodiversity Habitat Index	Change in gamma diversity, driven by changes to species distributions (Allnutt et al., 2008)
Biodiversity Intactness Index (richness)	Change in proportion of original species richness remaining in a location (Newbold et al., 2015)
Red List Index (past distribution)	Change in species' Red List status under distribution criterion (hypothetical disaggregation of the abundance and distribution criteria, Bubb et al., 2009)
Indicators of State 3: Global extinction	
Number of species extinctions (birds & mammals)	Change in number of species that have been listed as extinct

IN BELGIUM

The Living Planet Index was calculated for Belgium and results were published in the first Living Planet Report Belgium[22] (WWF, 2020) from a collaboration between WWF, Natagora, Natuurpunt, the Belgian Biodiversity Platform, the RBINS and other experts from public institutions[23]. This work constituted an unprecedented effort to assess the state of biodiversity at the national level. The report presents the state and evolution of biodiversity in Belgium for the period 1990-2018.

The Living Planet Index was calculated to measure change in population size of 283 vertebrate species (birds, mammals, amphibians, reptiles and insects) in Belgium. Species specific to wetlands and natural open environments

([22]) Click here for the version in Dutch, here for the French version of this document.
([23]) See also https://www.biodiversity.be/5424/

have experienced a modest average increase in their populations. In contrast, species inhabiting agricultural areas have suffered a dramatic decline, with forest species (particularly birds) also facing notable, though less severe, reductions. According to some of the consulted experts (*cf*. subsection 3.3), it would be worth to update the LPI for Belgium (Pers. Comm., 2024b).

The indicator "Red List Index of butterflies"[24] measures change in aggregate extinction risk across 75 species of butterflies. It is based on genuine changes in the number of species in each category of extinction risk on The IUCN Red List of Threatened Species and is expressed as changes in an index ranging from 0 to 1. In general, in Flanders[25], a slight improvement can be observed between 2011 and 2021. For forest and grassland butterflies, the chance of extinction has decreased, for heathland butterflies it remained unchanged. It also remains unchanged for the common butterflies[26].

Instituut Natuur- en Bosonderzoek also calculated a multispecies index (MSI) for plant species for Flandres. This MSI for plant species has shown a stable trend since 1950. Of the general plant species, 167 species are significantly improving, *vs*. 205 species that are declining. The poll of "winners" include thermophilic species and species from nutrient-rich habitats, while the "losers" include species from nutrient-poor grasslands and aquatic species (Schneiders et al., 2021).

4.1.4. Scale-dependence in estimating biodiversity change

Biodiversity operates across multiple spatial and temporal scales, each revealing unique patterns and processes. Spatial scales range from local ecosystems, where individual species interactions shape diversity, to regional or global landscapes, where broader ecological and biogeographical trends dominate. Similarly, temporal scales can span short-term changes, such as seasonal species migrations, to long-term evolutionary or climate-driven shifts. These varying scales influence the way biodiversity is measured and interpreted, with different metrics capturing different facets of change. Understanding these scales is essential because trends observed at one level, such as a local increase in species richness, may mask declines or disruptions at broader scales. This section explores the importance of scale-dependence in biodiversity monitoring, highlighting the challenges and opportunities in aligning measurements across diverse spatial and temporal contexts.

As noted by Leroy et al. (2023), different metrics of biodiversity may display varying trends, and biodiversity dynamics can even exhibit opposite trends depending on the spatial or temporal scale of observation. For example, a local increase of diversity metrics may be the result of generalist species[27] colonisation, as this process is generally faster than the specialist's[28] extinction (Leroy et al., 2023). Thus, this increase of diversity may be temporary, and diversity is expected to decline with specialist species extinction. The new generalist species colonising an area may not provide the same ecosystem functions as the former specialist species thus can threaten the viability of the ecosystem (Leroy et al., 2023). Ecosystem's state, condition and dynamics can only truly be assessed using a combination of metrics and scale.

Consideration of the spatial scale is also important in monitoring biodiversity and finding a common spatial unit on which biodiversity indices can be measured or calculated is crucial. Moersberger et al. (2024) stresses that biodiversity monitoring throughout Europe lacks coherence in spatial coverage and temporal resolution. Another

(24) See European Red List of Butterflies for more information.
(25) See *e.g.*, https://www.vlaanderen.be/inbo/en-GB/datasets/national-checklists-and-red-lists-for-european-butterflies/detail
(26) See https://www.vlaanderen.be/inbo/indicatoren/rode-lijst-index-voor-dagvlinders for more information.
(27) Generalist species have broad ecological niches. They can thrive in a variety of environments and utilise a wide range of resources, making them more adaptable to changing conditions. For instance, a bird species that feeds on a diverse diet of seeds, fruits, and insects would be classified as a generalist
(28) Specialist species are organisms that have narrow ecological niches. They rely on specific resources, habitats, or environmental conditions to survive and reproduce. For example, a bird species that feeds exclusively on one type of insect or nests only in a particular tree species would be considered a specialist.

challenge pointed by McElderry et al. (2024, Preprint) is that sampling methodologies, but also various spatial and temporal scales, may vary according to regions and disciplines, making it difficult to aggregate the collected data.

In order to align monitoring efforts, GEO BON developed the concept of EBVs which are designed to be scalable – they can be represented at different spatial and temporal scales according to the trends analysis requirements (GEO BON, n.d.). *"EBVs can be visualised as biodiversity observations at one location over time, or in many locations, aggregated in a time series of maps"* (GEO BON, n.d.).

In the Flanders Nature Report 2014, Stevens et al. (2015) recalls that the elements composing the ecosystem service cycle can be equally found in local, regional and global levels. In other words, ecosystems have no distinct geographical nor temporal borders, *"for a policy that seeks to focus on ecosystem services, incorporating and integrating multiple scale levels is therefore a major challenge."*

Several papers highlight a "biodiversity conservation paradox": while species richness often remains stable over time at local scales, significant changes in species composition and plant species cover suggest shifts in community dynamics (Dornelas et al., 2013; Jandt et al., 2022; Mark et al., 2013). Consequently, focusing solely on species presence or richness may obscure critical biodiversity changes with potential implications for ecosystem functioning, highlighting the need for more comprehensive monitoring that includes abundance and compositional metrics.

KEY POINTS

- Biodiversity evolution may display opposite trends depending on the scale of observation;
- A local increase of biodiversity is not necessarily beneficial for the ecosystem intrinsic value (*i.e.*, its ability to deliver services);
- Greater spatial coverage and common temporal resolution is needed to monitor biodiversity including, where biologically appropriate, beyond administrative boundaries.

4.2. The role of biodiversity in the delivery of ecosystem services

How does biodiversity affect our living conditions can be translated into the concept of ecosystem services, which were classified and popularised thanks to the pioneering work of the Millennium Ecosystem Assessment (MEA)[29] (2005). The Millennium Ecosystem Assessment (2005) defines ecosystem services as "*the benefits people obtain from ecosystems*". The ecosystem approach is seen as an essential bridge between nature sectors and social actors and enables to raise awareness among the public and policy/decision-makers (Stevens et al., 2015). Potschin & Haines-Young (2011) refer to the ecosystem service concept debate as a paradigm shift because it questions the way we conventionally value nature and becomes equally part of political and scientific agendas.

([29]) The Millennium Ecosystem Assessment (MEA) was called for by the United Nations Secretary-General Kofi Annan in 2000. Initiated in 2001, the objective of the MEA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MEA has involved the work of more than 1,360 experts worldwide. Their findings, contained in five technical volumes and six synthesis reports, provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems.

The report of the MEA published in 2005 (MEA, 2005) defines four main categories of ecosystem services: 1) supporting services; 2) regulating services; 3) provisioning services; and 4) cultural services. Here below, some examples for each of the four ecosystem services categories, as defined by the MEA in 2005:

1. *Supporting services*: biodiversity; nutrient cycling and photosynthesis; primary production; and soil formation;
2. *Regulating services*: Air quality regulation; climate regulation; natural hazard regulation; erosion regulation; water regulation; water purification and wastewater treatment; pollination; and regulation of pests and human diseases;
3. *Provisioning services*: Food; fresh water; fibre and ornamental resources; genetic resources; and biochemical; natural medicines; and pharmaceuticals;
4. *Cultural services*: cultural diversity; spiritual and religious values; knowledge systems; educational values; inspiration; aesthetic values; social relations; sense of place; cultural heritage values; and recreation and ecotourism.

The Common International Classification of Ecosystem Services (CICES) is another classification system, developed by the European Environment Agency (EEA). This classification recognises three categories out of the four categories originally defined by the MEA – it does not include the "supporting services" category. The first version was published in 2013 and revised in January 2018 CICES (V5.1)(Haines-Young & Potschin, 2018). Since then, the latest version (V5.2) was released based on the experience gained by the user community.

The ecosystem approach considers a bigger picture of the state of nature than the biodiversity approach. Yet, the two approaches are strongly interlinked and causal relationships between biodiversity and ecosystem services are poorly understood. Norton et al. (2018) uses the concept of natural capital to emphasise the role nature plays in provisioning ecosystem services and highlights the need to agree on metrics that can be linked to natural capital assets underpinning ecosystem functions and services. Borma et al. (2022) argues that biodiversity is too often translated into species richness and other attributes of biodiversity should also be considered to fully assess the impact of biodiversity on ecosystem services. For example, Dasgupta & Levin (2023) shows that functional diversity, *i.e*. the number of functional groups in an ecosystem, is strongly linked to the productivity of ecosystems in terms of maintenance and regulating services they provide. Dasgupta & Levin (2023) give the example of soil in which different groups of organisms contribute to soil health in different ways (Archaea[30], bacteria and fungi decomposes plant residues, *etc*.) and stresses that *"without these diverse species playing different roles, the soils would fail to support the global food system".* Ecosystem services like pollination and pest control depend heavily on species diversity. For example, diverse pollinator populations enhance agricultural productivity, while buffer zones mitigate pesticide runoff into wetlands.

The very role of biodiversity in delivering ecosystem services is well described by the literature. As an example, provided at the global scale, OECD (2023) explains that biodiversity encompasses diversity at genetic, species and ecosystem levels, ensuring the functioning of natural systems. The decline of biodiversity diminishes the capacity of ecosystems to provide essential services, threatening food security, health, water supply and disaster resilience. As stressed above, pollination illustrates this role vividly. Nearly 75% of global crops depend partly on pollinators such as bees, butterflies and bats, services worth up to USD 577 billion annually. Their decline directly threatens nutrition, food production and human health, particularly in fragile contexts where coping capacities are limited. Soil biodiversity is equally critical: it regulates fertility, reduces pest outbreaks and enhances resilience against droughts, floods and fires. When degraded, it contributes to lower yields, reduced nutritional quality and greater disaster risk. While healthy ecosystems act as buffers against systemic shocks, regulating climate, filtering water, and sustaining fisheries and forests, biodiversity loss amplifies fragility, especially in areas highly dependent on natural resources. It can trigger food price shocks, displacement, governance breakdown and conflict over scarce resources. The

([30]) More information is available here about those single-celled microorganisms.

collapse of ecosystems may also heighten the risk of zoonotic diseases, linking biodiversity directly to human health security. Overall, biodiversity is not only a source of ecological richness but a foundation of socio-economic stability. Its conservation and restoration are therefore central to sustaining ecosystem services, reducing fragility and ensuring resilience in the face of environmental and societal challenges (OECD, 2023).

In the Nature Flanders Technical Report, Demolder et al. (2014) illustrates the intertwined relationship between the different aspects of biodiversity and ecosystem services (Figure 7).

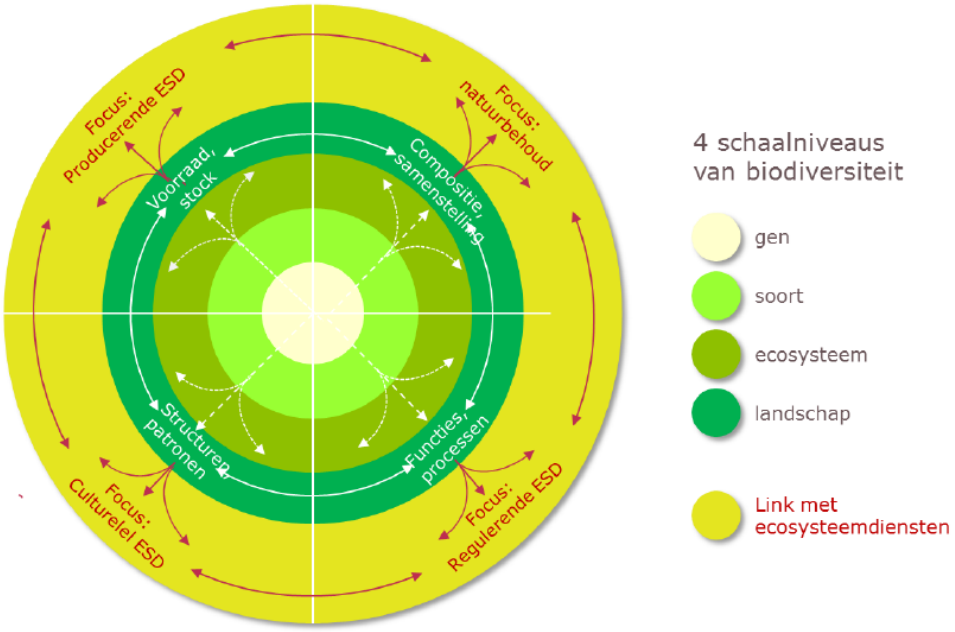

Figure 7: The four organisational levels biodiversity (genetic diversity, species diversity, ecosystem diversity and landscape diversity) are presented within each perspective (composition of species, stocks, processes & function, structures & patterns) and link.

At the EU level, the Mapping and Assessment of Ecosystems and their Services (MAES) concentrated efforts towards harmonising and developing assessment methods and mapping of ecosystem services. It aimed to implement the Target 2 – Action 5 of the EU biodiversity Strategy to 2020, adopted in 2011 by the EU. Member States were asked to 1) Map and assess the state of ecosystem and their services in their national territory and 2) support evidence-based policymaking by promoting the integration of the ecosystem knowledge into accounting and reporting systems. The Belgian Biodiversity Platform facilitated the collaboration between the EU working group and the Belgian regions.

The main outcome of MAES was an agreed analytical framework including standards (including a typology for ecosystem services – the CICES) and indicators for mapping ecosystem condition and services. There remains to be done a final assessment – using the MAES analytical framework - of the state and trends of ecosystems at EU aggregated level (Maes et al., 2020).

In the attempt of setting-up an indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy, the MAES working group have identified several gaps and challenges. One of the challenges is that many indicators do not quantify the role of ecosystems for regulation and maintenance services but rather indicates the pressure on ecosystems, their conditions or the impacts certain activities may cause on ecosystems (Maes et al., 2016). Maes et al. (2016) also highlights the uncertainty around the relationships between biodiversity, ecosystem functioning and ecosystem services. There should be further research investigating the link between specific aspects of biodiversity such as species diversity and the delivery of ecosystems services.

An indicator is also being developed within the KM-GBF. The proposed indicator is defined as the average rate of change in the provision of a set of ecosystem services in a particular time period compared to a baseline year, for a country or globally. The concepts, definitions and classifications used in this indicator are based on the SEEA Ecosystem Accounting. The SEEA Ecosystem Accounting includes a reference list of ecosystem services, grouped into provisioning, regulating and maintenance, and cultural services.

Another challenge pointed by Jacobs et al. (2014) is that there are several indicators for ecosystem services (see *e.g.*, Crossman et al., 2013; Maes et al., 2013), but it is often unclear whether the proposed indicator refers to the ecosystem or to the benefits, and, demand, supply and use are often confused.

IN BELGIUM

Mapping ecosystem services in Flanders highlights the critical role of grasslands and forests in carbon storage and flood regulation. These kinds of data are essential for prioritising conservation in land-use planning (Stevens et al., 2015). Such mapping can be visualised via a dedicated viewer.

In Wallonia, various experts have evaluated the capacity of specific ecosystems to ecosystem services on a 1 to 5 scale (SPW, n.d.). The result of this map is shown in Section 4.5.2 (Figure 12) and can also be visualised on the Walloon geoportal WalOnMap.

In the Belgian Part of the North Sea, the Sustainable Marine Ecosystem Services (SUMES) project evaluates the capacity of the marine ecosystem to deliver specific products and services – and allows to gain a better understanding of cause-effect chains. Experts developed a model encompassing methods and indicators for ecosystem services, risk assessment and life-cycle analysis. Deliverables in the form of reports can be found of the SUMES website.

KEY POINTS

- Key-aspects of biodiversity should be assessed to understand their impacts on the delivery of ecosystem services;
- At the EU level, the MAES working group is developing a framework for assessing ecosystem services;
- The relationships between biodiversity, ecosystem functioning and some services are still currently not well understood.

4.3. The state of biodiversity in Belgium

Belgium has a rich tapestry of biodiversity data, which are divided between the federal (see below) and regional levels. Based on a consensus among all the authorities involved, the federal government takes the lead on international agreements and broad policy frameworks, and it is competent *e.g.* for environmental matters in the marine areas under Belgian jurisdiction (the “Belgian part of the North Sea”), military domains, and railway embankments. Regions - Flanders, Brussels and Wallonia - manage most data collection, habitat protection, and policy development and implementation within their territories. This regional focus can lead to data compatibility issues, but initiatives like the Belgian Biodiversity Platform and collaboration efforts by the RBINS are promoting data standardisation and national integration for a more comprehensive picture of Belgian biodiversity.

The Belgium National Biodiversity Strategy presents specific objectives in order to stop biodiversity decline in Belgium and reach the targets set by the CBD. The Strategy also considers other commitments made at European and international levels. It provides a framework for policymaking and development of actions – and include the responsibilities of the different governments in Belgium. The latest update of the strategy was published in 2013 and presents the objectives that had to achieve by 2020 (CBD National Focal Point, 2013). The website https://www.biodiv.be/ collects all information on the implementation and progress state of the CBD.

More recently, in 2024, the National Strategy for Biodiversity working group prepared an advice note over the update of the Belgian national 2020-2030 strategy for biodiversity which was approved by both the General Federal Assembly for Sustainable Development (CFDD) and the Board of Environment of the Brussels-capital Region (CERBC). The note calls for a rapid revision of the National Strategy for Biodiversity in order to meet the international objectives in which Belgium is committed – the current strategy is not ambitious enough and does not provide a sufficiently strong framework for integrating and coordinating the different approaches undertaken at different political levels throughout the country (CFDD, 2024). Because nature conservation and environment are regional competences, regions play a crucial role in developing strategies in favour of biodiversity and as such, coordination between regions is needed to the achievement of international targets at the Belgian national level (CFDD, 2024).

The federal report on the state of the environment is edited by the FPS Health, Food Chain Security and Environment and unfolds in two parts. Part 1 is dedicated to the study of the marine environment (FPS Health, 2025a) and part 2 is focused on federal environmental policies (FPS Health, 2025b). The latest report is the fourth publication and encompasses the 2019–2023-time range. Part 1 is based on a more extensive report of the Belgian Marine Strategy, presented in more details in § 4.3.4 of this report. Part 2 depicts the environmental landscape in Belgium around eight environmental thematics – among which biodiversity. The federal actions undertaken in favour of biodiversity and along with their effectiveness are presented in the report. For example, information on the state of pollinators – which are under the radar of the federal authority – is given in the report. On the 381 indigenous bee species identified, 45 are extinct and 113 are threatened. Other species are either not threatened or not sufficiently known.

The 2020 Living Planet Report Belgium (WWF, 2020) is an unprecedented effort of assessing the state of biodiversity at the Belgian level. Experts from different public institutions and NGOs, among which WWF, Natagora, Natuurpunt, the Belgian Biodiversity Platform and the RBINS, collaborated to give a comprehensive picture of the evolution of 283 vertebrate species for the period 1990-2018. The reports show that the trend is slightly positive (+0.2%) but also shows that it exists big discrepancies depending on the species and habitats. Studied species of wetlands and natural open areas show an increase in population size while population size of studied species specific to larger agricultural environments has decreased the most, especially birds. According to some of the consulted experts, it would be worth to update the LPI for Belgium (Pers. Comm., 2024b).

Belgium[31] is bound by the Birds and Habitats EU Directive and pursue efforts to align with the EU Biodiversity strategy for 2030. The Directives require constant monitoring of a specific number of species and habitats, considered of interest by the EU (the targeted species or habitats are either vulnerable, at risk of extinction, rare, endemic or emblematic). This involves 165 and 45 bird's species, 75 and 69 flora and fauna (excluding birds) species and 41 and 46 habitat types, respectively for Wallonia and Flanders. The analysis is based on the conservation state of the species and habitats of interest and also on more general indicators such as the Red List, which assess the extinction risk of species.

For the analysis of the biodiversity condition in Belgium, one can refer to the work done by the Walloon and Flanders regions, respectively the State of the Walloon Environment website (Diagnostic Environnemental de la Wallonie - biodiversité, SPW ARNE, n.d.), created by the Service Public de Wallonie, pole Agriculture, Ressources naturelles et Environnement (SPW ARNE) and the Flanders Nature Reports and indicators, published by INBO every two year since 1999 (Michels et al., 2023).

([31]) Given that the Birds and Habitats Directives are EU obligations, they also apply to the Brussels-Capital Region, and at the federal level with regard to the marine environment.

4.3.1. Flanders

Instituut voor Natuur en Bosonderzoek is the independent research institute for Nature and Forests of the Government of Flanders that substantiates and evaluates biodiversity policy and management through applied scientific research, data and knowledge dissemination. Since 1999, the institute publishes the Nature Report Flanders every two year and since 2014, reports synthesis are also available in English. The reports give overviews of the state and trend of biodiversity in Flanders based on indicators, in-depth analysis and evaluations, outcomes of policy initiatives and possible future scenarios.

The Nature Report Flanders 2014 initiated the Flanders Regional Ecosystem Assessment (REA) which unfolds in three phases (Stevens et al., 2015). The assessment of biodiversity is preferred through the ecosystem approach which bridges the gap between the nature sector and other social actors. This approach is considered as a key element in the current biodiversity policy.

- Phase 1: Nature Report Flanders 2014 – State and trends of ecosystems and their services in Flanders;
- Phase 2: Nature Report Flanders 2016 – Working with nature;
- Phase 3: Nature Report Flanders 2018 – Nature outlook 2050: Inspiration for the nature of the future.

Next, the following reports were published:

- Nature Report Flanders 2020 – Facts and figures for a new biodiversity policy;
- Nature Report Flanders 2023 – Working together on the Flemish biodiversity policy of the future.

The Nature Report Flanders 2020 investigates the state of biodiversity in Flanders and the most pressing factors acting on biodiversity (Schneiders et al., 2021). It also provides an assessment of the progress towards European policy targets for 2020. Through the Nature Report Flanders 2023 report, INBO investigates how Flanders can achieve the goals of the European Green Deal and the related Biodiversity Strategy.

In the framework of the European Habitat and Bird Directive, INBO established a set of long-term monitoring programmes to support and evaluate nature policy in Flanders (Westra et al., 2019). These programmes focus on habitat quality, species trends and the natural environment, with the coordination of NGOs and the help of volunteers. A practical guide has been developed to help implement monitoring initiatives and enhance their effectiveness. Strong collaboration and interaction with policymakers are sought. Results of species monitoring are available on the data portal.

Nine ecosystems are found in Flanders and Brussels-capital Region (Stevens et al., 2015) – listed in descending order of the percentage of Flanders and Brussels coverage:

1) Cropland (37.8%);
2) Urban ecosystems (30.4%);
3) Grasslands (17.0%);
4) Woodland and forest (11.4%);
5) Water (2.1%);
6) Heathland and inland dunes (0.6%);
7) Estuaries, mudflats and salt marshes (0.4%);
8) Coastal dunes and beach (0.1%);
9) Wetlands (0.1%).

Some 44,000 species are known in Flanders, the vertebrates accounting for only 1% of species present in Flanders, vascular plants represent 5%, algae represent 12% and fungi and mushrooms include 19% of the species (Stevens et al., 2015). The largest group, which is also the most unknown, is the invertebrate groups which accounts for over 60% of all species in Flanders according to Stevens et al. (2015). These authors stress that the distribution and population trend is known for only a small proportion of species, mainly including vascular plants and vertebrates

and in the case of invertebrates, only distinct groups of insects such as butterflies or dragonflies are well-studied and very little is known about microorganisms or soil organisms (Stevens et al., 2015).

In the recent years, population trend of bird species were also investigated by Vermeersch et al. (2020). Those authors discuss the results of several long-running breeding bird monitoring programmes in Flanders between 2013 and 2018. Those authors discuss a total of 182 species. Almost all of these are breeding birds in Flanders, except for a few rare introduced species. The known short- and long-term trends for breeding bird species (2007–2018 and 1980–2018, respectively) are largely similar. In the short term, a higher proportion of species are declining, while in the long term, more species are described as "fluctuating". In general, bird species associated with agricultural areas are declining sharply. Long-distance migrants (sub-Saharan migrants) also show an overall negative trend. Forest birds, as a group, show a more moderate picture, but are also declining on average, especially due to the individual trends of long-distance migrants among these species. Finally, species linked to swamp vegetation also appear to be under significant pressure.

Recently, INBO launched the Flemish Biodiversity Portal, fed by GBIF data and built on the Atlas of Living Australia technology. It consolidates information from research, monitoring programmes, citizen sciences, species lists and geographics information system layers.

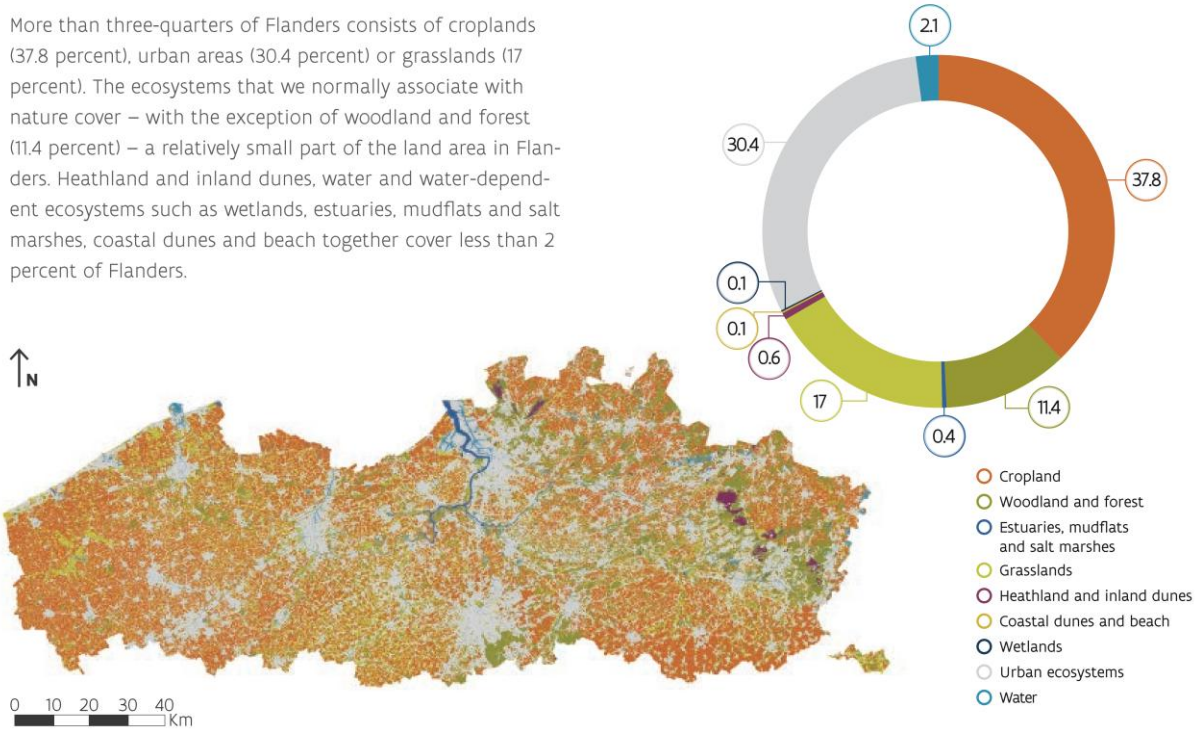

Figure 8: Geographical distribution and proportional area of the nine ecosystems in Flanders and Brussels-capital Region (Stevens et al., 2015).

4.3.2. Wallonia

In Wallonia, the State of the Walloon Environment website and more specifically the page dedicated to biodiversity topics (Diagnostic Environnemental de la Wallonie - biodiversité, SPW ARNE, n.d.) is the reference for evaluating the state of biodiversity within the Region. According to this webpage, Wallonia hosts between 30,000 and 35,000 species including microorganisms, fungi, plants and animals.

Like for the rest of Belgium, Wallonia is bound by the Birds and Habitats EU Directive and pursue efforts to align with the EU Biodiversity strategy for 2030. The analysis of the biodiversity condition in Wallonia follows the targets of those Directives, which requires constant monitoring of a specific number of 165 bird's species, 75 flora and fauna (excluding birds) species and 41 habitat types. For example, taking the case of indigenous birds species, the state of each specie is assessed through the conservation state for the period 2013-2018 and population trends between the periods 2007-2012 and 2013-2018 (SPW ARNE, n.d.).

The Diagnostic Environnemental de la Wallonie – biodiversité (SPW ARNE, n.d.) warns that more common species are excluded from the EU directives and consequently receive far less attention than their abundance and prevalence would suggest. The distinction is made between the extraordinary biodiversity, made visible thanks to existing monitoring programmes, and the ordinary biodiversity, more widespread, which would deserve more attention as those species also show declining trends. In order to overcome this gap and cover more exhaustively the state of biodiversity in Wallonia, Diagnostic Environnemental de la Wallonie – biodiversité (SPW ARNE, n.d.) provides an analysis of the state of biodiversity linked according to the type of environment they are found Those environments includes forests, croplands, open (including heathlands, peatlands, calcareous grasslands, *etc.*) and aquatic.

This observation was also made by an interviewed biodiversity expert which noted the taxonomic bias in Wallonia: the most studied and field monitored species are the protected species, that are already vulnerable; and more common species do not get as much attention, although their decline is also alarming (Pers. Comm., 2024a).

The study related to Vulnerability assessment to increase Wallonia's resilience to climate change sponsored by the Agence wallonne de l'Air et du Climat (AwAC) describes the vulnerability of the Walloon territory regarding specific climatic risks (Harchies et al., 2025).

4.3.3. Brussels

In Brussels, an inventory of the Brussel's flora exists and lists 793 different plant species. Among these species, 215 are non-native (Bruxelles Environnement, 2011). The plant diversity varies a lot spatially and some semi-natural areas contains up to almost 300 species per square kilometre, whereas, in some other places, only 50 different species are observed for the same surface. As shown in the Nature Flanders Report (Stevens et al., 2015)(Figure 8), Brussels-Capital Region is essentially covered by an urban ecosystem.

4.3.4. Belgian Part of the North Sea

The Belgian marine strategy ensues from the European MSFD. The area of application for this Directive is the Belgian part of the North Sea, representing a surface of 3 454 km².

The MSFD sets up a series of goals (11 qualitative descriptors – D1 to D11) that Member States must achieve to reach or maintain good environmental status. In Belgium the implementation of the European directive is coordinated by the DG Environment (FPS Health, Food Chain Safety and Environment), which is backed up by the MUMM scientific service (Management Unit of the Mathematical Model of the North Sea) of the RBINS for the monitoring and assessment of the status.

The third Belgian MSFD assessment is the second update after the initial assessments of 2012 and reports the state of each descriptor (D1 to D11) based on monitoring data collected during the period 2016-2021. The report is also based on wider-range analysis conducted in the OSPAR region.

Biodiversity is monitored through different components of the D1-objective (sea birds, marine mammals, fish, cephalopods, pelagic habits) – but also food web (D4) and seabed habitats (D6).

Seabirds' populations are monitored through abundance indicators and breeding productivity. The overall state of sea birds species is not good, due to their low breeding productivity, resulting in a decline of many species (État belge, 2025).

The harbour porpoise (*Phocoena phocoena* Linnaeus, 1758), the common seal (*Phoca vitulina* Linnaeus, 1758) and the grey seal (*Halichoerus grypus* Fabricius, 1791) are the very few marine mammal species found in the Belgian Part of the North Sea, present all year-round. The population of harbour porpoises remained stable throughout the year it was assessed; its distribution shifted southwards within the North Sea. Seal - both common and grey - populations have increased since 1992, although population at that time had been severely depleted. Grey seal populations are still increasing nowadays while common seals population are recently in decline (État belge, 2025).

Fish species sensitive to fishing pressure are assessed through a "recovery" indicator. Populations abundance of predators such as sharks and rays is also monitored because there are valuable indicators of the potential recovery of vulnerable fish species. A positive trend has been observed for the thornback rays from 2012 to 2020 and from 2021-2022 a slight decrease is noted. A small decline of the small spotted catshark is observed after 2020.

The Belgian Register of Marine Species (BeRMS) is an inventory of the local marine species found in the Belgian Part of the North Sea, compiled by the VLIZ. The inventory counts a total of 2058 species.

4.4. Identified threats to biodiversity: an overview

Biodiversity across the globe faces an intricate web of interconnected threats that jeopardise ecosystems and the services they provide. These threats, primarily driven by human activities, manifest in various ways, including climate change, habitat destruction, pollution, overexploitation, and the spread of invasive alien species. While these drivers operate on a global scale, their impact at the national level is shaped by specific socio-economic and ecological contexts. In Belgium, pressures caused by the dense population, intensive land use, and industrial development exacerbate these challenges, necessitating a detailed understanding of the underlying drivers to formulate effective conservation strategies.

4.4.1. Threats to biodiversity at global level

Biodiversity is experiencing an unprecedented decline on a global scale, driven by a range of interconnected anthropogenic and environmental factors. Addressing these threats requires a comprehensive understanding of their mechanisms, interconnections, and cascading effects on ecosystems and human well-being.

HABITAT DESTRUCTION AND FRAGMENTATION

The transformation of natural landscapes for agriculture, urbanisation, and infrastructure development remains the most significant driver of biodiversity loss globally. Habitat destruction and fragmentation reduce the availability of space for wildlife, disrupt ecological connectivity, and isolate populations, leading to declines in genetic diversity and increased extinction risks (Pereira et al., 2024). Deforestation, particularly in tropical regions that host most of the Earth's biodiversity, has dramatically reduced the extent of pristine ecosystems. Deforestation for monoculture crops such as palm oil, soybeans, and cattle grazing further exacerbates this issue by creating homogenous landscapes[32] with limited ecological value.

([32]) The use of fertilisers, pesticides, drainage and/or irrigation is most of the time required in such landscapes, which creates additional pressure.

In fragmented landscapes, species that depend on contiguous habitats are disproportionately affected. Large carnivores and migratory species, for example, are particularly vulnerable to habitat fragmentation as they require extensive ranges to meet their ecological needs. Pereira et al. (2024) highlight that habitat loss at the genetic, species, and ecosystem levels compromises ecosystems' ability to deliver critical services such as water regulation, carbon sequestration, and nutrient cycling.

The marine habitat is subject to another type of disruption called “ocean sprawl”. This refers to the effect of adding artificial, engineered structures to the marine environment, such as harbour walls, offshore wind farms and oil and gas platforms. These structures create new habitats for new communities and can act as stepping stones for non-indigenous species (Degraer et al., 2023).

CLIMATE CHANGE

Climate change is emerging as one of the most pervasive threats to global biodiversity. Rising temperatures, altered precipitation patterns, and an increase in the frequency and intensity of extreme weather events are fundamentally reshaping ecosystems. These changes force species to adapt, migrate, or face extinction. Shen et al. (2024) demonstrated that climate-induced phenological shifts, such as earlier flowering or breeding times, can disrupt ecological interactions, such as those between plants and pollinators. These mismatches ripple through food webs, destabilising ecosystems and reducing their resilience.

Moreover, biodiversity loss can amplify the effects of climate change through feedback mechanisms. Weiskopf et al. (2024) emphasise that the decline of diverse plant assemblages reduces ecosystems' carbon storage capacity. Using the BILBI[33] macroecological model, developed by the Australian research centre CSIRO, they predicted that global plant species richness will decline significantly by 2050. This decline is linked to reductions in biomass and carbon stocks, underscoring the need to prioritise biodiversity restoration in global climate mitigation strategies. Initiatives focusing solely on increasing ecosystem extent without enhancing diversity risk failing to achieve their intended climate benefits.

Climate change impacts the ocean in various ways, including rising temperatures and increased acidification. As ocean waters warm, mobile marine species tend to migrate northward or to deeper water. Meanwhile, acidification disrupts the calcification process in many marine organisms. Additionally, the growing frequency of marine heatwaves can threaten the survival of certain species.

OVEREXPLOITATION OF NATURAL RESOURCES

Overexploitation, including overfishing, aggregate extraction, unsustainable hunting, and excessive logging, is a critical driver of biodiversity loss. These activities deplete populations, disrupt ecological balance, and reduce genetic diversity. Dasgupta & Levin (2023) argue that overharvesting often disproportionately targets large-bodied and keystone species, which play pivotal roles in maintaining ecosystem stability. For example, overfishing not only depletes fish stocks but also alters marine food webs, leading to cascading effects that can destabilise ocean ecosystems (Daskalov et al., 2007; Baum & Worm, 2009; Pershing et al., 2015; Pint et al., 2025).

Unsustainable logging activities contribute to habitat destruction and fragmentation while also depleting resources that many species depend on. Especially in tropical forests, unsustainable hunting practices, particularly in biodiversity hotspots, further exacerbate species declines. The global demand for wildlife products, including bushmeat and traditional medicines, places additional pressure on already vulnerable populations.

([33]) Biogeographic Infrastructure for Large-scaled Biodiversity indicators (BILBI) uses best available biological and environmental data, modelling and high performance computing to assess biodiversity change at fine spatial resolution across the global land surface.

POLLUTION

Pollution is another pervasive driver of biodiversity loss, affecting terrestrial, freshwater, and marine ecosystems. Nutrient runoff from agricultural activities leads to eutrophication in aquatic environments, creating hypoxic "dead zones" where life cannot be sustained (Finn et al., 2023). Freshwater ecosystems, already among the most threatened globally, are particularly vulnerable to such pollution.

Plastic pollution, predominantly affecting marine environments, poses severe risks to biodiversity. Marine species ingest plastics or become entangled in debris, leading to injury or death. Additionally, chemical pollutants, including pesticides and heavy metals, accumulate in food webs, causing reproductive and developmental issues in wildlife.

INVASIVE ALIEN SPECIES

The introduction of invasive alien species, often facilitated by global trade and transportation networks, disrupts native ecosystems and drives declines in local biodiversity. Invasive species can outcompete native species for resources, alter habitat structures, and introduce new diseases. Isbell et al. (2023) emphasise that invasive species have become one of the leading global drivers of biodiversity loss, requiring coordinated international efforts for management and prevention. For instance, invasive plants like kudzu (*Pueraria montana* (Lour.) Merr.) and water hyacinth (*Pontederia crassipes* Mart.) can dominate ecosystems, reducing the diversity and abundance of native flora and fauna.

INTERACTIONS AND COMPOUNDING EFFECTS

These threats do not act in isolation but often interact, amplifying their combined impact on biodiversity. For example, climate change can increase the invasiveness of certain species by creating favourable conditions for their establishment, while habitat fragmentation can limit species' ability to migrate in response to climate shifts. Similarly, pollution can weaken species' resilience to other stressors, making them more vulnerable to overexploitation and habitat degradation. It is also important to stress that local and global effects interact: effects of human activities at local scale (*e.g.*, farming or wind farm installations) can be affected by global changes. While the first one can be managed by local governance, the second cannot be managed locally. Thus, local effects are the results of these interactions.

4.4.2. Threats to biodiversity: the case of Belgium

Belgium, characterised by its high population density and intensive land use, faces significant threats to its biodiversity. These challenges, driven by habitat degradation, pollution, climate change, invasive species, and other anthropogenic factors, endanger ecosystems that provide essential services like water purification, flood regulation, and carbon sequestration. While these threats mirror global trends, Belgium's geographic, ecological, and socio-economic context adds layers of complexity. This section explores the key drivers of biodiversity loss in Belgium, synthesising insights from the literature to provide a detailed understanding[34].

HABITAT DEGRADATION AND FRAGMENTATION

Urbanisation and agricultural intensification have profoundly altered Belgium's natural landscapes, leading to significant habitat loss and fragmentation. Wetlands, grasslands, and forests have been drained or converted for agricultural use, infrastructure, or urban expansion. Torfs (2024) highlights that more than 75% of biodiversity in Flemish grasslands is at risk due to habitat fragmentation, pollution, and changes in land management practices.

([34]) More information for Flanders are available in Schneiders et al. (2020).

Grasslands, in particular, require specific conservation approaches, such as grazing or mowing, to maintain their ecological integrity.

Forest fragmentation is another concern, as small, isolated patches cannot sustain viable populations of many species. Connectivity between habitats is increasingly disrupted *e.g.* by Belgium's extensive road networks, creating barriers for species movement and gene flow. Habitat loss and fragmentation also exacerbate the impacts of other threats, such as climate change and invasive species, by reducing the ability of species to migrate or adapt.

In the marine area, the concept of "ocean sprawl" refers to the increasing proliferation of engineered, artificial structures in coastal and offshore marine environments, analogous to urban sprawl on land. In Belgium, the addition of artificial habitats such as wind farms, aquaculture installations or energy islands can provide habitat for new (*i.e.* non-indigenous) species, possibly adding more pressure on indigenous species (Pers. Comm., 2025). But they can also represent opportunities for protected species [35].

POLLUTION

Pollution, particularly nitrogen deposition from agriculture and industrial activities, is a major threat to biodiversity in various places in Belgium. High nitrogen levels from fertilisers and industrial emissions lead to soil acidification and eutrophication of water bodies, impacting both terrestrial and aquatic ecosystems. Heathlands, which are nutrient-poor ecosystems, are particularly sensitive to nitrogen deposition. Excess nutrients favour fast-growing, nitrogen-loving plant species that outcompete native flora, reducing biodiversity (EEA, 2024)[36].

As noted in Torfs (2024) nitrogen deposition has become one of the most pressing threats to Belgium's grasslands, with over 75% of biodiversity at risk. Current mitigation measures, such as reducing fertiliser application, remain insufficient to reverse these trends.

Aquatic systems are similarly affected, with nutrient runoff causing algal blooms that deplete oxygen levels, leading to "dead zones" where aquatic life cannot survive. Depicker et al. (2020) emphasise that urban and industrial runoff further compounds these effects, degrading water quality and threatening species that rely on clean aquatic habitats. Pesticides and herbicides used in agricultural practices add to the pressures on biodiversity, harming non-target species, including critical pollinators such as bees and butterflies.

CLIMATE CHANGE IMPACTS

Rising temperatures and altered precipitation patterns driven by climate change are reshaping Belgium's ecosystems. Wetlands, which are highly dependent on stable hydrological conditions, are particularly vulnerable to changes in water availability. European Environment Agency highlights that climate-induced drying or flooding disrupts wetland ecosystems, reducing species richness and ecosystem functionality. Amphibians, waterbirds, and aquatic plants are among the species most at risk[37].

Grasslands and forests[38] are also experiencing shifts in phenology, such as earlier flowering or breeding times, which can lead to mismatches in species interactions and cascading ecological effects. Depicker et al. (2020) warn that extreme weather events, such as heatwaves and heavy rainfall, further stress these ecosystems, reducing their resilience to other threats.

The marine ecosystem is affected by a combination of increased temperature – including the increased occurrence of heat waves – and ocean acidification, causing calcification problems in marine organisms. A summary of the main

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([35]) For more details, see ocean sprawl facilitates dispersal and connectivity of protected species
([36]) See also here for more information.
([37]) See *e.g.*, the impacts assessment of air pollution on ecosystems.
([38]) More information for Flanders is available in Van der Aa et al. (2015) on the effects of climate change on forests and nature.

effects of climate change on Belgian coastal and marine ecosystems is presented in Cerac's note published in October 2024 (Cerac, 2024).

WILDFIRES

While wildfires are less common in Belgium than in Mediterranean regions, they have significant localised impacts when they occur. In 2011, wildfires affected over 2,000 hectares of biologically valuable areas within the Natura 2000 network, including the Kalmthoutse Heide and Les Hautes Fagnes (Depicker et al., 2020). These fires often occur in protected areas, threatening vulnerable species[39] and promoting the growth of invasive or undesired plant species.

In forested areas, wildfires reduce ecosystem services such as timber production and water supply. Bladon et al. (2014) note that severe wildfires in watersheds can degrade water quality, leading to higher treatment costs. Despite these risks, indicators assessing the contribution of forests to water supply in the context of wildfires remain limited (Maes et al., 2016), highlighting the need for improved monitoring and management strategies.

In parallel with this report, a similar analysis is being done about the wildfires and related risks in Belgium. More information about wildfires can be found in the report dedicated to wildfires risks in Belgium prepared by the NGI.

INVASIVE ALIEN SPECIES

Belgium's role as a transportation hub in Europe increases its vulnerability to invasive alien species. These species, often introduced through trade and travel, outcompete native species, alter habitat structures, and introduce diseases. Notable examples include the American bullfrog *Rana catesbeiana* (Shaw, 1802) of the Ranidae family and the Polygonaceae Japanese knotweed (*Reynoutria japonica* Houtt.)[40], both of which have significant ecological impacts[41].

Marine invasive species include the Pacific or Japanese oyster (*Crassostrea gigas*, Thunberg, 1793), the North American bivalve mollusc or Atlantic razor clam (*Ensis directus*, Conrad, 1843), the Sea walnut (*Mnemiopsis leidyi*, A. Agassiz, 1865), the Slipper limpet (*Crepidula fornicate*, Linnaeus, 1758) and the Japanese wireweed (*Sargassum muticum* (Yendo) Fensholt). *Crepidula fornicate* and the macro-algae *S. muticum* currently pose a threat to oyster cultivation in the Spuikom in Oostende.

European Environment Agency emphasises that invasive species reduce native species richness and disrupt ecosystem functions, making it harder for ecosystems to recover from other stressors like climate change and pollution. Current efforts to control invasive species in Belgium face challenges, including insufficient resources and coordination among stakeholders. Public awareness campaigns and stricter biosecurity measures are essential to prevent further introductions.

INTERACTIONS BETWEEN THREATS

The threats to biodiversity in Belgium often interact, amplifying their combined impacts. For example, habitat fragmentation limits species' ability to migrate in response to climate change, while pollution can weaken ecosystems, making them more susceptible to invasive species. Climate change may also increase the frequency and severity of wildfires, compounding the impacts on vulnerable habitats.

([39]) Alongside some plant species (*e.g.*, some herbaceous plants, certain shrubs, *etc.*), the most vulnerable species are those with a lower ability to move in the face of fire, especially amphibians and reptiles, as well as certain species of butterflies, *etc*.
([40]) *Reynoutria sachalinensis* (F.Schmidt) Nakai and the hybrid *Reynoutria* × *bohemica* Chrtek & Chrtková were both added to the EU list of invasive alien species during summer 2025.
([41]) See *e.g.*, https://www.iasregulation.be/ for more information.

ADDRESSING BIODIVERSITY LOSS IN BELGIUM

Belgium must align its conservation efforts with the EU Biodiversity Strategy for 2030, which emphasises expanding protected areas[42], restoring degraded ecosystems, and reducing pollution. Specific actions should include:

- Habitat Restoration: Prioritise the restoration of wetlands, grasslands, and forests to enhance biodiversity and ecosystem services;
- Pollution Mitigation: Implement stricter regulations to reduce nitrogen emissions and pesticide use in agriculture;
- Climate Adaptation: Develop strategies to mitigate the impacts of climate change on vulnerable ecosystems, particularly wetlands and forests;
- Invasive Species Control: Strengthen monitoring and management efforts to prevent the introduction and spread of invasive species;
- Ecosystem Monitoring: Address data gaps, particularly regarding the impacts of wildfires and pollution on ecosystem services.

4.4.3. Conclusion

The biodiversity crisis is a multifaceted challenge that manifests at both global and local scales, driven by a complex interplay of anthropogenic and natural factors. Globally, habitat destruction, climate change, overexploitation of resources, pollution, and invasive species are the primary threats, often interacting to amplify their collective impact. Locally, Belgium faces similar challenges compounded by its high population density and intensive land use. The fragmentation of habitats, nitrogen pollution, and the introduction of invasive species are particularly pressing issues in the Belgian context.

Effectively addressing biodiversity loss requires a comprehensive, integrated approach that considers these drivers' interconnected nature. Global frameworks, such as the KM-GBF, provide a roadmap for conservation, but local adaptations and targeted actions remain crucial for meaningful progress. Belgium's alignment with the EU Biodiversity Strategy for 2030 and EU Nature Restoration Regulation underscores the importance of collaborative and science-driven solutions.

By understanding these threats in detail, conservation efforts can prioritise restoring critical habitats, mitigating pollution, adapting to climate change, and managing invasive species. Strengthening ecosystem monitoring and filling critical data gaps will be key to assessing the effectiveness of these measures and ensuring the resilience of biodiversity and ecosystems for future generations.

KEY POINTS

1. Global Threats to Biodiversity:
    - Habitat destruction and fragmentation, driven by agriculture, urbanisation, and deforestation, are the most significant drivers of biodiversity loss globally;
    - Climate change disrupts species distributions, phenology, and interactions, exacerbating other biodiversity threats;

([42]) As "this is an objective to be reached by Member States collectively", there is no direct obligation under the EC Communication on the EU Biodiversity Strategy 2030 for Belgium to increase the area of protected areas for the benefit of biodiversity (*cf*. § 9 of the Council of the EU's relevant conclusions of October 2020).

- Overexploitation of resources, including overfishing and unsustainable logging, depletes populations and destabilises ecosystems;
- Pollution, particularly from nutrient runoff and plastics, creates hypoxic zones in aquatic ecosystems and harms wildlife health;
- Invasive alien species outcompete native species and alter ecosystems, requiring coordinated international management efforts.

2. Belgium-Specific Threats:
   - Habitat degradation and fragmentation from urbanisation and agriculture reduce biodiversity in critical ecosystems such as wetlands and grasslands;
   - Ocean sprawl caused by the artificial structures installed in the Belgian Part of the North Sea together with the numerous harbours both contribute to the proliferation of non-indigenous (and potentially invasive) species by providing habitats and by introducing those species;
   - Nitrogen pollution from fertilisers, industrial emissions, intensive livestock farming, transport and households leads to eutrophication, soil acidification, and loss of native plant species;
   - Climate change-induced shifts in temperature and precipitation affect *e.g*. wetlands and forests, reducing their functionality and species richness;
   - Wildfires, though less frequent, impact biologically valuable areas and promote invasive species growth;
   - Belgium's role as a transportation hub increases the introduction and spread of invasive species, threatening native biodiversity.
3. Interconnected Nature of Threats:
   - Threats often interact, amplifying their impacts. For example, climate change increases the invasiveness of certain species and the frequency of wildfires;
   - Habitat fragmentation limits species' ability to migrate in response to climate change, while pollution weakens ecosystem resilience.
4. The Role of Policy Frameworks:
   - Global and local conservation strategies must work in tandem to address biodiversity threats;
   - Belgium's alignment with the EU Biodiversity Strategy for 2030 and EU Nature Restoration Regulation provides a strong foundation for addressing its specific challenges.

4.5. Mapping the risks posed by biodiversity loss and modelling the future evolution of biodiversity (projections)

It is widely acknowledged that spatially explicit data[43] are essential for managing terrestrial ecosystems, mitigating climate change, preventing biodiversity loss, and addressing the ensuing risks (Lang et al., 2023; Potschin & Haines-Young, 2011; WWF, 2023). More generally, mapping efforts' objectives are three-fold: (*i*) delineate areas where biodiversity must be protected; (*ii*) assist policymakers in prioritising their choices and identify problems – including identifying synergies or trade-offs between different ecosystem services; and (*iii*) communicate with the public or among different stakeholders.

Effective biodiversity conservation relies heavily on the integration of geospatial data with biodiversity monitoring initiatives. Geospatial data, such as species distribution maps, habitat assessments, and ecosystem health indicators, provide crucial insights into where biodiversity loss is most severe, where conservation efforts should be prioritised

([43]) Spatially explicit data refers to information that includes specific geographic locations or spatial coordinates, allowing for detailed mapping and analysis of patterns, distributions, and relationships across a defined area.

and where the higher potential risks are. Jetz et al. (2019) propose a set of essential biodiversity variables for mapping and monitoring species populations.

In the context of ecosystem assessment and ecosystem services, Potschin & Haines-Young (2011) emphasises that "*a geographical perspective can provide important new, critical insights into the place-based approaches to ecosystem assessment that are now emerging*". Spatially explicit data allow for the identification of biodiversity hotspots, vulnerable ecosystems, climate drivers, and the impacts of human activities like urbanisation and agricultural expansion. By integrating geospatial data into biodiversity monitoring systems, it is possible to:

- Track changes in habitat cover over time, providing early warnings of biodiversity loss;
- Map species distributions to understand how populations are shifting due to climate change or habitat fragmentation;
- Support the creation of risk maps that highlight areas at greatest risk of biodiversity loss, allowing for more targeted and thus possibly more efficient conservation efforts.

As exposed in section 4.2, MAES aimed to implement the Target 2 – Action 5 of the EU Biodiversity Strategy to 2020 and required Member States to map and assess the state of ecosystems and their services in their national territory to integrate this ecosystem knowledge in decision-making processes and support stakeholders' discussions.

4.5.1. Mapping the risks posed by biodiversity loss at global level

As stressed in the Planetary Boundaries report published by Cerac in July 2024, overshooting planetary limits comes along with risks and it is important to define what lies behind the term "risk". The risk is the combination of three factors: hazard, vulnerability and exposure and is defined as the probability of being harmed by a hazard.

The Biodiversity Risk Filter tool developed by the WWF is an example of a recent attempt to translate biodiversity-related data into a risk score. In short, the tool is designed to help companies and investors prioritise action for business resilience regarding risks linked to the loss of biodiversity. The risk is given in terms of the potential impacts industrial sectors have on biodiversity, and also in terms of their dependencies on biodiversity. The tool allows you to give a response plan that is location-specific: where they are exposed to the highest risk and what are the factors driving these risks. This enables us to prioritise the required further investigations or actions.

The calculation of the risk score can be broken down into four levels of data processing. The first level consists of the metrics comprising the raw data sets of biodiversity and ecosystems in specific locations (WWF Biodiversity Risk Filter, 2023). Data are spatially aggregated or transposed to a common scale. For terrestrial data, the spatial unit used is the watershed as this is considered to represent functional coherence in terms of biodiversity (WWF Biodiversity Risk Filter, 2023).

The Biodiversity Risk Filter complements global tools such as the Biodiversity Intactness Index (BII), which assesses the functional integrity of ecosystems by estimating the remaining biodiversity in a given area (Pereira et al., 2024). Tools like the BII and PREDICTS database (*cf.* subsection 9.2) leverage spatial data to analyse human pressures on biodiversity, focusing on habitat loss and species distribution changes (Hudson et al., 2017).

Mapping at the global level is also supported by initiatives like the Copernicus Land Monitoring Service, which provides high-resolution datasets through CORINE Land Cover. The European CORINE Land Cover classification allows to spatially delineate ecosystems in Europe on the basis of the CICES classification system for ecosystem services (Maes et al., 2016). These data are essential for delineating ecosystems and tracking land-use changes that directly impact biodiversity (Candotti et al., 2022). The integration of these tools enhances the ability to identify global biodiversity hotspots and prioritise conservation actions in regions at the highest risk.

The ENCORE tool, developed by the United Nations Environment Programme World Conservation and the Natural Capital Finance Alliance, assists businesses and financial institutions in assessing their dependency on natural capital. The ENCORE database provides a dependency score on 21 ecosystem services for 86 business processes.

ENCORE divides natural capital into 8 distinct ecosystem components (atmosphere; land geomorphology; minerals; ocean geomorphology; soils and sediments; species; structural and biotic integrity; water). Related datasets are provided for each of the ecosystem components. The species component is assessed with the use of the Biodiversity Intactness Index, developed by the Natural History Museum of London (Newbold et al., 2015).

While ENCORE provides a broader analysis of natural capital risks, the Biodiversity Risk Filter focuses specifically on biodiversity-related risks, offering organisations complementary tools based on their needs.

4.5.2. Mapping the risks posed by biodiversity loss in Belgium

Mapping efforts in Belgium focus on identifying areas most affected by biodiversity loss, particularly in relation to nitrogen deposition, habitat fragmentation, and urban expansion.

LifeWatch Belgium has played a key role in advancing biodiversity mapping by combining species observations with high-resolution land cover data. Their modelling platform integrates harmonised variables about soil properties, such as soil depth, drainage, topography and climate to create detailed maps of species abundance and habitat suitability. Their analysis focuses primarily on Wallonia (Figure 2 in section 4.1.1). However, expanding these efforts to Flanders and Brussels remains a significant challenge. The relevance of carrying out this work should therefore be analysed.

LifeWatch's analyses are based on geographic datacubes of irregular polygons designed to support modelling and mapping purposes. For Belgium, the datacubes have a spatial scale of 2 m, based on the land cover data resolution. Those datacubes represent ecotopes, which is the smallest ecological distinct unit in a landscape mapping system. Similar to ecosystems, ecotopes's definition comprises both biotic and abiotic components but focuses on spatial patterns rather than functional processes. Ecotopes may be used to map ecosystems at finer scale. Figure 9 presents the ecotopes of Belgium as of 2015 and is based on 2-m resolution land cover data.

The CORINE Land Cover dataset, used in conjunction with Belgium-specific datasets, provides valuable insights into habitat degradation and urbanisation patterns. These tools allow policymakers to spatially delineate ecosystems and prioritise areas for restoration or protection based on biodiversity value (Maes et al., 2016).

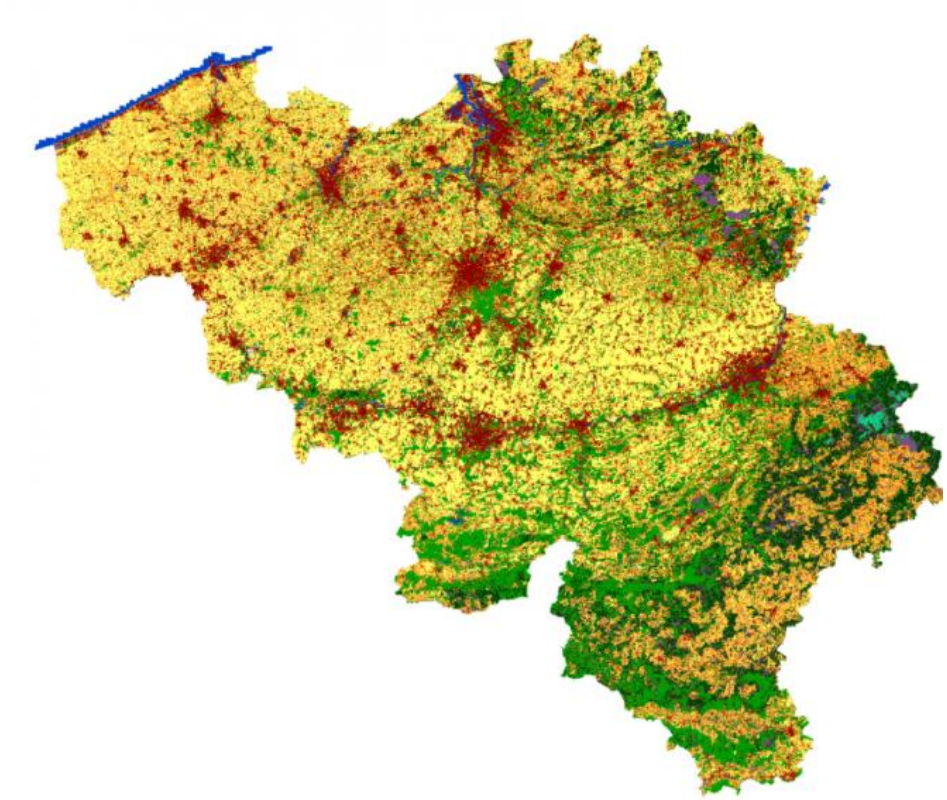

Figure 9: Ecotopes of Belgium in 2015 (LifeWatch, n.d.).

FLANDERS

Nitrogen deposition maps in Natura 2000 areas highlight critical biodiversity hotspots facing ecological pressures. In Flanders, over 75% of sensitive habitats exceed nitrogen critical loads, leading to shifts in species composition and ecosystem function (Torfs, 2024). The Vlaamse Milieumaatschappij provides a commented map showing nitrogen deposit levels in Flanders (Figure 10).

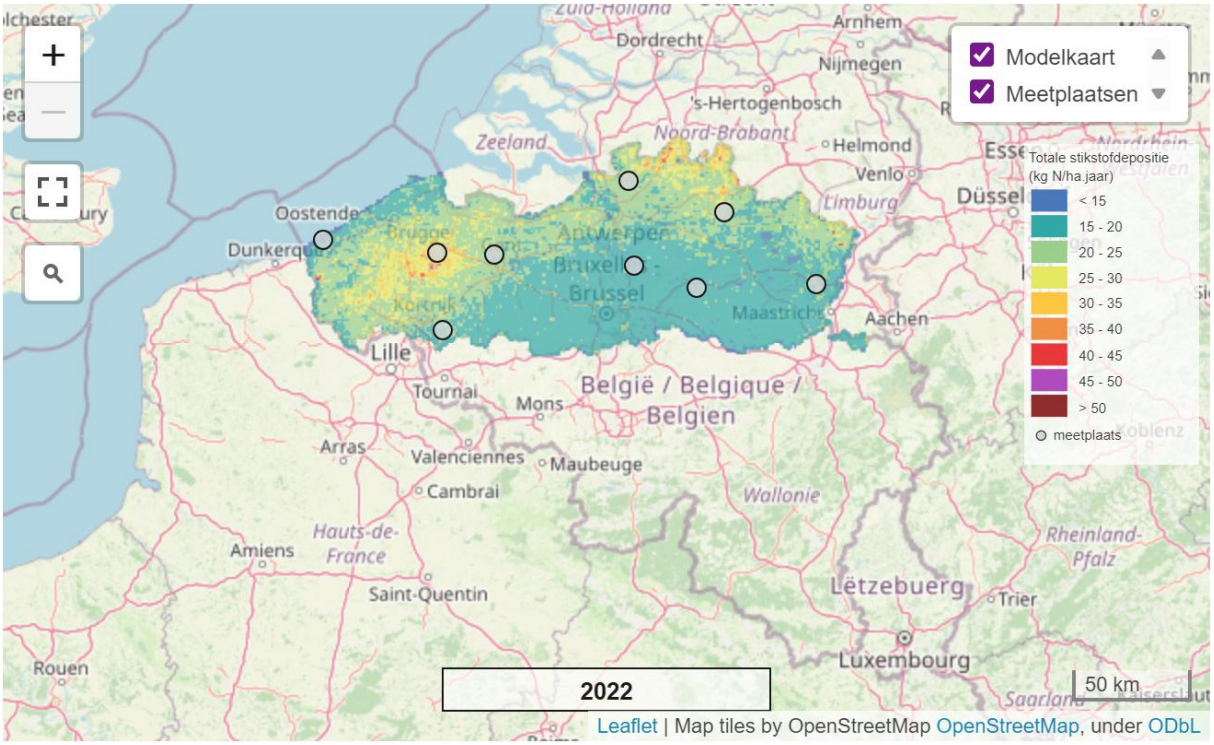

Figure 10: Nitrogen deposition map in Flanders in 2022 (Nitrogen deposit levels in Flanders).

Regarding habitat fragmentation[44] and more generally land use change[45] in Flanders, the Land Use Map Flanders was developed to monitor those changes more frequently and with a higher spatial resolution. Flanders land use datasets for 2016 and 2019 are publicly available through the Digitaal Vlaanderen portal. It contains four levels with a total of 69 land cover and land use classes with a resolution of 1 are (100 m²). These data can be combined in various maps. Schneiders et al. (2021) analysed the changes between 2013 and 2016. The main patterns in the land use changes are the increase in urban and built-up areas and the systematic conversion of grassland into arable land: these changes are statistically significant[46].

A mapping exercise exists in Flanders – the Biological Valuation Map (BVM) – which is a full inventory of the biological environment and land cover (Figure 11). The map is established from field-driven survey of land cover and vegetation. The mapping project started in 1978 on demand of the national government which requested a map covering the entire territory. The first version (1978-1996) provided a global overview of the biologically valuable landscapes; the second version (1998-2010) was significantly improved in terms of methodology and accuracy; and finally the third version (2013-2025) is essentially restricted to Natura 2000 zones due to budgetary constraints (De Saeger et al., 2018).

The Flemish Biodiversity Portal, which consolidates biodiversity data for Flanders, includes a geographic information system tool, accessible to the employees of the Flemish government.

(44) More information on habitat fragmentation in Flanders are available online here.
(45) Further information on the map showing the actual land use within the Flemish Region for the reference year of 2019 are available online on Land use - Flanders - state 2019.
(46) At the time of drafting this report, INBO plans to carry out the analysis again soon using the 2019 and 2022 data.

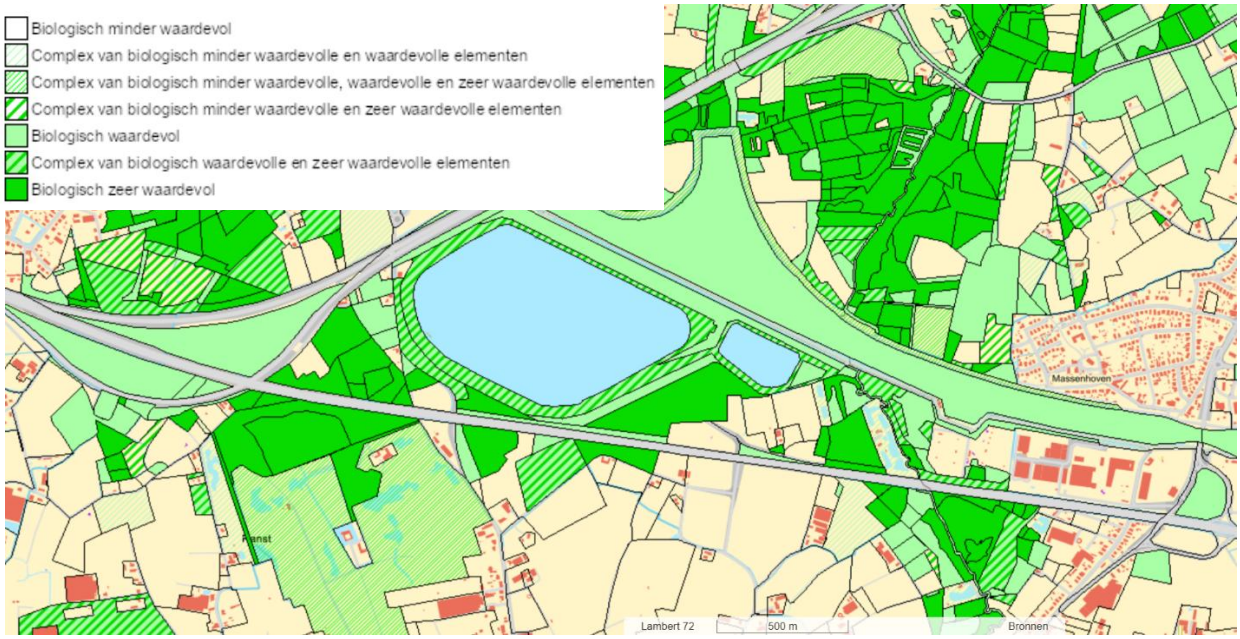

Figure 11: Biological Valuation Map (Geopunt Digitaal Vlaanderen, 2023).

WALLONIA

In Wallonia, the ecosystems and the services they deliver were mapped following a matrix-based approach: the rows corresponding to ecosystems typologies and the columns corresponding to the different ecosystem services (Figure 12). Each cell of the matrix was assigned a score ranging from 0 to 5 according to the capacity of the ecosystem to deliver a specific service. The score is the result of experts' judgements and deliberation during workshops sessions in Octobre 2021. These maps help comparing the gap between what ecosystems can actually deliver in terms of services, and the existing need of those services in that area.

Riparian zones, essential for water regulation and biodiversity, are another focal point in regional mapping efforts. Recent studies in Wallonia emphasise the importance of restoring riparian habitats to improve connectivity and reduce fragmentation (SPW, 2023).

The study related to Vulnerability assessment to increase Wallonia's resilience to climate change sponsored by the AwAC was officially released in June 2025. As a result of this work, a total of 700 maps were produced showing the vulnerability of the Walloon territory regarding specific climatic risks (Harchies et al., 2025).All the maps can be visualized through the portal specifically developed for the project Portail Climat – AwAC.

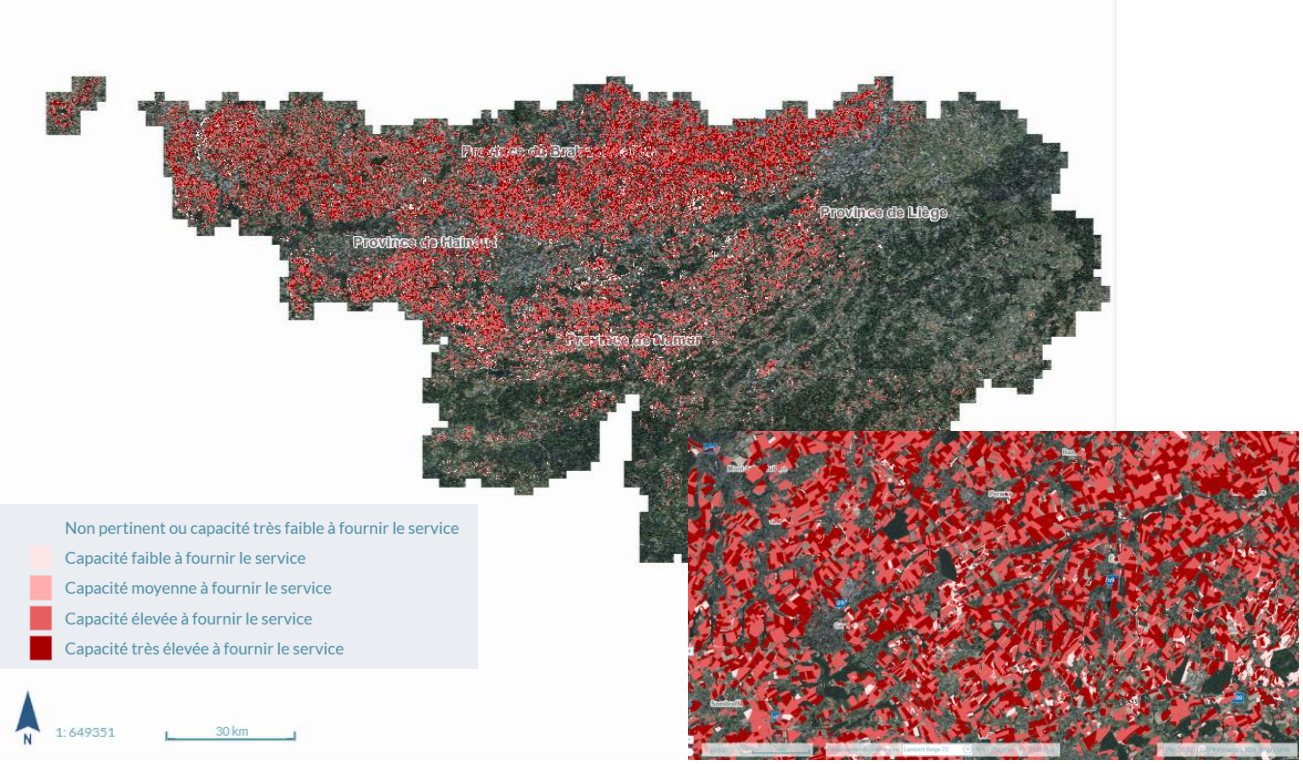

Figure 12: Matrix-based ability of ecosystems to deliver ecosystem services: food production from crops (SPW, 2023).

BELGIAN PART OF THE NORTH SEA

In the Belgian part of the North Sea, the biological value of all available ecosystem elements with associated spatial distribution information was assessed and mapped via the BWZee project. The marine Biological Valuation Map is based on the spatial distribution of sea birds and macrobenthos, covering the map fully; while epi- and hyperbenthos data cover only selected area of the map.

CONCLUSIONS

A map showing where biodiversity is most at risk - or "a biodiversity loss risk map" - would constitute a useful tool enabling the prioritisation of areas requiring restauration and/or protection. The biological diversity of a place (of defined perimeter) would receive a label according to its endangered potential - the same way IUCN labels work for endangered animal species. However, the realisation of such kind of map for Belgium faces several challenges. Firstly, spatial data on pressures such as land-use change, pollution, and climate impacts are either incomplete or not sufficiently fine-grained to accurately reflect local and regional dynamics. Secondly, the available biodiversity data are fragmented across different regions and sectors, often collected using inconsistent methodologies, which hinders comprehensive integration. Additionally, there is a lack of standardised indicators and uniform criteria for assessing biodiversity loss risk, making it difficult to develop a cohesive framework. Finally, the absence of a centralised platform to harmonise data sharing and analysis further complicates the process, highlighting the need for enhanced collaboration and methodological alignment among stakeholders.

Despite the limitations mentioned above, there exists several spatially explicit datasets or maps in Belgium – provided that significant efforts are done towards data integration to some extent, harmonisation to inform about the state of biodiversity at specific places and scales. Combining those datasets, for example the CORINE land cover or ecotopes datasets with the biological valuation map in Flanders or the ecosystem services matrix in Wallonia,

already provides insights on the richness of determined landscape and assist policymakers in their efforts to select areas where biodiversity must be protected.

4.5.3. Modelling future evolution of biodiversity (projections)

Modelling evolution of biodiversity is yet another important approach to fill temporal and spatial gaps inherent to current biodiversity-related knowledge. Models are necessary to extrapolate local data to larger spatial scales. A further step is to make predictions about future biodiversity evolution. In this section, various models serving distinct purposes (estimating current or future state of biodiversity) are presented.

While field metrics provide foundational biodiversity data, models help predict biodiversity trends and interactions with environmental factors. Indices can in turn be incorporated into models describing variations in time and space of biodiversity. More specifically, Species Distribution Modelling (SDM), also known as Ecological Niche Modelling (*sensu* Thuiller 2024), is a "methodology – a set of procedures, definitions, and techniques – built on a foundation of core ecological (Whittaker et al., 1973) and biogeographical (Holdridge, 1947) concepts about the relationship between species distributions (or other biotic response variables describing aspects of biodiversity) and the physical (abiotic) environment. […] Provided appropriate data are available, SDMs can be applied to any taxa, including marine, terrestrial, and freshwater species, and at any grain and extent" (Elith & Franklin, 2013).

An example of an attempt to gather and exploit global biodiversity data on a wide range of taxonomic groups is the Projecting Responses of Ecological Diversity In Changing Terrestrial Systems (PREDICTS) database, developed by the Natural History Museum of the UK (Yue et al., 2023; Phillips et al., 2021). The database brings together species abundance site-level data from studies worldwide, allowing the estimation of biodiversity measures such as species richness and compositional similarity, which compares disturbed and undisturbed ecosystems (Hudson et al., 2017). Mixed-effects models are used to account for variability in the data, improving the reliability of biodiversity assessments (Hudson et al., 2017).

Projecting Responses of Ecological Diversity In Changing Terrestrial Systems (PREDICTS) only considers the impact of land-use change to estimate biodiversity change, while the magnitude of biodiversity change may be greater due to other drivers, although land-use change has been considered as the main driver on biodiversity for the last decades (Valdez et al., 2023). Another limitation pointed by Valdez et al. (2023) is that the database does not distinguish between native and non-native species.

Models such as PREDICTS can be used to appraise future trends of biodiversity and ecosystem services, yet those models are hardly comparable, and the uncertainties of those predictions are difficult to assess (Pereira et al., 2024).

BILBI model developed by the Australian research centre CSIRO estimates biodiversity change at fine spatial resolution at the global scale. The model combines biological data of more than 300 million records for over 400,000 species and baseline environmental surface data to output spatial distribution of biodiversity (CSIRO website, BILBI – Macroecological Modelling). Figure 13 give a visual representation of the components of the system making up the BILBI.

Unlike static indices such as the IUCN Red List, using population trends to assess the risk of extinction is more suitable to make predictions about the evolution of species status (Finn et al., 2023).

In Brussels, the Sonian Forest is expected to undergo important change due to climatic pressure. A study of the distribution of 26 tree species in this forest under different climate scenarios shows that beeches will be most affected by the upcoming climate (Daise et al., 2009). A similar study was conducted for specific trees species present in Flanders with final objective to increase the resilience of forests in Flanders in response to climate change (Desie et al., 2022).

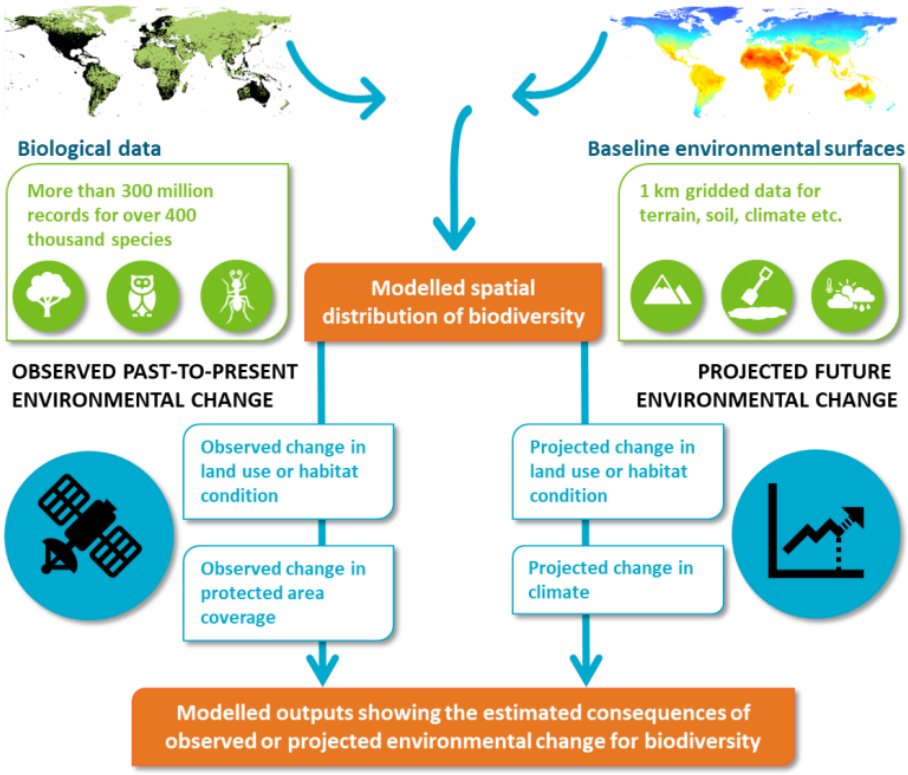

Figure 13: Components of the system making up the BILBI (image from CSIRO website, BILBI – Macroecological Modelling).

4.6. Bending the curve of biodiversity loss in Belgium by leveraging global initiatives

Biodiversity loss represents a complex and urgent challenge, requiring targeted actions at local levels and robust collaboration with global frameworks. Belgium, a nation marked by intensive land use and ecological diversity, has both an opportunity and an obligation to align its strategies with global initiatives. This section examines how leveraging global biodiversity databases, assessing the current state of biodiversity mitigation efforts in Belgium, integrating global initiatives, and learning from neighbouring countries can collectively aid in reversing biodiversity loss.

4.6.1. Global biodiversity databases

There are many international actors in favour of nature restoration and protection throughout the world. The International Union for Conservation of Nature is a union membership of governments and civil society created in 1948 aiming towards sustainable development and nature protection. International Union for Conservation of Nature is putting efforts in halting biodiversity loss by providing methodologies, data and expertise. Their most well-known product is the "Red List of Threatened Species" conservation tool which gives global extinction risk status of animal, fungus and plant species. The extinction risk ranges from critically endangered, endangered, vulnerable to least concern. Although the risk status is really helpful to grasp the current species' condition, it fails to inform about the rate of decline of species and ongoing extinctions (Etat de l'environnement wallon, SPW ARNE, n.d.; Finn et al., 2023). Finn et al. (2023) shows that for species currently listed as "non-threatened" in the Red List, 33% are declining.

Another weakness of the IUCN Red List status is that it fails to take genetic status into account, as pointed by Mastretta-Yanes et al. (2024).

McElderry et al. (2024, Preprint) points out important global geographic and taxonomic gaps in biodiversity monitoring: some regions of the world are better covered than others and some species are underrepresented. The global database of the International IUCN reflects the taxonomic discrepancy (McElderry et al., 2024, Preprint): it contains distribution data for over 80% of vertebrate species, 14% of vascular plants and 2% of invertebrate species despite this last group being the majority of animal species; additionally, the database includes only 0.4% of known microbes while these constitute the majority of all species on Earth.

Finn et al. (2023) suggest defining warning thresholds to alert proactively about the decline of biodiversity, the same way as the Planetary Boundaries framework defines the limits of environmental changes within which human societies remain stable. Even though this type of approach has received some criticism, the work undertaken positively highlights the limited knowledge around population abundances at global scale (Finn et al., 2023).

International Union for Conservation of Nature has developed other tools such as the IUCN Red List of Ecosystems and the Integrated Biodiversity Assessment Tool (IBAT). These tools provide ecosystem-level insights and spatial biodiversity assessments, enabling policymakers to prioritise conservation actions in critical areas. In Belgium, the Belgian Biodiversity platform plays the role of the national focal point for the IUCN, ensuring alignment with global conservation objectives.

The concept of ecosystem services was popularised by the MEA launched in 2000 by the UN Environment Programme and published in 2005. The more recent creation of global initiative is the “Intergovernmental Platform for Biodiversity and Ecosystem Services” (IPBES). In Belgium, the Biodiversity Platform is the national focal point for the IPBES.

Indices can, in turn, be incorporated into models describing variations in time and space of biodiversity. An example of an attempt to gather and exploit global biodiversity data on a large number of taxonomic groups is the PREDICTS database project (refer to Appendix in 9.2.5 for a more detailed description of the project), developed by the Natural History Museum of the UK. The database brings together species abundance data from studies worldwide, allowing the calculation of biodiversity measures like species richness and compositional similarity, which compares disturbed and undisturbed ecosystems (Hudson et al., 2016). Mixed-effects models are used to account for variability in the data, improving the reliability of biodiversity assessments (Hudson et al., 2016). Models such as PREDICTS can be used to appraise future trends of biodiversity and ecosystem services, yet those models are hardly comparable, and the uncertainties of those predictions are difficult to assess (Pereira et al., 2024).

Recent advances in biodiversity data collection emphasise the inclusion of genetic diversity indicators, as highlighted by Mastretta-Yanes et al. (2024). Genetic diversity is a critical aspect of resilience in ecosystems, ensuring adaptability to environmental changes and disturbances. The KM-GBF underlines the necessity of integrating genetic diversity metrics into global databases. However, challenges in standardising and scaling genetic data remain, necessitating international collaboration to bridge this gap.

The platform Observation.org gathers species occurrence data uploaded by citizens all around the world. The dataset currently comprises 250 million observations and continues to grow. Data quality is checked by species experts working with smart technology and artificial intelligence. The open data is found on the GBIF. These citizen science initiatives not only provide data on common species but also enhance public engagement in biodiversity monitoring.

Furthermore, remote sensing technologies are increasingly being integrated into global biodiversity databases. Tools such as the GBIF and satellite-based observations from programmes like Copernicus provide high-resolution, real-time data on land-use changes and habitat degradation. These datasets enable dynamic monitoring of ecosystems, facilitating more accurate and timely conservation actions.

IN BELGIUM

Belgium's integration with global databases enhances its ability to track biodiversity trends and prioritise conservation efforts. Tools like IBAT allow Belgian policymakers to identify key biodiversity areas (KBA), aligning national conservation priorities with international goals. Moreover, the PREDICTS database offers insights into the impacts of urbanisation and agricultural intensification, which are critical issues for Belgium's fragmented landscapes.

The reliance on global biodiversity databases also underscores the importance of local data quality. Belgium must continue to contribute robust, standardised data to these platforms to ensure accurate global assessments. Collaborative initiatives between Belgian research institutions and international organisations can strengthen the nation's role in advancing biodiversity science.

4.6.2. Global initiatives for biodiversity loss mitigation relevant for Belgium

Belgium actively engages with global biodiversity initiatives to strengthen its conservation strategies, leveraging frameworks and tools that provide scientific rigor and policy direction. Among these, the KM- GBF, the IPBES Global Assessment Report, and the GEO BON stand out for their influence on national policies and actions. These initiatives provide scientific guidance, policy frameworks, and standardised tools that enable Belgium to address biodiversity loss comprehensively while fulfilling its international obligations.

4.6.2.1. Global initiatives

THE KUNMING-MONTREAL GLOBAL BIODIVERSITY FRAMEWORK

Adopted during the 15th Conference of the Parties to the CBD, the KM-GBF establishes ambitious targets to halt and reverse biodiversity loss by 2030. Its "30 by 30" goal (*i.e.*, to protect 30% of terrestrial and marine areas globally by 2030) has directly informed Belgium's biodiversity commitments. For instance, the Flemish and Walloon regions have initiated actions to expand protected areas and enhance ecological connectivity in line with Global Biodiversity Framework (GBF) targets[47].

Global Biodiversity Framework also emphasises the equitable sharing of benefits arising from genetic resources, aligning with Belgium's efforts under the Nagoya Protocol. These commitments drive national strategies to integrate biodiversity into economic sectors, particularly agriculture and forestry[48], and enhance financial mechanisms for conservation. Belgium's alignment with GBF is evident in its Updated Belgian National Biodiversity Strategy for 2030 (NBS), which incorporates GBF principles to address habitat restoration, pollution mitigation, and climate adaptation.

([47]) See e.g., the "Vlaams Ecologisch Netwerk" (VEN; Flemish Ecological Network) and the connection between the different parts of the VEN is achieved through the "Integraal Verweving en Ondersteunend network" (IVON; Integral Interweaving and Support Network).
([48]) It is important to note that many forestry-related policies have already been fully implemented at the regional level in Belgium. In addition, the implementation of various forest management projects in Flanders gives prominence to the concept of biodiversity. The EU funded Interreg "Dutch-Belgian/Flanders" eco2eco project is a good illustration of this. This project has, for example, made it possible to define the concept of "tree-oriented forest management" ("Het boomgericht bosbeheerconcept"). This concept creates conditions that strengthen nature objectives and optimise forest management measures to further enhance natural value. Thus, the outcomes of the eco2eco project provide an alternative to existing management systems for those who wish to combine various objectives in their forests where appropriate (Sauren et al., 2020).

THE IPBES GLOBAL ASSESSMENT REPORT

The IPBES Global Assessment Report (IPBES, 2019) serves as a cornerstone for understanding the root causes of biodiversity loss and identifying transformative solutions. Its emphasis on governance, financial mechanisms, and integrated approaches has influenced Belgium's policymaking. Key areas of alignment include:

- Integrating biodiversity goals into EU's Common Agricultural Policy (CAP) Strategic Plan for Flanders, focusing on sustainable farming practices;
- Prioritising urban biodiversity projects, such as green infrastructure initiatives *e.g.* in Brussels, Ghent and Antwerp, to align with IPBES recommendations on urban ecosystem restoration.

By incorporating IPBES findings, Belgium seeks to balance ecological conservation with socio-economic development, ensuring policies address both environmental and human well-being.

GEO BON AND THE ROLE OF STANDARDISED MONITORING

Belgium's biodiversity monitoring efforts benefit from tools provided by the GEO BON. Group on Earth Observations Biodiversity Observation Network's Essential Biodiversity Variables (EBVs) provide a standardised framework to track biodiversity changes at genetic[49], species, and ecosystem levels. These variables support Belgium in fulfilling its international reporting obligations under the CBD and the European Biodiversity Strategy for 2030.

For example, Belgium utilises GEO BON's methods to enhance data collection and analysis for its contributions to the GBIF. These tools improve the accuracy and comparability of biodiversity assessments, facilitating evidence-based policymaking.

Furthermore, GEO BON's collaborative approach aligns with Belgium's commitment to international cooperation. Partnerships with EU initiatives, such as European Biodiversity Observation Network (EU BON), enhance Belgium's capacity to leverage global expertise and resources for biodiversity monitoring and restoration.

4.6.2.2. European initiatives

THE EUROPEAN BIODIVERSITY STRATEGY FOR 2030

The EU's biodiversity strategy for 2030 is "a comprehensive, ambitious and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030, and contains specific actions and commitments". Through specific actions and commitments, the strategy aims at putting Europe's biodiversity on the path of recovery by 2030. The Nature Restoration Law is a core element of the biodiversity strategy, and serves to make the nature restoration target binding. Actions taken involves introducing measures to enable better implementation and track progress. Two online tools were developed to visualise the progress in implementing the strategy:

- An actions tracker providing updates on the state of implementation of the strategy's actions;
- A EU Biodiversity Strategy Dashboard showing the progress to the quantified biodiversity targets.

The target dashboard shows progress at the European level and EU member states' levels. The quantified biodiversity targets are divided into sub-targets whose progress is assessed through indicators. A unique value of indicator is given at national scale for each EU country.

([49]) In Belgium, INBO, the University of Liège and the RBINS are members of the Genetic Composition Working Group of the GEO BON Network. The aim of this group is to develop genetic monitoring and make genetic data available to the greatest extent possible in the public domain. This will provide the best possible scientific basis for decision-making on biodiversity strategies.

For example, the sub-target 4.1 – species show no deterioration in conservation trends and status – is assessed via the common bird index, calculated at the European scale. It shows that the population size of common farmland bird species has been declining since 1990, the chosen year of reference (Figure 14).

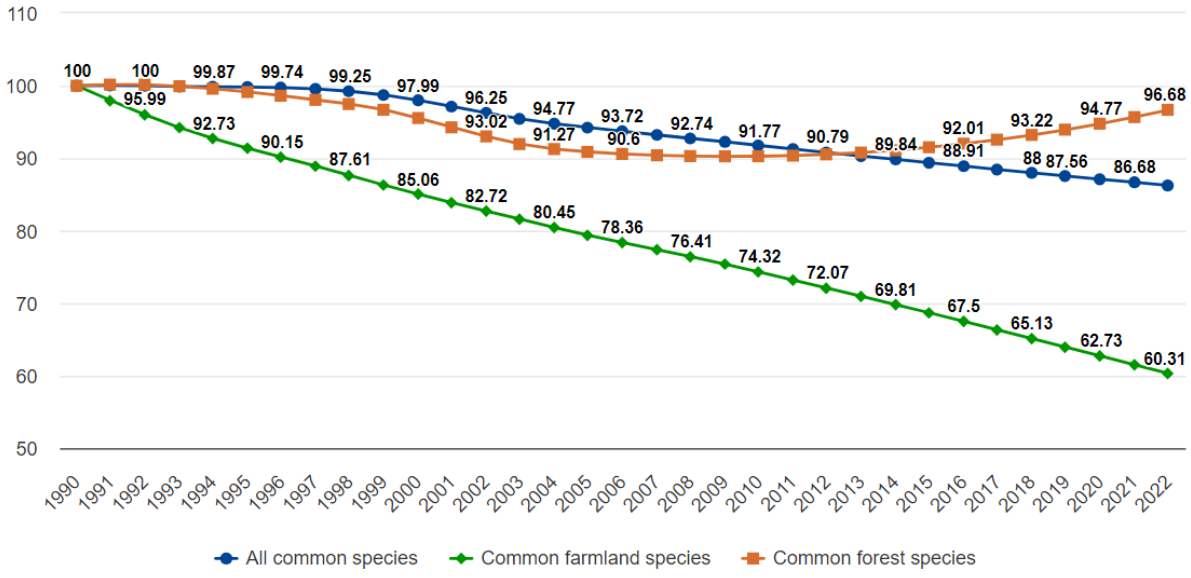

Figure 14: Common bird index by type of species (from EU Biodiversity Strategy Dashboard).

NATURA 2000

[The Natura 2000 protected areas network - European Environment Agency (europa.eu)]

Natura 2000 is a European network of protected natural areas (peatlands, forests, rivers, boulders/rocks, caves) and semi-natural areas (meadows, heathlands, *etc*.) or specific habitats for specific animal or plant species. This network aims at maintaining biodiversity within the selected areas using a common framework defining the criteria for habitats conservation as well as fauna and flora conservation.

The Natura 2000 sites were proposed by the EU countries under the Birds and Habitats directives:

- The Birds Directive (1979, amended in 2009) included classification of Special Protection Areas (SPA) for 194 highly threatened bird species and for all migratory birds;
- The Habitats Directive (1992) applied the same principle to designate legally protected areas, named Sites of Community Importance (SCI) for 233 habitat types listed in Annex I of the Directive and 900 species listed in Annex II. Within SCIs, Special Areas of Conservations (SAC) must be designated.

The Natura 2000 network comprises these three types of areas (SCI, SCIs/SACs).

Natura 2000 sites are protected through a series of policy tools, which have been translated into national legislation. The Habitat Directive requires EU member states to report on the conservation status of habitats and species. It also requires taking some action measures to compensate for projects impacting negatively on the conservation of these areas.

In Belgium, the management of the Natura 2000 network is the responsibility of regions, except for maritime site within the Belgian Part of the North Sea which falls under the responsibility of the federal level. Specific websites dedicated to Natura 200 sites visualisation have been developed by the regions.

- FPS Health, Food Chain Safety and Environment, Federal Government: Marine laws, directives and conventions;
- SPW, Wallonia: Réseau Natura 2000 en vigueur;
- Bruxelles Environnement, Brussel: Atlas;
- ANB, Flanders: Natura2000.

The table below presents the surface occupied by Natura 2000 for each Region.

Table 3: Surface of Natura 2000 sites in Belgian's regions (data updated in 2013, retrieved from http://www.archives.biodiv.be/implementation/cross-cutting-issues/protected_areas/natura-2000-belgium).

	Territory (ha)	Natura 2000	
		Surface (ha)	% of territory
Brussels	16,200	2,375	14.7%
Flanders	1,352,200	166,322	12.3%
Wallonia	1,684,400	220,945	13.1%
Federal Government/ Belgian part of the North Sea	346,200	124,929	34.2%
TOTAL	**3,399,000**	**514,571**	**15.1%**

RIVERS CONTRACTS

River contracts represent an innovative and collaborative tool for achieving integrated water management. Originating in response to the EU Water Framework Directive (2000), which mandates integrated river basin management, these contracts enable stakeholders to work collectively to address diverse water-related challenges. Venturini & Visentin (2024) describe river contracts as "*voluntary agreements between stakeholders for managing water bodies and involve participatory, evidence-based action plans*."

In Wallonia, 14 river contracts have been established, encompassing a wide range of themes, including:

- Nature conservation and the preservation of aquatic ecosystems: These efforts aim to safeguard biodiversity and maintain the ecological integrity of water bodies;
- Agriculture and forestry: Initiatives focus on promoting sustainable land use practices that balance production needs with environmental conservation.

In Flanders, seven river contracts have been established, mainly to limit the risk of flooding, but also to facilitate fish migration and/or to store water in nature reserves.

By fostering collaboration among diverse stakeholders and aligning with EU directives, river contracts not only enhance integrated water management but also contribute to broader conservation goals, including the protection of biodiversity and the delivery of essential ecosystem services.

River contracts also play a critical role in supporting European projects that emphasise biodiversity and ecosystem services. Notable examples include:

- Life Riparias: Addressing the challenges posed by invasive species in aquatic environments across regions through targeted management strategies;
- Life Belini: Focusing on the quality of surface waters and the renaturation of temporary immersion zones, which are vital for flood mitigation and the restoration of ecosystem functions.

Through these two projects - Life Riparias and Life Belini – Belgian authorities are working together to optimise the management of those environmental issues – namely invasive species in aquatic environment and surface water quality – across administrative boundaries of the Flemish, Walloon and Brussels-Capital regions.

LIFE PROGRAMME EU'S FUNDING INSTRUMENT FOR THE ENVIRONMENT AND CLIMATE ACTION

The Nature and Biodiversity sub-programme will aim at the protection and restoration of Europe's nature and halting and reversing biodiversity loss. Thus, the Life Nature and Biodiversity sub-programme will continue to fund nature conservation projects, in particular in the areas of biodiversity, habitats and species. It will support projects that contribute to the implementation of the EU Birds and Habitats directives, and in particular the development and management of the Natura 2000 network, and the IAS Regulation, and will support achieving the objectives of the EU's biodiversity strategy for 2030, part of the EU Green Deal.

EUROPEAN TOPIC CENTRE ON BIODIVERSITY AND ECOSYSTEMS (ETC BE)

The European Topic Centre on Biodiversity and Ecosystems (ETC BE) is a consortium of 24 organisations supporting the EEA in biodiversity and ecosystem assessment. Active under a 2023–2026 partnership agreement, it provides critical data and analysis to inform EU biodiversity policies such as the Biodiversity Strategy for 2030, the Farm to Fork Strategy, and the Zero Pollution Action Plan. Its contributions include monitoring frameworks, systemic assessments of biodiversity loss and ecosystem pressures, and detailed technical reports addressing societal challenges to conservation.

For Belgium, ETC BE's insights help address pressures like urbanisation, industrial activities, and intensive agriculture, which threaten the country's ecosystems. The Centre's data and frameworks enable Cerac to assess biodiversity risks and prioritise areas for restoration, ensuring local actions align with broader European trends and targets. Its systemic assessments are particularly valuable for Cerac's risk analysis, offering a holistic understanding of biodiversity and ecosystem threats at both national and international levels.

KNOWLEDGE CENTRE FOR BIODIVERSITY (KCBD)

The Knowledge Centre for Biodiversity[50], part of the European Commission's Joint Research Centre (JRC), consolidates scientific knowledge on biodiversity, supporting strategic planning and EU targets such as the 2030 Biodiversity Strategy. Using tools like the Copernicus Earth Observation Programme, the CORINE Land Cover dataset, and *in-situ* data, it provides high-quality assessments of ecosystem health, land-use changes, and ecosystem services. In Belgium, KCBD data, enriched by local contributions from organisations like INBO, enable detailed

([50]) But see also the Eklipse initiative: "Eklipse was established in 2016 to help governments, institutions, businesses and NGOs make better-informed decisions when it comes to biodiversity in Europe".

analyses of challenges such as habitat fragmentation and support policy development for sustainable land and ecosystem management.

BIODIVERSITY INFORMATION SYSTEM FOR EUROPE (BISE)

Biodiversity Information System for Europe (BISE) integrates biodiversity data, policies, and tools to support EU conservation efforts. Established by the European Commission and EEA, it aligns with the EU Biodiversity Strategy for 2030, providing insights into protected areas, ecosystem health, and biodiversity pressures like urbanisation and pollution. Interactive tools, such as GIS-based mapping, help identify biodiversity hotspots and ecosystem service risks.

Biodiversity Information System for Europe's tools and indicators are crucial for Cerac to track biodiversity trends and environmental pressures in Belgium, such as urban sprawl and pollution impacts. Its ecosystem assessments and mapping capabilities help identify biodiversity hotspots and prioritise interventions. By aligning its initiatives with EU directives accessed through BISE, Cerac ensures compliance and enhances collaboration opportunities with other Member States for transboundary conservation projects.

4.6.3. Current state of biodiversity loss mitigation in Belgium

Belgium has made significant strides in addressing biodiversity loss, leveraging national, regional, and EU-level frameworks to develop comprehensive mitigation strategies. However, the country faces persistent challenges, particularly in translating policy objectives into tangible conservation outcomes.

One cornerstone of Belgium's biodiversity strategy is its alignment with the EU Biodiversity Strategy for 2030. In Belgium via the Updated Belgian National Biodiversity Strategy for 2030, protected areas cover a substantial proportion of its territory, around 15% for Natura 2000 sites (Table 3). Yet, challenges remain in effectively managing these areas to ensure connectivity and functionality for biodiversity conservation (EEA, 2023)[51].

The Belgian Biodiversity Platform is a key initiative that supports efforts to reverse biodiversity loss by providing a collaborative framework for research, policy, and practice in Belgium. It serves as a national focal point for biodiversity knowledge, connecting scientists, policymakers, and other stakeholders to foster evidence-based decision-making. Through its comprehensive data-sharing platforms, thematic networks, and involvement in global biodiversity initiatives like GBIF and IPBES, the Platform enhances Belgium's capacity to address biodiversity challenges. By aligning national actions with international strategies, it contributes to the development of innovative, science-driven solutions for biodiversity conservation.

The Belgian Biodiversity Alliance (BBA) brings together public and private Belgian stakeholders supporting national, European and global biodiversity objectives. The alliance defined a series of 10 objectives that are key to biodiversity issues in Belgium. Those were defined around 2 main axes :1) the first axe is about expanding the green-blue network and 2) the second axe intends to reach net-positive Belgian production and consumption. Each objective is precisely quantified and is set to be achieved by 2030. To achieve the targets, any public or private actor is invited to register their action(s) linked to one or more objectives through an online form, which will be later published upon approval of the BBA secretariat.

More precisely, at the federal level, the BiodiversiScape programme seeks to embed biodiversity considerations into every aspect of land and infrastructure development. Its ambition is to move beyond isolated measures, such as green roofs or ponds, by establishing technical guidelines and practical actions that can be widely adopted. Initially

([51]) The priorities for Natura 2000 are to (*i*) bring current habitats and living areas into good condition, (*ii*) achieve additional surface areas or conservation objectives, (*iii*) control external environmental pressures, and (*iv*) establish appropriate and functional connections on a landscape scale. Connectivity between Natura 2000 areas should be ensured and maintained through other measures and instruments.

led by federal agencies, the initiative ultimately aims to engage developers, the private sector and non-federal land managers. BiodiversiScape encourages a wide range of practical measures that both restore and enhance biodiversity while improving landscapes, such as:

- Water features – Creating ponds or watering holes, swales (noues/wadi's) with native riverbank plants or native flower meadows for wetlands, infiltration zones to provide essential microhabitats for amphibians, reptiles, insects, birds, and wildlife; infiltration into the soil regulates excess water;
- Forestry and hedges – Planting native trees, sustaining diverse forests, and establishing mixed hedges to reduce soil erosion, enhance habitats and connect ecological corridors;
- Wildlife passages – – Countering land fragmentation through fishways and smaller-scale interventions, such as amphibian crossings or passages for small wildlife (*e.g.*, hedgehogs – *Erinaceus europaeus* Linnaeus, 1758);
- Natural regeneration – Allowing natural processes to unfold by leaving areas fallow, retaining dead trees, or enabling colonisation by new indigenous plant species;
- Pollinator support – Planting flower meadows and creating habitats for bees, butterflies, bats and other pollinators;
- Diverse green spaces – Reducing maintenance costs and boosting ecological value by planting varied species and vegetation layers; and
- Sustainable management – Replacing chemicals with natural alternatives (*e.g.*, mulching, grazing), avoiding invasive species, and carefully managing banks and ditches. Late mowing, as recommended by the "No Mow May" initiative[52], allows plants to continue growing at a crucial time when pollinators need to feed to fulfil their role;

This programme also recognises the importance of integrating biodiversity into urban areas, through *ad hoc* measures like:

- Campaigns allowing pollinators to thrive, such as the "No Mow May" initiative;
- Green roofs and façades transform buildings into ecological assets, cooling urban areas, filtering pollutants and providing shelter for birds and insects;
- Bird-friendly design reduces fatalities from window collisions through blinds, screens or less reflective glass;
- Urban habitats such as balcony gardens, fruit trees, animal shelters and small green zones attract birds, bats and small mammals; and
- Greening car parks, footpaths and leisure areas with porous paving, flower strips or hedges both enhances biodiversity and reduces water run-off.

A key tenet of the BiodiversiScape programme regarding sustainable construction and renovation is embedding biodiversity into all stages of the process. This includes assessing existing ecological value, preserving or enhancing habitats, and maximising opportunities for flora and fauna at building, district and city levels. The overall aim of this programme is to demonstrate that biodiversity can be protected and promoted through both large-scale strategies and small, everyday actions. By making these measures part of mainstream planning, design and maintenance, the initiative seeks to build greener, more resilient landscapes and urban spaces where nature and people coexist.

Bebiodiversity[53] is another Belgian Federal strategy initiated by the Directorate-General Environment of the Belgian FPS Health, Food Chain Safety and Environment. The objective is three-fold: 1) raise awareness in the general public, businesses and public authorities about biodiversity preservation; 2) mobilise entrepreneurs and consumers towards more biodiversity-friendly consumption and 3) set an example in terms of integrating biodiversity.

([52]) More information is available here.
([53]) Home - Understanding Biodiversity Issues in Danger | BeBiodiversity

Private sector involvement is exemplified by BeeOdiversity, which leverages bee ecosystems to monitor biodiversity and pollution while offering nature-based solutions for businesses. Their EU-supported projects showcase the potential of AI for predictive analytics in environmental management. Together, these initiatives underscore Belgium's commitment to fostering collaboration, innovation, and data-driven approaches in preserving its biodiversity.

Finally, innovative citizen science with platforms like Waarnemingen.be / Observations.be empower individuals to contribute data on species distribution and environmental changes, which are critical for monitoring biodiversity trends and addressing challenges such as invasive species.

FLANDERS

The large-scale SIGMA was designed mainly to (*i*) protect Flanders from flooding, (*ii*) "boost valuable river nature", and develop (*iii*) recreational activities on and along the water and (*iv*) river's accessibility for inland navigation. This plan is implemented both by De Vlaamse Waterweg nv and ANB. Giving the Scheldt and its tributaries more space provides an unique opportunity for their ecosystems to be restored. More generally, it gives nature a solid boost and helps to realise some of the EU conservation objectives.

Every year, species protection programmes are established in Flanders by the Minister of the Environment. The binding measures in such a programme ensure that one or more endangered species in Flanders can recover. These are European or Flemish protected species. A species protection programme is created in consultation with all stakeholders and has a term of 5 years and can be extended if necessary. At the moment of drafting this report, 27 species protection programmes are running.

Pollution mitigation efforts have also seen progress, with Belgium implementing stricter nitrogen emission standards for agriculture under its Nitrogen Action Plan. Through the "Flemish Programmatic Approach to Nitrogen"[54] the Government of Flanders is implementing general and (area-)specific measures to limit the harmful impact of nitrogen in the air on people's health and the environment. These specific measures consider the location of businesses close to European protected Habitats Directive areas or Special Protection Areas[55] and their impact on nature. The Department of Environment, together with policy experts from other entities, reports on the progress of the various nitrogen measures of the PAS and the Nitrogen Decree in an annual progress report. However, challenges persist in balancing agricultural productivity with ecosystem health. Maes et al. (2016) emphasise that nitrogen deposition remains a significant threat to sensitive habitats, such as heathlands and forests, highlighting the need for more targeted interventions.

At the time of writing the current report, the Government of Flanders is working on a new Blue Deal: an ambitious and coherent vision that will better equip Flanders to cope with the consequences of climate change. Drought, flooding, and water quality are increasingly challenging. This Blue Deal aims to provide a robust response to these challenges, even though the funds available for its implementation are still under discussion.

The Flemish Action Plan Wild Pollinators (active from 01/10/21 till 31/12/29)[56] is an initiative to combat the decline of wild pollinators, such as bees and hoverflies. The plan contains 37 concrete actions aimed at conserving and restoring existing wild pollinator populations.

Under the Updated Belgian National Biodiversity Strategy for 2030 which outlines key priorities, including habitat restoration, sustainable land-use practices, and species protection. initiatives to restore wetlands, such as the Zwin Nature Park in Flanders, were realized to rehabilitate critical habitats for migratory birds and other species.

([54]) "Programmatische Aanpak Stikstof" commonly abbreviated to PAS.
([55]) SPA-H; European Habitats Directive.
([56]) This project is active from 1 October 2021 until 31 December 2029.

Additionally, the Government of Flanders has implemented Eco-Accounts, a tool designed to offset biodiversity loss from development projects by financing conservation measures elsewhere (Torfs, 2024).

WALLONIA

In Wallonia, tools like Forestimator provide advanced cartographic resources for managing Walloon forest ecosystems, supporting sustainable practices and informed decision-making.

THE BELGIAN PART OF THE NORTH SEA

In the Belgian Part of the North Sea, the Belreefs project aims at restoring oyster reef once abundant in this part of the sea. The project is commissioned by the Marine Environment Department of the FPS Health, Food Chain Safety and Environment. Oyster reefs provide crucial habitats for other marine organisms, and also provide a series of ecosystem services such as water purification, nitrogen fixation, and seabed protection. The project reached a significant milestone this year (2025) with the installation of 200,000 young oysters surrounding an old shipwreck at 30 kilometres off the Belgian coast.

4.6.4. Neighbouring countries initiatives for biodiversity loss mitigation of possible relevance for Belgian stakeholders

Belgium's neighbouring countries, the Netherlands, France, Germany, and Luxembourg, have also developed diverse and innovative strategies to address biodiversity loss. These initiatives often integrate biodiversity conservation with broader environmental and socio-economic goals, such as climate adaptation, water management, and local governance. By examining these initiatives, Belgium can identify practical solutions and best practices to enhance its conservation framework and align with European biodiversity targets.

THE NETHERLANDS: INTEGRATING BIODIVERSITY INTO WATER MANAGEMENT

The Netherlands exemplifies how biodiversity conservation can be effectively integrated with water management strategies. The Room for the River Programme addresses flood risks while simultaneously restoring ecological functions in floodplains. This initiative reallocates space for rivers to expand during high water levels, reducing flood risks for urban areas while creating habitats for wetland species. Areas such as the Waal River corridor have seen significant ecological improvements, with increased species richness in riparian zones and restored hydrological connectivity (Scholten et al., 2019).

Complementing this, the Delta Nature Framework focuses on the ecological restoration of estuarine ecosystems in the Dutch delta. This initiative has led to the recovery of salt marshes and tidal flats, which are crucial habitats for migratory birds and estuarine fish species. The combination of these programmes underscores the Netherlands' ability to balance ecological integrity with water management.

The Nationaal Dashboard Biodiversiteit (National Biodiversity Dashboard) further supports these efforts by providing a centralised platform to monitor biodiversity trends. By aggregating data on species distributions, ecosystem health, and human activities, the dashboard facilitates evidence-based policymaking and ensures transparency in conservation outcomes (Dutch Ministry of Agriculture, Nature, and Food Quality, 2023).[57]

([57]) But see also:

- *Methods for analyses* and *Exploring biodiversity risks for the Dutch financial sector* from the joint milestone study Indebted to nature published in June 2020 by De Nederlandsche Bank (DNB) and the Planbureau voor de Leefomgeving (PBL) Netherlands Environmental Assessment Agency; as well as
- *Climate Risks in the Netherlands – Current status*, published in May 2024 by the PBL and available in Dutch here.

Figure 15: Nationaal Dashboard Biodiversiteit (National Biodiversity Dashboard).

FRANCE: ENHANCING CONNECTIVITY AND CLIMATE ADAPTATION

France's biodiversity initiatives emphasise ecological connectivity and resilience to climate change. The Trame Verte et Bleue (Green and Blue Infrastructure) initiative addresses habitat fragmentation by creating ecological corridors that connect fragmented landscapes. This network facilitates species movement across agricultural and urban areas, ensuring genetic flow and reducing the risk of local extinctions. The programme is particularly relevant for Belgium, where dense urbanisation and infrastructure development have severely fragmented natural habitats.

In response to climate challenges, France has developed the Climessences Platform, a tool that integrates climate projections into biodiversity planning. It offers localised data on climate impacts, enabling targeted conservation actions to safeguard vulnerable species and habitats. For instance, forest managers use Climessences to identify tree species resilient to future climate conditions, guiding reforestation efforts that enhance both biodiversity and ecosystem services.

Additionally, the Observatoire des Forêts Françaises (French Forest Observatory) provides a comprehensive understanding of forest health and biodiversity. By monitoring the effects of climate change, pollution, and land-use changes, this initiative informs sustainable forest management practices, ensuring the resilience of forest ecosystems. Such monitoring frameworks could serve as a model for Belgium's forest conservation efforts, particularly in the Ardennes region.

GERMANY: NATIONAL-LEVEL STRATEGIES FOR BIODIVERSITY

Germany's National Strategy on Biological Diversity (NBS) takes a holistic approach to biodiversity conservation by integrating it into various sectors, including agriculture, forestry, and urban planning. The strategy emphasises the restoration of degraded ecosystems and promotes sustainable resource use. This cross-sectoral integration ensures that biodiversity considerations are embedded within broader economic and social policies, offering a blueprint for Belgium to mainstream biodiversity goals across governance levels.

The Insect Protection Action Plan exemplifies targeted efforts to address specific biodiversity challenges. By reducing pesticide use, restoring flower-rich habitats, and promoting organic farming, the plan tackles the alarming decline of insect populations, particularly pollinators (BMUV, 2019). Pollinators are essential for agricultural productivity

and ecosystem health, and similar initiatives could significantly benefit Belgium's agricultural sector, which faces pollinator shortages due to habitat loss and pesticide overuse.

LUXEMBOURG: LOCALISED BIODIVERSITY EFFORTS

Luxembourg's Nature Pact demonstrates the potential of municipal-level engagement in biodiversity conservation. This initiative incentivises local governments to implement conservation actions, such as restoring green spaces, managing invasive species, and promoting biodiversity-friendly urban planning. Financial and technical support from the national government ensures that municipalities have the resources to execute effective conservation projects.

The Monitoring and Evaluation Programme complements these efforts by tracking biodiversity trends, habitat conditions, and ecosystem services. By emphasising collaboration among researchers, policymakers, and NGOs, the programme fosters data sharing and adaptive management, providing a model for Belgium to enhance its monitoring systems and integrate local and national conservation efforts.

KEY LESSONS FROM NEIGHBOURS

1. Integrated Approaches
   Initiatives like the Room for the River and Delta Nature Framework highlight the value of integrating biodiversity conservation with water management. Belgium can apply similar strategies to enhance ecological resilience along its major river systems, such as the Scheldt[58] and Meuse.
2. Connectivity Solutions
   France's Trame Verte et Bleue demonstrates the importance of creating ecological corridors to address habitat fragmentation. This approach is particularly relevant for Belgium's fragmented landscapes, offering opportunities to reconnect ecosystems across urban and agricultural areas.
3. Data-Driven Policy
   The Nationaal Dashboard Biodiversiteit and Luxembourg's monitoring frameworks underscore the necessity of centralised, data-driven tools for tracking biodiversity trends and evaluating conservation impacts. Based on existing regional initiatives[59], and considering the specific institutional characteristics of our country, such initiatives could prove inspiring for Belgium.
4. Sectoral Integration
   Germany's National Strategy on Biological Diversity shows the benefits of embedding biodiversity goals into broader policy frameworks. This cross-sectoral approach could help Belgium align biodiversity objectives with agricultural, urban, and possibly some forestry policies.
5. Climate Adaptation
   Tools like Climessences provide a roadmap for incorporating climate projections into biodiversity planning. This could inspire improvements to initiatives already underway in Belgium and help to enhance its preparedness for the risks to biodiversity caused by climate change.
6. Local Engagement
   Luxembourg's Nature Pact highlights the importance of engaging municipalities in biodiversity conservation. Once again, based on existing initiatives *e.g.* at the regional level[60], the relevance of replicating this model at the national level could be analysed. For example, this would strengthen the capacities of local governments and communities, thereby ensuring that conservation efforts are both inclusive and effective.

([58]) But see *e.g.*, the already existing Sigma Plan for the Scheldt and its tributaries.
([59]) See *e.g.*, for Flanders: Natuurindicatoren.be and statistiek-vlaanderen/statistieken.
([60]) As an illustration, almost every municipality in Flanders is part of a Regional Landscape, with an understanding of the region's unique features and a robust local network.

CONCLUSION

Various and sometimes innovative initiatives in the field of biodiversity have been developed by neighbouring countries. The work carried out by the Planbureau voor de Leefomgeving and De Nederlandsche Bank is a striking example of this[61], being particularly remarkable. Although much has already been successfully achieved in Belgium, some of these initiatives could still be relevant.

5. Is monitoring biodiversity through national forest inventories a good model?

Forests are ideal ecosystems for biodiversity monitoring due to their ecological, economic, and cultural significance. Covering nearly a quarter of Belgium's landscape, forests are home to diverse species, often harbouring unique biodiversity both within their interiors and along their edges with other ecosystems. They provide crucial ecosystem services, including water cycling, soil conservation, and climate regulation, which span all major categories of ecosystem services. Decades of scientific monitoring have produced extensive datasets on forest composition, structural dynamics, and associated environmental conditions, making forests well-documented and valuable reference ecosystems for biodiversity assessments. This established body of data and research, particularly in Europe, underscores the potential of forests as a focus for biodiversity monitoring, despite the evolving threats they face.

Forests host high levels of biodiversity, sometimes very specific, both within those ecosystems and at their interfaces with other ecosystems. Their health is strongly interlinked with ecosystem services, they provide diverse and critical services (*e.g.*, water cycling and filtration, soil conservation, heat regulation, *etc*.) that belong to provisioning, cultural, regulating and maintenance/supporting ecosystem services and is also of great importance in climate regulation through carbon sequestration (Marín et al., 2021; Pretzsch et al., 2023).

Ette et al. (2023) emphasise that forest inventories, due to the number of forest parameters they comprise, have the potential to overcome data deficits for biodiversity monitoring, even on large spatial scales. This idea is also supported by Borghi et al. (2023), according to whom, the robust sampling protocols behind National Forest Inventories (NFI's) provide important information regarding ecological forest monitoring. NFI's data have usually been collected for several decades and relate to the composition (and stage of development) of plant species, their structure and, in some cases, other environmental parameters such as soil type, slope, or presence of wetlands.

Global datasets such as those provided by the Global Forest Biodiversity Initiative (GFBI) offer a strong spatial representation of forest biodiversity but are less comprehensive in terms of temporal coverage (Shen et al., 2024).

([61]) But see also the analysis carried out by Giglio et al. (2023).The authors investigate the effects of physical and regulatory risks related to biodiversity loss on US economic activity and asset values.

While initiatives like the International Cooperative Programme (ICP) offer valuable long-term monitoring of forest conditions across temporal and spatial dimensions (Michel et al., 2024). Led by the FAO, the ongoing Global Forest Resources Assessment (also known as "FRA 2025"), "*examines the status of, and trends in, more than 60 forest-related variables in 236 countries and territories in the period 1990–2025. FRA 2025 data are collected using commonly agreed terms and definitions and guidelines through a transparent, traceable reporting process and a well-established network of officially nominated national correspondents that covers 191 countries and territories*".

In Belgium, forest inventories are the responsibilities of the regions, respectively managed for Flanders and Wallonia by the ANB and the Département de la Nature et des Forêts (DNF), respectively. The data from the respective inventories serve as the basis for the FAO FRA 2025 mentioned above. The first regional inventory developed by the Walloon Region laid the groundwork of forest inventories in Belgium, especially for key elements like sampling design and essential variables to measure. Consequently, notable similarities can be observed among the three regions, allowing for generally reliable estimates of the significance and evolution of Belgian forests over time (Rondeux et al., 2010).

In Flanders, Van Loy et al. (2003) conceived a scoring system to assess and monitor the status of biodiversity-related aspects based on Flemish Forest inventory data. Relying on a selected number of forests characteristics, they developed an "authenticity index" as a measure of potential biodiversity. To better meet policy demands and international reporting obligations, Wouters et al. (2008) developed a design and manual for the second inventory. Some important adjustments have been made to the sampling scheme, the choice of the variables and the sampling methodology.

Significant adjustments have also gradually been made over time to the methodology of the "Inventaire permanent des ressources forestières de Wallonie." These adjustments have focused on *e.g.* measuring the herbs and shrubs in the understory, assessing the volume and condition of deadwood, and determining both location and frequency of the re-census.

Nevertheless, using forest inventories to robustly assess some of the elements of biodiversity would require expanding the scope of their applications. Harmonising reporting methods across Belgian regions, where appropriate, could also be beneficial to achieve this goal. Regardless of certain criticisms that may be levelled at them by some stakeholders[62], these regional inventories have the undeniable advantage of already being in place and fully operational. They are also implemented by highly qualified staff who are particularly committed to their work, not to say devoted.

Could these inventories' basic principles serve as a blueprint for monitoring the biodiversity of grasslands, rivers, and coastal and marine ecosystems over time?

([62]) *E.g.*, some economic stakeholders have questioned the reliability of certain forecasts based on data from these inventories. They have highlighted the small number of survey points covered each year compared to the dynamic evolution of forest stands.

6. Conclusions

Biodiversity loss is a critical challenge, intricately linked to ecological, economic, social, and health dimensions. This pre-analysis identifies the methodologies used to assess biodiversity and its trends, and the gaps and challenges linked to these methodologies. It also highlights the efforts made in developing indicators dedicated to informing and promoting decision-making processes.

For assessing the risks on society posed by biodiversity loss, the literature showed that the current preferred approach is related to assessing ecosystem services. This approach efficiently bridges the gap between nature and society and embodies the concepts of supply and demand. Another approach is to consider threshold indices values, as exemplified by the planetary boundary concept. The threshold approach focuses on achieving a global state of nature that must be maintained to stay within planetary boundaries, whereas the ecosystem services approach is more tailored to meet society's economic needs, taking supply and demand into account, but with the risk of neglecting essential aspects of nature.

By going through the literature, it appears clear that the risk caused by biodiversity loss is location-specific. Therefore, the assessment should include a spatial dimension, since the likelihood of a physical hazard to occur depends on the site's specific conditions and vulnerability to the given hazard. Risk level is determined by the interplay of physical hazard probability, vulnerability and exposure.

When it comes to assessing and mapping the risks associated with biodiversity loss and ecosystem services decline, the report presents pioneering works done by *e.g*. the WWF (Biodiversity Risk Filter) and the United Nations Environment Programme World Conservation and the Natural Capital Finance Alliance (ENCORE tool).

This report also identifies the key drivers of biodiversity loss in Belgium, including habitat fragmentation, nitrogen deposition, invasive species, and climate change, while emphasising the importance of addressing these threats through targeted and harmonised efforts. Our findings also highlight the interconnectedness of biodiversity with societal well-being, ecosystem resilience, and national economic stability.

Finally, Belgian's biodiversity knowledge landscape is strongly shaped by regional institutions and, but to a lesser extent, non-governmental organisations (NGOs). Regions have autonomy in developing their own monitoring schemes but are, in parallel, required to implement European Directives and report progress towards international commitments. On the national scale, the Biodiversity platform plays a crucial role as it (*i*) brings together biodiversity experts from across the country, and (*ii*) serves as national focal point for several flagship international organisations (including IUCN, IPBES).

Belgium has ownership in:

- Collecting field data (realised by regional institutions, NGOs or citizens):
    - Forests inventories,
    - Keystone or indicator species monitoring,
    - Occurrence data for tracking species distribution,
    - Ecosystem health data;
- Collecting aerial photos or LiDAR data (realised by the Regions).

Belgium depends on:

- International agreements – it must report on specific species (*e.g.*, European protected species);
- Remote sensing programmes (EU Copernicus Earth Observation Programme, NASA Modis, Landsat, *etc.*) for the collection of some satellite data;
- The development of internationally used and comparable biodiversity indicators.

METHODOLOGIES AND DATA INTEGRATION: THE ACCURACY OF FIELD DATA

Biodiversity metrics are the building blocks of biodiversity knowledge. Ground-sourced measurements are often involved, which provide detailed insights into biodiversity in a specific area. Efforts to fill taxonomic gaps, particularly for underrepresented groups like invertebrates and microorganisms, will be critical for generating reliable and actionable assessments.

- Area specific: provides information at local levels, where most ecosystem-specific knowledge and data reside;
- Species abundance is costly to collect but occurrence data, which is more easily available, can be used as a proxy for abundance;
- In some cases, monitoring abundance efforts can be funnelled to keystone or indicator species;
- Opposite trends may be noted depending on the scale of observation (time or space);
- There are two main ways used to assess biodiversity: per species for an entire territory or per group of species present in a specific habitat;
- Greater spatial coverage and common temporal resolution is needed to monitor biodiversity, mainly in the case of species capable of moving over distances exceeding *e.g.* regional limits (some birds, certain ungulates, *etc.*).

THE POWER OF REMOTE-SENSING...

The numerous advantages of remote sensing (such as analysing vegetation health and height and detecting ecosystems fragmentation and urban expansion into ecologically sensitive areas, to name but three) have been known and well described for several decades. Artificial intelligence and deep learning methods are now also routinely applied to this type of image. However, when it comes to biodiversity, there are still a few areas that would require further investigation.

- Remote sensing provides a relevant tool for large-scale standardised data and robust temporal coverage;
- There is a knowledge gap on how to transpose remote sensing measurements into biodiversity metrics;
- Satellites images are currently mostly used for forests monitoring or characterisation purposes. The relevance of using spaceborne LiDAR in deciduous forest stands for height monitoring over time should be assessed;
- If combining satellite and field data to evaluate natural capital metrics linked to ecosystem services is well known, its relevance could be further explored for specific parts of biodiversity, such as underground biodiversity.

... COMBINED WITH FIELD DATA

To fully capture the intricacies of biodiversity, ecosystems, and their evolution over time, satellite data can be supplemented with *in situ* monitoring. Field data from national and regional agencies[63] can be integrated into analysis. This ensures that remote observations are validated and provide a nuanced understanding of ecosystem health. In Belgium, entities like ANB, INBO, DNF and Brussels Environment contribute critically to field data collection and processing – often together with universities and/or research centres.

- Essential Biodiversity Variables, identified by GEO BON, integrate ground-sourced and remotely sensed data, facilitating standardised biodiversity assessments and cross-country comparisons.

([63]) Including species occurrence records, habitat condition reports, and environmental quality assessments.

BRINGING TOGETHER DATA IN THE DEVELOPPEMENT OF INDICATORS

A major priority identified by this analysis is the need to agree on common metrics and indices for assessing the state of biodiversity. These should encompass genetic, species, and ecosystem diversity to capture the complexity of biodiversity changes. There is a rapidly evolving landscape of tools, metrics and frameworks applied to business and financials' impacts and dependencies on biodiversity.

- Recent international agreements such as the KM-GBF and European Directives and Regulations on biodiversity have accentuated the need of finding common ways of measuring/monitoring biodiversity, assess the progress towards the objectives and evaluate the effectiveness of restauration over time and space[64];
- Indicators for functional and structural biodiversity, providing information about the health of ecosystems, are currently mainly developed for forest and water managements;
- Effective biodiversity monitoring and loss mitigation require data at a common spatial scale, such as watersheds, habitats, or biogeographic regions;
- Aggregating or transposing data to standardised scales will enhance comparability and support more cohesive conservation strategies;
- Harmonising temporal grains in biodiversity assessments will enable better tracking of trends over time and improve the predictive power of models;
- New development of possible interest in the Belgian context: the Sustainable Ecology and Economic Development (SEED) framework consolidates the multiple dimensions of biodiversity (genetic, species and ecosystems) across various taxa (plants, animals and microbial) into a single measure of biocomplexity at every location.

THE ECOSYSTEM SERVICES APPROACH

The ecosystem services framework is the most practical and tangible approach for evaluating the impact of biodiversity loss on society. This concept provides a structured way to assess the value of biodiversity in providing services such as provisioning, regulation, culture, and support. The ecosystem approach considers the bigger picture of the state of nature than the biodiversity approach does. For these reasons, the ecosystem services approach is preferable for assessing the risks to Belgium associated with human- and/or climate-induced changes. However, the relationships between biodiversity, ecosystem functioning, and certain services are not always well understood.

- Broadly speaking, a paradigm shift is needed in the way we conventionally value nature;
- Some indicators do not quantify the role of ecosystems for regulation and maintenance services but rather indicates the pressure on ecosystems, their conditions or the impacts certain activities may cause on ecosystems;
- In Wallonia, the "Matrice des capacités des écosystèmes à fournir des services" which indicates the capacity of ecosystems to provide specific services is based on experts personal opinion, it is not based on quantitative data;
- Some key-aspects of biodiversity should be assessed to understand their impacts on the delivery of ecosystem services;
- Functional diversity, *i.e*. the number of functional groups in an ecosystem, is linked to the productivity of ecosystems;
- At the EU level, the MAES working group had developed a framework for assessing ecosystem services.

(64) This is a decision of the Conference of Parties of the CBD.

STATE OF BIODIVERSITY IN BELGIUM

Belgium's diverse yet vulnerable ecosystems are under constant pressure from urbanisation, industrial activities, and agricultural practices. The Living Planet Report Belgium (WWF, 2020) constituted an unprecedented effort to assess the state of biodiversity at the national level. The report focuses on the state and evolution of vertebrate species biodiversity in Belgium for the period 1990-2018. It concludes that species specific to wetlands and natural open environments have experienced a modest average increase in their populations. In contrast, species inhabiting agricultural areas have suffered a dramatic decline, with forest species (particularly birds) also facing notable, though less severe, reductions.

- In Belgium, species in agricultural environment suffer the greatest decline in biodiversity;
- The ordinary biodiversity (*i.e.*, more common species) is not well monitored in Belgium;
- Including microbes and invertebrates is crucial for evaluating biodiversity. Many microorganisms that play an important role in supporting and regulating ecosystem services are under-monitored. This is especially true for soil ecosystems;
- Of all the species found in Belgium, protection is primarily focused on vertebrates (*cf*. Living Planet Report Belgium, 2020) and the European protected species (Habitats/Birds/Water Framework Directives);
- Some keystone species are well monitored (*e.g.*, LifeWatch sensor networks), while some other groups are largely overlooked (see *e.g.*, most terrestrial and aquatic micro-organisms).

The note, prepared by the National Strategy for Biodiversity working group, outlines the importance of revision of the Belgian Strategy for Biodiversity[65] in order to meet international objectives to which Belgium is committed (CFDD, 2024). The working group points out the lack of a robust framework for integrating biodiversity data generated across the different administrative levels within the country. Because biodiversity conservation is a regional competence, the achievement of international targets in Belgium depends heavily on coordination between the regions (CFDD, 2024).

SOCIETAL IMPACTS OF BIODIVERSITY LOSS AND RELATED RISKS

Understanding how biodiversity loss affects the Belgian society is a key focus for ongoing research. Understanding the impact of biodiversity loss on Belgian society is a priority area for current and future research. Due to the increasing likelihood that climate- and anthropogenically induced hazards will negatively impact biodiversity in Belgium[66], there is an urgent need to invest more in understanding the impact of biodiversity loss on our society. This includes, but is not limited to, analysing the risks to:

- Food sovereignty and related economic costs: declining biodiversity, in Belgium and countries involved in food trade with Belgium[67], threatens food production systems. This endangers crop diversity, soil health[68], and pollination services[69], all of which are essential to ensuring food security. This decline/loss also potentially disrupts other industries dependent on ecosystem services, such as the water supply and management sector[70], increasing operational risks and costs;

- Social equilibrium: ecosystem degradation can exacerbate social inequalities, as vulnerable communities are disproportionately affected by biodiversity loss and reduced access to natural resources;

([65]) See also the Updated Belgian National Biodiversity Strategy for 2030, published in April 2025.
([66]) As evidenced by the increasing risks posed by wildfires.
([67]) Risk to strategic imports due to biodiversity loss.
([68]) Risks to soil ecosystems due to climate hazards and human-induced factors/drivers.
([69]) Risk to food production due to pollinator decline.
([70]) Risk to industry from water stress due to biodiversity loss.

- Health and well-being: biodiversity underpins essential ecosystem services, such as air and water purification, which are directly linked to public health[71] and quality of life;
- Resilience to climate events: ecosystem degradation reduces resilience to extreme climate events, such as flooding, droughts, and storms, increasing societal vulnerability.

7. Next steps

This work identified a series of possible next steps to enhance understanding of the state and evolution of biodiversity in Belgium, as well as the potential impact of its decline on Belgian society.

BRINGING TOGETHER DATA IN THE DEVELOPPEMENT OF INDICATORS

If deemed appropriate and in line with Belgium's diversity, particularly at the institutional level, our country could prioritise the creation of a comprehensive database of biodiversity data from all Regions. Harmonising methodologies and integrating Belgium's data into global platforms such as GBIF and GEO BON would enhance monitoring efforts and inform conservation strategies.

Aligning Belgium's biodiversity strategy with international frameworks provides an opportunity to scale up conservation efforts. Collaborative initiatives with neighbouring countries, leveraging their best practices and innovative approaches when relevant, can further strengthen Belgium's biodiversity governance.

MAPPING AND DOWNSCALING BIODIVERSITY INDICATORS TO A LOCAL SCALE

Downscaling of the SEED biocomplexity index/the EBVs/the Biodiversity Intactness Index at a common relevant spatial unit (watershed/ecosystem/ecotope/habitat) for the Belgian territory will allow to gain insights on the spatial distribution of biodiversity loss and intensity.

The update of the LPI for Belgium can also provide meaningful insight on the rate of decline and can be used as input for mapping purposes.

MAPPING THE RISKS LINKED TO BIODIVERSITY LOSS

The varied biodiversity measurements (field and remote sensing measurements, indicators, and frameworks) and the difficulty of "capturing" biodiversity due to its multiple dimensions (ecosystems, species, genetics, *etc*.) make assessing biodiversity loss risks challenging. Those risks are clearly linked to the specific characteristics of each location, and risk assessment tools have been developed for the private sector (*e.g.*, the WWF Biodiversity Risk Filter). Having said that, considering the stage of knowledge and methodology on the topic, but also the fact that some of the numerous existing initiatives remain poorly coordinated, a map showing where the highest risks linked to the decline of biodiversity (a biodiversity loss risk map) is still seen as far-fetched. As already partially shown at the regional level, the assessment of ecosystem services (or habitats' vulnerability), linked to georeferenced data on ecosystems, may already provide an idea of where the main threats are located.

There is a geographical mismatch between ecosystem services declines and the associated risks to society. Ecosystem services are declining where nature is most present, and the associated physical hazards occur in nature-

([71]) Risk to human health due to biodiversity loss.

rich areas. The greatest vulnerability and exposure to the physical hazards are in densely populated areas, as well as in nature-poor areas which are, namely, the cities.

THE ECOSYSTEM SERVICES APPROACH

The ecosystem approach to assessing the risks posed by biodiversity loss (as proposed for Flanders by Stevens et al., 2015) seems to be a good way forward. It is important to identify biodiversity metrics that are crucial to assess key ecosystem services in Belgium. Additionally, it is worth continuing to investigate the question "how does biodiversity loss affects Belgian society", from various aspects such as:

- Economic costs (functioning of industries that depends on the availabilities of environmental goods such as water, pollination, *etc.*);
- Social equilibrium (in what extend can it exacerbate social inequalities?);
- Health and well-being;
- Resilience to extreme climate events (floodings, storm, drought, *etc.*);
- Food sovereignty.

In Flanders, VITO takes part in several Natural Capital Accounting (NCA) projects to quantify the value of ecosystems. A pilot project also took place in Flanders initiated by the Vlaams Planbureau voor Omgeving. The study explores the possibilities of applying NCA in Flanders with a number of pilot accounts for the years 2013 and 2016 (De Nocker et al., 2020).

THE CASE OF INVASIVE ALIEN SPECIES (IAS)

This topic has been deliberately left out of the scope of this work for the reasons given at the beginning of the report. Nevertheless, we know that research and close monitoring of IAS are important, among other reasons, due to the financial risks that these species pose to society. But it is also important because IAS can introduce additional undesirable species (*i.e*. unnoticed and unintentionally), which can lead to further damage (*e.g*., a pest outbreak). Additionally, it is important to note that spatial analysis is highly relevant in the IAS field, as the DIARS project has pointed out. Biodiversity loss can promote or accelerate biological invasions. In such a scenario, invasive species benefit from biodiversity loss. Conversely, biodiversity loss can be induced by biological invasions. Note that these scenarios do not necessarily lead to a decline in all services initially provided by the affected ecosystem. For example, soil cover and protection against erosion may not be affected or may even be enhanced.

We therefore recommend carrying out an IAS-specific risk assessment, for instance, on their impact on Belgian key infrastructures[72].

BELOWGROUND BIODIVERSITY

Studies such as those by Dasgupta & Levin (2023) and OECD (2023) at a larger scale, and by Stevens et al. (2015) in the specific Belgian context, have all concluded that very little is known about microorganisms in general and soil organisms more specifically. According to OECD (2023), a degraded soil biodiversity contributes to lower yields, reduced nutritional quality and greater disaster risk, while Dasgupta & Levin (2023) stress that *"without these diverse species[73] playing different roles, the soils would fail to support the global food system".* But the research on this very topic remains scarce, especially in Belgium.

Given (*i*) this lack of research on the topic, (*ii*) our limited resources and (*iii*) the objectives we were pursuing, it was not possible to gather enough technical or scientific studies on soil biodiversity in the Belgian context. While this

([72]) Engineering structures, roads, railway lines, waterways, buildings, *etc.*
([73]) *E.g.*, Archaea, bacteria and fungi.

result does not suggest that such literature is unavailable, this situation confirms that this aspect of biodiversity tends to attract less interest than others. Nevertheless, as stated above, this belowground biodiversity is widely recognised as being fundamental to the proper functioning of most of our ecosystems, playing a crucial transversal role[74]. We therefore believe that the risk to Belgium posed by the loss of soil biodiversity should be the subject of an in-depth analysis.

THE BIODIVERSITY AND SECURITY NEXUS FOR BELGIUM

A large number of studies were, and still are, conducted at a global level (see *e.g.*, Whitaker et al., 2025) and in some of our neighbouring countries to investigate the relationship between climate and security[75]. The inspiring work carried out by the German Federal Intelligence Service[76] and its partners is a prime example of this. In their report, these authors explain that it is expected that "Biodiversity will shrink, and plants will be increasingly susceptible to insect pests, leading to failures in agriculture and forestry". NATO, of which our country is a member, is also investing increasingly in analysing the effects of climate change on the effectiveness of military equipment[77]. However, these analyses rarely focus on biodiversity loss. At best, it is given only marginal attention. What about Belgium?

Apart from in the context of food security, this pre-analysis has not identified any research that examines the relationship between biodiversity loss (or the disruption/decline of ecosystem services) and national security in Belgium. Nevertheless, the climate-security nexus deserves to be fully investigated in the Belgian context, considering potential cascading effects on biodiversity and/or ecosystem services and subsequent collateral damage on our security.

([74]) "Soils, rich in biodiversity and vital for ecosystem function regulation, are highly vulnerable to these pressures, affecting nutrient cycling, soil fertility, and resilience. Soil also crucially regulates climate, influencing energy, water cycles, and carbon storage." (Eisenhauer et al., 2024)
([75]) The climate and security nexus refers to the implications of climate change (and environmental degradation) on security and defence: "As temperature records soar and extreme weather events increase worldwide, we are witnessing a simultaneous shift in the global political landscape: New and old conflicts have been flaring up, interstate war has returned, while other, long-standing violent conflicts and civil wars continue to rage." (Rothe et al., 2025)
([76]) Bundesnachrichtendienst (BND).
([77]) Visit *e.g.*, NATO - Topic: Environment, climate change and security or https://www.nato.int/nato_static_fl2014/assets/pdf/2024/7/pdf/240709-Climate-Security-Impact.pdf

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9. Appendix

9.1. Extract of biodiversity data in Belgium

Belgium has a rich tapestry of biodiversity data, which are divided between the federal and regional levels. Based on a consensus among all the authorities involved, the federal government takes the lead on international agreements and broad policy frameworks, and it is competent *e.g.* for environmental matters in the marine areas under Belgian jurisdiction (the "Belgian part of the North Sea") military domains and railway embankments. Regions - Flanders, Brussels and Wallonia - manage most data collection, habitat protection, and policy development and implementation within their territories. This regional focus can lead to data compatibility issues, but initiatives like the Belgian Biodiversity Platform and collaboration efforts by the RBINS are promoting data standardisation and national integration for a more comprehensive picture of Belgian biodiversity. The table below presents an overview of some of the existing datasets related to biodiversity in Belgium. Note that this is not an exhaustive list.

Table 4: Non-exhaustive list of existing biodiversity-related datasets in Belgium.

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Species distribution map	RBINS	Belgian Species List	Online reference in naming and occurrence of ~32,000 animals, plants and fungi species in Belgium. For every species, information is given, among others, over: - Conservation status - Distribution - Habitat - *etc*. Belgian Species List - Dataset - Belgian biodiversity data portal	GBIF: http://www.gbif.org/dataset/39653f3e-8d6b-4a94-a202-859359c164c5 Belgian species list website Belgian Species |Royal Belgian Institute of Natural Sciences (bmdc.be)	Yes, occurrence	Belgium	-

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Species distribution map + species population trend	EEA	CDR Species report	Collection arranged under the relevant reporting obligations and agreement Annex of the Habitats Directive by biogeographical and marine regions Main results of the surveillance under Article 11 for Annex II, IV & V species Information for two biogeographical areas (CONT, ATL), only for 85 species? - Conservation status - Population abundance - Habitat - Main pressures/threats ranking - Natura2000 coverage & conservation measures	Factsheet (europa.eu)	Yes, occurrence	Belgium	- 2001-2012 - 1988-2012
Ecological requirements of species	LifeWatch Belgium	GPS bird tracking network	Data on the migration behaviour and habitat use of medium to large-sized birds	Movebank GBIF	-	-	-

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Ecological requirements of species	LifeWatch Belgium	Fish tracking	Marine and freshwater fish tracking using acoustic telemetry gathering data on migration routes, the effects of anthropogenic barriers and habitat selection. The database stores both the occurrences and the metadata.	Data gathered in Belgium are stored in a central PostgreSQL database. An interactive online web interface, developed in PHP using Symfony framework gives access to all occurrences and metadata stored and analysed in the European Tracking Network (ETN) database and published on GBIF and OBIS. ETN - European tracking network (lifewatch.be)	Yes	Europe; Belgium	-
Species distribution map + species population trend + ecosystem health data	LifeWatch Belgium	Bats data	Monitoring the presence of bats along the Belgian coast on a long-term basis. Bats are an important indicator species for the wellbeing and functioning of the ecosystem. Changes in bat population are linked to an alteration in biodiversity.	Motus Wildlife Tracking System	-	World; Belgian coast	-

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Species distribution map + species population trend + ecosystem health data	LifeWatch Belgium	Plankton data	Plankton are often used as indicators of (marine) ecosystem health and as early warning systems of change and are consequently required to be monitored by legislative directives, like the Marine Strategy Framework Directive (MSFD).	Index of /lifewatch/	Yes	Belgian part of the North Sea	
Species distribution map + species population trend + ecosystem health data	LifeWatch Belgium	Shells & Molluscs	Shells and molluscs are good indicators of changes in the ecosystem. Their occurrence and abundance reflect changes in shallow marine waters caused by climate change (…).	SeaWatch-B citizen science program through the annual Big Seashell Surveys SEAWATCH-B | Strandobservatienetwerk	-	Belgian coast	Since 2014
Ecosystem health data	LifeWatch Belgium	Environmental monitoring	-	-	-	-	-
Species distribution map + Species population trends	LifeWatch Belgium	Terrestrial mammals	Data captured from a camera trap network on the abundance, distribution, behaviour and temporal activity of medium-to-large mammals.	Data are stored and analysed in Agouti, and data is formatted into the data exchange format "Camtrap DP (tdwg.org)". Observations are exported to GBIF.	-	World; Belgium	Since 2017

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Species distribution map	LifeWatch Belgium	Marine mammals (underwater acoustics)	Marine mammals are at the top of the marine food web; they are an indicator of ecosystem health.	All data gathered and metadata are stored in a central PostgreSQL database hosted by VLIZ. The online data repository "underwater acoustics" is part of the European Tracking Network. Data can be visualised, explored and downloaded using the Rshiny application Data explorer LifeWatch Data Explorer and the LifeWatch Data R package.	-	-	Since 2018
Habitat maps	LifeWatch Belgium	Ecotopes	Geographic datacube providing information about: - Ecotope content - Individual variables (topography, land cover, soil depth, temperature, precipitation, snow dynamics, marginal soil proportions, soil drainage, height, spatial context, other climatic variables) - Variable combinations	LifeWatch-FWB: UCL - Geomatics	Yes	Belgium	2015
						Wallonia	2006;2010;2015;2018;2022

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Satellite data for biodiversity loss	LifeWatch Belgium	LC biodiversity variables	Geographic datacube providing information about: - Greenness (NDVI, start and end of vegetation period, length of the peak period, anomalies) - Snow - Fire - Sun	LifeWatch-FWB: UCL - Geomatics	Yes	Europe	1999 - 2021
Species distribution map + species population trend	LifeWatch Belgium	Habitat models	Abundance/distribution models for: - Birds - Vegetation - Butterflies - Plants	LifeWatch-FWB: UCL - Geomatics	Yes	Wallonia	2006 - 2015
Habitat maps	EEA	European Ecosystem Map	Ecosystem type (EUNIS level 2 classification) derived from CORINE Land Cover and additional spatially explicit European datasets	Ecosystem types of Europe (europa.eu)	Yes	Europe; Belgium	-
Biodiversity loss risk map	NGI	Top10Vector – Soil Cover and Vegetation	Top10Vector – Land cover and vegetation is the vector data set of the land use of unbuilt land areas in Belgium. This data set includes three classes. First class: dry and unbuilt areas or areas not used as roads. Second class: hedges. Third class: linear vegetation. This data set can be bought via the corresponding hyperlink.	geo.be | Top10Vector – Soil cover and vegetation	Yes	Belgium	2017

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Satellite data for biodiversity loss	NGI	CORINE High Resolution Layers – Belgium 2012	This product contains 6 raster layers 20 x 20 m grid.): - Forest types - Grassland - Imperviousness - Permanent water bodies - Tree cover density - Wetlands The product is in the form a raster	geo.be | CORINE High Resolution Layers - Belgium 2012	Yes	Europe; Belgium	2012
Satellite data for biodiversity loss	NGI	CORINE High Resolution Layers – Belgium 2015	This product contains 5 raster layers (20 x 20 m grid): - Dominant leaf type - Grassland - Imperviousness - Tree cover density - Wetness and water	geo.be | CORINE High Resolution Layers-Belgium 2015	Yes	Europe; Belgium	2015
Satellite data for biodiversity loss	NGI	CORINE Land Cover-2012-Belgium	Polygonal layer representing the land cover in Belgium for the year 2006 and 2012. The polygons are spread over 32 classes from the CORINE Land Cover legend. The minimum map unit is 25 ha, and the conceptual scale is 1:100,000. The data set also contains a polygon layer showing changes of more than 5 ha n the land cover 2006 and 2012.	geo.be | CORINE Land Cover-2012-Belgium	Yes	Europe; Belgium	2012
Satellite data for biodiversity loss	NGI	CORINE Land Cover-2018-Belgium	Polygonal layer representing the land cover in Belgium for the year 2012 and 2018. The polygons are spread over 32 classes from the CORINE Land Cover legend. The minimum map unit is 25 ha, and the conceptual scale is 1:100,000. The data set also contains a polygon layer showing changes of more than 5 ha n the land cover 2012 and 2018.	geo.be | CORINE Land Cover-2018-Belgium	Yes	Europe; Belgium	2012; 2018

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Biodiversity Loss Risk Map	NGI	Riparian Zones	Riparian zones represent transitional areas occurring between land and freshwater ecosystems, characterised by distinctive hydrology, soil and biotic conditions and strongly influenced by the stream water. They provide a wide range of riparian functions (*e.g.*, chemical filtration, flood control, bank stabilisation, aquatic life and riparian wildlife support, *etc.*) and ecosystem services. Two complementary product groups provide detailed information on the state and characteristics of riparian zones across Belgium: 1. Land Cover / Land Use (LCLU) 2. Green Linear Elements (GLE)	geo.be | Riparian Zones https://land.copernicus.eu/en/products/riparian-zones	Yes	Europe; Belgium	2012
Biodiversity Loss Risk Map	NGI	Natura 2000	Natura 2000 (N2K) is a network of core breeding and resting sites for rare and threatened species, as well as for some rare natural habitat types which are protected in their own right. This dataset contains the sites in Belgium.	geo.be | Natura2000 Belgium https://www.eea.europa.eu/en/datahub/datahubitem-view/6fc8ad2d-195d-40f4-bdec-576e7d1268e4 (European dataset)	Yes	Europe; Belgium	2012
Tree species distribution map	Mauri et al (2017)	Tree occurrence dataset	Harmonised tree (~200 species) distribution datasets at species and genus levels, involving 19 EU Member States (including Belgium), INSPIRE-compliant 1 km² grid	A high-resolution pan-European tree occurrence dataset (figshare.com)	Yes	Europe; Belgium	-

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Ecosystem health data	ICP Forests	Forest condition dataset (Level I)	Comprehensive compilation of information on the condition of forests in Europe and beyond ICP Forests monitors forest condition at two monitoring intensity levels: The **Level I** monitoring is based on 5706 observation plots (as at 2023) on a systematic transnational grid of 16 x 16 km throughout Europe and beyond to gain insight into the geographic and temporal variations in forest condition. The **Level II** intensive monitoring comprises 640 plots (as at 2022) in selected forest ecosystems with the aim to clarify cause-effect relationships. At present 42 countries in Europe and beyond participate in ICP Forests. All data are available upon request.	Monitoring and Research; Michel et al. (2024)	Yes	Europe	-
Tree species distribution map	San-Miguel-Ayanz et al. (2016) from the Joint Research Centre (European Commission)	European atlas of forest tree species	Data from National Forest Inventories		Yes	Europe	

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Forest inventory data	SPW – DGO3 – Département de la Nature et des Forêts – Direction des Ressources Forestières – Cellule Inventaire Permanent des Ressources Forestières de Wallonie	Inventaire Permanent des Ressources Forestières de Wallonie (IPRFW)	Récoltes de données en continu	L'IPRFW, une précieuse source d'informations (wallonie.be)	Yes	Wallonia	Since 1994
Species distribution map + Species population trends	Citizen-based	Observations.be	Global biodiversity platform for citizen science and monitoring developed in The Netherlands. Through a mobile app, users can add observations on fauna and flora, including information such as: - Date (mandatory) - Time - Species (mandatory) - Number of individuals The location is extracted if the uploaded photo is geo-localised. The partners for Belgium are Natuurpunt (Flanders), Natagora (Wallonia). The initial developer is Naturalis en Zostera (NL).	Welcome - Observations.be	Yes	World; Belgium	Since 2004

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Protected areas	Biodiversity Indicators Partnership - Bird Life	"Protected Aera Coverage of Key Biodiversity Areas'	Protected areas are delineated locations that are recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. Key Biodiversity Areas (KBAs) are sites that contribute to the global persistence of biodiversity, of which 18,000 have been identified on land and at sea. This indicator shows trends over time in the degree to which KBAs are covered by protected areas.	Biodiversity Indicators Partnership (bipindicators.net)	Yes	World	-
Protected areas[78]	Agentschap Natuur & Bos	Natuurgebieden	Natural zones in Flanders, shown as points on a map.	ANB Belevingssite Map (natuurenbos.be)	Yes	Flanders	-

([78]) But see also protected areas reported to the EU, available here; as well as the Special Protection Zones ("Speciale beschermingszones") of the Natura 2000 network.

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Forest inventory	Agentschap Natuur & Bos	Vlaamse Bosinventaris (VBI)	Dataset with: - Forest surface; - Tree species; - Forest type; - Biodiversity (essence, authenticity index, function diversity, invasive species, deadwood; - Vulnerability (Ellenberg index); - Sustainable management and conservation; Measuring network of 1 x 0,5 km First assessment campaign (1997-1999) – VBI1 Second assessment campaign (2009-2018) – VBI2 Third assessment campaign (2019-2021) – VBI3 Regional inventories are held every 5 to 10 years. Fieldwork is realised two times a year (summer and winter)	The database can be provided by the Agentschap voor Natuur en Bos on demand. Bosinventaris | Agentschap voor Natuur en Bos Several links to scientific papers are mentioned on the webpage.	Yes	Flanders	Every 10 years
Protected areas	Agentschap Natuur & Bos	Vlaamse parken: Nationale parken Vlaanderen & Landscapsparken	There are 4 National Parcs in Flanders (which were selected in 2022): - Bosland - Brabantse Wouden - Hoge Kempe - Scheldevallei There are 5 Landscape Parcs in Flanders: - Zwinstreek - Vlaamse Ardennen - Hart van Haspengouw - Maasvallei Grenzeloss bocageland	-	Yes	Flanders	-

Data group	Data provider	Dataset name	Description of dataset	Source URL/Data infrastructure	Geographical component	Geographic scope	Date range
Species distribution map + abundance	Agentschap Natuur & Bos	Wolf in Vlaanderen	-	Distribution and abundance map is available to view here: De wolf in Vlaanderen | Agentschap voor Natuur en Bos	Yes	Flanders	-
	Agentschap Natuur & Bos	Patrijs (umbrella specie)	Standardised counting protocol since 2021 for partridges.	-	?	Flanders	-
	Agentschap Natuur & Bos	Vleermuizen in Vlaanderen	Information over bats species in Flanders	-	?	Flanders	-
Index	Institute for Forestry and Game Management	Authenticity index	Based on Flemish forest inventory data	Van Loy et al. (2003) Assessing and monitoring the status of biodiversity-related aspects in Flemish (inbo.be)	Yes	Flanders	2003
Correlation analysis	SPW	Fichier écologique des essences	*« Le Fichier écologique des essences est un outil d'aide à la décision pour déterminer l'adéquation essence/station au service des gestionnaires d'espaces forestiers et naturels. »*	Fichier écologique des essences (fichierecologique.be)	Yes	Wallonia	-

9.2. More biodiversity initiatives

9.2.1. The European Topic Centre on Biodiversity and Ecosystems (ETC BE)

The European Topic Centre on Biodiversity and Ecosystems (ETC BE) is a critical part of the EEA's support framework, consisting of a consortium of 24 organisations across Europe. This centre operates under a partnership agreement for the period 2023-2026 and is tasked with delivering accurate and actionable information on biodiversity and ecosystems. The data, research, and assessments produced by ETC BE are pivotal for informing and shaping EU policies and responses to biodiversity loss.

Key Contributions of ETC BE:

1. Support for Policy and Implementation ETC BE actively supports the development and implementation of key EU biodiversity policies, including the EU Biodiversity Strategy for 2030, the Farm to Fork Strategy, and the Zero Pollution Action Plan. By providing evidence-based insights, ETC BE ensures that these policies are well-grounded and aligned with the latest scientific knowledge. This collaboration enhances the effectiveness of initiatives aimed at halting biodiversity loss and restoring ecosystems.
2. Monitoring and Progress Assessment The centre has developed robust monitoring frameworks and assessment tools to measure the status of biodiversity and ecosystems across Europe. These tools are instrumental in tracking progress toward environmental goals set out in major policy frameworks, such as the European Green Deal and the 8th Environment Action Programme. Regular updates and indicators generated by ETC BE enable a comprehensive evaluation of ecosystem health and highlight where further action is needed.
3. Integrated Systemic Assessments ETC BE conducts in-depth assessments that consider cumulative pressures, climate change impacts, and socio-economic drivers affecting ecosystems. These systemic evaluations provide a holistic view of the challenges faced and are essential for crafting mitigation and adaptation strategies. By addressing the interconnections between biodiversity loss, climate change, and human activities, ETC BE's assessments support long-term, sustainable solutions.
4. Research and Technical Reports The centre has produced various reports that explore societal factors and systemic challenges related to biodiversity loss. For example, recent studies have focused on identifying societal enablers and barriers to reversing biodiversity decline. These reports serve as critical resources for policymakers and stakeholders, offering insights that can inform decision-making and policy design.

Specific Relevance to Belgium:

Belgium’s diverse yet vulnerable ecosystems are under constant pressure from urbanisation, industrial activities, and agricultural practices. European Topic Centre on Biodiversity and Ecosystems’ data and insights are particularly valuable for identifying key areas for conservation and restoration in Belgium. By situating local biodiversity data within a broader European context, ETC BE enables a more comprehensive understanding of regional and international biodiversity trends, which is crucial for coordinated and effective conservation strategies.

9.2.2. The Knowledge Centre for Biodiversity

The Knowledge Centre for Biodiversity of the European Commission serves as a pivotal hub for integrating, analysing, and disseminating scientific knowledge on biodiversity across Europe. As part of the Joint Research Centre (JRC), the KCBD’s sophisticated mapping and assessment efforts are essential for tracking biodiversity changes, understanding ecosystem services, and supporting strategic environmental planning. This report explores the KCBD’s

methodologies and data sources, highlighting their significance for biodiversity conservation and how they can be leveraged in Belgium, particularly by organisations like Cerac.

Knowledge Centre for Biodiversity's mission addresses the complexity of biodiversity loss, which demands a multi-faceted and science-based approach. Central to this mission is the provision of high-quality data and tools that empower stakeholders to develop policies and practices that are effective and aligned with the EU Biodiversity Strategy for 2030. This strategy sets ambitious goals to protect and restore ecosystems, and the KCBD plays a crucial role in supplying the necessary knowledge to achieve these targets.

Methodologies and Data Integration:

Knowledge Centre for Biodiversity's work is founded on a combination of high-resolution data and advanced scientific techniques. Remote sensing, particularly through the Copernicus Earth Observation Programme, provides consistent and up-to-date satellite imagery. This imagery allows the KCBD to monitor land cover changes, assess habitat loss, and observe human impacts on natural landscapes. For instance, Copernicus data have been instrumental in tracking deforestation, analysing vegetation health, and detecting urban expansion into ecologically sensitive areas (European Commission, 2023).

Yet, to fully capture the intricacies of Europe's ecosystems, the KCBD complements satellite data with *in-situ* monitoring. Field data from national and regional agencies, including species occurrence records, habitat condition reports, and environmental quality assessments, are integrated into the analysis. This ensures that remote observations are validated and provide a nuanced understanding of ecosystem health. In Belgium, organisations like the INBO contribute critical data, enriching the KCBD's assessments and making them highly reliable (EEA, 2023).

A cornerstone of the KCBD's mapping framework is the CORINE Land Cover dataset, which categorises land cover types across Europe. The CORINE Land Cover dataset is crucial for analysing land use changes, such as urbanisation and agricultural intensification, and their impact on biodiversity. By overlaying this data with biodiversity indicators, the KCBD can identify areas experiencing significant ecological stress. For example, the dataset has highlighted regions in Belgium where intensive agriculture has fragmented habitats, prompting discussions on sustainable land management practices (JRC, 2023).

Mapping Ecosystem Services:

In addition to physical mapping, the KCBD focuses on evaluating ecosystem services, which are categorised into provisioning, regulating, and cultural services. These services are vital for human well-being and environmental stability, and the KCBD's detailed assessments help quantify their value.

Provisioning services, such as food and freshwater, are mapped using agricultural yield data and hydrological models. In Belgium, where agriculture is a key economic sector, understanding the distribution of these services helps balance productivity with environmental conservation. Regulating services, like carbon sequestration and flood mitigation, are assessed through vegetation cover and soil carbon data. Knowledge Centre for Biodiversity's work has shown how forested areas in Belgium serve as critical carbon sinks, emphasising the need for their preservation. This information is essential for Cerac, which can use it to develop strategies that enhance climate resilience through nature-based solutions, such as reforestation and wetland restoration (JRC, 2023).

The Knowledge Centre for Biodiversity also evaluates cultural services by analysing recreational use of natural spaces and their socio-economic benefits. In densely populated areas like Belgium, where green spaces are limited yet crucial, mapping these services informs urban planning and promotes sustainable tourism. By leveraging this information, Cerac can engage local communities and advocate for policies that protect these valuable landscapes while enhancing public health and recreation (European Commission, 2023).

Indicators and Methodologies for Assessment:

A critical component of the KCBD's work is the development of indicators that provide insights into ecosystem health and the pressures they face. The Habitat Fragmentation Index is a prime example. It measures the extent of habitat disruption caused by infrastructure and urban sprawl, which is a significant concern in regions like Flanders. This index allows Cerac to identify where ecological corridors or green infrastructure are most needed, supporting efforts to reconnect fragmented landscapes and sustain biodiversity (EEA, 2023).

Another essential tool is the Biodiversity Intactness Index (BII), which quantifies the remaining biodiversity in a given area compared to its original state. By accounting for species population trends and habitat quality, the BII offers a comprehensive view of how human activities impact ecosystems. For Cerac, this index is crucial for assessing the ecological impact of environmental crises, such as industrial spills, and for measuring the success of remediation efforts. It provides a clear metric for prioritising conservation actions and ensuring that interventions yield tangible biodiversity gains (European Commission, 2023).

Knowledge Centre for Biodiversity also tracks environmental pressures through indicators that monitor urbanisation, pollution, and climate change. Data from the European Pollutant Release and Transfer Register (E-PRTR) help assess the effects of industrial emissions, while climate models predict the impact of warming temperatures on ecosystems. Climate Risk Assessment Centre can use these insights to address threats proactively, implementing strategies that minimise pollution and promote sustainable practices (JRC, 2023).

Potential Challenges and Limitations of KCBD Data and Tools

While the KCBD provides an invaluable suite of data and analytical tools for biodiversity assessment and environmental planning, there are inherent challenges and limitations that should be considered when applying these resources. Acknowledging these limitations is crucial for setting realistic expectations for Cerac and emphasising the need to supplement KCBD data with local information where necessary.

1. Data Resolution and Granularity: One of the primary challenges of using KCBD data lies in the resolution of satellite imagery and land cover datasets, such as those provided by the Copernicus Earth Observation Programme and the CORINE Land Cover dataset. While these data sources offer comprehensive coverage and are suitable for regional and national assessments, they may lack the fine-scale detail needed for site-specific analyses or localised projects. For example, planning precise conservation measures or urban green infrastructure in a densely developed city like Brussels may require higher-resolution data than what KCBD currently offers (European Commission, 2023).

2. Variability in Local Conditions: Biodiversity indicators and ecosystem service assessments developed by the KCBD are based on standardised methodologies that ensure consistency across Europe. However, these methodologies may not fully account for the unique environmental conditions, cultural practices, or socio-economic factors present in specific regions. In Belgium, for instance, the fragmented nature of habitats and the diverse landscape types across Wallonia and Flanders may necessitate additional calibration of KCBD indicators to ensure they accurately reflect local biodiversity dynamics (EEA, 2023).

3. Data Integration and Validation Needs: Effective environmental management often requires the integration of multiple data sources. While KCBD data provide a robust foundation, they are most effective when combined with local *in-situ* monitoring and field data. For example, species occurrence records and habitat quality assessments collected by Belgian research institutions like INBO can significantly enhance the accuracy and relevance of KCBD ecosystem models. This integration requires coordinated data-sharing efforts and collaboration between Cerac and local stakeholders, which can be resource-intensive and complex (JRC, 2023).

4. Temporal Limitations: Ecosystem and biodiversity data are continually evolving, and there may be time lags in updating datasets. This limitation can affect the timeliness of environmental assessments, particularly in dynamic landscapes where rapid land-use changes occur. For Cerac, it is essential to consider these temporal gaps and, where necessary, conduct supplementary field surveys or use additional real-time monitoring systems to ensure up-to-date information for decision-making.

5. Uncertainty in Predictive Models: The KCBD uses advanced predictive models, including machine learning, to forecast future ecosystem changes and assess potential impacts of environmental pressures. While these models are powerful tools for scenario planning, they are inherently uncertain due to the complexity of ecological systems and the unpredictability of human activities. Climate Risk Assessment Centre should interpret these model outputs with caution and consider using them as one of several decision-support tools rather than relying on them exclusively (European Commission, 2023).

Addressing the Limitations

To mitigate these challenges, Cerac can adopt a multi-faceted approach by:

- Supplementing KCBD Data: Integrating local, high-resolution datasets and *in-situ* monitoring results can improve the granularity and accuracy of assessments.
- Collaborating with Local Experts: Engaging with research institutions and local environmental agencies can help calibrate KCBD indicators to reflect regional biodiversity patterns more accurately.
- Continuous Data Validation: Establishing ongoing data validation and monitoring processes ensures that assessments remain current and reliable.

By acknowledging and addressing these limitations, Cerac can maximise the utility of KCBD resources while ensuring that environmental strategies are both effective and locally relevant.

9.2.3. The Biodiversity Information System for Europe (BISE)

The Knowledge Centre for Biodiversity of the European Commission serves as a pivotal hub for integrating, The BISE stands as a cornerstone of Europe's efforts to consolidate, analyse, and disseminate biodiversity information. Established through a collaboration between the European Commission and the EEA, BISE serves as an integrated gateway to a wealth of data and resources that underpin biodiversity conservation and ecosystem management. Its purpose is to facilitate the implementation of the EU's biodiversity strategies, streamline reporting, and support informed decision-making across the continent.

Biodiversity Information System for Europe is not merely a data repository, but a comprehensive platform designed to guide stakeholders through the complexities of biodiversity policies, assessments, and scientific research. The system's structure reflects its mission to serve a diverse audience, including policymakers, researchers, and environmental organisations, by providing access to a wide array of data, indicators, and strategic guidance.

Structure and Core Functions

At the heart of BISE is a robust integration of information on European biodiversity policies and strategies. The platform is deeply aligned with the EU Biodiversity Strategy for 2030, which sets ambitious goals to halt biodiversity loss and restore ecosystems. Users of BISE can explore legislative frameworks, such as the Habitats and Birds Directives, gaining a comprehensive understanding of the legal foundations for biodiversity conservation in Europe. This policy-centric aspect of BISE is invaluable for aligning conservation initiatives with EU priorities and ensuring compliance with environmental legislation.

Equally important is BISE's extensive collection of biodiversity data and indicators. These resources cover a range of topics, including the status of species and habitats, the extent of protected areas, and the pressures impacting biodiversity, such as pollution and land use change. Indicators available on BISE are essential for monitoring trends and measuring progress toward EU biodiversity targets. For example, metrics on ecosystem health and conservation status help stakeholders assess the effectiveness of policies and pinpoint areas requiring urgent intervention.

The system also excels in delivering ecosystem assessments and mapping tools. Biodiversity Information System for Europe provides a holistic view of ecosystem health, highlighting how various ecosystems function and the services they provide to society. These assessments are crucial for understanding the benefits of ecosystems, such as pollination, water purification, and carbon sequestration, and for informing sustainable land-use planning. Interactive maps allow users to visualise biodiversity data spatially, making it easier to identify areas that are biodiversity hotspots or those facing significant environmental pressures.

A key aspect of BISE is its emphasis on knowledge sharing and collaboration. The platform functions as a repository of research findings, case studies, and best practices, facilitating the exchange of innovative approaches across EU Member States. By showcasing successful conservation projects and lessons learned, BISE helps build capacity and fosters the replication of effective biodiversity management strategies. This collaborative spirit enhances Europe's ability to address biodiversity challenges cohesively and efficiently.

Another critical function of BISE is its role in supporting reporting and monitoring. The platform aids Member States in fulfilling their obligations under various biodiversity-related directives by providing standardised tools for data collection and reporting. This harmonised approach ensures consistency in biodiversity monitoring across Europe and contributes to a unified effort in meeting global conservation targets, such as those set by the CBD.

Methodologies and Data Integration

Biodiversity Information System for Europe stands out for its integration of diverse data sources, using both cutting-edge technology and field-based monitoring. High-resolution satellite imagery from programmes like Copernicus is used to track land cover changes and assess habitat loss. These data are combined with *in-situ* monitoring from national agencies, which adds accuracy and context to the assessments. For example, species occurrence records and habitat quality data collected across Europe are essential for validating remote sensing observations.

The platform also employs Geographic Information System (GIS) technology to visualise data, enabling stakeholders to explore spatial patterns of biodiversity. This integration of remote sensing and field data provides a comprehensive view of ecosystem dynamics, from terrestrial to marine environments. The use of GIS not only facilitates data analysis but also enhances the ability to develop evidence-based policies and conservation strategies.

Challenges and Limitations

Despite its numerous strengths, BISE does come with certain challenges and limitations. One of the most notable issues is the resolution of the data. While BISE provides extensive coverage suitable for regional and national assessments, the data may not be detailed enough for highly localised projects. For example, in densely developed areas or regions with complex land-use patterns, organisations like Cerac may need to supplement BISE data with higher-resolution, site-specific datasets to ensure precise environmental assessments.

Another challenge lies in the standardisation of methodologies. Biodiversity Information System for Europe employs standardised approaches to ensure consistency across Europe, but these may not fully account for the unique environmental conditions of specific regions. In Belgium, for instance, the fragmented nature of habitats and varied landscape types across Wallonia and Flanders might require additional calibration of BISE indicators to reflect local biodiversity more accurately.

Furthermore, there are gaps in data coverage and updates. While BISE aims to provide comprehensive and timely information, some datasets may have delays in updates or gaps in coverage, particularly in areas where ecosystems are changing rapidly. For effective risk management, Cerac might need to conduct supplementary field surveys or utilise additional data sources to keep their assessments current.

Lastly, integrating BISE data with local monitoring efforts can be resource intensive. Effective use of BISE data often requires collaboration among multiple stakeholders and the establishment of robust data-sharing mechanisms, which can be complex to coordinate. However, these efforts are crucial for achieving a holistic and accurate understanding of biodiversity.

Practical Applications for Cerac

For Cerac, the wealth of information and tools provided by BISE offers numerous opportunities to enhance biodiversity monitoring and environmental risk management in Belgium. The platform's comprehensive policy information can help Cerac ensure that its conservation strategies are aligned with EU directives, such as the Habitats and Birds Directives. This alignment not only facilitates compliance but also enhances Cerac's capacity to secure EU funding and collaborate on transboundary conservation projects.

Biodiversity Information System for Europe's ecosystem assessments and mapping tools are particularly valuable for identifying priority areas for conservation and tracking environmental pressures. For instance, Cerac can use spatial data from BISE to pinpoint biodiversity hotspots or regions where ecosystem services are at risk. This information is critical for planning nature-based solutions, such as wetland restoration or the creation of ecological corridors, which are essential for climate adaptation and biodiversity enhancement.

Moreover, BISE's indicators on urbanisation, pollution, and climate change provide a foundation for developing targeted risk management strategies. By understanding the spatial distribution of environmental pressures, Cerac

can implement proactive measures to mitigate these threats. For example, data on urban heat islands and flood-prone areas can inform the design of green infrastructure projects that simultaneously improve biodiversity and increase urban resilience.

To maximise the benefits of BISE, Cerac should also consider integrating these resources with local datasets and collaborating with Belgian research institutions like INBO. This complementary approach ensures that assessments are both comprehensive and locally relevant, ultimately supporting more effective environmental management.

9.2.4. WWF Biodiversity Risk Filter

The Biodiversity Risk Filter is a tool developed by the WWF to help companies and investors prioritise action for enhancing business resilience regarding risks linked to the loss of biodiversity. The tool is composed of 4 modules:

1) Inform: Biodiversity dependencies and impacts for industries;
2) Explore: spatial distribution of indicators assessing biodiversity health. They make use of 33 different indicators, which include:
    - Diversity and intactness of ecosystems,
    - Diversity and abundance of species and genes, and
    - Provision of ecosystem services;
3) Assess: biodiversity-related business risk, both physical and reputational (regulatory risks will be added in the future);
4) Respond: Mitigate biodiversity risks and enhance resilience - Coming soon!

The tool combines both the impact and dependencies of certain sectors on biodiversity. This is done by merging geospatial data on the state of biodiversity and ecosystem services and other relevant data on biodiversity. So far, the tool is based on 50 datasets spanning the entire planet. The tool allows to give a response plan that is location-specific: where they are exposed to the highest risk and what are the factors driving these risks. This enables to prioritise the required further investigations or actions.

The tool allows the user to register georeferenced sites and generate maps for these areas. For example, it gives the number of sites per risk category. Risk categories are defined as follows:

1) Provisioning services;
2) Regulating & supporting services – enabling;
3) Regulating services – mitigating;
4) Cultural services;
5) Pressures on biodiversity;
6) Environmental factors;
7) Socioeconomic factors;
8) Additional reputational factors.

Those categories are broken down into several indicators. For example, provisioning services encapsulate water scarcity, limited timber availability, limited wild flora & fauna availability, limited marine fish availability. Regulating & supporting services are indicated by soil condition, water condition, air condition, ecosystem condition, pollination, *etc*., each indicator is given a risk score. The risk score can either be linked to the dependency of business (regarding what their business relies on) on biodiversity or the reputational risk which is linked to the negative effect a business can have on biodiversity.

The methodology is described in the WWF Biodiversity Risk Filter: methodology documentation (2022).

"The risk hierarchy consists of the following four levels:

- *Level 4: metrics, comprises the raw global data sets that measure different aspects of biodiversity and ecosystems in a specific location [...];*
- *Level 3: indicators […];*
- *Level 2: risk categories […];*
- *Level 1: risk types […]."*

The explore module (exploring biodiversity importance and integrity) informs about the level 3 risk hierarchy – indicators. Indicators are produced from the raw data sets (56 global datasets) which is processed in two ways:

1) Alignment of spatial scales

"The datasets use a variety of spatial scales and data needs to be spatially aggregated or transposed to a common scale. For terrestrial areas, the WWF BRF follows the WWF WRF assessment unit to the level of HydroSHED Level 7 (Lehner & Grill, 2013) as this represents a degree of functional coherence at a biodiversity-level."

2) Translation of raw data to risk score classes

"The data sets provide data in a variety of different units. So, the raw data was translated into the five risk score classes (i.e., given a value from 1 to 5). This normalisation process allows for easy comparison between indicators and allows indicators to be aggregated with others."

"It should be noted that the WWF BRF is based on the best available data sets. While data sets are updated on a regular basis, the WWF BRF is not intended to provide an assessment of real-time biodiversity-related risk conditions."

For more information on what were the metrics used and how those were aggregated into indicators, refer to those documents:

- WWF (2024) WWF Biodiversity Risk Filter Summary of Indicators & Metrics version 2.0, October 2024;
- WWF (2024) WWF Biodiversity Risk Filter Indicator Documentation version 2.0, October 2024.

9.2.5. More about PREDICTS

Scientists behind the PREDICTS project (Phillips et al., 2021) argue that biodiversity indicators should encompass multiple taxonomic groups in order to give a representative picture of the state of nature (from the NHM website, PREDICTS page, 2024). Whereas most biodiversity indicators are usually focused on a single taxonomic group.

This database (including species abundance data and distribution) allows the researcher to calculate various measures of biodiversity such as the total number of species (species richness) and the compositional similarity, defined on the PREDICTS website page as *"how similar each site's ecological community is to near-undisturbed sites".*

Combining models of abundance and compositional similarity allowed researchers behind the PREDICTS projects to develop a biodiversity indicator called the "Biodiversity Intactness Index" which shows an estimated percentage of the original number of species that remain and their abundance in any given area.

Statistical analysis of the data from the PREDICTS database relies on "mixed-effects" models to account for variations in data structure, sampling techniques and sampled species.

"PREDICTS pulls together species abundance data from studies around the world. These studies cover a broad range of taxa, including plants, fungi, invertebrates and vertebrates, to model how human activities impact biodiversity.

"Over 500 researchers contributed their raw biodiversity data to the PREDICTS database that can be downloaded from the Museum's data portal. This data set is now taxonomically and geographically extensive and fairly representative. This data set is openly available for anyone to use.

The PREDICTS database holds data from across all major terrestrial animal, plant and fungal groups. The database contains over 2% of all species named by science, with good coverage across most major groups.

Most of the data in the PREDICTS database are from arthropods, particularly insects, which is appropriate as insects are the most species known to science.

Most of the rest of the data are from plants, especially vascular plants (tracheophytes); this reflects their high diversity (over 400,000 species, many times more than the number of terrestrial vertebrate species) and crucial role as the base of food chains.

Vertebrates are over-represented relative to their diversity, but this bias is much reduced compared with other global data sets and indicators. We don't have as many data sets on fungi and non-arthropod invertebrates as we would like, but they are at least represented."

9.3. The Cerac-NGI cooperation agreement in brief

In 2022, a cooperation agreement between the Directorate-General for the Environment of the FPS Health, Food Chain Safety and Environment and the NGI on geographical information, within the framework of the establishment of the OCAD Climate (now Cerac), was established. This agreement defines the cooperation sought by the Directorate-General for the Environment and NGI in preparation for the establishment of the Cerac and provides a framework for the geo-information-related missions carried out by the NGI for this centre.

The analysis began in August 2024 and was supposed to be completed by December 2024, as outlined in the agreement. But to ensure the quality of the document and incorporate subsequent comments from various experts, Cerac and NGI have decided to extend their collaboration beyond the agreed-upon end date to finalise this report.

An initial offer of services from the NGI was made in April 2023 to the Cerac with the aim of identifying the needed geospatial information regarding risks linked to climate and biodiversity. One of the deliverables was a document entitled "Identification of Geospatial Information needed for Biodiversity Loss Assessment", which was delivered in April 2024. It gave a first and high-level overview of the Geospatial Information needed and available within Belgium related to biodiversity.

A second offer was made in July 2024 to pursue collaboration between the Cerac and NGI regarding biodiversity and climate risks. Under this agreement the subjects "Biodiversity loss" and "Wildfires" were investigated. This document focuses on the first theme and presents the results of the Cerac and NGI experiences, literature review, interviews/knowledge exchange sessions specifically on biodiversity in Belgium and abroad[79]. Initial guidelines were formulated by the Cerac to tackle the subject and were constantly redefined during weekly consultations between the two parties.

([79]) Findings useful for assessing the risks associated with wildfires are presented in a separate document accessible online here.

9.4. Acronyms and Abbreviations

Acronym	Full name
ANB	Agentschap Natuur & Bos
AwAC	Agence Wallonne de l'Air et du Climat
BBA	Belgian Biodiversity Alliance
BCRA	Belgian Climate Risk Assessment
BELSPO	Belgian Science Policy Office
BeRMS	Belgian Register of Marine Species
BII	Biodiversity Intactness Index
BILBI	Biogeographic modelling Infrastructure for Large-scaled Biodiversity Indicators
BISE	Biodiversity Information System for Europe
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CERAC	Climate Risk Assessment Center
CERBC	Board of Environment of the Brussels-Capital region
CFDD	General Federal Assembly for Sustainable Development
CICES	Common International Classification of Ecosystem Services
CORINE	Coordination of Information on the Environment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DG	Directorate General
DNB	De Nederlandsche Bank (The Netherlands)
DNF	Département de la Nature et des Forêts
EEA	European Environment Agency
EBVs	Essential Biodiversity Variables
EMBRC	European Marine Biological Resource Centre
EMO BON	European Marine Omics Biodiversity Observation Network
ENCORE	Exploring Natural Capital Opportunities, Risks and Exposure
ERIC	European Research Infrastructure Consortium
ETC BE	European Topic Centre on Biodiversity and Ecosystems
ETN	European Tracking Network
EU	European Union
EU BON	European Biodiversity Observation Network
FPS	Federal Public Service
FWB	Fédération Wallonie-Bruxelles
GBF	Global Biodiversity Framework
GBIF	Global Biodiversity Information Facility
GEO BON	Group on Earth Observations Biodiversity Observation Network
GFBI	Global Forest Biodiversity Initiative
GIS	Geographic Information System
GxABT	Gembloux Agro-Bio Tech
IBAT	Integrated Biodiversity Assessment Tool

ICESat-2	Ice, Cloud, and land Elevation Satellite-2
ICP	International Cooperative Programme
ILVO	Instituut voor Landbouw-, Visserij- en Voedingsonderzoek
INBO	Instituut voor Natuur en Bosonderzoek
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPRFW	Inventaire Permanent des Ressources Forestières de Wallonie
IRS	Indian Remote Sensing
IUCN	International Union for Conservation of Nature
IVON	Integraal Verwevings- en Ondersteunend Netwerk
JRC	Joint Research Centre
KBA	Key Biodiversity Areas
KCBD	Knowledge Centre for Biodiversity
KM-GBF	Kunming-Montreal Global Biodiversity Framework
LIDAR	Light Detection And Ranging
LPI	Living Planet Index
MAES	Mapping and Assessment of Ecosystems and their Services
MEA	Millennium Ecosystem Assessment
MODIS	Moderate Resolution Imaging Spectroradiometer
MSFD	Marine Strategy Framework Directive
MSI	Multispecies index
MUMM	Management Unit of the Mathematical Model of the North Sea
NASA	National Aeronautics and Space Administration
NASA EO-1	National Aeronautics and Space Administration Earth Observing-1
NBS	National Biodiversity Strategy
NCA	Natural Capital Accounting
NDVI	Normalised Difference Vegetation Index
NGI	National Geographic Institute
NGO	Non-Governmental Agency
PAS	Programmatische Aanpak Stikstof
PBL	Planbureau voor de Leefomgeving (The Netherlands)
PREDICTS	Projecting Responses of Ecological Diversity In Changing Terrestrial Systems
RADAR	Radio Detection And Ranging
RBINS	Royal Belgian Institute of Natural Sciences
REA	Flanders Regional Ecosystem Assessment
SAR	Synthetic-Aperture Radar
SAC	Special Areas of Conservations
SCI	Sites of Community Importance
SEEA	System of Environmental Economic Accounting
SEED	Sustainable Ecology and Economic Development
SPA	Special Protection Areas
SPOT	Satellite pour l'Observation de la Terre
SPW	Service Public de Wallonie

SPW ARNE	Service Public de Wallonie, pôle Agriculture, Ressources naturelles et Environnement
SUMES	Sustainable Marine Ecosystem Services
UCL	Université Catholique de Louvain
ULiège	Université de Liège
UN	United Nations
UNEP	United Nations Environment Programme
VBI	Vlaamse Bosinventaris
VEN	Vlaams Ecologisch Netwerk
VITO	Vlaamse Instelling voor Technologisch Onderzoek
VLIZ	Vlaams Instituut voor de Zee/Flanders Marine Institute
VRE	Virtual Research Environments
WWF	World Wildlife Fund

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