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Development of a Biodiversity Impact Assessment Application

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Abstract

In the context of modern environmental management, assessing the impact of corporate activities on areas with high biodiversity has become essential to support truly sustainable development. Regulatory pressures and growing environmental awareness are pushing many companies to integrate biodiversity criteria into their sustainability strategies, particularly to comply with Corporate Sustainability Reporting Directive (CSRD) and Carbon Disclosure Project (CDP) requirements. The CSRD mandates reporting obligations for companies on environmental impact, including biodiversity, while the CDP, still voluntary for this aspect, is expected to become mandatory, requiring companies to identify the biodiversity zones impacted by their sites.

However, existing tools for biodiversity risk screening—such as the Integrated Biodiversity Assessment Tool (IBAT) and the Biodiversity Risk Filter (BRF)—present limitations in terms of accessibility, cost, adaptability, and transparency. This thesis builds upon a critical review of those tools and internal solutions previously used at EcoAct, identifying gaps that hindered effective biodiversity integration into corporate strategies.

It describes the design, development, and implementation of a custom web application for assessing biodiversity impact at corporate sites, developed for EcoAct, an environmental and climate consulting firm. The application allows consultants to input geospatial data and instantly explore biodiversity impact through automated visualizations and analyses—without requiring external software. This process leverages seven to eight databases that provide detailed geospatial information on areas with high biodiversity concentrations, including UNESCO sites, locations with diverse habitats, and regions with various ecosystems or species. Using these data, the application assesses the impact of corporate sites on biodiversity, allowing consultants to conduct in-depth, data-driven analyses of corporate biodiversity impact.

The goal is to create a practical and intuitive interface that simplifies and enhances the accuracy of the corporate biodiversity impact assessment process. The application, developed entirely in Python, combines front-end and back-end components to facilitate the analysis and visualization of environmental data. Key features include interactive dashboards, automated biodiversity risk indicator calculations, and customizable reporting, enabling

assessments to align with CSRD and CDP requirements in a compliant and timely manner. This internal structure simplifies access to relevant environmental data and improves operational efficiency, reducing analysis time and costs.

The development process was structured into multiple phases, from data collection and preprocessing to software architecture design. The backend was built using PostgreSQL for structured data management, Docker for a stable deployment environment, and MinIO for handling large geospatial datasets. The front-end, designed with Dash, provides an intuitive user interface that enables seamless navigation through biodiversity data. Special attention was given to data integrity, incorporating algorithms for biodiversity indicator calculations and automatic filters to handle inconsistencies.

Beyond regulatory compliance, this application represents a significant step towards digitalizing biodiversity management, reinforcing EcoAct's capacity to deliver advanced environmental solutions. By providing an integrated and user-friendly system, the tool fosters improved decision-making, greater corporate awareness, and more effective monitoring of biodiversity impact.

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Chapter 1

Introduction

1.1 The Project

In the field of modern environmental management, assessing the impact of company sites on biodiversity has become essential for fostering sustainable development. Companies, consultants, and stakeholders are increasingly aware of the need to monitor and mitigate the effects of human activities on local ecosystems. However, collecting, analyzing, and visualizing geographical data related to biodiversity often proves to be complex and time-consuming.

This project aims to address these challenges by developing an innovative application designed to evaluate the biodiversity impacts of company sites on surrounding ecosystems. The tool is intended for use by consultants and clients, allowing them to input geographical and ecological data, which will generate visualizations and analyses of biodiversity impacts. These impacts include threats to endangered species, at-risk habitats, migratory corridors, water resources, UNESCO sites, and other key biodiversity areas.

The primary objective is to create a practical and user-friendly tool that simplifies biodiversity impact assessments. The user interface is designed according to the company's style guidelines to ensure consistency and ease of use, while prototyping tools were employed to create a smooth and effective user experience that facilitates access to critical data.

The application is fully developed in Python and integrates both front-end and back-end components. It operates within a Linux-based virtual machine, using Docker for containerization and GitHub for version control. The interactive user interface was built with Dash, a Python framework for analytical web applications. In the development process, public databases were extensively researched and efforts were made to explore and secure access to private databases as necessary.

By offering a direct and intuitive interface, the application promotes the digitalization and precision of biodiversity impact assessments, enhancing the efficiency of current environmental management practices.ce the effectiveness of current practices.

1.2 Project Scope and Structure

This report is organized to reflect the key stages of the project's development, starting with the technical background and existing architecture of the company. In particular, the focus will be on how the existing technical frameworks were leveraged to build the Biodiv-App, the application developed during this project.

Throughout the project pipeline, involvement was maintained across all phases. The majority of the coding and implementation work was carried out independently, with guidance and support from the technical lead provided as needed. The product ownership phase required close collaboration with biodiversity experts, who contributed key ecological insights. These insights were then integrated into the tool's functionality to ensure alignment with biodiversity management goals and compliance requirements. A significant portion of the project involved researching existing biodiversity assessment tools and reports, analyzing their structures, and identifying strengths and weaknesses in their approaches. Based on these analyses and guided by the regulatory frameworks of the Corporate Sustainability Reporting Directive (CSRD) and the Carbon Disclosure Project (CDP), a custom solution was developed to address the specific needs of consultants and corporate clients in biodiversity impact assessment. The application is designed to streamline these processes, offering features that directly respond to the evolving requirements of these regulations.

The development of this internal application showcases the intersection of research, innovation, and digital solutions in the context of environmental consulting. By transforming raw data into actionable insights, EcoAct strengthens its capacity to deliver high-value information to clients, reinforcing its position as a leader in climate and environmental solutions.

1.3 EcoAct

EcoAct is an international leader in climate and environmental consultancy, specializing in providing solutions that help businesses and territories address the challenges of climate change. With a strong focus on sustainability, EcoAct partners with clients to integrate climate and nature considerations into their core strategies, promoting sustainable transformations that respect planetary boundaries.

EcoAct plays a key role in driving this transformation by offering expertise in environmental impact assessments, strategic sustainability planning, and the implementation of effective measures to reduce carbon emissions and protect biodiversity. The company's services help clients navigate the complex landscape of sustainability reporting and comply with emerging standards, such as the Taskforce on Nature-related Financial Disclosures (TNFD) and the Science-Based Targets for Nature (SBTN).

The company's mission, "Your partner for a sustainable transformation," encapsulates its vision of guiding organizations toward a low-carbon, sustainable future. EcoAct places climate and nature at the heart of its actions, providing strategic insights and practical solutions that enable businesses to adopt environmentally sustainable practices while ensuring long-term economic viability. For more information, visit EcoAct's website.

1.4 Importance of Sustainable Transformation

Sustainable transformation is critical in today's context of escalating environmental challenges and climate crises. It refers to the comprehensive shift in business practices, policies, and corporate mindsets toward sustainability. This transformation is vital not only for mitigating climate change and preserving biodiversity but also for ensuring the long-term resilience of ecosystems and societies.

For businesses, sustainable transformation goes beyond regulatory compliance. It involves embedding sustainability into every aspect of operations, from supply chain management to product development and governance. This holistic approach helps reduce environmental impacts, strengthens resilience to climate risks, improves stakeholder trust, and creates new business opportunities.

In an increasingly competitive market, where consumers, investors, and regulators demand transparency and accountability in environmental performance, companies that proactively embrace sustainability are better positioned to thrive.

1.5 Sustainable Transformation and Data Management

Effective data management is a cornerstone of sustainable transformation, especially in the context of growing environmental challenges. For EcoAct, the ability to manage and analyze climate and biodiversity data is critical. This project, carried out within the Climate Data Analytics (CDA) team, exemplifies how data-driven solutions can enhance EcoAct's services and decision-making processes.

The CDA team plays a pivotal role in this transformation by leveraging data science to create digital tools that support EcoAct's value proposition. The application developed through this project helps address the complex challenges of climate and biodiversity data management, transforming raw data into actionable insights that drive sustainable business practices and inform decision-making in response to climate change.

Biodiversity impact assessments are a vital component of modern environmental management. With growing awareness of biodiversity's importance to both ecosystems and human well-being, it is increasingly essential for companies and governments to monitor and mitigate the impact of their activities on biodiversity. This section introduces the concept of biodiversity impact assessments, outlining their relevance in environmental management and the current approaches used to conduct them.

Preserving biodiversity is increasingly a priority in environmental management for several key reasons:

- **Ecological Sustainability**: Biodiverse ecosystems are more resilient to disturbances such as climate change and human activities. Maintaining biodiversity is essential for ensuring the long-term stability of ecosystems.

- **Economic and Social Benefits**: Biodiversity supports a range of economic activities, providing resources such as food, natural fibers, and pharmaceuticals. It also contributes to social well-being through ecosystem services that improve quality of life. Additionally, biodiversity helps sustain the food chains that maintain ecosystem balance and indirectly support human life.

- **Regulatory Compliance and Social Responsibility**: Companies face increasing pressure from regulators and society to assess and manage the impacts of their operations on biodiversity. This is becoming a crucial element of corporate sustainability strategies.

Chapter 2

Context and State of the Art: Biodiversity Management in Companies

In recent years, biodiversity has become a central focus in companies' sustainability strategies. With the tightening of regulations such as the Corporate Sustainability Reporting Directive (CSRD) [1] and the increasing pressure from investors and stakeholders through the Carbon Disclosure Project (CDP)[2], companies are increasingly called upon to assess and manage the impact of their activities on ecosystems. This section aims to analyze the state of the art concerning practices, tools, and current challenges related to corporate biodiversity management.

2.1 CSRD and CDP Requirements for Biodiversity

The CSRD mandates companies to integrate a double materiality analysis into their reporting strategies:

- **Financial Materiality**: Companies must evaluate how biodiversity loss may impact their economic performance in the short, medium, and long term.
- **Impact Materiality**: It is necessary to analyze how corporate activities contribute to biodiversity loss, with particular attention to specific operational sectors, natural resources, and geographical sites.

The CDP, through its disclosure platform, requires companies to report their practices and progress concerning biodiversity, emphasizing transparency in actions taken and identified risks. Companies must report key metrics such as:

- The extent of protected or restored areas due to their initiatives.
- The reduction of emissions or the use of pollutants.
- The number of species directly protected by corporate activities.

These requirements have prompted companies to prepare detailed reports to comply with such regulations. Consequently, many companies turn to expert consultants, such as EcoAct, for support in analysis and reporting. EcoAct employs a range of advanced tools and methodologies to help organizations evaluate and communicate their biodiversity impacts.

2.2 Tools and Frameworks Supporting Biodiversity Management

A variety of tools that facilitate the collection and analysis of biodiversity-related data to respond to the requirements of the CSRD and the CDP can be used. The most common tools include:

- **Globio**: This tool helps translate pressures on natural resources into tangible impacts on biodiversity. Globio employs ecological modeling to assess the cumulative impact of human activities on various species and habitats, providing a clear picture of the consequences of corporate practices on biodiversity.
- **Global Biodiversity Score (GBS)**: This tool calculates a company's biodiversity footprint by assessing its impacts across the entire value chain. GBS integrates data on land use, resource consumption, and pollution, offering a score that helps companies understand and reduce their biodiversity impact.
- **Integrated Biodiversity Assessment Tool (IBAT)**: IBAT provides critical data on Key Biodiversity Areas (KBAs), assisting companies in evaluating the impact of their activities in sensitive regions. It

combines information from multiple sources, including global databases and local ecological assessments, to provide a comprehensive view of ecological relevance.

- **Biodiversity Risk Filter (BRF)**: This tool enables companies to identify and manage biodiversity-related risks by integrating local and global metrics. The BRF uses a methodology based on ecological data and environmental conditions to evaluate the potential risks associated with specific corporate activities.

EcoAct, in particular, relies heavily on the Integrated Biodiversity Assessment Tool (IBAT) Biodiversity Risk Filter (BRF) to conduct comprehensive analyses for their clients.

2.2.1 Integrated Biodiversity Assessment Tool (IBAT)

The Integrated Biodiversity Assessment Tool (IBAT) [3] is a pivotal resource used by EcoAct to provide critical data on Key Biodiversity Areas (KBAs). This tool helps organizations assess the potential impact of their operations in regions that are ecologically sensitive and rich in biodiversity. IBAT integrates information from several key databases, including the World Database on Protected Areas (WDPA), KBAs, and the IUCN Red List, to deliver a comprehensive overview of biodiversity relevance.

Certain databases are essential for clients to meet the requirements of the Corporate Sustainability Reporting Directive (CSRD). These include the KBA, WDPA, and the IUCN Red List. However, these databases are exclusively owned by IBAT, an online platform that provides biodiversity data. This initiative is the result of a collaboration among various conservation organizations, including BirdLife International and the International Union for Conservation of Nature (IUCN).

The exclusive ownership of these three critical databases creates a practical necessity for organizations like EcoAct to utilize IBAT. Since access to KBA, WDPA, and the IUCN Red List is restricted to IBAT, clients cannot directly leverage these vital resources without engaging with this platform. Thus, for any analysis regarding the proximity of their sites to sensitive biodiversity areas, clients must rely on IBAT.

IBAT employs a systematic methodology that combines various ecological data sources to evaluate biodiversity risks. The key features of IBAT include:

- **Mapping of Biodiversity Hotspots**: IBAT enables users to visualize and analyze the geographic distribution of biodiversity hotspots, which is crucial for identifying areas that require conservation attention.

- **Impact Assessment**: The tool allows companies to assess how their activities may influence local biodiversity, including potential threats to species and habitats.

- **Integration with Corporate Strategies**: By aligning biodiversity data with corporate sustainability goals, IBAT supports companies in developing more effective strategies for biodiversity conservation and management.

Through the use of IBAT, EcoAct assists its clients in making informed decisions regarding their environmental impact and in fulfilling the regulatory requirements set forth by the CSRD and CDP.

2.2.2 Biodiversity Risk Filter (BRF)

The Biodiversity Risk Filter (BRF) [4] is another essential tool that EcoAct employs to help organizations identify and manage biodiversity-related risks associated with their operations. This tool uses a robust methodology that integrates local and global biodiversity metrics, providing a nuanced view of the ecological risks a company may face.

Key features of the BRF include:

- **Risk Identification**: The BRF enables companies to identify specific biodiversity risks associated with their activities, including land use changes, resource consumption, and pollution impacts.

- **Data-Driven Insights**: By leveraging ecological data and environmental conditions, the BRF offers insights that inform risk management strategies, allowing companies to implement more sustainable practices.

- **Integration with Business Operations**: The tool aligns biodiversity risk assessments with corporate operations, ensuring that environmental considerations are integrated into business decision-making processes.

By utilizing the BRF, EcoAct helps clients navigate the complexities of biodiversity management and develop strategies that align with best practices for sustainability and compliance with regulatory requirements.

2.3 Limits and Challenges in Corporate Biodiversity Management

Despite the growing availability of tools and frameworks, significant limitations still hinder effective biodiversity management by companies:

- **Absence of a Universal Indicator**: Biodiversity is a complex and multidimensional phenomenon, making it difficult to summarize corporate impacts in a single metric, unlike climate change.

- **Lack of Universal Tools**: While there are numerous tools, none can cover all biodiversity-related issues. Companies must therefore select the tools most suitable for their specific needs.

- **Difficulty in Integrating Local and Global Approaches**: For a comprehensive analysis, it is essential to combine local impact assessments, which are often more visible and measurable, with global impacts that may include complex, multi-phase value chains.

The current landscape of corporate biodiversity management is rapidly evolving. Although there are many challenges, the available tools offer companies a solid foundation for understanding and mitigating their biodiversity impact. Compliance with the requirements of the CSRD and the CDP not only strengthens corporate transparency and accountability but also significantly contributes to global ecosystem conservation.

Chapter 3

Statement of the Problem

3.1 Addressing Regulatory Challenges in Biodiversity Reporting

As previously stated, the project aims to address the increasing regulatory demands imposed by the CSRD and the CDP. The CSRD mandates that companies integrate a dual materiality analysis that includes both the financial risks and opportunities stemming from biodiversity loss and the direct impacts of business activities on ecosystems. Concurrently, the CDP calls for increased transparency regarding biodiversity-related risks and the actions taken to preserve it. The growing focus on biodiversity necessitates that companies equip themselves with tools capable of monitoring and managing these issues effectively. While EcoAct has successfully utilized external tools like BRF and IBAT to comply with these requirements, the reliance on these external solutions poses limitations regarding the customization of analyses, access to data, and integration into internal operational processes.

However, relying on these external tools presents challenges, including **limited customization**, access to data, integration into internal operational processes and **ongoing costs**. To enhance its capacity for biodiversity management and reduce dependency on third-party solutions, EcoAct is now committed to developing its own independent tool. This initiative will empower EcoAct to tailor analyses specifically to its needs, streamline operations, and mitigate costs associated with external services. By creating a bespoke solution, EcoAct aims to not only comply with regulatory requirements but also to establish a leading-edge approach to biodiversity management.

3.1.1 Moving Beyond External Tools

With EcoAct's growing experience in biodiversity management and the increasing need for tailored technological solutions, the project to develop an internal application has emerged. This new tool, specifically designed to meet CSRD and CDP requirements, enables EcoAct to achieve independence from external tools such as BRF and IBAT, providing key advantages:

- **Customization and Flexibility**: The new application is designed to be fully customizable, allowing EcoAct to tailor biodiversity analyses to its specific needs. This means that the company can now manage its data and metrics more effectively, without depending on external tools that may not address sector-specific or supply chain peculiarities.

- **Integration of Processes**: The application seamlessly integrates with EcoAct's internal systems, facilitating real-time data collection and analysis. This allows for quicker and more informed decision-making, particularly regarding priority areas for biodiversity conservation.

- **Increased Efficiency and Cost Savings**: Being independent in using its own biodiversity management tool reduces reliance on third-party solutions, positively impacting costs and operational efficiency. Analyses are conducted internally, optimizing resources and improving the timeliness of corrective or preventive actions.

3.1.2 Key Functionalities of the New Tool

The new application developed by EcoAct is based on a series of advanced features that make it a comprehensive tool for biodiversity management:

- **Interactive Dashboard**: Enables real-time visualization of biodiversity impact, with the ability to segment data by geographical site, business activity, or specific natural resource.

- **Automated Risk Analysis**: Utilizing advanced algorithms, the application can automatically identify areas at risk for biodiversity, allowing decision-makers to intervene proactively.

- **Customizable Reporting**: The application automatically generates detailed reports that meet CDP and CSRD disclosure requirements, reducing the time needed for documentation preparation and ensuring regulatory compliance.

- **Monitoring and Conservation Targets**: In addition to risk management, the tool allows setting specific targets for ecosystem conservation and restoration, providing a clear view of progress toward corporate sustainability objectives.

3.1.3 Strategic Benefits for EcoAct

With the development and implementation of this new application, EcoAct is now better equipped to address biodiversity challenges in a more autonomous and responsive manner. This tool not only effectively responds to CSRD and CDP requirements but also represents a step towards a more integrated and personalized approach to corporate sustainability management.

By gaining independence from tools like BRF and IBAT, EcoAct reinforces its position as a leader in biodiversity management innovation, providing a concrete example of how companies can integrate advanced technological solutions to tackle sustainability challenges.

3.2 From ECLR to Biodiv-App: The Transition

3.2.1 ECLR: Strengths and Limitations

Historically, EcoAct has managed climate risks through the EcoAct Climate Risk Platform (ECLR) [5], a bespoke application designed to monitor and manage climate-related risks associated with business operations. This platform serves as a climate risk assessment and visualization tool that evaluates the vulnerability of organizations' physical sites to 28 distinct climate change hazards. It is aligned with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) and the EU Taxonomy, ensuring that companies can effectively identify, mitigate, and adapt to vulnerabilities posed by climate change.

The ECLR application included a module for biodiversity risk assessment, albeit in a limited form. While ECLR integrated some functionalities related to biodiversity risk, these were based on climate and environmental data and relied on risk indices that provided a high-level overview rather than in-depth analysis.

However, as the CSRD and CDP reporting requirements on biodiversity increased, the need for a swift and specific update to address biodiversity concerns became evident.

To address these new needs quickly, we decided to implement a "quick win" on ECLR by adding new indices and specific biodiversity databases. This enhancement allowed us to temporarily improve biodiversity risk management by better assessing the potential impacts of climate change on sensitive ecosystems while simultaneously expanding the scope of services provided to clients. However, the limitations of ECLR in fully capturing biodiversity risks necessitated the development of a more dedicated solution tailored specifically for comprehensive biodiversity management.

3.2.2 Expanding ECLR for Quick Wins

To extend ECLR's capabilities and integrate new biodiversity risk assessments, we introduced an integration of seven new indicators based on 7 databases. This allowed for enhanced accuracy in risk assessment through the analysis of client site proximity to biodiversity-sensitive zones.

- **Input**: The location of the client site is provided as a geographic point (latitude, longitude).
- **Methodology**: The process involves creating a buffer around the client site. This buffer serves as a zone of influence, allowing for a more accurate assessment of nearby biodiversity areas. The algorithm selects the nearest polygon or point within this buffer, calculating the distance to biodiversity zones and generating an indicator related to proximity to areas of biodiversity significance based on the distance and on the buffer proposed by the CDP, as indicated in the first figure. It's important to note that the algorithm developed for this application (ECLR) will be reused in the subsequent Biodiv-App.

CDP

Overlap	6+
Adjacent *(sharing borders)*	6
0-5 km	5
5-10 km	4
10-25 km	3
25-50 km	2
50-70 km	1
+70km	0

Echelle	0-500m	]500m-5km]	5-10km	10-25km	25-70km	+70km
Exposure level	Extreme	High	Medium-high	Medium	Low-medium	Low
Couleurs	Rouge					Blanc

Figure 3.1: *On the left, the CDP scale for biodiversity indicators. On the right, the slightly modified scale used in ECLR to ensure consistency with existing indicators, which only had six values.*

- **Output**: Two main results:
  - The **minimum distance** between the client site and the nearest zone of biodiversity, based on integrated database data.
  - A **biodiversity indicator** based on the minimum distance, inspired by the table proposed by the CDP, which evaluates the proximity of sensitive biodiversity sites relative to the business site.

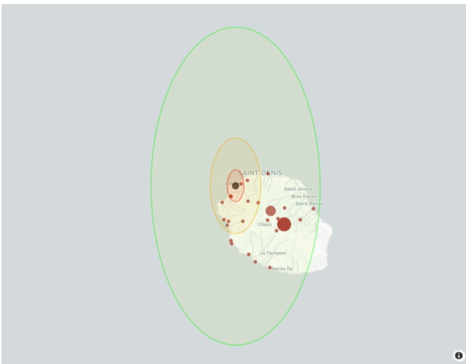

Figure 3.2: *Calculation of distance using points from the client site to biodiversity zones.*

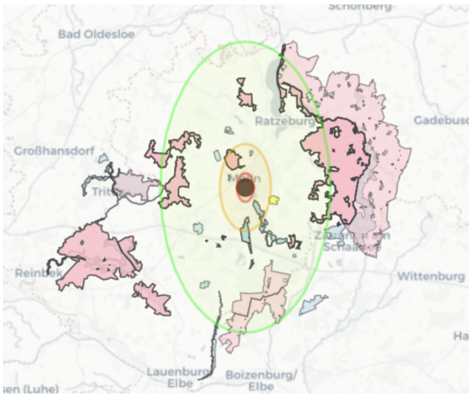

Figure 3.3: *Calculation of distance using polygons representing biodiversity zones.*

3.2.3 Key Technical Contributions

During this phase of the project, significant contributions were made in the following areas:

- Collection and cleaning of the databases used for the analysis.
- Development of the methodology and algorithms for calculating distances, intersections, and other relevant metrics.

While the ECLR application is discussed, the focus of this Thesis will be on the application, Biodiv-App, which addresses the requirements of biodiversity risk assessment more comprehensively. However, the main algorithm developed for ECLR will be reused in the Biodiv-App.

3.2.4 The Need for a New Approach

The limitations of the ECLR application included:

- Access to ECLR was limited to climate risk consultants within EcoAct, restricting the application's use for more specific biodiversity-related purposes.
- The complexity of the interface and workflow made it challenging to use ECLR exclusively for biodiversity analysis.
- ECLR had to adhere to the format and rules of the original climate risk framework, limiting flexibility in addressing biodiversity specifics: The application allowed for the input of only a point as the client site and it also constrained the output to the previously mentioned metrics. This limitation was significant, as the objective was to generate an aggregate indicator that could provide more comprehensive data related to the polygons surrounding the client site. The requirements set forth by the CSRD and CDP necessitate the total number of areas nearby, as well as distances and other analyses that have been subsequently conducted and will be presented in the following sections.

Due to ECLR's limitations, we decided to develop a dedicated new application called Biodiv-App, designed exclusively for managing and assessing biodiversity risks. This new tool is crafted to respond directly to the needs of the CSRD and CDP that we underlined before.

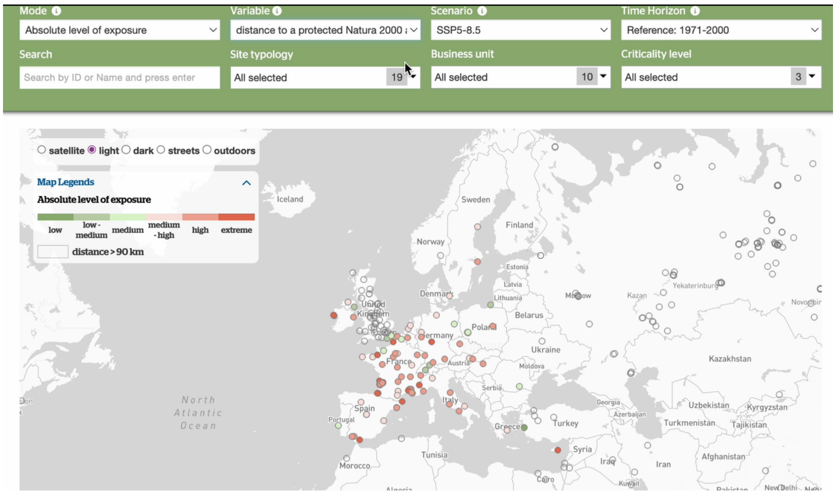

Figure 3.4: *Screenshot of the ECLR application displaying the biodiversity indicators.*

3.2.5 Introducing Biodiv-App: A Next-Gen Biodiversity Tool

Following the development of ECLR, the need for a more specialized tool led to the creation of Biodiv-App. This application focuses exclusively on biodiversity risk assessment, providing a more flexible and comprehensive solution for analyzing the proximity of business sites to sensitive biodiversity zones.

- **Input**: The application has been designed with the capability to handle both geographic points (latitude, longitude) and polygons, allowing for flexible geographical representations of client sites from the outset.
- **Methodology**: Similar to ECLR, Biodiv-App uses a buffer around the client site to define a zone of influence. However, the key difference lies in the flexibility of the buffer's size, which depends on the type of industry of the client site. This allows for a more tailored analysis of the potential impact on nearby biodiversity-sensitive areas.

  More detailed information on the customization and algorithm will be provided in the methodology section later in this thesis.

- **Output**: Biodiv-App generates two key results from its analysis, among others:
  - The **distance** from the client site to each biodiversity-sensitive zone situated in the specific buffer.
  - The **total number** of biodiversity-sensitive areas near the client site for each database.

Biodiv-App represents a significant improvement over ECLR in several respects for the Biodiversity community of EcoAct: In the subsequent sections, the methodology adopted for the development and implementation of Biodiv-App will be explored.

Chapter 4

Methodology

The methodology employed in this project follows a structured approach aimed at delivering a robust and user-friendly application. While progressing with the project, the methodology for calculating biodiversity indicators required concurrent research. This involved consulting biodiversity experts and exploring existing reports to ensure that the development was grounded in best practices.

The key components of the methodology include, on one side, **Defining the Biodiversity Indicators** establishing relevant and actionable indicators based on biodiversity metrics. Concurrently, on the other side, there is the actual development of the project, **Iterative Project Workflow** emphasizing continuous feedback and refinement throughout the development process.

In the following sections, we will explore the methodology for indicator computation in detail.

4.1 Definition of the Indicator Calculations

The primary focus of the methodology revolves around the definition of key biodiversity indicators that guide the application's functionality. These indicators are based on established biodiversity metrics and are designed to provide actionable insights for users. However, the urgency of this task stems from the fact that the biodiversity sector is rapidly evolving, and as such, precise and established metrics are often lacking. Given this context, it is crucial to establish a **buffer** around client sites to assess their potential impacts on significant biodiversity areas. This buffer serves as a critical zone of consideration, allowing us to evaluate how activities at the client site may affect surrounding ecosystems and habitats.

With the understanding that there are currently no universally recognized buffer standards, and limited concrete information on effective biodiversity impact measurement, it was imperative to conduct thorough research to determine the most practical approaches for developing the application. We sought inspiration from existing reports and frameworks, analyzing what methodologies could be adapted for our needs based on the resources at our disposal.

Specifically, the buffer in the Biodiv App is inspired by the new format of disclosure reports from IBAT [6], developed to assist companies in meeting the requirements of the CSRD and the CDP.

4.2 Project Workflow

The project followed an iterative workflow model, emphasizing continuous feedback and refinement. This approach allowed for the adaptation of the application to meet evolving requirements and to integrate user insights at various stages of development. Key phases included requirements gathering, design prototyping, development, and testing.

1. **Requirements Gathering** *Objective*: To capture the needs of the client and end-users. *Approach*: Prior to the start of development, comprehensive research was conducted into the domain of biodiversity assessment, examining existing tools and practices. This involved both desk research and consultations with biodiversity experts, which proved invaluable in defining the application's core functionalities. These insights were critical for refining the requirements and ensuring the application would meet the real-world needs of its users.

2. **Data Sources Research** *Objective*: To identify and evaluate relevant biodiversity databases that can provide the necessary data for the application. *Approach*: This phase involved a thorough exploration of existing biodiversity databases, standards, and frameworks that align with the requirements gathered. Emphasis was placed on understanding the quality, accessibility, and relevance of the data provided by these sources, which would be critical in informing the application's functionalities and ensuring compliance with reporting standards.

3. **Design**
   Objective: To plan the system architecture and user interface (UI) in detail.
   Approach: The design phase involved close collaboration with biodiversity experts to conceptualize the structure and flow of the application. Iterative feedback was incorporated to ensure the design addressed key user pain points.
   Activities:

   - **Architecture Design**: The pre-existing architecture model established by the CDA team of EcoAct was adapted. The goal was to leverage existing infrastructure while introducing customizations where required.
   - **UI Prototyping**: Whimsical was used to develop wireframes and mockups for the application's UI. These prototypes were essential for visualizing the user experience and refining the interaction flow before development began.

4. **Development**
   Objective: To implement the functionalities and features defined during the design phase.
   Activities:

   - **Frontend Development**: The frontend was built using Dash, a Python-based framework that facilitates the creation of interactive, data-driven web applications.
   - **Backend Development**: FastAPI, a modern Python framework for building APIs, was employed to handle backend logic and RESTful API interactions.
   - **Database Development**: PostgreSQL was chosen for database management due to its robustness and scalability, ensuring smooth data handling and storage.
   - **Version Control**: Git was utilized for version control, enabling efficient collaboration, version tracking, and code management throughout the development process.

5. **Testing**
   Objective: To validate the application's functionality and ensure it in-

tegrates well with other systems.
Approach: The testing phase focused on functional and integration testing. Technical supervisors and biodiversity experts were involved in performing end-to-end tests to simulate real-world scenarios, ensuring the application behaved as expected under realistic conditions.

6. **Deployment**
Objective: To deploy the application in a production environment and monitor its performance.
Activities:

   - **Deployment Process**: Azure was utilized for cloud hosting, while Docker containers ensured consistent deployment across different environments.
   - **Testing in Production**: Following deployment, the application will enter a month-long testing phase where biodiversity experts will compare its functionality against existing solutions and provide feedback. This feedback loop will be essential for iterating on the application and refining its performance.
   - **Future Iterations**: After the testing phase, additional development cycles are planned to implement improvements and address any issues identified during the feedback process.

Chapter 5

Development

This chapter provides an in-depth overview of how requirements were defined, the design process, and the technical development that followed, ensuring a clear understanding of the tool's evolution. The chapter is structured according to the different components and processes that were critical to the successful realization of the project:

- **Application Architecture Overview**: A general description of the existing architecture adopted by the CDA team of EcoAct, as it forms the foundation for the development of this application.
- **Detailed examination of each phase of the project pipeline**:
  - **What was done:** A step-by-step breakdown of each phase.
  - **How it was done:** A description of the methodologies and strategies used to implement each phase.
  - **Tools and Frameworks:** For each stage, the specific tools, technologies, and frameworks employed are highlighted.
- **Methodology for Distance Calculations and Buffer Consideration:** A detailed overview of the techniques used for calculating distances and evaluating buffers around client sites, addressing the importance of these elements in assessing biodiversity impacts.

This approach ensures that every aspect of the pipeline is thoroughly addressed, providing a complete overview of both the processes and technologies that shaped the development of the biodiversity assessment tool.

5.1 Application Architecture Overview

5.1.1 EcoAct's Python-Based Development Framework

The development of the tool adheres to the Python-based architecture commonly employed by the Climate Data Analytics (CDA) team at EcoAct. The company's development framework, known as EcoDev, is composed of multiple repositories and libraries designed to streamline the creation of Python applications. These resources were leveraged to ensure consistency and efficiency in the development process.

At the outset, the existing standard architecture utilized by the organization was carefully examined to understand how it could be adapted to this project. The EcoDev framework includes several core components that facilitate development, deployment, and integration. The architecture is divided into various stacks [7], which are outlined below.

5.1.2 EcoDev Core Components

The EcoDev framework is composed of several repositories, each serving a specific role in the development process:

- **EcoDev Infra:** This repository provides the architectural foundation for EcoDev applications, utilizing off-the-shelf Docker images for components such as Traefik, PostgreSQL, and various application stacks (e.g., Bookstack, Keycloak, Minio). It enables efficient deployment and management of the underlying infrastructure.

- **EcoDev Core:** A library that includes low-level helper methods for FastAPI and SQLModel. It aims to streamline database connection setup and ORM interactions. It includes functions like `create_db_and_tables` to facilitate the creation of database schemas.

- **EcoDev Front:** A simplified library built on Dash Mantine Components, offering customizable components and layout helpers. It aims to expedite the development of user interfaces while minimizing dependencies on external libraries that may frequently change.

- **EcoDev Cloud:** Provides helper methods for interacting with cloud storage solutions such as AWS S3 and Azure Blob. It allows for seamless data read/write operations, making cloud integration straightforward and efficient.

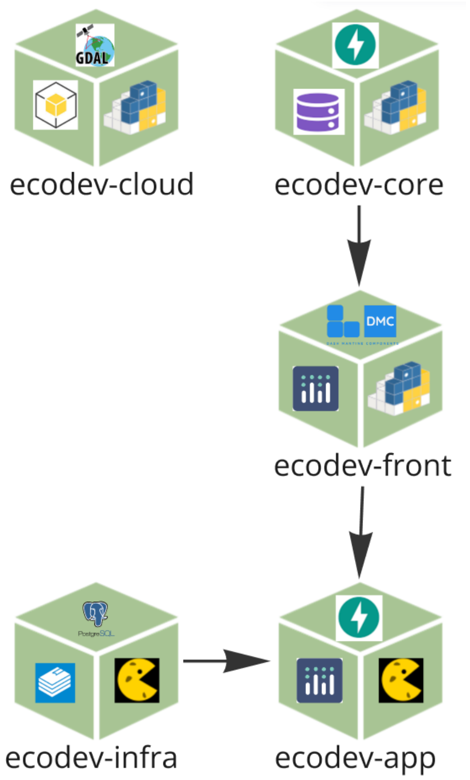

Figure 5.1: *General Structure of EcoDev Repositories*

Each component in the EcoDev ecosystem plays a vital role in creating a cohesive environment for developing, deploying, and maintaining applications. The overall structure allows developers to leverage reusable code, thereby enhancing productivity and resource efficiency across projects.

5.1.3 Key Technologies

To complement the architectural components, several key technologies and libraries are used to ensure the application is both robust and efficient:

- **Docker**: Ensures a consistent development and deployment environment, simplifying the management of dependencies and system configurations.

- **Dash**: Enables the creation of interactive web applications for data visualization, allowing intuitive interaction without requiring web development language skills.

- **FastAPI**: A framework that streamlines API development, making it efficient and straightforward, particularly useful for building robust backends.

- **SQLModel**: Provides an Object-Relational Mapping (ORM) layer that simplifies database interactions, integrating well with FastAPI.

- **Pandas**: An essential library for data manipulation and analysis, facilitating fluid operations on DataFrames from various sources.

- **Pydantic**: Promotes a structured approach to coding in Python, enhancing code readability and maintainability through strong typing.

These technologies are fundamental to the realization of the application and will be discussed in detail in subsequent sections, where their functionalities and specific uses within the project will be elaborated upon.

5.2 Requirements Gathering

The process of gathering requirements involved comprehensive engagement with stakeholders and biodiversity experts to identify key functionalities that the application must offer. This includes:

- Engaging in discussions with biodiversity experts to understand necessary functionalities and exploring the requirements outlined in the CSRD and CDP frameworks.

- Analyzing existing biodiversity tools to identify gaps and opportunities for improvement.

- Compiling a comprehensive list of essential features, such as data visualization capabilities, robust reporting functions, and user-friendly interfaces.

5.2.1 Core Functionalities for Compliance

To ensure that the application effectively supports both business operations and regulatory compliance, the following core functionalities have been identified:

- **Integration with biodiversity databases**: Enables automatic retrieval and validation of environmental data to align with reporting standards such as CSRD and CDP.
- **Automated report generation**: Facilitates the preparation of sustainability reports by structuring biodiversity impact data according to regulatory requirements.
- **Interactive data visualization tools**: Enhances data accessibility for stakeholders by presenting biodiversity-related information in a clear and engaging format.
- **User authentication and role-based access control**: Ensures secure access to sensitive biodiversity data and aligns with organizational governance structures.

5.2.2 Overview of Reporting Standards

To ensure compliance with global sustainability frameworks, the application aligns with the following key reporting standards:

Corporate Sustainability Reporting Directive (CSRD)

- **Nature**: Mandatory for large companies and all listed companies in the EU.
- **Focus**: Requires comprehensive reporting on sustainability impacts, including biodiversity.
- **Key Requirements**: Companies must report the number and area of sites they affect near protected areas, enhancing transparency and accountability.

Table 5.1: *CSRD Requirements*

Disclosure Requirement Code	Requirement	Status
E4-5	Number of sites owned, leased or managed in or near protected areas or key biodiversity areas that undertaking is negatively affecting	Mandatory
E4-5	Area of sites owned, leased or managed in or near protected areas or key biodiversity areas that undertaking is negatively affecting	Mandatory
IRO-1	Locate - develop a list of locations where the undertaking is interfacing with locations in or near biodiversity-sensitive areas	Voluntary

Carbon Disclosure Project (CDP)

- **Nature**: Voluntary reporting framework that encourages companies to disclose environmental impacts.
- **Focus**: Initially focused on carbon emissions, it now includes biodiversity-related questions.
- **Key Requirements**: Companies must use data from biodiversity databases to report impacts on legally protected areas, UNESCO sites, and other biodiversity-sensitive regions.

Table 5.2: *Biodiversity-Sensitive Areas and Organization's Activities*

Type of Area Important for Biodiversity	**Indicate whether any of your organization's activities are located in or near these areas**
- Legally protected areas - UNESCO World Heritage sites - UNESCO Man and the Biosphere Reserves - Ramsar sites - Key Biodiversity Areas - Other areas important for biodiversity	- Yes - Yes (partial assessment) - No - Not assessed - Data not available

By focusing on the critical aspects of biodiversity data, the project aims to create a tool that effectively supports organizations in their environmental assessments and reporting obligations.

5.3 Data Sources Research

The second phase of the project involved gathering relevant data from various sources. Several biodiversity databases was undertaken to identify those that align with the specified requirements. The research emphasized the necessity of incorporating reliable data sources to enhance the tool's functionality and ensure compliance with established reporting standards. This step was crucial for building a reliable foundation for the application. The process included:

1. **Exploration and Collection of Databases:**
   The team accessed databases from online repositories, governmental and non-governmental organizations. These sources provided essential geographical and biodiversity data required to assess the environmental impact of various projects.

2. **Evaluation of Data Quality and Availability:**
   The collected data underwent a thorough evaluation to assess its accuracy, completeness, and relevance to the project. Each dataset was checked for missing or erroneous values, and formats were reviewed to ensure compatibility with the tools being used.

5.3.1 Exploration and Collection of Databases

The following **Global Biodiversity Databases** were identified as vital resources for informing the application, as they consistently addressed each specified requirement.

- **IUCN Red List**: [9] Provides assessments of species conservation statuses, serving as a key reference for conservation planning.
- **World Database on Protected Areas (WDPA)**: [10] Offers comprehensive data on protected areas, essential for evaluating global biodiversity conservation efforts.
- **Key Biodiversity Areas (KBA) Database**: [11] Identifies critical sites for biodiversity conservation, guiding strategic initiatives in habitat protection.

In addition to global resources, several significant **France Biodiversity Databases** were identified:

- **Base Espaces Protégés**: [12] This database catalogs protected areas in France, providing information on their locations, management, and ecological significance.
- **Inventaire des Zones Naturelles d'Intérêt Ecologique, Faunistique et Floristique (ZNIEFF)**: [13] The ZNIEFF inventory identifies natural areas of ecological, faunistic, and floristic interest, highlighting sites that are crucial for biodiversity conservation.
- **Liste Rouge des Espèces Menacées en France**: [14] This red list assesses the conservation status of threatened species in France, offering essential data for conservation planning and prioritization.
- **Trame Verte et Bleue (TVB)**: [15] This initiative aims to create a network of green and blue corridors to enhance ecological connectivity across the landscape, facilitating the movement of species and the preservation of ecosystems.
- **European Base Natura 2000**: [16] As part of the European Union's Natura 2000 network, this database provides information on sites designated for the protection of habitats and species of European importance.

These French databases are generally accessible to the public, promoting transparency and facilitating research and conservation initiatives.

5.3.2 The Role of Conservation Organizations for data collection

Conservation organizations, such as the International Union for Conservation of Nature (IUCN) and the Critical Ecosystem Partnership Fund (CEPF), play a pivotal role in biodiversity data collection and analysis. IUCN collaborates on vital databases like the IUCN Red List and the WDPA, while CEPF provides financial support for conservation initiatives in biodiversity hotspots.

In France, the National Inventory of Natural Heritage (INPN) offers extensive databases related to protected areas and biodiversity, significantly supporting national conservation efforts.

Together, these organizations and databases form a comprehensive ecosystem of resources that underpin biodiversity assessment and conservation strategies.

5.3.3 Evaluation of Data Quality and Availability

One of the primary challenges in biodiversity impact assessment is the availability and quality of data. High-quality data are essential for accurate assessments and effective decision-making, but several issues can arise:

- **Sparse Data Coverage**: In many regions, especially in developing countries or remote areas, biodiversity data may be sparse or unavailable. This lack of data coverage can hinder comprehensive assessments and limit the ability to make informed decisions.

- **Data Accuracy and Reliability**: The accuracy and reliability of biodiversity data can vary widely. Data may be affected by errors in collection methods, outdated information, or inconsistencies between different data sources.

- **Access and Sharing Issues**: Access to high-quality biodiversity data can be restricted due to proprietary data policies or lack of data-sharing agreements. In particular, two of the most important databases, the World Database on Protected Areas (WDPA) and the Key Biodiversity

Areas (KBA), are not accessible for commercial use. This limitation is significant as it restricts companies and researchers from fully utilizing these crucial datasets for biodiversity impact assessments. Currently, the Integrated Biodiversity Assessment Tool (IBAT) holds a monopoly on access to these databases, which can lead to challenges in obtaining comprehensive and up-to-date biodiversity information for decision-making.

Additionally, while other databases were identified during the research, they were found to be private and not available for direct download. Efforts to contact these organizations often resulted in referrals back to IBAT, further emphasizing its monopoly over access to critical data. Negotiations for access were attempted but ultimately unsuccessful.

The databases listed above, with the exception of IUCN, were successfully downloaded and examined. However, it is important to note that IBAT's control over the WDPA and KBA restricts their use for commercial purposes, and therefore, these datasets were not included in the application.

5.3.4 Final selection of Biodiversity Databases

In conclusion, the following biodiversity databases were utilized in this application: **Base Espaces Protégés**, **Inventaire des Zones Naturelles d'Intérêt Ecologique, Faunistique et Floristique (ZNIEFF)**, and the three separate databases under the **Trame Verte et Bleue (TVB)** initiative, which include **corridors, reservoirs, and watercourses**. Although the **Key Biodiversity Areas (KBA)** were included in the application for testing and informational purposes, the data cannot be shared with the client due to commercial use restrictions.
Through the selection and analysis of available data sources, we can guarantee comprehensive and accurate results for biodiversity assessment in France. However, we cannot extend this completeness to a global level, as we only have access to databases specific to France that can be shared with the client. Actually, the only two world database that we have in the application are KBA database, which cannot be shared and biodiversity hotspots, which, although representing important ecological regions, are too large to provide detailed and contextualized analyses, thus limiting their utility in specific assessments. Therefore, we focus on local resources to ensure a more relevant and useful analysis for conservation purposes.

5.4 Data Cleaning and Analysis

5.4.1 Data Format

Geographical data frequently comes in various formats, such as PDF, Excel, and shapefiles (SHP). To ensure seamless integration into Geographic Information Systems (GIS), special attention was given to standardizing the data formats. Shapefiles were prioritized for their accuracy in representing spatial data and their compatibility with the tools and libraries used in this project.

5.4.2 Data Cleaning and Preparation

Once the data was collected, a basic cleaning and preparation process was initiated. This initial phase involved addressing null values, managing outliers, and ensuring that the data was in a suitable format for analysis. After performing this preliminary cleaning, we proceeded to convert the coordinate formats to ensure consistency across datasets. The system needed to support data ingestion from various sources while maintaining data integrity and quality. A key focus of this phase was on cleaning the coordinate data, which is the most critical attribute for the analysis. Without accurate coordinates, any further analysis would be ineffective. Only after addressing the coordinate-related issues did we shift attention to cleaning the remaining attributes, particularly managing missing values (NaN), although none of these attributes were as crucial as the spatial data itself.

5.4.3 Handling Inconsistent Data

During the preparation phase, several inconsistencies were identified across datasets. These included mixed coordinate formats, incorrect entries, and other anomalies that could compromise the analysis. A systematic approach was employed to detect and correct these inconsistencies. The datasets were thoroughly reviewed, and necessary adjustments were made to ensure consistency and accuracy.

5.4.4 Coordinate Format Conversion

Geographical data from different sources often contained coordinates in varying formats. While some datasets used the latitude-longitude (lat-lon) format, others employed the reverse longitude-latitude (lon-lat) format. To prevent potential errors in data analysis or map visualization, it was essential to standardize all coordinates into a single, consistent format. The chosen format was the **WGS84** coordinate system, recognized as the global standard used by most GIS tools.

The WGS84 system was selected because it serves as the default format for geospatial libraries such as **Geopy**, **Shapely**, and **Plotly**, which were integral to the project's geospatial analysis and map visualization. Ensuring that all datasets were converted and aligned with the WGS84 format enabled accurate mapping, seamless integration across diverse datasets, and reliable visualization within the application.

5.4.5 Testing and Validation of Data

After the initial basic cleaning, coordinate conversions, and geometry cleaning, we were able to pass to the testing phase, which focused on verifying:

- Data integrity after transformations and cleaning.
- Accuracy of geographical visualizations, including polygon shapes and spatial relationships.
- Consistency of distance calculations and spatial analysis results.

One of the primary methods for validating the data was through the visual plotting of the databases on a world map. This graphical representation allowed us to identify any anomalies in the data, such as polygons plotted in incorrect locations or unexpected outliers.

For example, during this phase, we noticed that some datasets that were supposed to represent regions in France were instead appearing in other parts of the world. Upon investigation, it became clear that the issue was due to inverted coordinate values. Latitude and longitude values were mistakenly swapped in only some records, causing the polygons to be plotted far from their intended locations.

To resolve this issue, a filtering function was implemented. This function would cross-check the location of each polygon with the expected country. If a polygon was supposed to be in France but was located elsewhere, the function automatically inverted the coordinates. In cases where inversion did not resolve the issue, the problematic data entries were flagged for further review or removed from the dataset if necessary.

5.4.6 Polygon Visualization and Adjustment

During the visualization process, challenges were encountered with polygon display. These geometric complexities often led to distorted or inaccurate representations of spatial data, as illustrated in Figure 5.2. The issues arose primarily because the exterior coordinates of the polygons were not correctly captured, resulting in improper rendering of the shapes.

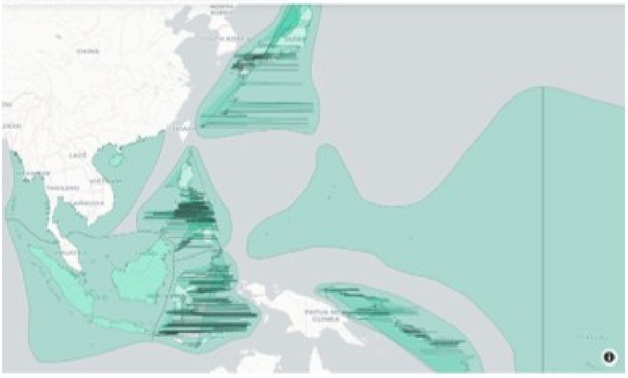

Figure 5.2: *Polygon rendering issue with incorrect exterior coordinates*

To address these visualization issues, the first attempt involved applying geometric transformations using the **convex hull** and **concave hull** techniques. The convex hull technique was used to generate the smallest convex shape that could enclose a set of points, which helped simplify complex polygons with sharp angles. By focusing solely on convex hulls, we ensured that when angles were convex, they did not create rendering problems. This approach led to an improved visualization, as seen in Figure 5.3.

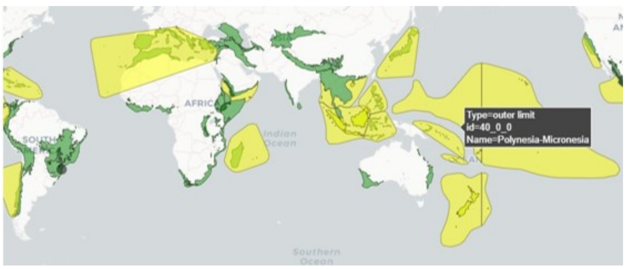

Figure 5.3: *Polygon rendering after applying the convex hull technique*

Additionally, adjustments were made to the *alpha* parameter, which controls the level of approximation of the convex-concave hulls. Fine-tuning this parameter helped manage the correctness of the polygon, contributing to a clearer representation of the geometric shapes.

5.4.7 Handling Multipolygons and Holes

During the development process, another significant challenge arose when working with **multipolygons**, particularly those that contain **holes**. A multipolygon is a geometry that consists of multiple polygons, often representing a large area that may have voids or exclusions, such as lakes or other geographic features that should not be part of the main polygon. Properly handling these complex shapes is essential for accurate visualization and data integrity in spatial analysis. The problem can be observed in Figure 5.4, where the initial representation failed to distinguish between the exterior boundaries (the shell) and the interior voids (the holes), leading to erroneous or incomplete visualizations and overlapping.

Figure 5.4: *Multipolygon with incomplete rendering of holes*

The issue primarily stemmed from the **incomplete extraction and handling of the polygons' interior and exterior coordinates**. In a GIS context, each polygon can have one or more **exterior boundaries** (known as shells) and, optionally, one or more **interior voids** (known as holes). In the case of multipolygons, each polygon in the group may also contain its own set of holes. When visualizing such geometries, failing to differentiate between the shell and the holes results in incorrect mappings, often showing overlapping polygons or completely ignoring the interior voids. This situation can cause misrepresentation of geographic regions, as seen in Figure 5.4.

To resolve these issues, the following approach was implemented:

- **Extracting Shell and Hole Coordinates**: The exterior boundary (shell) of each polygon was extracted using the `exterior.xy` method, which retrieves the x and y coordinates of the shell. These coordinates were then combined into a list of tuples, representing the polygon's exterior.

- **Handling Holes**: The next step involved extracting the coordinates of the interior voids (holes). For each polygon, the `interiors` attribute provided access to the interior rings that represent the holes. The `xy` method was applied to each interior ring to obtain the x and y coordinates of the holes. These coordinates were also zipped together to create a list of tuples for each hole.

- **Combining Coordinates**: After extracting the shell and hole coordinates, they were combined into a single structure where the shell was listed first, followed by the coordinates of the holes. This structure allowed the map visualization tool to correctly display the polygon with its holes subtracted from the shell.

The code snippet below illustrates this process:

```
# Extracting the shell
a, b = final_polygon.exterior.xy
coordinates = list(zip(a, b))
# Extracting the holes
holes = [list(zip(*hole.xy)) for hole in final_polygon.
    interiors]
# Combining shell and holes
all_coordinates = [coordinates] + holes
```

The results of this approach can be seen in Figures **??**, where the polygons are correctly visualized with their holes properly handled and subtracted from the exterior boundaries.

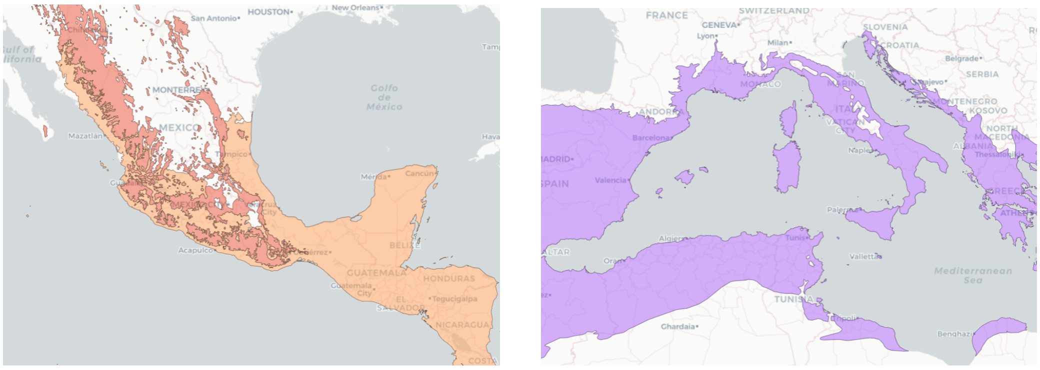

Figure 5.5: *Multipolygon with holes properly handled in the visualization*

This approach allowed for the accurate representation of **multipolygons** and **polygons with holes**. The application could now handle complex geographic regions with voids and ensure that the data could be visualized in a way that was true to its real-world counterpart.

This testing approach not only ensured the geographical accuracy of the polygons but also improved the overall integrity of the spatial data, guaranteeing that the visualizations within the application reflected real-world geographical features correctly.

5.5 Design

The design phase involved close collaboration with biodiversity experts to conceptualize the structure and flow of the application. Iterative feedback was incorporated to ensure the design addressed key user pain points.

The pre-existing architecture model established by the CDA team at EcoAct was adapted to leverage existing infrastructure while introducing customizations where required. Whimsical was utilized to develop wireframes and mockups for the application's UI. These prototypes were essential for visualizing the user experience and refining the interaction flow before development began.

5.5.1 Design Process and Prototyping

The design phase is crucial for ensuring an intuitive user interface and a smooth user experience. Throughout this process, various methodologies and tools were employed to create the app's interface and user experience.

In particular, **Whimsical** was used, a prototyping tool that allows for quick and visual wireframe and mockup creation. This enabled the exploration of different design solutions and usability testing before the actual development began.

The first prototype created is shown in Figure 5.6. This prototype is inspired by interfaces of existing web applications such as BRF (WWF Risk Filter Suite), known for their user-friendliness and appealing design. Elements from these applications were incorporated while adhering to the guidelines and best practices provided by the Climate Data Analytics (CDA) team at EcoAct.

Through this design process, initial feedback was gathered, and necessary adjustments were made to ensure that the final interface met user needs.

Additionally, feedback was received from the Product Owner (PO) and biodiversity experts, who will be the future users of the app. This iterative design approach allowed for continuous improvement and refinement of the user interface.

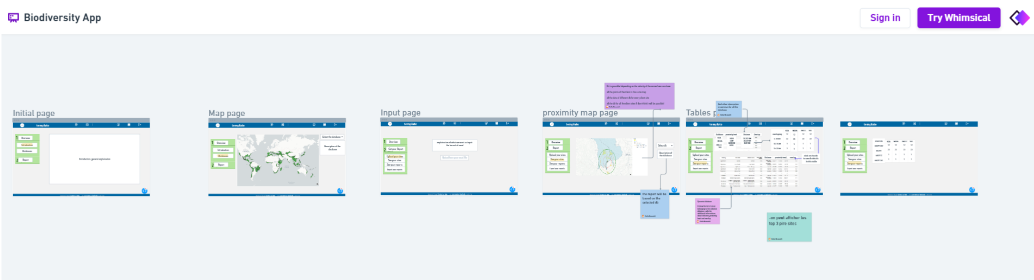

Figure 5.6: *First prototype*

5.6 Back-end Development

The back-end development phase is crucial for building a robust, scalable, and efficient application. It manages server-side logic, database interactions, and facilitates smooth communication between the front-end and the data layer.

In this context, we had to manage two distinct types of databases: eight geospatial databases, primarily in **shapefile format**, containing biodiversity information, and a separate database for client-specific data extracted in real-time from Excel files uploaded by consultants, in **csv format**. This dual approach ensures efficient storage and retrieval of both extensive biodiversity datasets and specific client information while addressing different project requirements.

To manage the deployment and scalability of our back-end, we rely on containerization technologies such as **Docker**, which streamlines the setup and execution of the application. In addition, multiple technologies were employed to achieve the desired functionality and performance, including:

- **Docker**: Utilized for containerization and to manage the application's launch.

- **FastAPI**: A modern web framework that allows for the rapid development of APIs.

- **SQLAlchemy and SQLModel**: Object Relational Mappers that facilitate database interactions.

- **PostgreSQL**: A relational database management system used for structured client data.

- **MinIO**: A high-performance distributed object storage solution, ideal for handling large biodiversity datasets.

- **pgAdmin**: A graphical interface for managing PostgreSQL databases.

These technologies collectively contribute to building a seamless back-end architecture that supports the application's functionality. The following sections delve deeper into these components, starting with Docker.

5.6.1 Docker

The `ecodev_infra` repository plays a pivotal role by utilizing **Docker** to manage the application's launch. Docker simplifies the creation, execution, and management of containers, which include everything needed to run a piece of software, such as the code, runtime, libraries, and system tools.

Docker Components

- **Images**: Read-only templates used to create containers, built from a Dockerfile.
- **Containers**: Running instances of Docker images, ensuring isolated execution environments.
- **Dockerfile**: A text document specifying all the commands to assemble an image.
- **Docker Compose**: A tool for defining and running multi-container applications via a `docker-compose.yml` file.
- **Volumes**: Mechanism to persist data generated by containers.
- **Networks**: Built-in networking capabilities allowing inter-container communication.

Application Management Docker automates the process of packaging an application and its dependencies, ensuring that the application runs consistently across different environments. The following commands manage the application lifecycle:

- `docker compose build -no-cache`: Builds Docker images as specified in the `docker-compose.yml` file.
- `docker compose up`: Starts the services defined in the `docker-compose.yml` file.
- `docker compose down`: Stops the container when the application is no longer needed.

5.6.2 FastAPI and PostgreSQL

For building the back-end API, **FastAPI** was chosen due to its performance and ease of use. It enables rapid API development with asynchronous capabilities and is commonly used alongside **PostgreSQL** for structured data storage. PostgreSQL is an open-source relational database known for its robustness and efficiency in handling transactions and complex queries.

pgAdmin is employed as a graphical user interface for PostgreSQL, providing an intuitive environment for database management. While **PostGIS** was considered for geospatial data storage, its integration was deemed infeasible due to project constraints. Instead, client-specific data, including latitude and longitude, is stored directly in PostgreSQL.

To optimize data retrieval, a supplementary table stores pre-calculated results related to the analyses of client sites, enabling quick access to processed information without requiring repeated calculations.

5.6.3 MinIO

To efficiently manage large biodiversity datasets, MinIO was selected as an object storage solution. It is compatible with Amazon S3 APIs and provides high performance, accessibility, and scalability. MinIO ensures seamless handling of extensive biodiversity-related data while allowing for flexible storage policies.

5.6.4 Database Design and Integration of Raw Data

Using **SQLAlchemy** and **SQLModel**, a relational database was designed with two primary tables:

- A table storing client points along with the required attributes.
- A supplementary table holding pre-calculated data representing the neighboring points for each client.

This structure ensures efficient data retrieval while maintaining the integrity of the application's dataset.

Input Data Validation To ensure data quality, insertors were developed to handle the transformation and validation of raw Excel data before insertion into the database. Input validation includes:

- Notifying consultants of missing attributes, requiring resubmission when necessary.
- Eliminating rows with missing latitude and longitude values.
- Assigning default values to missing non-critical attributes.

Additionally, logging mechanisms track data import processes, providing visibility into insertion activities and ensuring transparency in data management.

By structuring data management and validation processes efficiently, the back-end system ensures reliability, performance, and compliance with biodiversity reporting standards.

5.7 Front-end Development

The front-end of the application is a critical component as it directly interacts with users, providing an intuitive and responsive interface for data visualization and interaction. This section outlines the technologies and design principles employed in the development of the front end, specifically focusing on the use of Dash.

5.7.1 User Interface Design: Dash

The front-end is built using **Dash**, a powerful library that facilitates the creation of interactive web applications. Dash allows for the rapid development of data-driven interfaces with minimal coding, leveraging Python's capabilities to provide a seamless user experience. The design of the user interface (UI) prioritizes usability and accessibility, ensuring that users can navigate the application easily and interact with the features intuitively.

Dash employs several key concepts that enhance the interactivity of the application:

- **Identifiers:** Each component in Dash is assigned a unique identifier that distinguishes it from other components. These identifiers are essential for referencing components in callbacks, which manage the dynamic updates of the UI. For example, when a component triggers an event—such as a mouse click or a value change—Dash uses the component's identifier to determine the source of the event and update the appropriate elements accordingly.
- **Callback Functions:** Dash automatically invokes callback functions whenever an input component's property changes. These functions facilitate the interaction between components by updating the properties of output components based on the new values of input properties. For instance, when a user modifies a dropdown selection, the associated

callback function processes the new selection and updates a corresponding output component—such as a graph or text display—accordingly. This real-time interactivity is a hallmark of Dash applications.

- **Modal Windows:** Modal windows in Dash are pop-up interfaces that appear above the main application content, providing additional information, warnings, or confirmation prompts. They enhance user interaction without disrupting the workflow, allowing for context-specific information delivery. Modals can be triggered by user actions, such as button clicks, and they typically center on the screen, obscuring the underlying content until closed by the user. This design pattern helps maintain a clean interface while effectively presenting critical information.

- **Data Storage:** Dash provides mechanisms to store data temporarily, enabling the passing of information between different pages. For instamce, to pass the project ID, which aids in identifying the data for exploitation throughout the project.

- **Graphing and Visualization:** Leveraging **Plotly**, Dash seamlessly integrates rich, interactive data visualizations, making it ideal for applications that rely heavily on data representation. Plotly's capabilities allow the creation of various graphs, including line charts, bar charts, and scatter plots, all of which can be updated dynamically based on user interactions.

- **Deployment Capabilities:** Dash applications can be easily deployed on various servers, enabling accessibility to users through web browsers. The compatibility with containerization tools like Docker further simplifies the deployment process, ensuring that the application runs consistently across different environments.

By incorporating these features, Dash creates a highly interactive and user-friendly front-end experience, ensuring that users can effectively engage with the data and functionalities provided by the application.

5.7.2 Page Structure and Back-end Interaction

The structure of the application pages is designed to facilitate seamless interaction with the back end. Each page is thoughtfully organized, allowing users to navigate efficiently through different functionalities.The UI remains responsive, providing users with real-time feedback as they interact with the application.

UX/UI Design and Usability Considerations In addition to technical implementation, the design process for the UI included extensive considerations for user experience (UX). Key principles such as simplicity, consistency, and accessibility were prioritized to ensure that all users, regardless of their IT skills, can effectively use the application. Throughout the development process, feedback was continuously sought from users (consultants), allowing for ongoing modifications to the interface based on their suggestions. This iterative approach ensured that the application remained user-friendly and effectively conveyed complex biodiversity data while enhancing the overall user experience.

5.8 Deployment

During the development process, best practices were integrated; however, prior to deployment, a final review ensured that the code was clean, logical, and well-structured.

5.8.1 Cleaning and Documentation of the Code

This review included the following steps:

- Verifying the **organization** of folders and files to confirm a logical arrangement while removing any unused components.
- Optimizing the code and fragmenting functions to enhance **clarity** and **reusability**. This focus applied not only to the algorithms but also to the front end. Components were organized to facilitate generalization and allow for their use across different parts of the application, ensuring that the same component or method could be reused with different attributes as needed.
- Adding comprehensive comments throughout the code (**stringdoc**), to make it easily understandable for all team members and future developers.

- Writing thorough **documentation** was also considered essential to provide guidance and context for the codebase.

5.8.2 Deployment Process

The deployment itself was carried out in a cloud environment, utilizing Microsoft Azure, which provided robust infrastructure and services tailored for cloud-based applications.

Microsoft Azure was chosen for deployment due to its comprehensive suite of cloud services, which support the application's scalability and flexibility requirements. Azure's infrastructure allows for easy integration of additional services and tools, enabling the application to adapt to changing user needs while maintaining high performance and availability.

5.9 Methodology for Distance Calculations

This section details the methodology employed for calculating distances and evaluating the buffers surrounding client sites. The urgent need for precise metrics in the evolving field of biodiversity is acknowledged, as there are currently no universally accepted buffers or concrete guidelines for assessing biodiversity impacts. Buffers are essential for understanding how client activities may influence significant biodiversity areas.

To address this gap, comprehensive research into existing reports was conducted, alongside consultations with biodiversity experts. The aim is to define practical strategies that align with the latest standards in biodiversity reporting while providing clear and actionable insights. The methodology focuses on defining biodiversity indicators that guide the application's functionality.

5.9.1 Distance Calculation

The first step involves calculating the distance between the client site and the nearest biodiversity zone. Client sites are represented as points, while the database may contain either points or polygons that represent biodiversity zones. The method of distance measurement depends on this distinction: if the biodiversity zone is represented by a point, the distance is measured directly from the client site. Conversely, if the biodiversity zone is represented by a polygon, the minimum distance between the client site and the polygon is calculated. This approach ensures a precise assessment of how client activities interact with surrounding biodiversity.

5.9.2 Operation-Based Buffer

The next step is to classify the client site according to specific rules, which involves developing a methodology to determine the impact of the client site on the biodiversity zone. Buffers are applied around the points representing client sites. This approach differs from existing applications like ECLR, as it is inspired by the new format used in IBAT disclosure reports. Within EcoAct's biodiversity team, there had always been a focus on the need for buffers that account for the varying impacts different industries can have on biodiversity. These buffers are designed to reflect both the characteristics of the client site and the surrounding significant biodiversity areas, ensuring a more tailored and precise impact assessment. Actually, different industries contribute varying levels of disturbance, affecting local wildlife and habitats. Factors such as light pollution, noise, and chemical runoff can differ significantly based on the nature of the activities conducted. For instance, industrial activities such as mining may have a more profound impact on surrounding biodiversity compared to low-input agriculture, due to the scale and nature of operations.

For this reason, as users input information about client sites, they must select the type of activity. The corresponding buffer will then be automatically assigned based on this input, enabling a more precise analysis compared to existing tools like ECLR, which lack this functionality. ECLR's design follows a standardized format that does not allow clients to specify the industry type, limiting its ability to account for the varying environmental impacts of different activities.

5.9.3 Biodiversity Significance Indicator

Based on the criteria outlined in the **IBAT Disclosure Report** [6], a biodiversity significance indicator is defined to categorize client sites according to the buffer zones. Each protected biodiversity area is assigned a significance score that reflects its proximity to the client site. The significance score is directly linked to the buffer distance, which varies depending on the type of operation carried out at the client site.

The figure below presents a table from the IBAT report, which defines the buffer distances based on different types of operations. These buffers help assess the biodiversity significance of a site by determining its proximity to protected zones. Client sites will undergo further analysis based on their assigned biodiversity significance score, ensuring a comprehensive evaluation of potential environmental impacts.

Table 3. Criteria used to assess the biodiversity significance of each location based on the proximity of the site to a key biodiversity area or protected area relative to the appropriate buffer size based on the type of operation.

Buffer Distance	Type(s) of operation	Biodiversity Significance			
		None	Low	Medium	High
5 km	Offices, Warehouses, Low-input agriculture	> 5 km	1.5 - 5 km	0.5 - < 1.5 km	< 0.5 km
10 km	High-input agriculture, Onshore wind, Construction, Oil and gas (terrestrial)	> 10 km	3 - 10 km	1 - < 3 km	< 1 km
20 km	Offshore wind, Oil and gas (marine), Hydropower	> 20 km	6 - 20 km	2 - < 6 km	< 2 km
50 km	Mining	> 50 km	15 - 50 km	5 - < 15 km	< 5 km

Figure 5.7: *Buffer Definition from IBAT Disclosure Report*

Chapter 6

Results

This chapter presents the key results achieved through the development of the web application for biodiversity analysis. It summarizes the most significant outcomes of the project, followed by a detailed description of the application's features, functionalities, and the analyses performed to empower consultants in biodiversity assessments. Additionally, the chapter covers the functionality verification processes to ensure the application operates correctly, feedback received from consultants during the initial presentation, and any error corrections made during development, along with planned future improvements.

6.1 Key Achievements

The web application developed serves as a fully functional platform for biodiversity analysis, integrating multiple data sources and providing consultants with an intuitive interface to evaluate areas of interest. While the foundational architecture of the application and the basic structure of the navigation bars were in place, the majority of the development—including all core functionalities and the design of the user interface beyond the navigation—was completed during this phase. The following are the key achievements:

6.1.1 Geospatial Visualization

A critical achievement was the ability to visualize geospatial data accurately, plotting complex polygons, including convex and concave shapes, as well as multipolygons with internal holes. This ensures that biodiversity-sensitive areas are displayed without issues such as polygon overlaps or missing features, providing a clear and interactive representation of the data.

6.1.2 Page Management and Data Transfer

Effective management of multiple pages was achieved, with consistent information transfer across pages. Key details such as user sessions and project data are successfully passed between different parts of the application, ensuring a smooth and integrated user experience.

6.1.3 Excel Data Import and Validation

A robust system for importing Excel files was implemented, complete with data validation mechanisms. The uploaded data is validated before being stored in a PostgreSQL database, ensuring that the application processes only accurate and usable information.

6.1.4 Biodiversity Impact Analysis

A core feature of the application is its ability to identify biodiversity-sensitive areas near client sites. It calculates potential impacts using industry-specific buffer zones, following guidelines from the IBAT disclosure reports. This functionality allows for an accurate assessment of how client activities may affect surrounding biodiversity areas, facilitating detailed biodiversity impact assessments. By integrating multiple data sources and employing a user-friendly interface, the application enhances decision-making processes for consultants, ensuring they have the necessary insights to address biodiversity concerns effectively.

6.1.5 Performance Optimization

The application's performance was optimized to handle large datasets efficiently. By restricting function execution to within callbacks and avoiding unnecessary calls, the system maintains high responsiveness and efficient data processing even under heavy data loads.

6.1.6 Optimized Use of Databases

The application differentiates between the use of *MinIO* for file storage and *PostgreSQL* for relational data, optimizing data storage based on the specific nature of the data being processed. This allows for more efficient data management across different types of tasks.

6.1.7 Advanced Analytical Capabilities

The developed web application facilitates **comprehensive biodiversity analyses** by integrating diverse data sources. Key analyses include the identification of sensitive and non-sensitive sites near client locations, highlighting the proximity of client sites to protected areas and Key Biodiversity Areas (KBAs). Visualizations such as bar and pie charts provide insights into site distributions, while detailed tables present proximity data, specific site reports, and unique attributes for each biodiversity database. This suite of analytical tools empowers consultants to assess biodiversity impacts effectively and make informed conservation decisions. Furthermore, the application is enriched by the **visualization of client sites** on the map, allowing for verification when uncertainties arise and providing a clear report to clients that illustrates the locations of nearby protected areas.

6.2 Web Application Features and Functionalities

The developed web application provides an intuitive navigation system that allows users to explore various functionalities related to biodiversity analysis. The main navigation bar offers options to view a comprehensive map of biodiversity databases and access the reporting and analysis section. For a clearer understanding of the application's features, each page described in this section is accompanied by a corresponding figure in the Annexes, which helps visualize the interface and key functionalities.

6.2.1 Biodiversity Database Exploration Page

This page enables users to access the complete biodiversity database, featuring detailed definitions and descriptions that enhance understanding of the data's significance. A dynamic selection menu on the left allows users to choose a database, which simultaneously updates the map display and the corresponding description.

6.2.2 Project Initialization Page

The project initialization page allows users to either select an existing project or start a new one. Users can upload a template file for data entry. It is essential for the client to fill in the template according to the provided instructions before uploading it back into the application.

6.2.3 Input Check Page

Upon uploading the file, users are redirected to the input check page, where they can review the map displaying all client sites. This map helps to identify any anomalies in the data, such as transposed latitude and longitude values. Additionally, a table indicates any errors found in the input data. Users are presented with two options: they can either correct the errors in the Excel file and upload it again or choose to continue with the current data. If they choose to proceed, the application will automatically remove rows with coordinate errors, while incomplete values in other attributes will be retained since they do not impact the overall analysis. This flexibility ensures that users can effectively manage their data while still moving forward with their analyses.

6.2.4 Analysis Selection Page

On the analysis selection page, users can choose among three types of analyses: bar charts, pie charts, or tables. A callback function dynamically updates the visualizations based on the user's selection.

Bar charts provide insights into sensitive and non-sensitive sites, summarizing the number of client sites located near biodiversity areas and generating reports that highlight their proximity to key biodiversity areas and protected areas in particular, as they are the most important databases.

Pie charts present a broader perspective, indicating the proportion of total client sites that overlap with each biodiversity database, enabling consultants to grasp the distribution of sites across various databases easily.

Tabels If users opt for tables, a dropdown menu allows for further dynamic selection of the specific table they wish to display.

The tables include a series of comprehensive reports:

- **The Worst Client Site**: Identifies the client sites with the highest number of nearby biodiversity-sensitive areas, highlighting the worst-performing client sites based on the total number of nearby sensitive zones.

- **Site-Specific Reports**: For each client site, the report details how many areas from each database are in proximity.

- **Closest Site Information**: A table that lists the closest sensitive site for each client, reporting multiple entries when distances are equal for different sensitive biodiversity areas.

- **Comprehensive Proximity Table**: This provides a detailed list of all nearby polygons for each client site, including distance, the name of the corresponding database, and biodiversity significance.

- **Database-Specific Attributes**: Each biodiversity database has a dedicated table that displays unique attributes, such as the number of species present, habitat types, and IUCN category classifications.

6.2.5 Client Sites Visualization Page

This page enables users to visualize the client site on a map, making it easier to identify any anomalous data points or verify the general accuracy of the data. This page also serves as a documentation tool, allowing users to take screenshots for client reporting. Users can filter the data displayed based on the biodiversity database and the specific client site being visualized.

6.2.6 Report Download Page

The final page allows users to download essential reports. Currently, two types of reports are available for export: one provides **analyses on client sites for each biodiversity database**, resulting in eight sheets—one for each database, with diverse attributes presented in each sheet. The other report consolidates information on **nearby sites related to client sites**, including common data such as distance, biodiversity significance, zone names (if available), and the related biodiversity database for the specific site.

6.3 Functionality Verification

To ensure the correct functioning of the application, a series of internal tests were conducted prior to its presentation to all the consultants. These tests aimed to verify that key functionalities, such as geospatial data visualization and report generation, were fully operational.

A comprehensive approach was taken to test the application. All phases of the site were navigated systematically, allowing for an assessment of whether each process unfolded correctly. This involved logging messages throughout the testing process to capture any anomalies or issues. The testing was conducted by 5-6 users, including both technical testers who are familiar with potential weaknesses in applications developed in-house and members of the biodiversity community, who provided insights into the logical flow and usability of the tool. This dual approach ensured that not only the technical functionality was verified but also that the application met the practical needs of its intended users.

Additionally, we tested the application using real case scenarios by employing an Excel file provided by the client. This file had been utilized by the consultants in their work with the client, allowing us to simulate the actual conditions under which the application would operate. Since the consultants had already used the Biodiversity Reporting Framework (BRF) in their analysis, we were able to make preliminary comparisons between our application's results and those obtained from the BRF. While this comparative analysis has been initiated, it is still in the preliminary stages and will be further developed.

6.4 Consultant Feedback

The initial reactions from the biodiversity consultants during the application's presentation were very positive. Many of the consultants were not previously aware of the project, so they were pleasantly surprised by the application's functionality and its user-friendly interface. They appreciated how effectively the platform integrated various data sources and provided clear insights into biodiversity analyses.

Looking ahead, the consultants plan to test the application in real-world scenarios during the next month. They will compare its performance against existing commercial tools to assess its accuracy and overall utility in their daily work. This comparative analysis will help determine how well the application meets their professional needs and whether it can enhance their biodiversity assessment processes.

6.5 Error Correction and Improvements

During testing, numerous minor bugs were identified and resolved, leading to recommendations for additional analyses. As a result, new tables and bar charts have been incorporated, as previously demonstrated in the results section. However, the primary concern remains the application's slow data processing speed.

While some improvements have already been implemented—such as optimizing function calls, displaying only essential data, and pre-calculating the table of neighboring sites in the PostgreSQL database rather than calculating them on-the-fly—further enhancements are necessary. One significant planned improvement is the installation of the extension **PostGIS** in PostgreSQL. This will enable the inclusion of geospatial data and facilitate the management of all considered databases directly within PostgreSQL and FastAPI. By doing so, we can perform geospatial operations directly through SQL, significantly speeding up the processing times.

Chapter 7

Conclusions

The development of the biodiversity analysis web application marks a significant advancement in assessing and managing biodiversity impacts related to corporate sites. This project has successfully created an intuitive tool that aids consultants in evaluating ecological implications, particularly in light of increasing regulatory demands such as the Corporate Sustainability Reporting Directive (CSRD) and the Carbon Disclosure Project (CDP).

Feedback from initial presentations to biodiversity consultants has been overwhelmingly positive, indicating the application's potential to enhance workflow and streamline analyses. The application offers centralized access to multiple biodiversity databases and integrated geospatial visualizations, which facilitate faster decision-making and increase efficiency.

While the application holds promise for reducing costs for EcoAct and attracting new clients, it also faces limitations, such as the reliance on IBAT-controlled databases and challenges in maintaining up-to-date biodiversity data. These factors highlight the need for further exploration of accessible solutions for biodiversity reporting.

In conclusion, the biodiversity analysis web application not only contributes to current environmental management practices but also lays the groundwork for future innovations in biodiversity assessment. With ongoing refinement based on user feedback, this tool has the potential to significantly enhance the integration of biodiversity considerations into corporate sustainability strategies.

Chapter 8

Further Improvements

In this section, additional enhancements that can be implemented to further optimize the performance of the application are outlined:

8.1 PostGIS Integration

Integrating PostGIS into the PostgreSQL database will provide the capability to handle geospatial data more effectively. This integration will allow for more complex spatial queries and analyses to be performed directly in the database, thereby reducing the computational load on the application server and improving response times.

All insert and retrieval functions must be adjusted, and new class structures should be created accordingly. However, these modifications are relatively minor, as the existing code is well-organized and prepared for such changes.

The inclusion of PostGIS will also enable the storage of client points as polygons rather than just latitude and longitude points. The existing code is already set up to calculate overlaps and distances with client sites treated as polygons. The only limitation currently preventing this functionality is the lack of support for handling input .shp files and the inability to store geometries in PostgreSQL. With PostGIS, these capabilities will become feasible.

Optimized Querying Utilizing the spatial indexing features of PostGIS will allow for more efficient execution of queries, especially when dealing with large datasets. This enhancement will significantly improve the overall performance of the application when processing geospatial data.

8.2 Category-Based Reporting

A planned feature is the addition of options to generate custom reports based on specific categories. For instance, consultants may wish to generate reports solely on legally protected areas or on databases that can be directly shared with clients.

8.3 More Accurate Impact Indices

Improvements will be made in the methodology for calculating impact indices, making them more accurate and relevant for the analysis of protected areas or at-risk zones. The integration of a density map to calculate the direct impact on specific areas is another anticipated innovation.

8.4 Expansion of Database Connections

An important development will focus on expanding the range of connections to new biodiversity databases, offering even more in-depth and complex analyses. This will increase the coverage of available information for consultants.

Chapter 9

Discussion

9.1 Impact on Consultants' Work

The web application has the potential to significantly influence the daily workflow of biodiversity consultants. Although the current version has some limitations, it already demonstrates the ability to optimize consultants' work processes. The centralized access to multiple biodiversity databases and the integrated geospatial visualizations greatly facilitate analysis and decision-making in shorter timeframes.

The application **increases efficiency** by reducing the need for consultants to access various external data sources or rely on costly paid tools. As the application evolves based on further tests, it can be integrated into the daily operations of consultants, offering a robust tool for biodiversity impact assessments.

Moreover, the application offers **customization and control** over the data used, as it does not depend on external providers. This flexibility allows consultants to tailor their analyses and functionalities more precisely to client needs. In conclusion, this internal tool is beneficial as it will continue to be developed according to the consultants' specific requirements, ensuring streamlined results without the need for excessive or irrelevant data.

9.2 Commercial Potential and Benefits for Clients

The primary commercial advantage of the application is the potential to significantly **reduce costs** for Ecoact. By using this internally developed platform, the company can avoid the high fees associated with paid biodiversity tools like IBAT. This makes the application attractive to clients looking to minimize expenses related to environmental impact management.

Additionally, the application has the potential to **attract new clients** by offering a competitive alternative to existing tools. By providing a less expensive yet efficient service, it can become a valuable addition to EcoAct's existing portfolio of consultancy services.

9.3 Study Limitations and Encountered Issues

This study revealed several limitations and challenges that should be addressed to improve biodiversity impact assessments:

- **IBAT's Monopoly on Critical Databases:** A significant challenge is the reliance on biodiversity databases controlled by IBAT, which holds a monopoly over the most important data sources. Regulatory frameworks like CDP (Carbon Disclosure Project) and CSRD (Corporate Sustainability Reporting Directive) specifically request the use of these databases. This raises questions about whether national or international regulations are, in effect, mandating the purchase of a specific paid service, which is not a common practice. Further research is required to investigate the implications of this and whether alternative databases or solutions can be leveraged to meet reporting requirements.

- **Rapid Evolution of Data:** Biodiversity data evolves quickly, making it challenging to maintain up-to-date and relevant assessments. Continuous updates to databases require adaptable tools and methodologies to ensure accurate results.

- **Standardization Issues of Biodiversity Indicator:** There is a lack of universally accepted standards for calculating biodiversity indicators, which can lead to inconsistencies in assessments across different projects or regions.

These limitations highlight the need for further research to explore more open and accessible solutions for biodiversity reporting. It will be crucial to investigate whether other databases or innovative tools can be leveraged to reduce dependency on proprietary services while still adhering to regulatory requirements.

9.4 Contribution to the Sustainable Development Goals (SDGs)

The development of the Biodiv-App significantly supports the achievement of three key Sustainable Development Goals (SDGs): **Life on Land (SDG 15)**, **Climate Action (SDG 13)**, and **Responsible Consumption and Production (SDG 12)**. By enabling companies to assess and understand the biodiversity impacts of their operations, this application directly contributes to **SDG 15**, which focuses on preserving terrestrial ecosystems and biodiversity. The app helps companies identify risks to sensitive species and habitats, providing essential insights that encourage practices to minimize negative environmental impacts and support conservation efforts.

The application also aligns with **SDG 13** by fostering sustainable business practices that consider biodiversity as a factor in climate resilience. Biodiverse ecosystems are more resilient to climate impacts, and by identifying risks to biodiversity, companies using the Biodiv-App can indirectly support climate adaptation by helping to maintain ecological systems that play critical roles in carbon storage, water cycle regulation, and soil fertility.

Furthermore, **SDG 12** is addressed through the app's promotion of responsible production practices. By highlighting the ecological footprint of various operational sites, the Biodiv-App encourages companies to adopt sustainable practices and make informed decisions that reduce resource depletion and biodiversity loss. Through customizable reporting aligned with CSRD and CDP standards, the tool fosters transparency, helping companies manage biodiversity impacts in ways that align with their sustainability goals and regulatory obligations.

The Biodiv-App represents an innovative solution that addresses multiple aspects of sustainability. By promoting biodiversity assessments, climate resilience, and sustainable resource management, this project underscores the interconnectivity of SDGs and positions corporate biodiversity management as a key component of broader environmental stewardship.

Chapter 10

Annexes

10.1 Pages of the Web Application

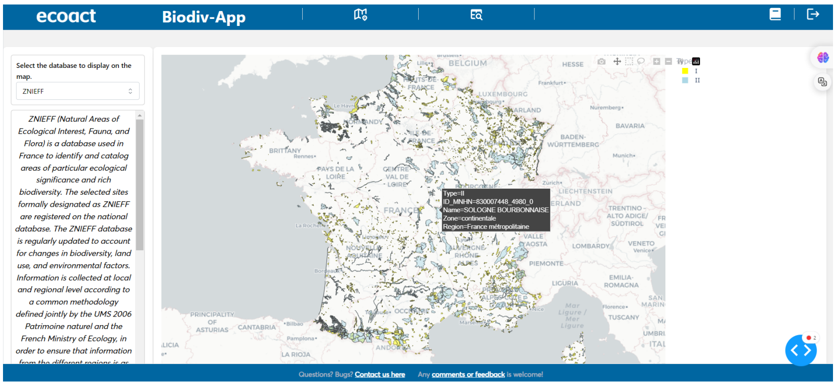

Figure 10.1: ***Biodiversity Database Exploration Page:*** *Example of a database in SHP file format, displaying polygons.*

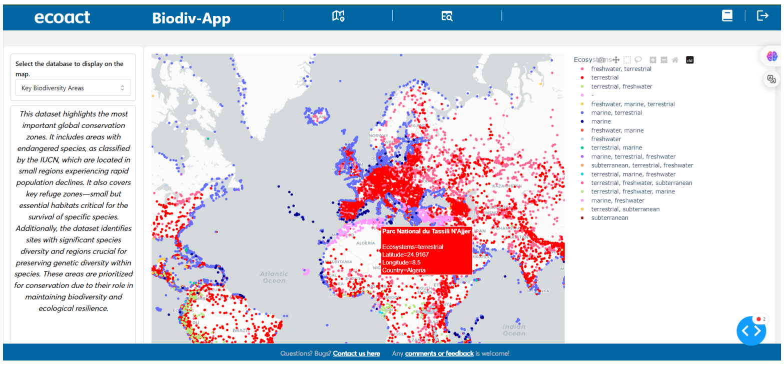

Figure 10.2: ***Biodiversity Database Exploration Page***: *Example of a database in CSV file format, represented with points (latitude, longitude).*

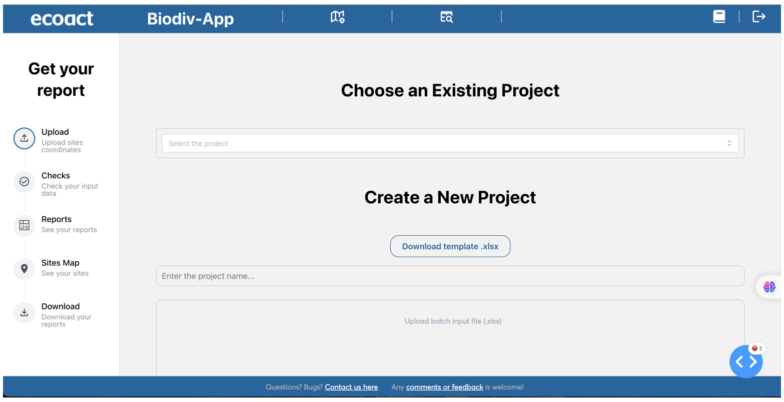

Figure 10.3: ***Project Initialization Page***: *Interface for uploading client data and create a new project or choosing an existing project.*

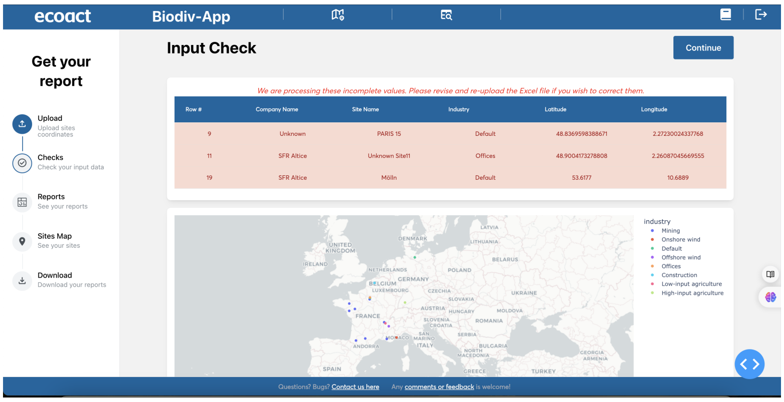

Figure 10.4: ***Input Check Page***: *Page for verifying data inputs before processing.*

Figure 10.5: ***Analysis Selection Page****: Options for displaying analysis results in bar charts.*

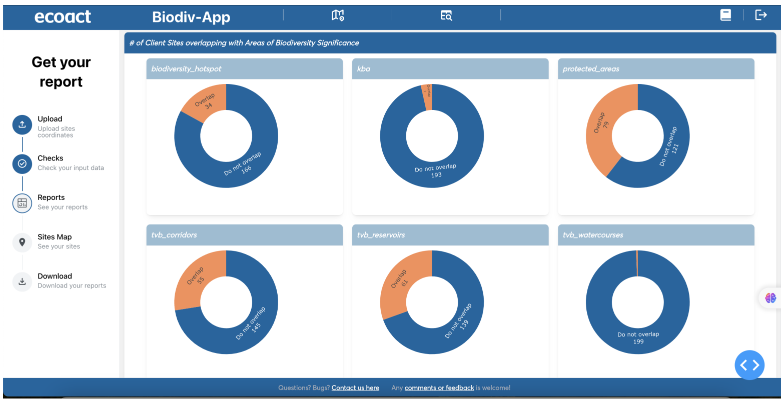

Figure 10.6: ***Analysis Selection Page****: Options for displaying analysis results in pie charts.*

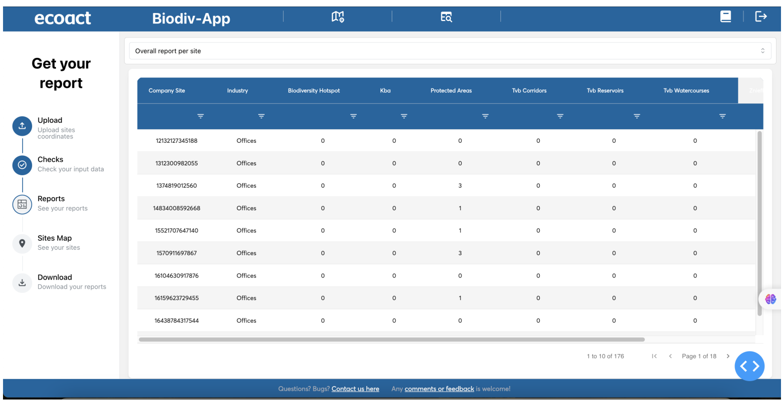

Figure 10.7: ***Analysis Selection Page****: Table showing the overall report per client site.*

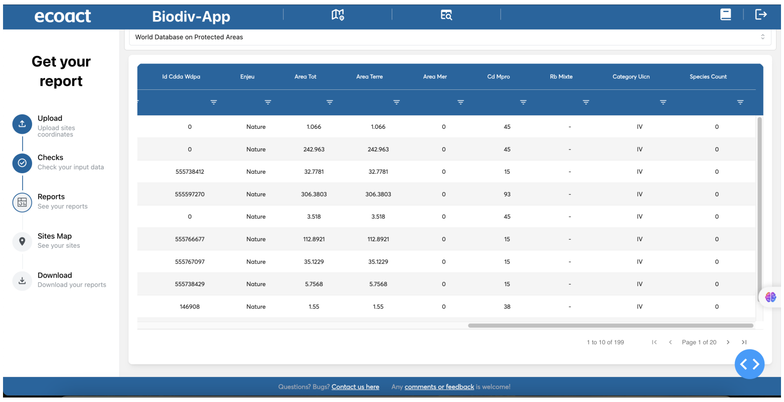

Figure 10.8: ***Analysis Selection Page***: *Table displaying specific databases along with their attributes.*

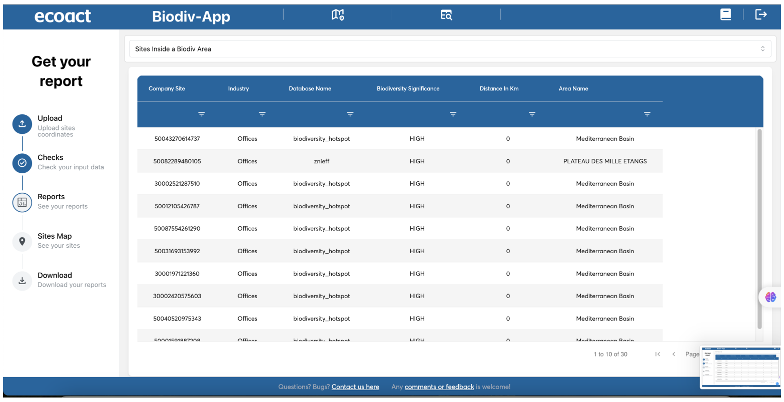

Figure 10.9: ***Analysis Selection Page***: *Table displaying client sites located within areas of biodiversity significance.*

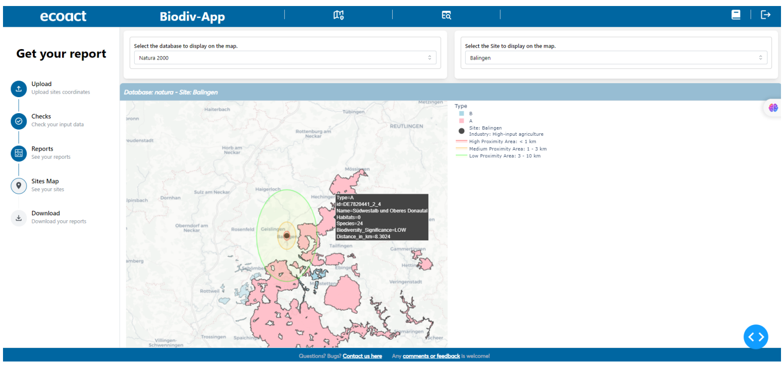

Figure 10.10: ***Client Sites Visualization Page***: *Example of a database in SHP file format, displaying polygons.*

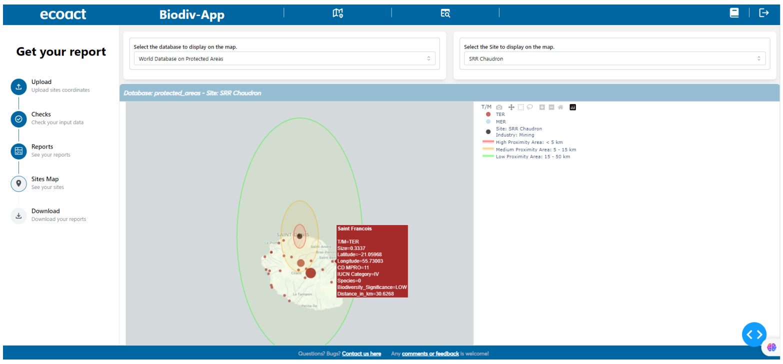

Figure 10.11: ***Client Sites Visualization Page****: Example of a database in CSV file format, represented with points (latitude, longitude).*

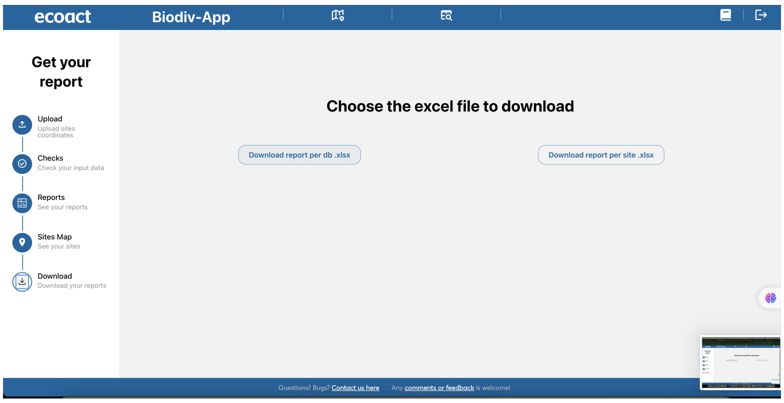

Figure 10.12: ***Report Download Page****: Interface for downloading analysis reports.*

10.2 Useful Biodiversity Tools and Websites for Reporting

This section outlines various tools and resources that can aid in the preparation and reporting of biodiversity impacts in accordance with the ESRS E4 guidelines. The tools are categorized based on their utility in different stages of biodiversity assessment and reporting.

Scientific Training and Definitions

- Convention on Biological Diversity (CBD): https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-fr.pdf
- IPBES: Summary for policymakers of the global assessment report on biodiversity and ecosystem services.

Materiality Analysis Tools for mapping sectors, value chains, and specific operations associated with biodiversity impacts include:

- TNFD: Guidance on the identification and assessment of nature-related issues: The LEAP approach.
- ENCORE: Exploring Natural Capital Opportunities, Risks, and Exposure: https://encorenature.org/en
- SBTN: High Impact Commodity List, Materiality Screening Tool.
- IBAT: Integrated Biodiversity Assessment Tool: https://www.ibat-alliance.org/
- WWF: Biodiversity Risk Filter: https://riskfilter.org/biodiversity/home

Sensitive Areas Key resources for identifying sensitive areas:

- Réseau Natura 2000: Protected areas network: https://www.ofb.gouv.fr/le-reseau-natura-2000
- UNESCO World Heritage Sites: Sites recognized for their cultural and natural significance: https://whc.unesco.org/fr/list/

- Key Biodiversity Areas (KBA).
- Other Protected Areas: Includes Ramsar Sites, World Database of Protected Areas.

Species and Ecosystems Essential databases and tools for species and ecosystems include:

- IUCN: Red List of Threatened Species: https://www.iucnredlist.org/
- IUCN: Global Ecosystem Typology: https://iucn.org/resources/conservation-tool/iucn-global-ecosystem-typology
- OneEarth: Global Map of Ecoregions: https://www.oneearth.org/navigator/?view=bioregions
- IBAT.
- UNEP-WCMC: Critical Habitat Screening Layer, Ocean Data Viewer, Global Forest Watch.
- Conservation International: Trends.Earth: https://docs.trends.earth/en/latest/
- Space Intelligence: HabitatMapper, Resource Watch.

Scenario Analysis Tools for conducting scenario analysis:

- Network for Greening the Financial System (NFGS): Scenarios Portal: https://www.ngfs.net/ngfs-scenarios-portal/
- University of Cambridge Institute for Sustainability Leadership: Nature Positive Hub.
- International Standards Organization (ISO): ISO/TC 331: https://www.iso.org/committee/8030847.html
- Principles for Responsible Investment (PRI): IFR Forecast policy scenario + nature: https://www.unpri.org/inevitable-policy-response/ipr-forecast-policy-scenario--nature/10966.article
- TNFD: Guidance on scenario analysis: https://tnfd.global/wp-content/uploads/2023/09/Guidance_on_scenario_analysis_V1.pdf?v=1695138235

Targets Resources for setting biodiversity targets:

- CBD: 2030 Targets: https://www.cbd.int/gbf/targets
- SBTN: Step 3. Measure, set, and disclose targets, Land Technical Guidance.
- TNFD: Guidance for corporates on science-based targets for nature: https://tnfd.global/wp-content/uploads/2023/09/Guidance_for_corporates_on_science_based_targets_for_nature_v1.pdf?v=1695138398

Indicators Standards and frameworks for biodiversity-related disclosures:

- CDSB: Framework application guidance for biodiversity-related disclosures.
- SASB: SASB Standards overview: https://sasb.ifrs.org/standards/
- CDP: Nature Policy Hub: https://www.cdp.net/en/policy/program-areas/nature-policy-hub
- GRI: GRI 101: https://www.globalreporting.org/standards/standards-develop
topic-standard-for-biodiversity/
- World Economic Forum: Principles of Planet Metrics: https://www.weforum.org/stakeholdercapitalism/planet/

Stakeholders Guidance on stakeholder engagement in biodiversity initiatives:

- IUCN: Stakeholder Engagement in IUCN projects: https://iucn.org/sites/default/files/2022-05/esms-stakeholder-engagement-guidance-not
pdf
- United Nations Human Rights (UNHR): Biodiversity and Human rights: https://www.ohchr.org/en/special-procedures/sr-environment/biodiversity-and-human-rights
- International Indigenous Forum on Biodiversity (IIFB): https://iifb-indigenous.org/
- TNFD: Guidance on engagement with Indigenous Peoples, Local Communities, and affected stakeholders.

Sectoral Classification Classification resources for different sectors:

- SASB: Find your industry: https://sasb.ifrs.org/find-your-industry/
- IUCN: Mainstreaming biodiversity into priority economic sectors: https://portals.iucn.org/library/sites/library/files/documents/2022-052-En.pdf
- TNFD: Additional guidance by sector: https://tnfd.global/tnfd-publications/?_sft_framework-categories=additional-guidance-by-sector

Bibliography

[1] Corporate Sustainability Reporting Directive (CSRD). *Information about the directive and its corporate applications.* https://www.thebiodiversityconsultancy.com/services/framework-alignment/corporate-sustainability-reporting-directive-csrd/.

[2] CDP (Carbon Disclosure Project). *Platform for companies to report their environmental sustainability.* https://www.cdp.net/en/?cid=315908478&adgpid=55107277875&itemid=&targid=kwd-385949528608&mt=b&loc=9198583&ntwk=g&dev=c&dmod=&adp=&gad_source=1&gclid=Cj0KCQjw3v03BhCqARIsAEWblcCs4LDR_E_QLXkY6Mk-o9PF0i5NAFE9NR0iLFgNB08a9Iu6k1a7ieoaAmWTEALw_wcB.

[3] Integrated Biodiversity Assessment Tool (IBAT). *Tool for assessing biodiversity and corporate impacts.* https://www.ibat-alliance.org/.

[4] Biodiversity Risk Filter (BRF). *Tool for assessing and managing biodiversity-related risks.* https://riskfilter.org/biodiversity/home.

[5] Climate Risks Tool by EcoAct. *Tool for analyzing climate risks and opportunities.* https://eco-act.com/service/climate-risks-tool/.

[6] Integrated Biodiversity Assessment Tool (IBAT). *Disclosure Preparation Report*. Available to download at: https://www.ibat-alliance.org/sample-downloads.

[7] EcoAct Documentation. *Resources and documentation for using EcoAct.* https://ecodev-doc.lcabox.com/.

[8] CDP Questionnaire. *Guidance for completing the CDP questionnaire on climate change.* https://cdn.cdp.net/

cdp-production/cms/guidance_docs/pdfs/000/003/912/original/CDP-climate-change-changes-document.pdf?1673628812.

[9] International Union for Conservation of Nature (IUCN). *IUCN Red List of Threatened Species.* https://www.iucnredlist.org/.

[10] Protected Planet. *World Database on Protected Areas (WDPA).* https://www.protectedplanet.net/en.

[11] Key Biodiversity Areas (KBA) Partnership. *Key Biodiversity Areas Database.* https://www.keybiodiversityareas.org/kba-data.

[12] French Ministry of Ecological Transition. *Base Espaces Protégés.* https://www.data.gouv.fr/fr/datasets/inpn-donnees-du-programme-espaces-proteges/.

[13] French National Institute for Biodiversity (INPN). *Inventaire des Zones Naturelles d'Intérêt Ecologique, Faunistique et Floristique (ZNIEFF).* https://inpn.mnhn.fr/programme/inventaire-znieff/presentation.

[14] French Ministry of Ecological Transition. *Liste Rouge des Espèces Menacées en France.* https://uicn.fr/liste-rouge-france/.

[15] French Ministry of Ecological Transition. *Trame Verte et Bleue (TVB).* https://www.ecologie.gouv.fr/trame-verte-et-bleue.

[16] European Commission. *Natura 2000 - The European Ecological Network.* https://ec.europa.eu/environment/nature/natura2000/index_en.htm.