EXPLORING THE PERCEIVED CHALLENGES IN THE PROVISION OF BIODIVERSITY-RESPONSIVE ENERGY SUPPLY

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ABSTRACT

EXPLORING THE PERCEIVED CHALLENGES IN THE PROVISION OF BIODIVERSITY-RESPONSIVE ENERGY SUPPLY

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The environmental impacts of energy infrastructure pose both direct and indirect threats to biodiversity and ecosystem continuity. This thesis investigates the relationship between energy supply systems and biodiversity conservation by combining a systematic literature review with a survey involving 147 employees from four major electricity distribution companies in Türkiye. Findings reveal a lack of spatial integration between protected areas and infrastructure planning, as well as fragmented data structures and poor institutional coordination that constrain effective decision-making. Furthermore, conventional environmental impact assessments often fail to incorporate biodiversity-specific parameters, undermining the alignment of infrastructure development with conservation objectives. In response, this study advocates for the development of GIS-based, user-driven decision support systems aligned with open data and FAIR principles to support biodiversity-responsive energy planning.

Keywords: Biodiversity, Energy Infrastructure, Data Management, Urban Infrastructure Planing

ÖZ

BİYOÇEŞİTLİLİĞE DUYARLI ENERJİ TEDARİĞİNİN SAĞLANMASINDA ALGILANAN ZORLUKLARIN ARAŞTIRILMASI

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Enerji arzı süreçlerinin biyoçeşitlilik üzerindeki etkileri hem doğrudan hem dolaylı biçimde ekosistem bütünlüğünü tehdit etmektedir. Bu tez, Türkiye'nin önde gelen dört elektrik dağıtım şirketinde çalışan toplam 147 personelin katılımıyla yürütülen bir anket çalışması ve sistematik bir literatür taramasına dayanarak, enerji altyapısı ile biyoçeşitliliğin korunması arasındaki ilişkileri ve veri temelli zorlukları incelemektedir. Bulgular, korunan alanlar ve enerji şebekesi planlaması arasında güçlü bir mekânsal entegrasyon eksikliği olduğunu; kullanılan verilerin parçalı yapısı ve kurum içi koordinasyon eksikliklerinin karar destek süreçlerini sınırladığını ortaya koymaktadır. Ayrıca, çevresel etki değerlendirme süreçlerinin biyoçeşitliliğe özgü parametreleri yeterince içermemesi, doğa koruma ile enerji arzı arasında uyum sağlanmasını güçleştirmektedir. Bu bağlamda, tez CBS tabanlı, kullanıcı odaklı ve açık veri ilkelerine dayalı karar destek sistemlerinin geliştirilmesini önermektedir.

Anahtar Kelimeler: Biyoçeşitlilik, Enerji Altyapısı, Veri Yönetimi, Kentsel Altyapı Planlaması

Her zaman inanan, destekleyen ve sabırla bekleyen aileme ve oyunlarıyla her zaman ruhumu hafifleten Ares'e…

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I anticipate that this study will enhance the establishment of more equitable and cohesive strategies between energy infrastructure planning and biodiversity conservation.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CBD Convention on Biological Diversity

EIA Environmental Impact Assessment

FAIR Findable, Accessible, Interoperable, Reusable

GIS Geographic Information Systems

IBA Important Bird Area

IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IUCN International Union for Conservation of Nature

KBA Key Biodiversity Area

LCA Life Cycle Assessment

NDVI Normalized Difference Vegetation Index

RAMSAR Convention on Wetlands of International Importance

SDG Sustainable Development Goal

SPSS Statistical Package for the Social Sciences

CHAPTER 1

INTRODUCTION

Urbanization, industrialization and increasing energy demand create serious pressures on natural resources, threatening the integrity of ecosystems. Energy infrastructure, one of the most visible examples of these pressures, stands out as a key element of sustainability not only in the production-consumption chain but also in the context of spatial interaction with nature. Infrastructures established in regions where electrical energy supply is provided in particular lead to environmental consequences such as habitat fragmentation, ecosystem destruction, land use changes and direct physical impacts on wildlife (Kalfas et al., 2023).

In this context, the development of strategies compatible with nature conservation principles in the planning and management processes of energy infrastructure is becoming increasingly important. However, the development of these strategies is directly related not only to technical competence but also to data governance approaches. The regions where electricity distribution services are provided often overlap with critical areas in terms of biodiversity; this necessitates the integration of biodiversity-related data in decision-making processes. Indeed, the literature frequently emphasizes that electricity infrastructure frequently overlaps with biodiversity-sensitive areas, leading to habitat fragmentation, the disruption of species migration routes, and the deterioration of ecosystem services (Guil et al., 2022; Katovich, 2024; Moreira, 2019). When biodiversity and energy infrastructure overlap, the consequences are often severe. Energy projects frequently affect protected regions such as KBAs, wetlands, or migration routes, resulting in habitat loss, increased wildlife mortality, and ecosystem fragmentation. Some of these impacts occur immediately, such as electrocution or collisions, while others are

indirect and long-term, including noise, water system changes, or the spread of invasive species (Moreira, 2019). Furthermore, biodiversity data is often fragmented, outdated, or incompatible with energy planning systems, complicating decision-making processes (Soares et al., 2018; Gallo et al., 2022). Therefore, not only improving technical capacity but also developing holistic data management approaches is seen as a critical need to achieve the balance between energy supply and nature conservation.

At this point, institutional differences, technical inadequacies and sectoral incompatibilities in data management processes hinder sustainable planning goals. In the existing literature, it is frequently emphasized that the collection of incomplete, scattered or non-standardized data on biodiversity makes it difficult to correctly assess environmental impacts and integrate them into decision support systems (Allard & Aydınoğlu, 2012; Anderson et al., 2020; Gadelha Jr. et al., 2020; Chamanara et al., 2021). Planning energy infrastructure in a way compatible with biodiversity is directly related not only to access to data, but also to how this data is managed, which institutions are involved in the process and on which digital and administrative grounds decisions are made. In this context, the diversity of data governance processes according to sectoral practices is of critical importance in understanding how energy companies interact with nature conservation goals. The digital capacity of the actors in the energy sector, the level of cooperation between institutions and the decision-making culture; It determines the extent to which biodiversity data is evaluated not only technically but also at institutional and administrative levels (Gallo et. Al., 2022). Therefore, typological frameworks that can analyze different data governance approaches are functional not only for understanding the digital transformation of cities, but also for resolving governance differences in the energy-biodiversity relationship (Duygan et al., 2021). This indicates a clear gap in the literature: while many studies emphasize technical solutions or ecological consequences (Guil et al., 2022; Katovich, 2024; Moreira, 2019), institutional-scale challenges and data governance problems remain underexplored (Allard & Aydınoğlu, 2012), particularly in the context of electricity

distribution networks located in biodiversity-rich regions (Anderson et al., 2020; Soares et al., 2018; Gallo et al., 2022; Duygan et al., 2021).

This master's thesis aims to examine data management practices for the protection of biodiversity in energy supply regions and to evaluate the challenges encountered in this area in a holistic way. The fundamental problem of this research is the inadequacy of existing systems for protecting natural areas threatened by the direct or indirect impacts of electricity infrastructure projects. However, the primary reason for the failure to effectively manage these risks is that biodiversity data is fragmented, outdated, and incompatible with energy planning systems (Anderson et al., 2020; Soares et al., 2018; Gallo et al., 2022). This leads to electricity distribution companies failing to adequately consider conservation priorities in their decision-making processes. In this framework, the relationship between energy infrastructure and biodiversity will be examined, while highlighting how fragmented data, institutional barriers, and limited integration with decision support systems hinder biodiversity-oriented decision-making (Soares et al., 2018; Gallo et al., 2022).

The main question of the research is defined as follows: **How can companies effectively integrate biodiversity conservation into energy supply processes while overcoming data-related and organizational challenges?**

The sub-research questions that are shaped based on this question are as follows:

• What are the main challenges companies face in protecting biodiversity during energy supply processes?

• Which types of data are used in conservation processes, and how do data-related challenges affect biodiversity protection?

• What strategies are currently applied to protect biodiversity, and how do these differ between urban and rural contexts?

• What are the most pressing institutional needs to strengthen biodiversity protection capacity in energy planning and supply?

This thesis aims to investigate how biodiversity conservation can be better integrated into energy supply processes by addressing data gaps, institutional barriers, and governance challenges. The research began with a literature review to identify the main challenges and the types of data commonly used. Based on these findings, a survey was designed and applied to staff working in electricity distribution companies. In the survey, participants rated the extent to which they experience different challenges, indicated the types of data they use, and described strategies applied in both general and urban contexts. They were also asked in an open-ended question what they see as the most fundamental need for improving biodiversity conservation.

The analysis combined both quantitative and qualitative approaches. On the quantitative side, regression analysis was conducted in SPSS, where perceived biodiversity conservation success was treated as the dependent variable and the rated challenges as independent variables. On the qualitative side, the responses to open-ended questions were analyzed through content analysis, and the frequency of recurring themes was calculated.

The scientific contribution of the research is that it links data governance, energy planning, and biodiversity with the broader literature on urban planning and sustainable infrastructure.

The basic concepts focused on in this study include:

• Biodiversity: It refers to the diversity of species, genetic structures and ecosystems living in a specific geographical region;

• Energy infrastructure: It is the physical systems used for electricity production, transmission and distribution;

• Data management/governance: It is the institutional approach that covers the processes of collecting, storing, sharing, standardizing and using data.

The introduction section outlined the general framework of the research; has revealed its conceptual basis, importance and purpose. Chapter 2 includes a literature

review addressing the relationship between energy infrastructure and biodiversity and the challenges of data management in this area. Chapter 3 describes the research methodology, including the systematic literature review, interviews, and institutional data analysis. Chapter 4 presents the findings of the study and discusses them alongside the literature. The final section summarizes the main conclusions, highlights the study's contributions, and offers suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a comprehensive review of the literature related to the relationship between energy infrastructure and biodiversity conservation. As global energy demands rise, the expansion of electricity networks into ecologically sensitive areas has brought about new challenges for sustainable planning. This chapter will first lay the conceptual foundations of biodiversity and energy supply, then explore the fundamental considerations for addressing ecological concerns when developing electrical energy infrastructure, as well as the fundamental challenges of protecting biodiversity and mitigating threats in regions currently receiving electricity. This review will synthesize information from both academic research and applied case studies to identify and address the gaps in the process of providing the necessary electrical energy supply and prioritizing ecological resources in urban infrastructure, along with strategic opportunities to address these gaps.

2.1 The Relationship Between Energy Supply & Biodiversity Conservation

As a result of increasing global energy demand, the environmental impacts of energy infrastructures are becoming increasingly evident. Electric transmission lines, transformer substations, and other related components that provide electricity supply not only support human settlements and economic growth, but also place significant pressure on natural ecosystems, landscape continuity, and biodiversity. The relationship between energy infrastructure and ecological integrity is getting bigger and more complicated. This has made finding the right balance between giving

people the infrastructure they need and protecting biodiversity a central issue in sustainability and urban planning (Kiesecker and Naugle, 2017; Soares et al., 2021).

Cities expanding into rural areas accelerate ecosystem fragmentation and reduce habitat quality in these areas. Protected areas, such as Key Biodiversity Areas (KBA), Ramsar sites, and other internationally designated regions, help maintain ecosystem services and conserve habitat-specific species, forming the backbone of global biodiversity strategies (Yong et al., 2024; He and Wei, 2023). Therefore, protecting biodiversity is now an important part of long-term spatial planning, especially when it comes to making sure that infrastructure grows in rural and peri-urban areas (Burgin, 2016).

The success of conservation policies depends on more than just the laws that are used to enforce them. It also depends on how biodiversity is included in policies that affect different areas, like transportation, energy, and mines. Wu et al. (2023), for example, say that in systems that are quickly urbanizing, the complicated interactions between ecological, economic, and social forces make it harder for species to survive. Therefore, quantifying and characterizing these pressures is a critical component of modern biodiversity management (Yong et al., 2024). Protected areas should not be viewed merely as exclusion zones but rather as adaptive management systems that support the delivery of ecological services under human influence. In northeastern Poland, for example, Sokol & Laska (2024) demonstrated that ecosystem services provided by water catchments bring simultaneous environmental and economic benefits, suggesting that conservation decisions should be made using multi-criteria evaluation models.

Energy infrastructure impacts biodiversity both directly and indirectly. This is a core issue in reconciling energy and ecology, and one that deserves detailed elaboration. Direct impacts include bird mortality from collisions or electrocution along transmission lines (Guil et al., 2022; Katovich, 2024), or the fragmentation of habitats by towers and maintenance roads. Increased accessibility can have indirect

effects, such as changes in land use, the introduction of invasive species, or pollution from light and noise. Because these effects build up over time and sometimes don't follow a straight line, project design and site selection should be based on more than just environmental rules. They should also be based on spatial, ecological, and social studies. As demonstrated in the Brazilian context, environmental variables can influence the operational efficiency of energy providers in unexpected ways, emphasizing the need for local context-specific adaptations (Leme et al., 2014; Ponitka & Boettner, 2020). These insights will be explored in more depth in subsequent sections.

Emerging technologies such as smart grids, remote sensing–based ecological monitoring, and nature-inclusive infrastructure design are increasingly seen as potential tools to mediate the tension between biodiversity and energy systems. Soares et al. (2018), on the other hand, say that these technologies alone are not enough because protected areas need their own strategic frameworks.

In the end, the connection between energy supply and biodiversity is not just about balancing two needs on opposite ends of the scale. It is a multi-scalar governance problem that needs various stakeholders, data sets, policy and strategy frameworks. The key to solving this problem is to make sure that biodiversity issues are taken into account at all steps of planning for energy infrastructure, from choosing a site and designing it to putting it in place, maintaining updated on it, and taking it down.

2.1.1 Understanding Biodiversity and Energy Supply

Before being able to understand the complicated and sometimes contradictory connection between ecosystems and energy infrastructure, it's necessary to be clear on what each term means. This part examines the structure and location of biodiversity and energy supply systems. It then looks at how these systems work together in different environments and operational processes. The aim is to explain

the foundational relationship between them—not only as conflicting but also as potentially reconcilable components of sustainable planning.

Energy supply refers to the entire system that enables the production, transmission, and distribution of electricity from source to consumer. It includes a broad spectrum of technical infrastructure such as power plants, high and low voltage lines, substations, and distribution units. These systems are necessary for contemporary life, but building and running them sometimes requires a lot of land, especially in rural and peri-urban areas. Transmission and distribution lines, which are examples of linear infrastructure, cover large areas and can break up natural habitats and make it harder for ecosystems to link (Guil et al., 2022; Katovich, 2024).

Biodiversity, however, includes a lot more than just the number of species. It encompasses genetic variation, interspecies interactions, habitat diversity, and the functional integrity of ecosystems. Biodiversity is the basis for many ecological processes and services that are important for human health, including as regulating the climate, filtering water, pollination, and soil fertility (Yong et al., 2024; Sokol & Laska, 2024). Protecting biodiversity is increasingly recognized in the literature as a crucial aspect of adapting to climate change, reducing disaster risks, and making sure that natural resources last for a long time (Kiesecker & Naugle, 2017; Moreira, 2019; Aticho et al., 2023).

But when biodiversity and energy infrastructure overlap in space or function, this connection doesn't always go smoothly. Energy projects often have an effect on regions that are sensitive or protected, such as KBAs, wetlands, or wildlife migration routes. This overlap can lead to big problems like habitat loss, more wildlife deaths, or ecosystems breaking up (Moreira et al., 2019). Some of these effects are immediate, like getting hit by a car or electrocuted, while others are more indirect, such noise pollution, changes in water systems, or the spread of non-native animals. These consequences can hurt ecosystems and the health of landscapes for a long time.

To better manage these impacts, we need to stop thinking of energy development and biodiversity conservation as competing goals. Instead, they should be seen as connected systems that must be planned and designed together. This kind of integrated approach focuses on making sure infrastructure development respects ecological sensitivity. For example, Ponitka and Boettner (2020) point out that identifying sensitive areas early—like breeding grounds or seasonal habitats—can help choose better locations for energy projects. Similarly, Kiesecker and Naugle (2017) highlight the importance of avoiding high-value ecological areas through wider landscape planning.

These challenges are not just ecological or technical. There are also administrative, legal, and social aspects that make the relationship between energy and biodiversity more complex (Gallo et al., 2022; Moreira, 2019; Soares et al., 2018). To deal with this, better data management, cooperation between sectors, and public involvement are needed (Allard & Aydınoğlu, 2012; Anderson et al., 2020; Chamanara & König-Ries, 2014). Tools like spatial decision support systems—which bring together biodiversity data and infrastructure maps—can help detect risky areas during the planning stage (Kiesecker & Naugle, 2017; Guil et al., 2022; Weber et al., 2023). Environmental Impact Assessments (EIAs) should also include detailed biodiversity indicators such as species trends, habitat connectivity, and ecosystem services, not just general environmental measures. In addition, using local ecological knowledge and listening to communities affected by projects can make the outcomes more acceptable and successful in the long run (Peck et al., 2023; Richardson et al., 2017).

To sum up, there are a lot of issues that affect the relationship between energy supply and biodiversity conservation. These include problems with space, technical limits, environmental concerns, and problems with how things operate in organizations. It require to look at how these systems work together in different areas and at different levels in order to fully understand this relationship. The next part will talk about the most important things to think about when planning for energy and biodiversity, especially when it comes to issues of space, policy gaps, and technical issues.

2.1.2 Key Considerations for Integrating Energy Infrastructure and Biodiversity

Making sure that biodiversity and energy infrastructure can exist together requires attention to several key areas—spatial, technical, institutional, and social. This part of the study focuses on the main factors that should be taken into account when planning energy infrastructure with biodiversity in mind. These include avoiding ecologically sensitive areas, applying environmentally friendly engineering solutions, involving local communities in decision-making, using detailed environmental assessment methods, and creating integrated institutional planning systems. This part shows how biodiversity concerns can be more carefully taken into account when planning and designing infrastructure by looking at these parts from interdisciplinary perspective.

Careful planning of land that helps find and stay away from ecologically sensitive places is a key part of making energy infrastructure more compatible with biodiversity. A lot of research has shown how important it is to map areas like Key Biodiversity Areas (KBAs), Ramsar sites, endemic species' places of residence, and wildlife migration paths to lower the risk of habitat loss (Kiesecker & Naugle, 2017; Guil et al., 2022). But it's harder to make infrastructure growth fit with conservation goals when spatial data systems aren't linked together. Katovich (2024) and Ponitka & Boettner (2020) both write about this problem and how the lack of coordinated data makes it hard for development and protection attempts to work together.

An important part of protecting environments is not only planning where things will be placed, but also how they will be built. Using building methods that are good for nature, like bird-safe power lines, solar panels that are suited to local habitats, and careful micro-siting, can help make infrastructure more eco-friendly (Guil et al., 2022; Moreira et al., 2019). Soares et al. (2018) say that choices made early in the planning process can have a big effect on how biodiversity is affected in the long-term. Another important part of sustainable planning is involving local people and

taking their traditional ecological knowledge into account. This kind of information isn't always taken into account when decisions are made at the top, but it can help make conservation plans that are more adaptable and widely accepted (Peck et al., 2023; Richardson et al., 2017). This kind of community involvement also helps people trust infrastructure projects and protect natural resources in the long-term. Environmental assessments shouldn't just look at general environmental indicators; they should also look at measures that are specific to biodiversity. Recent studies show how important it is to observe changes in habitat quality, figure out how vulnerable certain species are, and see how long ecosystem services will last (Yong et al., 2024; Sokol & Laska, 2024). Remote sensing and geospatial analysis are two tools that make it possible to keep an eye on how infrastructure changes biodiversity over time (Theron et al., 2021).

Lastly, it's important to have a strong and well-organized institutional system in order to implement plans well. Soares et al. (2021) and Kiesecker & Naugle (2017) say that flexible and open governance models that use development-by-design methods and spatial decision support tools are an effective concept. To successfully link planning for energy infrastructure with protecting biodiversity, it is important for institutions to work together, for policies to be clear and uniform, and for data to be properly integrated.

The next part will talk about the problems that actually occur in places where energy infrastructure already existing or is being built up. Some of these problems are restricted access to spatial data, trouble getting institutions to work together, and planning disagreements that make it harder to protect biodiversity.

2.1.3 Challenges of Conserving Biodiversity in Energy Supplying Regions

Concerns about biodiversity have become harder to include in plans for energy infrastructure as they continue to grow and spread across both land and water environments. These problems aren't just biological; they also have to do with

institutions, technology, and space. Studies have shown that there are places where the goals of developing energy and protecting biodiversity either clash or move in opposite ways. In this part, research from other sources is used to find and list the main problems that occur in places where energy infrastructure is being built or is already in the process of being built.

The review focuses on five main groups of problems that come up repeatedly in various contexts. Some of these are: too much pressure on habitats and species, lack of accurate data and gaps in tracking; issues with the design and selection of materials for infrastructure; limited government and institutional power; and planning-related disagreements like wrong land use. Each group shows a different, but often linked, aspect of the connection between biodiversity and energy systems. The list below gives an overview of these groups.

A detailed explanation of how the challenges were collected from the reviewed articles, compiled, and categorized into these groups can be found in Section 3.2.1.1 of the methodology, while the full list of challenges is provided in Appendix C.

Table 2.1 Key Challenges Identified in the Literature for Biodiversity Conservation in Energy Supply Regions

Challenges	**Frequency**	**Percentage**
Inability to monitor interactions between infrastructure and nature and assess long-term environmental impacts	55	21%
Lack of systematic data sharing and coordination among institutions	34	13%
Incompleteness, obsolescence, and lack of standardization in biodiversity data	30	11%
Failure to integrate protected areas and biodiversity priorities into energy infrastructure planning	26	10%

(Table 2.1 continued)

Challenges	**Frequency**	**Percentage**
Exclusion of environmental impacts from cost-benefit analyses in investment, planning, and decision-making processes	23	9%
Misalignment of electricity infrastructure with nature-based and environmentally sensitive principles	20	8%
Lack of systematic consideration of nature-based solutions in investment planning	18	7%
Insufficient institutional capacity for adopting new technologies and nature-based approaches	17	6%
Ambiguity in environmental regulations and inconsistency across local, national, and international frameworks	14	5%
Lack of financial prioritization of environmental investments and preference for financially driven decisions over environmental concerns	10	4%
Lack of awareness among institutional and technical units regarding environmental impacts and obligations	10	4%
Limited implementation of life cycle assessments (LCA) for electricity infrastructure	5	2%
Limited use of recycled and environmentally friendly materials	3	1%
TOTAL	**265**	**100,00**

As seen in the table, the most frequently cited challenge is the inability to monitor interactions between infrastructure and nature and assess long-term environmental impacts (21%). Linear infrastructure such as power lines, roads, and transformer substations lead to habitat fragmentation, hinder species mobility, and weaken ecological connections. This not only reduces habitat quality but also increases the risk of mortality for certain species. Numerous studies have demonstrated that power

lines, particularly those located along bird migration routes, can cause high losses due to collisions and electrocution (Guil et al., 2022; Katovich, 2023). Similarly, Hollmen et al. (2007) indicate that open power lines can also impact the habitats of diverse species, such as insects.

The second most frequently cited challenge is the lack of inter-institutional data sharing and the disorganization, outdatedness, or incompatibility of biodiversity data with energy planning systems (13% + 11%). Failure to ensure data integrity leads to weak spatial assessments and the oversight of early intervention opportunities. Soares et al. (2018) emphasize that biodiversity data, despite being available at various institutions, is not integrated with the energy sector. Costello & Wieczorek (2014) also note that the lack of standardized and accessible data makes long-term monitoring of environmental impacts difficult.

A third significant problem is the inadequate integration of protected areas and biodiversity priorities into energy planning (10%). Additionally, in many cases, the costs and benefits of energy projects are evaluated without considering their environmental impacts. As a result, nature-based solutions are often excluded from planning processes (7%). Burgin (2016) emphasizes that limiting biodiversity to green regions, especially in cities, ignores ecological values. Similarly, Aticho et al. (2023) highlight how rapid urban growth affects protected areas.

Another aspect that stands out in the table is the failure of infrastructure designs to consider ecological sensitivities (8%). Uninsulated power lines, extensive vegetation removal, or technical design errors can directly lead to species losses. Gilad et al. (2024) demonstrates that simple measures in power line design can significantly reduce bird mortality.

However, institutional capacity gaps are also a striking finding (6%). Delays in the adoption of new technologies or nature-based solutions, combined with the fragmented structure among energy and environmental institutions, exacerbate implementation challenges. Richardson et al. (2017) demonstrates that such

institutional fragmentation creates gaps in implementation even when environmental standards exist.

Finally, factors such as the limited implementation of life cycle assessments (LCA) (2%) and the low use of recycled or environmentally friendly materials (1%) hinder the systematic assessment of environmental impacts. Ajayi et al. (2022) emphasize that the long-term environmental impacts of energy networks can only be assessed holistically through a life cycle approach. In summary, the challenges fall into five main categories: ecological impacts, fragmented and non-standardized data and the inability to monitor them, ecological deficiencies in infrastructure design and material choices, lack of institutional coordination and limited governance capacity, and planning-related disagreements such as inappropriate land use decisions. This table shows that the main problem with providing energy that is sensitive to biodiversity is making sure that data is accurate and can be used together, both technically and at the level of governance. So, for long-term answers, we need to look at nature-based approaches and systematic data management at the same time.

In Türkiye, many of these problems show up in similar and often related ways. Türkiye is an a contributor to several international conservation agreements, such as the Ramsar Convention, the Convention on Biological Diversity, and the Bern Convention. However, it is still difficult to use biodiversity data in infrastructure development. The pilot interviews with energy businesses and sustainability departments in this research show that protected area data (such KBA, IBA, or Ramsar zones) are not easy to find in the current power grid inventory systems. Ecological sensitivity spatial data is sometimes stored on multiple platforms and needs to be combined by hand, which slows down and makes effect evaluations less accurate. Additionally, the lack of a consistent data governance framework among energy and environmental institutions makes it harder to make sure that site selection is sensitive to biodiversity. This fragmentation, together with the absence of standardized spatial decision support tools, underscores the critical necessity for

integrated, GIS-based planning frameworks that can promote early conflict identification and enhance biodiversity conservation in energy supply areas.

2.2 Data and Its Role in Biodiversity-Responsive Energy Planning

In order to design effective strategies for biodiversity conservation in energy-supplying regions, it is essential to understand the types of data that inform such strategies. This section begins by outlining the role of data in biodiversity studies, then classifies the types of data typically used in ecological assessments. The aim is to demonstrate why a comprehensive and interoperable data infrastructure is a prerequisite for aligning conservation objectives with energy infrastructure planning. This discussion also builds on the previous section's findings regarding the challenges of biodiversity conservation, particularly those related to data quality, availability, and integration.

The relationship between biodiversity and energy infrastructure is not only determined by physical interactions in the field, but also by how these interactions are recorded, interpreted, and planned for. A strong data infrastructure enables early identification of conflict zones, supports evidence-based impact assessments, and facilitates long-term monitoring. As Soares et al. (2021) emphasize, conservation strategies that lack reliable data are unlikely to be operationally effective or socially legitimate. Therefore, questions such as what type of data is collected, by whom, how frequently, and how it is processed, directly influence the efficacy of biodiversity protection mechanisms.

The biodiversity concept involves various dimensions—genetic, species, habitat, and ecosystem-level diversity—which in turn require diverse types of data. Biological inventory data, such as species distribution, habitat integrity, and population trends, form the ecological foundation of biodiversity analysis (Yong et al., 2024; Gadelha Jr. et al., 2020). However, infrastructure-specific data—such as cable type, voltage level, pole material, and installation year—are equally critical in understanding the

ecological impacts of energy systems (Katovich, 2024; Moreira et al., 2019). Integrating these two data domains—ecological and technical—enables more accurate spatial analyses and more effective mitigation planning.

Recent studies demonstrate the need to consider environmental, technical, and socioeconomic data together. For example, Guil et al. (2022) recommend considering bird migration routes, land cover, and vegetation density around power lines when assessing the impacts of power lines. Similarly, Theron et al. (2021) advocate for the use of long-term multispectral remote sensing methods to monitor habitat quality and detect ecosystem disturbances. These approaches demonstrate that biodiversity data is not limited to species lists; it also encompasses spatial, dynamic, and multi-scale datasets.

But just having data isn't enough. The usefulness of this data for planning depends on how well it works with geographic decision support systems. Data that cannot be displayed, overlaid, or evaluated in conjunction with energy infrastructure plans frequently remain limited to institutional silos and are excluded from decision-making processes (Soares et al., 2018). In the energy sector, the fact that multiple agencies handle environmental datasets and planning software separately makes this problem much worse. A strong data infrastructure for biodiversity-responsive energy planning should include more than just typical environmental data. Recent research underscores the significance of integrated, interoperable, and spatially explicit datasets.

First, ecological variables constitute the fundamental biological core. Species presence, abundance, and habitat connectivity are central to biodiversity assessments. Dong et al. (2024) emphasize that species distribution and population trends are critical in vulnerability analyses, while Sokół and Łaska (2024) combine biodiversity indicators with hydrological data at the basin scale to assess ecosystem services.

Second, the technical and physical characteristics of the energy infrastructure must be known for spatial impact analyses. Information such as pole material, voltage class, cable type, or year of installation are important for modeling ecological risks. Katovich (2023) recommends using such infrastructure characteristics to accurately model the risk of electrocution in birds. Moreira et al. (2019) also note that habitat degradation is closely related to the technologies and material types used. Third, environmental indicators such as slope, soil structure, land cover, and proximity to water sources should be used to model ecosystem sensitivity. Theron et al. (2021) monitored habitat quality in corridors with 25-year NDVI time series, while Guil et al. (2022) used vegetation and topographic features to assess bird collision zones.

Finally, socioeconomic data strengthen our understanding of human-nature interactions. Land ownership, traditional use patterns, and societal risk perception support ecological information. Traditional ecological knowledge obtained from local communities can be effective in identifying culturally significant biodiversity elements and developing accepted measures (Richardson et al., 2017; Peck et al., 2024).

For all this data to form a meaningful whole, digital systems must be interoperable, inter-institutional coordination must be ensured, and technical capacity must be increased. Soares et al. (2018) and Díaz et al. (2015) emphasizes that biodiversity data must be visualized, stratified, and analyzed to be valuable in energy planning.

Consequently, biodiversity data are multidimensional and critically important data sets generated through diverse methods. Integrating these data into energy infrastructure planning requires both conceptual clarity and technical capacity. The next section will discuss in detail the access issues, data fragmentation, and institutional constraints that hinder the effective use of these data.

2.2.1 What Sort of Data is Used in the Biodiversity Concept?

Understanding biodiversity from a planning perspective is not possible solely through species lists. A systematic data infrastructure is needed to capture the ecological, spatial, technical, and socio-environmental dynamics of natural and human systems. This section examines the main data types used in planning and conservation efforts, particularly where energy infrastructure intersects with ecologically sensitive areas. The aim is to demonstrate how different data types contribute to biodiversity assessments, guide decision-making processes, and facilitate integrated planning. This is explained by organizing the data into thematic clusters based on their sources and functions.

Recent research demonstrates that biological indicators alone are not sufficient to measure biodiversity (Yong et al., 2024; Guil et al., 2022). Assessing biodiversity patterns, pressures, and risks also requires the use of socio-spatial data, remote sensing inputs, and infrastructure-specific variables. In this context, the six key data areas deemed necessary for planning that takes biodiversity into account are: technical and structural infrastructure data, environmental impact and risk data, geographic and remote sensing data, biodiversity indicators, ecosystem services and social data, and field-based observation and monitoring protocols data.

A detailed explanation of how the types of data required were collected from the reviewed articles, compiled, and categorized into these areas can be found in Section 3.2.1.2 of the methodology, while the complete list of requiring data is provided in Appendix D.

Table 2.2 Types of Data Required for Biodiversity Conservation Based on Data Obtained from Literature Review

Topic Related to the Data	**Data**
Technical and Structural Data on Infrastructure	Type of materials used in electricity infrastructure (copper, aluminum, neodymium, etc.)
	Design features of power lines (conductor type, insulation)
	Structural characteristics of poles and surrounding environment
	Technical specifications of poles (type, phase conductor, insulation)
	Spatial data of planned infrastructure projects (location, length, number of poles, area)
	Current transformer capacity, energy quantity, voltage levels, connection status, and other substructure data
	Transformer age and brand
	Power outages
Environmental Impact and Risk Data	Bird collisions or electrocution and related mortality rates
	Fire incidents
	Oil leaks
	Carbon and greenhouse gas (CO_2, SF_6) emissions
	Use of hazardous chemicals
	Impact reports and follow-up notifications regarding infrastructure-related events

(Table 2.2 continued)

Topic Related to the Data	**Data**
Geospatial and Remote Sensing Data	Land use and land cover (LULC)
	Classified raster layers (forest, bare soil, agriculture, water, urban)
	Satellite imagery (OLI etc.)
	Time-series data (e.g., 2013–2021 NDVI)
Biodiversity Data	Biodiversity indicators (fauna/flora density, habitat quality)
	Global bird mortality data (especially scientific studies/cards)
	Bird migration routes
	Landscape quality indicators (habitat integrity, connectivity)
	Blue-green infrastructure spatial planning data
Social and Ecosystem Service Data	Social benefit indicators (recreation, aesthetic value, cultural compatibility)
	Service quality indicators (accessibility, satisfaction, duration of service)
Observation, Measurement, and Protocol Data	Field observation protocols and sample form templates used

One of the most important data groups in biodiversity-focused infrastructure planning is the technical and structural characteristics of energy systems. This includes conductor material types (e.g., copper, aluminum), insulation types, transformer capacities, infrastructure age, and location information. These data form the basis of life cycle assessments (LCA) and environmental impact analyses. Gallo et al. (2022) emphasize that the ecological footprint of energy distribution networks

is directly dependent on the material composition used. Similarly, Turconi et al. (2014) state that recyclability and embodied emissions in equipment design should be considered when determining environmental performance indicators.

The second important data group is risk and environmental impact records. Bird strikes, electric shocks, fires, hazardous chemical spills, and exposure to extreme weather conditions are included in this group. Katovich (2024) argues that infrastructure data should be analyzed with species-based measurements to create spatial risk models. Guil et al. (2022) argue that this impact data should be integrated into the early stages of design to prioritize measures in ecologically sensitive areas. Another important area is geographic and remote sensing data. Satellite imagery, NDVI (Normalized Difference Vegetation Index) time series, land cover classifications, and topographic analyses are used to monitor habitat fragmentation and change trends. Kennedy et al. (2014) and Theron et al. (2021) have demonstrated that such data support evidence-based conservation planning by identifying early indicators of stress in ecosystems.

Biodiversity indicators also play a critical role in ecological prioritization and risk assessments. This includes data such as bird migration routes, habitat connectivity, species population trends, species richness, and abundance. Moreira et al. (2019) emphasized that infrastructure investments in high-biodiversity regions are often incompatible because ecological indicators are not considered. Yong et al.. (2024) emphasize the importance of spatially explicit species data for conservation prioritization.

Another dimension of planning involves social data and ecosystem services. Cultural values, recreational activities, traditional ecological knowledge, and the community's view of nature fall into this category. Peck et al. (2023) and Richardson et al. (2017) state that incorporating such data into planning enhances the legitimacy of projects and, through local participation, yields stronger biodiversity outcomes.

Finally, field-based observations and monitoring protocols provide direct evidence for ecological and spatial patterns. Species observations, habitat disturbances, mortality records, and expert or citizen science contributions are valuable in this context. Díaz et al. (2015) emphasize that structured observation systems increase the reliability of biodiversity databases and facilitate rapid decision-making in energy projects.

In general, the types of data used in biodiversity-focused planning are diverse in terms of content and source. However, the effective use of these data depends not only on their availability but also on the extent to which they are standardized, interoperable, and spatially integrated. Even when high-quality data are available, institutional and structural issues hinder their use in decision-making processes. These issues will be discussed in the next section under "Challenges with These Data."

2.2.2 Challenges Related to These Data

The effective integration of biodiversity into energy infrastructure planning depends not only on the availability of ecological data but also on the quality, accessibility, and interoperability of these data. It is emphasized in the literature that this issue constitutes a complex problem area with its technical, institutional, technological and processual dimensions. For example, Allard and Aydınoğlu (2012) revealed that the dispersed structure of the data makes it difficult for researchers to use it; Costello & Wieczorek (2014) note that a lack of standards limits data sharing. Similarly, Soares et al. (2018) argue that data used in energy planning are often incompatible with ecological databases, weakening decision-making processes. Therefore, not only the availability of ecological data but also their up-to-date, accessible, and harmonious use across institutions is critical for considering biodiversity in energy planning. These issues have been divided into eight thematic groups, all of which make it more difficult to make timely and well-informed decisions regarding planning that takes

biodiversity into account. A detailed explanation of how the data-related challenges were collected from the reviewed articles, compiled, and categorized into these thematic groups can be found in Section 3.2.1.3 of the methodology, while the complete list of challenges is provided in Appendix E.

Table 2.3 Thematic Classification of Data-Driven Challenges Based on Literature Review

Category	**Issue**
Data Quality and Reliability Issues	Incomplete, incorrect, or low-quality data
	Lack of quality control
	Lack of standardization in time series data
	Taxonomic uncertainties
Data Accessibility, Sharing, and Openness	Limited access to data
	Lack of feedback mechanisms between data providers and users
	Absence of object-based identification systems in data (e.g., fixed species IDs)
Data Compatibility and Standardization Issues	Inconsistencies in data formats and content structures
	Incompatibility between sensor data and field data
	Inconsistencies between national and international data systems
Data Coverage and Representativeness	Limited geographic and thematic coverage of biodiversity data
	Exclusion of traditional knowledge systems
Data Infrastructure and Technological Limitations	Lack of long-term data storage systems
	Limitations of sensor technologies
	Inadequate use of proximal sensors (e.g., hyperspectral, LiDAR)

(Table 2.3 continued)

Category	Issue
Data Collection and Management Issues	Absence of systematic data management plans
	Lack of funding and infrastructure
	Lack of user contributions in public data portals
Disconnection Between Data and Application	Weak integration of data into conservation planning
	Limited use of data due to weak decision support systems

Two of the most frequently cited problems are limited monitoring capacity and a lack of baseline data. Methods of gathering data are usually erratic, too short, or too limited in scope to fully capture habitat dynamics or species behavior. Inadequate observation networks lead to substantial knowledge gaps about habitat loss, connectivity, and the cumulative effects of infrastructure (Richardson et al., 2017; Gallo et al., 2022). Theron et al. (2021) emphasize the need for long-term, multi-scale biodiversity data to accurately assess the impacts of infrastructure projects. However, one of the key obstacles is data quality and consistency. Ball-Damerow et al. (2019)'s review of 501 biodiversity studies revealed that 69% of the data contained geographic or taxonomic errors. Such errors can lead to inaccurate conclusions regarding species distribution models, conservation prioritization, and impact assessments. In Türkiye, most environmental data is stored on personal devices without backups, undermining data reusability and long-term reliability (Allard & Aydınoğlu, 2012). Another problem is the lack of data standards and format incompatibilities. Gadelha Jr. et al. (2020) and Chamanara et al. (2021) note that ecological and technical infrastructure data are stored in different formats. Technical data is often stored in engineering-oriented files, while ecological data follows academic classification systems. These differences range from coordinate systems to metadata definitions and spatial resolution levels, making it difficult to integrate data into spatial decision support systems (Ponitka & Boettner, 2020).

Finally, dependence on legacy systems and technological sustainability pose a serious threat to data continuity. Allard and Aydınoğlu (2012) emphasize that many historical datasets become unusable due to outdated software and file formats that are no longer supported. Because data management often occurs only after projects are completed, long-term data protection practices cannot be implemented, and data permanence is at risk.

The inability to incorporate data into decision support systems is yet another significant drawback. While it is theoretically possible to link biodiversity with infrastructure metrics (such as carbon emissions, SF_6 leakage, and material recyclability) using multi-criteria tools like life cycle assessment (LCA), Turconi et al. (2014) demonstrate that in reality, the required input data is frequently either unavailable or dispersed across incompatible platforms. This restricts the use of sophisticated analytical tools in practical decision-making.

Furthermore, transparency and collaboration are hindered by the fragmentation of institutional and inter-sectoral data. Energy companies often fail to collect biodiversity data in a systematic manner, and government agencies and academic researchers are working in a state of chaos. Michener & Jones (2012) call this a lack of "common language and shared data infrastructure," which restricts the potential for collaborative planning and comparative analysis.

Particularly when it comes to infrastructure, the evidence base supporting nature-based solutions has also come under fire. When comparing blue-green infrastructure to conventional approaches, Hoffman (2023) questions its efficacy for biodiversity, claiming that decision-makers lack standardized monitoring frameworks to assess ecological outcomes. This gap further emphasizes the need for reliable, quantitative data to evaluate the efficacy of such solutions.

Finally, the technical limitations of monitoring technologies must be addressed. In ecologically complex environments such as cloud-covered forests, underwater habitats, or subterranean regions, remote sensing tools such as Landsat often produce

incomplete or erroneous results. This issue is made worse by methodological inconsistencies between data collection and planning specifications, which restrict the feedback loop between observation and decision.

All things considered, these data-related issues impact all stages of the biodiversity–infrastructure interface, from implementation to assessment. They draw attention to the shortcomings of the current system as well as the reasons why poor choices are frequently made in real life. The following problems underscore the need for an integrated, sustainable, and interoperable data governance framework that supports the twin goals of biodiversity conservation and energy security while upholding the FAIR (Findable, Accessible, Interoperable, Reusable) data principles (Wilkinson et al., 2016; Lannom et al., 2020; Sterner & Elliott, 2023).

The following section will explore strategic ways to overcome these challenges by examining how biodiversity considerations can be systematically integrated into energy planning processes. This will include a review of the policy tools, infrastructure design principles, and spatial planning tools that support energy systems that respond to biodiversity.

2.3 Biodiversity Responsive Energy Supply Systems Strategies

To balance the development of energy infrastructure with the conservation of biodiversity, spatial planning, technical innovation, ecological design, and institutional collaboration must be considered all together. Recent studies have proposed different approaches that consider the ecological, technical, and governance dimensions of this process. While the methods differ, they all share a common goal: to reduce damage to biodiversity and strengthen the adaptability of infrastructure systems to changing environmental and technological conditions.

A detailed explanation of how the strategies were collected from the reviewed articles, compiled, and categorized can be found in Section 3.2.1.4 of the methodology, while the complete list of strategies is provided in Appendix F.

Table 2.4 Biodiversity Conservation Strategies: Thematic Synthesis Based on Literature Review

Strategy Category	**Strategy**
Environmentally Friendly Material Use and Life Cycle Assessment (LCA)FAIR dat and	The environmental impacts of critical materials should be monitored throughout their life cycle.
	The use of specific materials such as platinum and iridium should be monitored, and alternatives that reduce environmental risks should be considered.
	The use of recycled materials should be encouraged.
	Energy and water consumption in the production of strategic materials used in grid infrastructure should be reduced, and greenhouse gas emissions should be minimized.
	Material selection should be based on environmental impact, prioritizing low-impact materials.
Bird-Specific Conservation and Infrastructure Compatibility	Technical solutions such as insulation and increasing conductor spacing should be implemented to prevent bird electrocution on power lines.
	Bird mortality hotspots should be identified and preventive planning should be carried out in these areas.
	Insulation and technical modifications (e.g., perch guards, insulation covers) should be implemented globally.

(Table 2.4 continued)

Strategy Category	**Strategy**
Bird-Specific Conservation and Infrastructure Compatibility	Power line placement and height should be optimized according to bird behavioral patterns.
	Life cycle assessments, behavioral models, and vulnerability analyses for bird species should be conducted.
	Bird-specific risks (e.g., collision, electrocution) should be reduced through technical solutions while ensuring the reliability of power transmission.
	Bird-friendly pole designs and insulator systems should be installed to achieve dual benefits (protection + outage prevention).
Environmental Incident Monitoring and Management Systems	Electricity distribution companies should map and systematically report environmental incidents (e.g., bird deaths, wildfires).
	Incident management systems (e.g., SAP EH&S) should be used to ensure regular tracking of such data.
	Centralized digital monitoring of environmental incidents increases both response speed and prevention capability.
Standardized Monitoring and Data Sharing	Standardized environmental monitoring protocols should be developed.
	Data sharing should be encouraged in regions where impacts such as bird deaths cannot be properly assessed due to lack of data.
	Common, user-friendly databases should be created to allow all stakeholders to contribute data.

(Table 2.4 continued)

Strategy Category	Strategy
Decision Support and Impact Modeling Systems	Decision support tools capable of estimating the impacts of infrastructure projects should be developed and integrated into planning.
	Separate models should be implemented for specific effects like bird diversity, and scenario-based analyses should be conducted.
	Target-specific mitigation strategies should be developed and implemented for priority conservation species.
Corporate Environmental Governance and Liability Systems	Environmental management systems (e.g., ISO 14001) should be integrated to monitor and improve the company's environmental performance.
	Interdisciplinary collaboration should be supported, and the integration of energy and environmental fields should be promoted.
	Environmental obligations should be clearly defined, and enforcement mechanisms for violations should be clarified.

Considering biodiversity-sensitive areas in the early stages of infrastructure planning is one of the most frequently emphasized strategies. Tools such as Geographic Information Systems (GIS), Multi-Criteria Decision Making (MCDM), and scenario-based spatial models help decision-makers identify low-impact routes, assess ecological risks, and avoid areas of high conservation value. Weber et al. (2023), Kiesecker and Naugle (2017), and Soares et al. (2021) have shown the effectiveness of these tools in reducing planning conflicts. These methods are even more effective when supported by high-resolution data (e.g., habitat area (AOH), distribution area (EOO), and species distribution models). However, data

compatibility, metadata quality, and institutional capacity issues remain significant obstacles.

Another group of strategies focuses on reducing ecological impacts during the design and construction phases. Safer designs are recommended to reduce the risk of electrocution for birds, move infrastructure away from sensitive habitats, and, where possible, place cables underground. Tools such as Design of Experiments (DOE) and Life Cycle Assessment (LCA) are used to assess the environmental impacts of design decisions in terms of material use, emissions, recyclability, and land use (Leme et al., 2014; Turconi et al., 2014). In this context, the "Development by Design" model, which prioritizes the prevention, minimization, and compensation of impacts, is also gaining prominence (Urbano et al., 2024).

Monitoring and feedback systems are critical for understanding whether biodiversity targets are actually being met. Standard ecological monitoring methods (e.g., population tracking, habitat integrity indices, NDVI-based remote sensing) provide early warning. Guil et al. (2021) and Gilad et al. (2024) have demonstrated that continuous monitoring and flexible infrastructure adaptations can mitigate long-term impacts. Furthermore, citizen science and participatory monitoring initiatives increase data coverage and strengthen stakeholder trust.

Technological and institutional innovations are also important for data quality and inter-institutional collaboration. FAIR principles (findable, accessible, interoperable, reusable), spatial databases, and open-access platforms are prominent in this field (Ellwanger et al., 2024; Allard & Aydınoğlu, 2012). Coordination mechanisms are necessary to ensure that data generated by public institutions, universities, and energy companies can be used in collaborative decision-making processes. Furthermore, technologies such as digital twins, smart grids, and modular infrastructures enhance predictive impact assessments and increase adaptation in complex ecological environments (Kiesecker & Naugle, 2017).

Restoration-focused approaches are also increasingly being adopted. Habitat rehabilitation, reforestation, and blue-green infrastructure solutions are being used to compensate for infrastructure-related damage. These strategies are often associated with the "no net loss" (NNL) principle. However, Hoffman (2023) emphasizes that robust monitoring systems and long-term maintenance commitments are required for these solutions to be successful. Additionally, planning should take into account migration routes, breeding grounds, and officially recognized areas (e.g., Ramsar sites, Key Biodiversity Areas (KBA), and Important Bird Areas (IBA). Ignoring these areas results in habitat fragmentation and increased species risk (Guil et al., 2022; Yong et al., 2024; Katovich, 2024). Therefore, the establishment of avoidance thresholds, ecological connectivity corridors, and buffer zones is recommended.

Finally, strong governance and policy frameworks are necessary to integrate biodiversity into energy infrastructure. For this purpose, it is important to legally define environmental liabilities, standardize assessment criteria, and increase institutional capacity. Stakeholder participation, legal clarity, and inter-ministerial coordination are also essential for achieving both conservation and energy security goals (Richardson et al., 2017; Soares et al., 2021; Peck et al., 2023).

Overall, biodiversity-focused energy planning is not just about technical solutions. It is a holistic transformation process that combines ecological sensitivity, social responsibility, institutional alignment, and spatial foresight.

2.3.1 Geographic Information Systems as a Strategic Tool for Biodiversity-Responsive Energy Planning

To protect biodiversity in the face of growing energy infrastructure, simply developing strategies is not enough; tools are also needed to implement these strategies. Geographic Information Systems (GIS) and their integrated decision support tools come to the forefront in this regard. GIS enables the spatial integration

of ecological and technical data, thus enabling biodiversity-sensitive planning. Raza et al. (2024) and Kiesecker et al. (2017) emphasize that GIS is particularly effective in predicting risks by analyzing protected area boundaries, habitat degradation, and species distributions.

As discussed in previous sections, data fragmentation, lack of long-term monitoring, and the inability to integrate data into infrastructure inventories make it difficult to align energy and nature conservation objectives. Many strategies, such as species prioritization, corridor protection, and habitat restoration, require high-resolution spatial data. GIS's ability to integrate multi-source data across different formats and scales makes it a strategic asset rather than a supporting tool (Soares et al., 2018). The spatial analyses provided by GIS are not limited to the current situation. Farias et al. (2024) combined remote sensing and GIS as part of the MapBiomas project in Brazil to measure the impacts of land-use changes on species' habitats. Similarly, Tracey et al. (2013) examined the responses of lynx to urban sprawl using GIS-based models. Such studies help understand how species respond to risks and adapt to changing conditions.

GIS also allows for the prediction of potential future impacts, such as habitat fragmentation or species loss. Syeban and Opoku (2024) developed a GIS-based optimization model to reduce conflicts between agriculture, settlement, and energy uses. This example demonstrates the critical role of GIS in balancing different land-use needs with biodiversity goals.

Another important point is data standardization. Data such as species distributions, migration routes, or protected area boundaries are often stored in different institutions and in incompatible formats. Gadelha Jr. et al. (2020) demonstrate that this data can be combined into a common spatial system and transformed into analyzable layers thanks to GIS. Furthermore, the application of FAIR principles (findable, accessible, interoperable, reusable) enables the more effective use of ecological data in energy planning (Allard & Aydınoğlu, 2012).

Finally, GIS allows energy companies to use technical infrastructure data alongside nature conservation data. When grid information such as pole locations, power line routes, or voltage levels are overlaid with habitat data, conflict areas can be easily identified. This both guides design changes and enables the modeling of long-term environmental impacts. Thus, GIS strengthens participatory planning processes by increasing transparency, traceability, and accountability.To sum up, geographic information systems are a tactical instrument that facilitates the implementation of biodiversity-responsive approaches at various scales. In addition to filling in long-standing gaps in data and monitoring, GIS offers the technical framework required for integrated planning, scenario modeling, and decision-making. In this thesis, GIS is viewed as a fundamental planning tool that harmonizes ecological objectives with infrastructure design and spatial governance, rather than as a supplementary mapping tool.

2.4 Türkiye Context: Electricity Distribution, Production Companies and Biodiversity

The challenges faced in ensuring energy supply in Türkiye are largely similar to those expressed in the international literature. Türkiye is a party to numerous international conservation agreements, including the Ramsar Convention, the Convention on Biological Diversity, and the Bern Convention. However, significant challenges remain in effectively using biodiversity data in infrastructure projects. Pilot interviews conducted as part of this research reveal that protected area data (KBAs, KBAs, Ramsar sites, etc.) are not readily available in existing electricity grid inventory systems and will be detailed in the findings section. Spatial data related to ecological sensitivities are sometimes stored on different platforms and must be manually combined. This slows down assessment processes and reduces the accuracy of impact analyses. Furthermore, the lack of a consistent data governance framework among energy and environmental institutions makes it difficult to make biodiversity-sensitive site selections. This fragmented structure, coupled with the

lack of standardized spatial decision support tools, highlights the critical need for integrated GIS-based planning approaches that will enhance biodiversity conservation in energy supply regions and enable early detection of conflicts.

In Türkiye, electricity distribution is managed by 21 regional electricity distribution companies (EDAŞ). These companies are operated by various private sector groups under the supervision of TEDAŞ. On the electricity generation side, there are both public and private sector organizations. The largest public producer is Elektrik Üretim A.Ş. (EÜAŞ), which holds a dominant position in the sector in terms of installed capacity. In the private sector, companies such as ENKA Energy, Enerjisa Production, Cengiz Energy, Limak Energy, Eren Energy, Çelikler Holding, IC İçtaş Energy, İÇDAŞ, Aydem Energy, Aksa Energy, Zorlu Energy, Kalyon Energy, and Bilgin Energy stand out. These companies play critical roles in national supply security with their generation portfolios based on natural gas, hydroelectricity, coal, and renewable resources. Distribution companies in Türkiye and the regions they are responsible for are summarized below:

Table 2.5 Distribution Companies in Türkiye

Distribution Companies	**Regions/Provinces Served**
BEDAŞ	İstanbul (European Side)
AYEDAŞ	İstanbul (Anatolian Side)
Başkent EDAŞ	Ankara, Zonguldak, Kastamonu, Kırıkkale, Karabük, Çankırı, Bartın
Toroslar EDAŞ	Adana, Mersin, Osmaniye, Hatay, Kilis, Gaziantep
Dicle EDAŞ	Diyarbakır, Şanlıurfa, Mardin, Batman, Şırnak, Siirt

(Table 2.5 continued)

Distribution Companies	**Regions/Provinces Served**
VEDAŞ	Van, Muş, Bitlis, Hakkari
Aras EDAŞ	Erzurum, Ağrı, Kars, Iğdır, Ardahan, Bayburt, Erzincan
Çoruh EDAŞ	Trabzon, Giresun, Rize, Artvin, Gümüşhane
Fırat EDAŞ	Elazığ, Malatya, Bingöl, Tunceli
AKEDAŞ	Adıyaman, Kahramanmaraş
TREDAŞ	Tekirdağ, Edirne, Kırklareli
Gediz EDAŞ	İzmir, Manisa
Aydem EDAŞ	Aydın, Denizli, Muğla
MEDAŞ	Konya, Karaman, Aksaray, Kırşehir, Nevşehir, Niğde
OEDAŞ	Eskişehir, Afyonkarahisar, Bilecik, Kütahya, Uşak
Uludağ EDAŞ	Bursa, Balıkesir, Çanakkale, Yalova
SEDAŞ	Sakarya, Kocaeli, Bolu, Düzce
YEDAŞ	Samsun, Ordu, Çorum, Amasya, Sinop
Çamlıbel EDAŞ	Sivas, Tokat, Yozgat
KCETAŞ	Kayseri and its surroundings

Some companies operating in electricity generation and distribution in Türkiye are making their corporate commitments and practices related to biodiversity visible through public documents. These documents indicate that the sector is developing

an increasingly institutionalized framework around impact mitigation, compliance with standards, and monitoring and reporting. They also highlight the need for holistic industry standards in data governance, spatial decision support, and interoperability.

For example, Zorlu Enerji declares a "net positive impact" commitment for new renewable energy projects to be commissioned after 2030. It incorporates targets to reduce deforestation and biodiversity loss, actions focused on species protection, and facility-based performance monitoring through the BEYS (Biodiversity and Ecosystem Management System). The company's public website details its biodiversity risk report, afforestation/rehabilitation targets, and field implementations (e.g., bird strike prevention equipment, fish passage installation, and endemic species protection projects). This approach demonstrates that internal processes are in place for monitoring and reporting the impact hierarchy (prevention, minimization, rehabilitation/balancing measures) at the facility level. (Zorlu Enerji, n.d.)

Enerjisa Üretim, on the other hand, manages biodiversity processes through monitoring programs specific to each power plant type. It states that it conducts regular environmental measurements through fish population and water quality monitoring at HEPPs, bird and bat monitoring at WPPs, marine ecology studies at coastal facilities, and flora and fauna ecological assessment reports. Furthermore, a monitoring and reporting system has been defined through internal governance documents and a biodiversity declaration. This framework indicates that field-based monitoring and adaptive management approaches sensitive to seasonality and species composition are being established in the basins where the facilities are located. (Enerjisa Üretim, n.d.)

Furthermore, compliance with third-party standards at the project level is also observed to be strengthening. Fiba Enerji's "Günaydın Solar Power Plant Project Biodiversity Management Plan" (BMP) document systematically outlines critical

habitat/key species definitions, Zero Net Loss (NNL) and Net Gain targets, mitigation measures disaggregated by construction and operation phases, and monitoring and reporting mechanisms, with reference to international best practice criteria, particularly IFC PS6 and EBRD PG6. The document details the alignment of design decisions, such as conceptual definitions (protected area, natural/critical habitat, invasive species), project location and access roads, and underground transmission line preferences, with biodiversity sensitivities. This example demonstrates that biodiversity plans aligned with international standards can be prepared at the project level in Türkiye, and that the sector's integration capacity into the normative framework has increased (FIBA Enerji, 2024).

These practices demonstrate that the Turkish electricity sector has taken concrete steps toward bringing the biodiversity agenda to the operational level: (i) strengthening corporate governance through internal policies and systems (such as BEYS); (ii) expanding systematic monitoring and impact mitigation practices specific to each facility type; (iii) preparing plans aligned with reference standards such as IFC/EBRD in project files. However, a coordinated sector-wide standard for data governance, inter-institutional data sharing, spatial interoperability, and standard decision support tools (e.g., GIS-based common platforms) is not yet established. This limits the use of species and habitat data at a level that would enable early warning/conflict analysis integrated with distribution inventories. Lacking common indicators and comparable reporting across institutions, impact management becomes dependent on project-based best practices. Therefore, standardizing internal best practices at the industry level, supported by nationally interoperable data schemas and GIS-based decision support frameworks, is critical for simultaneously achieving energy supply security and biodiversity goals (Zorlu Enerji, nd).

CHAPTER 3

METHODOLOGY

This study examines the challenges associated with integrating biodiversity conservation into Türkiye's energy supply networks through a combination of qualitative and quantitative methodologies. The objective of the study is to identify deficiencies in data, coordination issues, and constraints on geographical decision-making. The methodology is centered on a data collecting phase utilizing a questionnaire and a structured statistical analysis.

3.1 Research Design and Rationale

The research employs an exploratory design that integrates structured survey data with systematic statistical analysis. Due to the scarcity of empirical data regarding how energy supply firms manage biodiversity-related information, particularly in the context of infrastructure design and monitoring, a field-based methodology was selected. The primary objective of the study is to ascertain how various functional divisions within energy companies manage data, the technical challenges they encounter, and the perceptions of their organizations regarding these difficulties. This approach enables the identification and comparison of systemic issues across 4 electricity energy supply companies (the names of the companies are withheld for ethical reasons).

Table 3.1 provides an overview of the research design by linking each sub-research question with the corresponding approach, data collection methods, and analysis techniques.

Table 3.1 Research Design Overview

Sub-research Questions	Research Approach	Data Collection Methods	Data Analysis Methods
What are the main challenges companies face in protecting biodiversity during energy supply processes?	Quasi-experimental	Likert-Scale ranking questions	Descriptive statistics, regression analysis
Which types of data are used in conservation processes, and how do data-related challenges affect biodiversity protection?	Quasi-experimental	Likert-Scale ranking questions	Descriptive statistics, regression analysis
What strategies are currently applied to protect biodiversity, and how do these differ between urban and rural contexts?	Exploratory	Open-ended survey questions	Frequency analysis, content analysis
What are the most pressing institutional needs to strengthen biodiversity protection capacity in energy planning and supply?	Exploratory	Open-ended survey questions	Frequency analysis, content analysis

3.2 Literature Review

The aim of the literature review in this thesis is to examine the environmental impacts of electricity distribution infrastructure and its role in managing biodiversity data in energy supply processes. Therefore, the review was limited to the following topics:

(a) electricity distribution networks and associated infrastructures (studies focusing on general energy systems and not directly linked to biodiversity were excluded);

(b) infrastructure-related biodiversity conservation (studies that only addressed conservation but did not relate to the energy sector were included to identify the data used);

(c) GIS and data-driven biodiversity-infrastructure interactions (conceptual or non-spatial discussions were included);

(d) management, planning, and decision-making frameworks addressing the integration of biodiversity data into energy sector practices.

In the first phase, the literature search was conducted using the Scopus database. In this process, complementary keywords were used to address the multidimensional relationship between energy infrastructure and biodiversity. Inclusion criteria were as follows:
Publications published between 2005 and 2025,
Directly addressing electrical infrastructure, biodiversity, or the GIS/data management relationship.
During the search, no additional filters were applied. Instead, the abstracts of the articles found in Scopus were examined, and the most relevant ones were selected.

The keywords used are as follows:

• "Biodiversity": As the core concept of the study, it was used to access the most comprehensive literature.

• "Environmental impact AND electricity distribution": This was selected to identify studies that directly address the environmental impacts of electricity distribution infrastructure.

• "Biodiversity AND power lines AND electricity": This was used to identify studies that examine the direct impacts of power lines on birds and other species.

• "Ecological network AND grid infrastructure": This was selected for spatial and planning-oriented studies addressing the interaction of grid infrastructure and ecological networks.

• “Biodiversity conservation AND Biodiversity areas”: This was added to identify literature on protected areas (KBA, IBA, Ramsar, etc.) and the strategies implemented in these areas. • “GIS AND biodiversity”: This section was used to examine studies on the use of Geographic Information Systems in biodiversity data management and decision support systems.

• “Species distribution modeling AND remote sensing”: This section was selected to identify studies that model species distribution, migration routes, and habitat changes using remote sensing techniques.

• “Energy transition AND biodiversity”: This section was selected to examine the impacts of energy conversion processes on biodiversity and emerging conservation approaches in this context.

• “Key biodiversity areas AND remote sensing”: This section was used to identify studies that use remote sensing methods in the monitoring and assessment of Key Biodiversity Areas (KBA).

• “Biodiversity conservation AND energy sector”: This section was selected to investigate biodiversity conservation strategies and institutional approaches in the energy sector.

• “Environmental impact AND infrastructure AND biodiversity”: This section was added to identify interdisciplinary studies examining the link between the environmental impacts of infrastructure investments and biodiversity. • "Biodiversity conservation AND urban infrastructure": This term was used to encompass studies addressing biodiversity in the context of infrastructure projects and nature-based solutions in urban areas.

These keywords were chosen to complement each other, enabling a holistic literature review encompassing both the infrastructure-biodiversity relationship and the dimensions of data management, monitoring, planning, and strategy development.

Table 3.2 Research Keywords Used

Keywords	Article Count
Biodiversity	10
Biodiversity conservation AND Biodiversity areas	10
environmental impact AND electricity distribution	10
Species distribution modeling AND remote sensing	10
environmental impact AND infrastructure AND biodiversity	4
key biodiversity areas AND remote sensing	4
biodiversity AND power lines AND electricity	3
GIS AND biodiversity	3
biodiversity conservation AND energy sector	2
biodiversity conservation AND urban infrastructure	2
Ecological network AND grid infrastructure	2
energy transition AND biodiversity	2
	62

After removing duplicates and out-of-scope studies, a total of 62 articles were identified which articles were read and evaluated, and only those that met the inclusion criteria were included. An examination of the distribution by keywords reveals that the most extensive literature was obtained through four keyword groups: Biodiversity, Biodiversity conservation AND Biodiversity areas, Environmental

impact AND electricity distribution, and Species distribution modeling AND remote sensing. Each search yielded 10 articles. This result demonstrates that the study covers both general biodiversity literature and more focused topics such as energy infrastructure, environmental impacts, protected areas, and species distribution.

Medium-density keywords included Environmental impact AND infrastructure AND biodiversity and Key biodiversity areas AND remote sensing (four articles each). These fields focus on infrastructure-biodiversity interactions and remote sensing monitoring of protected areas, adding a more technical and spatial dimension to the literature. Keywords that yielded a more limited number of articles included Biodiversity AND power lines AND electricity and GIS AND biodiversity (3 articles each), Biodiversity conservation AND energy sector, Biodiversity conservation AND urban infrastructure, Ecological network AND grid infrastructure, and Energy transition AND biodiversity (2 articles each). These groups, while small in number, offer specific contributions that directly examine the ecological impacts of energy infrastructure, sectoral transformations, and nature conservation approaches.

Each article was systematically entered into a table containing the following columns (See App. B):

• Keyword,

• Author/s,

• Article title,

• Research theme,

• Challenging issues/research questions,

• Contribution to my own thesis,

• What are the variables in biodiversity conservation?

This initial table formed the basis of the literature review and enabled each article to be categorized in detail.

3.2.1 Derived Tables from Literature Review

In addition to the main table, three additional tables were prepared to directly link to the research questions. The literature review conducted in this study was structured not only to summarize existing information but also to provide direct data for the research questions. Indeed, the three tables created perfectly align with the research questions. The question, "What are the main problems companies face in protecting biodiversity?" was answered with the challenges table; the question, "What types of data are used, and what problems are experienced with this data?" was answered with the data and data challenges table; and the question, "What strategies are being implemented to protect biodiversity?" was answered with the strategies table while comparing the answers from the survey. Furthermore, inferences regarding institutional needs were based on the findings obtained from these tables. Thus, the literature review served as an analytical tool to systematically support the research questions.

3.2.1.1 Challenges Mentioned in Literature

The challenges extracted from the articles were quite diverse in the initial phase (See App. C). Therefore, to create a more holistic and comparable framework for the analysis, challenges were regrouped based on similarities in content.

The basic logic behind grouping is to collect situations that are expressed differently in different articles but point to the same structural problem under a single heading. While some situations are grouped directly under the main heading, some longer narratives are grouped based on their shorter narratives.

For example:

• “Pole designs lack collision-prevention technical features”, “Power lines pose a serious mortality risk for species such as white storks” and “Habitat fragmentation

due to transmission lines” were grouped under teh category "direct impacts of energy infrastructure on fauna."

• “Complex legal and administrative regulations make it difficult to balance“, “Deficiencies in data lifecycles hinder systematic data analysis in sectors such as energy infrastructure” were grouped under the category "legal and institutional uncertainties."

• “Destruction of natural areas due to urbanization and agricultural development” and “Destruction of protected areas due to urbanization and transportation projects” were grouped under the heading "land use changes and habitat losses."

This grouping not only reduced the repetition of challenges identified across articles but also enabled the creation of more consistent themes in the analyses to be used in the thesis. As a result, more systematic and comparable categories were obtained, rather than a large and scattered list of challenges.

3.2.1.2 Data Mentioned in Literature

The types of data used in the articles related to biodiversity conservation span a wide range (See App. D). Initially, these data were listed directly based on the terms used in the articles, resulting in a rather scattered structure. This diversity was deduplicated to facilitate a more systematic analysis, and similar content was grouped under different headings. The basic logic behind grouping is that data expressed in different formats from different sources should be included in a single category if they serve the same analytical purpose.

For example:

• Technical inventory information such as pole type, line design, and transformer data were combined under the heading "Technical and structural data used in electrical infrastructure."

• Event- and risk-based data such as bird mortality, fire, oil leaks, and greenhouse gas emissions were collected under the category "Environmental impact and risk data."

• Spatial data such as satellite imagery, LULC classifications, raster layers, and NDVI time series were evaluated under the heading "Geographic and remote sensing data." • Species-based indicators such as fauna/flora density, migration routes, and species distribution maps are included within the scope of "Biodiversity Data."

• Data indicating human-environment interactions, such as recreation, service quality, and social benefit measures, are included under the heading "Social and Ecosystem Service Data."

• Additionally, data from direct measurement processes, such as field observations, sampling protocols, and metadata, are grouped under the category "Observation and Protocol Data."

In this way, the numerous data types expressed in scattered forms in the articles have been transformed into a more manageable structure, and six primary groups have been created that can be directly referenced in analyses to be used within the thesis.

3.2.1.3 Data-Related Challenges Mentioned in Literature

Data-based challenges within the articles were first extracted as raw statements or by making inferences from sentences; then, items with similar content and function were combined into superordinate categories (see App. E). The goal was to transform fragmented and repetitive statements into meaningful and usable thematic clusters for decision-making. By interpreting these difficulties, the number of headings was reduced to 35 and regrouping was done. The final framework consisted of seven main headings:

Table 3.3 Revised Data-Related Challenges Table

Challenge Type	**Data Challenges**
Data Incompleteness and Representation Issues	Lack of up-to-date, transparent, and reliable data on mining, biodiversity, and energy infrastructure in developing countries
	Lack of species-level data and data imbalances across taxonomic groups
	Lack of long-term monitoring data in protected areas
	Inadequate time-series data on habitat changes
	Lack of environmental data reflecting local microclimate differences
Data Standards and Lack of Comparability	Inconsistency of LCA data across sources, such as the inability to determine water use thresholds
	Lack of standardized data formats and measurement methods across different institutions and countries
	Failure to ensure the timeliness and appropriate formatting of species distribution data
	Inadequate recycling data, especially for critical metals
	Lack of data comparability due to lack of standardized protocols
	Low spatial resolution of data, hindering the detection of habitat-level impacts
Spatial and Temporal Data Mismatches	Lack of field validation of time-series remote sensing data such as NDVI
	Confusions such as observing habitat recovery or degradation in the same pixel
	Lack of long-term environmental monitoring systems and inadequate time-series data
Institutional and Administrative Data Sharing Challenges	Lack of coordination between institutions and a culture of data sharing Weaknesses
	Mismatches in duties, authorities, and data flows between local and central governments
	Lack of involvement of local communities and indigenous people in data production and sharing processes
	Inadequacy of open data systems and their lack of ease of use
Data Management Systems Inadequacy	Lack of systems compatible with the FAIR principles (Findable, Accessible, Interoperable, Reusable)
Inadequacy of Data Management Systems	Lack of management functions such as version tracking and metadata entry
	Data not updated or lost access over time
	Lack of flexible data systems that can be customized to user needs
	Weak interdisciplinary data integration
	Inadequate reporting or documentation of direct events, such as most bird strikes

(Table 3.3 continued)

Challenge Type	Data Challenges
Data Management Systems Inadequacy	Lack of systems compatible with the FAIR principles (Findable, Accessible, Interoperable, Reusable)
Inadequacy of Data Management Systems	Lack of management functions such as version tracking and metadata entry
	Data not updated or lost access over time
	Lack of flexible data systems that can be customized to user needs
	Weak interdisciplinary data integration
	Inadequate reporting or documentation of direct events, such as most bird strikes
Observation, Monitoring, and Evaluation Challenges	Insufficient consideration of species-based behavioral differences in impact assessment models
	Lack of cumulative impact analyses, focusing only on individual projects
	Inadequate modeling of habitat connectivity loss
	Difficulty in integrating multi-scale data in integrating ecosystem services into planning
Deficiencies in Data Use in Planning and Policy Processes	Lack of concrete indicators of biodiversity in urban planning
	Insufficient integration of ecological values in decision support systems
	Decision makers' inability to adequately integrate climate and Difficulty in evaluating biodiversity targets together
	Technical limitations in remote sensing data, such as cloud cover and sensor complexity
Monitoring Technologies and Technical Inadequacies	Inability to collect data in environments such as deep sea and underground due to technical reasons
	Methodological incompatibilities in time-series analyses of data from Landsat etc.
	Limitations of technologies that cannot directly monitor habitat quality

3.2.1.4 Strategies Mentioned in Literature

These tables make the strategies, challenges, and data dimensions highlighted in the articles visible (see App F.).

3.2.1.5 Survey Design

Findings obtained from the literature were directly used in the preparation of the survey form. The survey consisted of two parts:

Quantitative Part:

o Dependent variable: Participants were asked, “How well do you think your company protects biodiversity?”

o Challenges: Challenges derived from the literature were rated on a 1–7 Likert scale.

o Data: Participants were asked which data types they used.

Data challenges: Data challenges identified in the literature were assessed using a 1–7 Likert scale.

Qualitative Part

The primary reason for choosing open-ended questions in the qualitative section was to allow participants to freely express their experiences, perceptions, and suggestions without being limited to predetermined options. This provided an in-depth understanding of strategies, urban-rural differences, and institutional needs, which are frequently emphasized in the literature but may manifest differently within a company. Open-ended responses were evaluated to uncover the reasons behind the quantitative findings, capture unexpected themes, and provide original contributions to policy and practice. The open-ended questions posed to participants included:

o What strategies are implemented to protect biodiversity in business processes?

o Are there differences between strategies implemented in urban and rural areas?

o What is the fundamental institutional need to increase biodiversity conservation capacity?

3.3 Data Collection Process

A survey was employed to gather information from employees of the four largest electricity supply companies in Türkiye. These companies[1] are selected due to their substantial size, comprehensive coverage of urban and rural regions, and participation in national infrastructure planning procedures that consider biodiversity.

The questionnaire aimed to gather both objective and subjective data (See Appendix 1). The questionnaire included open-ended, multiple-choice, and Likert-scale items centered on the following themes:

- Perceived success in biodiversity-responsive electricity supply
- Biodiveristy-related challenges
- Data-related challenges
- Data types used in operations
- Biodiversity conservation strategies
- Differences in urban vs. rural strategies
- Institutional needs for biodiversity protection

A total of 147 staff participated in the survey. While the distribution by company and department cannot be disclosed due to confidentiality agreements, the respondents represented a wide range of departments. These included units such as GIS, Sustainability, Maintenance, Expropriation, Investment Planning, Failure Repair, and Construction Works. This diversity of departments ensured that the survey captured perspectives from both technical and administrative functions within electricity distribution companies.

[1] The names of the companies are withheld for privacy and ethical considerations; however, they are shared with the jury members during the thesis defence presentation.

Table 3.4 Descriptive Statistics of Respondents (n=147)

Variable	Category	n	Percentage
Gender	Female	52	35.4%
	Male	93	63.3%
	Prefer not to say	2	1.3%
Age	18–24	3	2.0%
	25–34	56	38.1%
	35–44	76	51.7%
	45–54	9	6.1%
	55+	2	1.4%
Experience	0–1 years	2	1.3%
	2–5 years	88	59.9%
	6–10 years	38	25.9%
	11+ years	19	12.9%

(Table 3.4 continued)

In terms of gender, 63.3% of participants identified as male, 35.4% as female, and 1.3% preferred not to disclose (Table 3.2). Regarding age, the majority of respondents were between 35–44 years old (51.7%), followed by those aged 25–34 (38.1%), 45–54 (6.1%), 18–24 (2.0%), and 55+ (1.4%) (Table 3.2). As for seniority in the sector, most participants had 2–5 years of experience (59.9%), while 25.9% had 6–10 years, 12.9% had over 11 years, and 1.3% had less than one year of experience (Table 3.2).

These distributions show that the sample includes employees with varying demographic profiles and professional experience, enhancing the validity of the findings.

3.4 Data Analysis

Two main analysis techniques were used in this study: multiple regression analysis and content analysis. Multiple regression analysis was applied to Likert-scale survey data to examine the relationship between perceived success in biodiversity data management and various challenges. This technique is frequently used in the social sciences to test the predictive power of multiple independent variables on a dependent outcome (Aiken and Stephen, 1991). Similar approaches have also been employed in recent empirical research, which highlights the usefulness of regression models in revealing organizational and sectoral dynamics (Peker, 2016). In this study, regression analysis specifically addressed Research Questions 1 and 2, concerning the main challenges faced by companies and the impact of them on biodiversity protection.

However, in regression analyses, multicollinearity, where independent variables are highly correlated with each other, can reduce the reliability of the estimated coefficients and even lead to misleading interpretations. As will be discussed later in this study, some variables were excluded from the analysis to avoid multicollinearity. However, this process also means that potentially significant explanatory factors may sometimes be omitted from the statistical analysis, thus limiting the scope of interpretation.

To overcome these limitations and enrich the quantitative findings, content analysis was conducted on open-ended survey responses. This qualitative technique enables the systematic categorization and interpretation of textual data, allowing researchers to identify recurring themes and patterns (Hsieh and Shannon, 2005). In line with Bryman's (2012) discussion of mixed-method designs, the integration of survey-based statistical analysis with content analysis provides a balanced framework by combining quantitative and qualitative perspectives. In this study, content analysis was applied to explore Research Questions 3 and 4, focusing on biodiversity strategies across urban and rural contexts, as well as the institutional needs required

to strengthen biodiversity protection capacity. Moreover, by systematically examining the textual responses, the content analysis provided additional insights into variables that might have been excluded or underestimated in the regression models, thereby compensating for the technical restrictions of the statistical method.

3.5 Research Limitations

This study is subject to two main limitations. First, the scope is limited to electricity supply companies in Türkiye and does not include third actors such as private contractors, environmental regulators, or NGOs; their inclusion could have improved our understanding of biodiversity-related planning issues. Second, although the sample encompassed a broad range of departmental representation, participation was voluntary, potentially leading to self-selection bias. Consequently, the study primarily examines institutional perceptions and their reported actions.

Despite these issues, the method provides a systematic overview of current data use, inter-institutional collaboration, and shortcomings in planning for biodiversity-integrated energy supply processes.

CHAPTER 4

FINDINGS & DISCUSSION

This chapter presents the survey results from 147 employees of Türkiye's four largest electricity power supply companies. The purpose of the survey was to find out how different companies think about and deal with protecting biodiversity, especially when it comes to using data, setting up technical systems, coordinating between institutions, and planning space. The results are grouped by theme, including Likert-scale ratings and some open-ended comments that were chosen as examples.

This section examines how challenges encountered in business processes for electricity supply affect employees' perceptions of companies' success in protecting biodiversity, as well as the strategies and needs employed in these processes. It begins by examining the challenges encountered in business processes, continues with an examination of both general and urban strategies implemented by companies, and discusses the steps employees require in these processes.

As discussed in the literature review, challenges are differentiated between biodiversity and data, and strategies are discussed in general and urban contexts.

4.1 Success in biodiversity-responsive electricity supply and challenges in business processes

This section first examines the impact of business process challenges on companies' success in protecting biodiversity using correlation and regression analyses derived from survey data. The findings are presented under three headings: (i) biodiversity-

related challenges, (ii) data-related challenges, and (iii) analyses that consider these two groups together.

4.1.1 Perceived biodiversity conservation success and biodiversity challenges in electricity supply

Companies' success in protecting biodiversity was analyzed based on employee responses to survey questions. To understand the impact of biodiversity-related challenges on this success, multiple regression analysis was conducted between biodiversity-related challenges and the company's success in protecting biodiversity. Biodiversity protection success, influenced by specific challenges encountered in business processes, was considered the dependent variable (DV), and challenges experienced in business processes were considered the independent variable (IV). As can be seen in the table below, correlation analysis was conducted before the regression analysis to examine the relationships between variables and identify potential multicollinearity.

Table 4.1 Pearson correlation of perceived biodiversity conservation success and biodiversity-related challenges

	DV	IV1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
DV: Success in Protecting Biodiversity	1,00													
IV1: Uncertainty of Regulations	-,082	1,00												
IV2: Cost concerns	-,382	,138	1,00											
IV3: Lack of Institutional Compliance	-,709	,228	,422	1,00										
IV4: Lack of Awareness	-,611	,056	,354	,578	1,00									
IV5: Weak Integration	-,407	,218	,417	,425	,290	1,00								
IV6: InadeIVuacy of Environmental Impact Analyses	-,114	,206	,335	,263	,229	,496	1,00							
IV7: Lack of Systematic Nature-Based Solutions	-,297	,269	,342	,440	,322	,496	,489	1,00						
IV8: Incompatibility of Infrastructure with Nature	-,258	,272	,222	,377	,277	,441	,392	,426	1,00					

(Table 4.1 continued)

	DV	IV1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
IV8: Incompatibility of Infrastructure with Nature	-,258	,272	,222	,377	,277	,441	,392	,426	1,00					
IV9: InadeIVuacy of LCA analyses	-,342	,522	,343	,439	,296	,381	,344	,450	,478	1,00				
IV10: Use of Environmentally Unfriendly Materials	,279	,050	,069	-,123	-,148	,134	,240	,104	,233	,144	1,00			
IV11: Inability to Monitor Infrastructure-Nature Interactions	-,168	,129	,325	,257	,247	,326	,414	,391	,441	,374	,158	1,00		
IV12: Lack of Systematic Data Sharing	-,668	,188	,463	,586	,499	,438	,269	,290	,331	,403	-,060	,254	1,00	
IV13: Lack of Standardization of Biodiversity Data	-,740	,237	,407	,666	,623	,446	,355	,344	,392	,462	-,169	,273	,623	1,00

Source: Output of SPSS

When the relationships between the variebles were examined, correlation coefficients above 0.50 were found between the lack of institutional alignment (IV3), lack of awareness (IV4), inadequacy in LCA analyses (IV9) and lack of standardization of biodiversity data (IV13), therefore these four variables were removed from the analysis in order to reduce multicollinearity.

Table 4.2 Pearson correlation of perceived biodiversity conservation success and biodiversity-related challenges (reduced multicollinearity)

	DV	IV1	IV2	IV5	IV6	IV7	IV8	IV10	IV11	IV12
DV: Success in Protecting Biodiversity	1,000									
IV1: Uncertainty of Regulations	-,082	1,000								
IV2: Cost concerns	-,382	,138	1,000							
IV3: Weak Integration	-,407	,218	,417	1,000						
IV4: Inadequacy of Environmental Impact Analyses	-,114	,206	,335	,496	1,000					
IV5: Lack of Systematic Nature-Based Solutions	-,297	,269	,342	,496	,489	1,000				
IV6: Incompatibility of Infrastructure with Nature	-,258	,272	,222	,441	,392	,426	1,000			
IV7: Use of Environmentally Unfriendly Materials	,279	,050	,069	,134	,240	,104	,233	1,000		
IV8: Inability to Monitor Infrastructure-Nature Interactions	-,168	,129	,325	,326	,414	,391	,441	,158	1,000	
IV9: Lack of Systematic Data Sharing	-,668	,188	,463	,438	,269	,290	,331	-,060	,254	1,000

Source: Output of SPSS

The analysis resulted in a three-step model. As seen from the following table, three of the nine variables included in the analysis were found to significantly affect the perceived biodiversity conservation success of electricity supply companies.

Table 4.3 Results of the Regression Analysis between "Biodiversity Conservation Success" and "Biodiversity-Related Challenges"

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.668[a]	.447	.443	1.619	.447	117.016	1	145	.000
2	.710[b]	.504	.497	1.539	.057	16.582	1	144	.000
3	.731[c]	.534	.524	1.497	.030	9.191	1	143	.003

a. Predictors: (Constant), Lack of Systematic Data Sharing

b. Predictors: (Constant), Lack of Systematic Data Sharing, Use of Environmentally Unfriendly Materials

c. Predictors: (Constant), Lack of Systematic Data Sharing, Use of Environmentally Unfriendly Materials, Weak Integration

d. Dependent Variable: **Biodiversity Conservation Success**

Source: Output of SPSS

These results show that three variables explain 53% of the variance in the perceived success. First, the "lack of systematic sharing of biodiversity data" made the largest contribution to explaining success at 45%. This aligns with Soares et al. (2018), who note that "*there is an evident need for empirical frameworks to assess and to compare alternative approaches, strategies and policies, to inform planners, designers and decision-makers*," and that "*coordinated planning, decisions and actions from many stakeholders across multiple jurisdictions are required to effectively improve urban sustainability*" (p. 178). As Soares et al. also stated, these deficiencies prevent the timely identification of ecological risks and can lead to missed early intervention opportunities. This result demonstrates that biodiversity issues within energy companies are more of an institutional issue than a technical one. The lack of data sharing is not merely a technical glitch, but also a sign that a culture of trust, collaboration, and transparency between institutions is not

sufficiently developed. Second, when the “use of environmentally unfriendly materials” is added to the model, the rate increases to 50%, and lastly, when the “weak integration” variable is added to these two variables, the percentage of variance in success explained increases to 53%. As both Moreira (2019) and Gallo et al. (2022) stated, inadequate data sharing and keeping ecological and technical data in different databases make it difficult to make integrated planning; Therefore, making databases intercommunicable is critical. Companies often make material choices based on cost advantages, but this short-term cost calculation ignores long-term ecological costs. This suggests that sustainability perspectives have not yet been fully reflected in decision-making processes. These results suggest that the most significant determining factor in staff's perceived success in biodiversity conservation is a lack of data sharing, followed by the environmental quality of the materials used and the level of integration between systems.

4.1.2 Perceived biodiversity conservation success and data-related challenges in electricity supply

To determine how staff perceptions of biodiversity conservation success are shaped by data-related challenges, responses to survey questions exploring data-related challenges were evaluated using correlation and regression analyses. Biodiversity conservation success, as affected by challenges encountered in business processes, was considered the dependent variable (DV), as in the previous section, and data-related challenges encountered in business processes were considered the independent variable (IV). As can be seen in the figure below, correlation analysis was conducted prior to the regression analysis to examine the relationships between variables and identify potential multicollinearity.

Table 4.4 Pearson correlation of perceived biodiversity conservation success and data-related challenges

	DV	IV1	IV2	IV3	IV4	IV5	IV6	IV7
DV: Success in Protecting Biodiversity	1,000							
IV1: Data Quality and Reliability Issues	,261	1,000						
IV2: Data Access, Sharing, and Openness Issues	,308	,710	1,000					
IV3: Data Compliance and Standardization Issues	,588	,473	,540	1,000				
IV4: Data Comprehensiveness and Representativeness Issues	,400	,585	,585	,498	1,000			
IV5: Data Infrastructure and Technological Inadequacies	,244	,416	,467	,448	,581	1,000		
IV6: Problems Related to Data Collection and Management Processes	-,662	-,074	-,117	-,317	-,216	-,048	1,000	
IV7: Disconnect Between Data and Application	-,684	-,047	-,071	-,279	-,140	-,057	,790	1,000

(Table 4.4 continued)

Source: Output of SPSS

Since IV1, IV2, IV3 and IV4 have high correlation coefficients with each other, only IV2 was used in the analysis, and among IV6 and IV7, IV7 was used and IV5 were also included to prevent multicollinearity.

Table 4.5 Results of the Regression Analysis between "Biodiversity Conservation Success" and "Data-Related Challenges"

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.662[a]	.439	.435	1.630	.439	113.419	1	145	.000
2	.702[b]	.493	.486	1.556	.054	15.301	1	144	.000
3	.712[c]	.507	.496	1.539	.014	4.023	1	143	.047

a. Predictors: (Constant), Data Collection and Management

b. Predictors: (Constant), Data Collection and Management, Data Access, Sharing and Opennes Issues

c. Predictors: (Constant), Data Collection and Management, Data Access, Sharing and Opennes Issues, Data Infrastructure and Technological Inadequencies

d. Dependent Variable: **Biodiversity Conservation Success**

Source: Output of SPSS

Multiple regression analysis reveals that the factor most strongly affecting biodiversity conservation success is problems related to “data collection and management” processes. This variable alone explains 43.9% of the variance. The findings reveal that inadequate data collection standards and management processes limit the effectiveness of planning and monitoring activities.

Secondly, “data access, sharing, and openness issues” increased the model's explanatory power by 5.4%. This result demonstrates that inadequate sharing of data among stakeholders and its lack of accessible formats negatively impacts the applicability of biodiversity conservation strategies.

Thirdly, “data infrastructure and technological inadequencies” increased the model's explanatory power by 1.4%, reaching a cumulative explanation of 50.7%. Weak technological infrastructure limits the capacity to monitor and assess the impacts of energy infrastructure on biodiversity.

Overall, the model results indicate that problems in data management are multi-layered, ranging from deficiencies in collection and management to data access and technological deficiencies.

4.1.3 Perceived biodiversity conservation success and challenges in electricity supply

When analyzing biodiversity-related challenges, it is observed that the highest variable affecting the perception of success is again related to data. This demonstrates that the factors affecting conservation success are not limited to ecological or field-based challenges. In energy-supply regions, data management issues are also critical for accurately identifying, monitoring, and mitigating impacts on biodiversity. Therefore, challenges directly related to biodiversity (e.g., regulatory uncertainties, poor integration, material use) and data-based challenges (e.g., data access, technological infrastructure deficiencies) were evaluated together

in a holistic model to test which factors contribute most strongly to the overall conservation success perceived by working staff. This aimed to reveal the interactions between field practices and data management processes.

In the model, a correlation analysis was conducted between all variables before considering biodiversity-related challenges and data management challenges together.

The variables are numbered as follows:

- DV: Success in Protecting Biodiversity
- IV1: Uncertainty of Regulations
- IV2: Cost concerns
- IV3: Lack of Institutional Compliance
- IV4: Lack of Awareness
- IV5: Weak Integration
- IV6: InadeIVuacy of Environmental Impact Analyses
- IV7: Lack of Systematic Nature-Based Solutions
- IV8: Incompatibility of Infrastructure with Nature
- IV9: InadeIVuacy of LCA analyses
- IV10: Use of Environmentally Unfriendly Materials
- IV11: Inability to Monitor Infrastructure-Nature Interactions
- IV12: Lack of Systematic Data Sharing
- IV13: Lack of Standardization of Biodiversity Data
- IV14: Data Quality and Reliability Issues
- IV15: Data Access, Sharing, and Openness Issues
- IV16: Data Compliance and Standardization Issues
- IV17: Data Comprehensiveness and Representativeness Issues
- IV18: Data Infrastructure and Technological Inadequacies
- IV19: Problems Related to Data Collection and Management Processes
- IV20: Disconnect Between Data and Application

Table 4.6 Pearson correlation of perceived biodiversity conservation success and challenges (IV1-IV10)

	DV	IV1	IV2	IV3	IV4	IV5	IV6	IV7	IV8	IV9	IV10
DV	1,00										
IV1	-,082	1,00									
IV2	-,382	,138	1,00								
IV3	-,709	,228	,422	1,00							
IV4	-,611	,056	,354	,578	1,00						
IV5	-,407	,218	,417	,425	,290	1,00					
IV6	-,114	,206	,335	,263	,229	,496	1,00				
IV7	-,297	,269	,342	,440	,322	,496	,489	1,00			
IV8	-,258	,272	,222	,377	,277	,441	,392	,426	1,00		
IV9	-,342	,522	,343	,439	,296	,381	,344	,450	,478	1,00	
IV10	,279	,050	,069	-,123	-,148	,134	,240	,104	,233	,144	1,00
IV11	-,168	,129	,325	,257	,247	,326	,414	,391	,441	,374	,158
IV12	-,668	,188	,463	,586	,499	,438	,269	,290	,331	,403	-,060
IV13	-,740	,237	,407	,666	,623	,446	,355	,344	,392	,462	-,169
IV14	,261	,157	,075	,008	-,032	,066	,299	,251	,135	,262	,214
IV15	,308	,148	-,020	-,045	-,044	,099	,226	,159	,145	,198	,168
IV16	,588	,031	-,158	-,292	-,326	-,087	,117	,039	-,035	-,025	,339
IV17	,400	,182	,022	-,084	-,099	,047	,336	,198	,221	,216	,242
IV18	,244	,153	-,052	-,016	-,038	,123	,301	,258	,252	,175	,217
IV19	-,662	,021	,343	,609	,525	,314	,180	,203	,301	,299	-,126
IV20	-,684	,114	,413	,643	,506	,371	,182	,266	,282	,334	-,098

(Table 4.6 continued)

Source: Output of SPSS

Table 4.7 Pearson correlation of perceived biodiversity conservation success and challenges (IV11-IV20)

	DV	IV11	IV12	IV13	IV14	IV15	IV16	IV17	IV18	IV19	IV20
DV	1,00										
IV11	-,168	1,00									
IV12	-,668	,254	1,00								
IV13	-,740	,273	,635	1,00							

(Table 4.7 continued)

	DV	IV11	IV12	IV13	IV14	IV15	IV16	IV17	IV18	IV19	IV20
IV14	,261	,240	-,100	-,072	1,00						
IV15	,308	,277	-,103	-,103	,710	1,00					
IV16	,588	,018	-,334	-,374	,473	,540	1,00				
IV17	,400	,263	-,156	-,163	,585	,585	,498	1,00			
IV18	,244	,251	-,169	-,111	,416	,467	,448	,581	1,00		
IV19	-,662	,242	,545	,630	-,074	-,117	-,317	-,216	-,048	1,00	
IV20	-,684	,220	,589	,577	-,047	-,071	-,279	-,140	-,057	,790	1,00

Source: Output of SPSS

Variables with a correlation coefficient above 0.50 (IV3, IV4, IV9, IV13, IV14, IV16, IV17, IV19, IV20) were removed from the analysis to prevent multicollinearity.

Table 4.8 Results of the Regression Analysis between "Biodiversity Conservation Success" and "Challenges"

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.668[a]	.447	.443	1.619	.447	117.016	1	145	.000
2	.710[b]	.504	.498	1.538	.058	16.807	1	144	.000
3	.739[c]	.545	.536	1.478	.041	12.906	1	143	.000
3	.766[d]	.587	.575	1.414	.041	14.126	1	143	.000
3	.773[e]	.598	.584	1.399	.041	4.016	1	143	.047

a. Predictors: (Constant), Lack of Systematic Data Sharing

b. Predictors: (Constant), Lack of Systematic Data Sharing, Data Access, Sharing, and Opnness Issues

c. Predictors: (Constant), Lack of Systematic Data Sharing, Data Access, Sharing, and Opnness Issues, Use of Environmentally Unfriendly Materials

d. Predictors: (Constant), Lack of Systematic Data Sharing, Data Access, Sharing, and Opnness Issues, Use of Environmentally Unfriendly Materials, Weak Integration

e. Predictors: (Constant), Lack of Systematic Data Sharing, Data Access, Sharing, and Opnness Issues, Use of Environmentally Unfriendly Materials, Weak Integration, Lack of Systematic Nature-Based Solutions

d. Dependent Variable: **Biodiversity Conservation Success**

Source: Output of SPSS

A five-step model was created as a result of multiple regression analysis. The first model included only “lack of systematic data sharing”, with an explanatory power of 44.7%. In the second model, the addition of “data access, sharing, and openness ıssues” increased the explained variance to 50.4%; in the third model, the addition of “use of environmentally unfriendly materials” increased the explained variance to 54.5%; in the fourth model, the addition of “weak integration” increased the explained variance to 58.7%; and in the fifth and final model, the addition of “nature-based system inadequacies” increased the explained variance to 59.8%.

In summary, the findings indicate that the most decisive factor in biodiversity conservation success is lack of data sharing, followed by data access issues, the environmental nature of the materials used, the level of integration between systems, and the inadequacy of nature-based systems. This result demonstrates that biodiversity conservation efforts are directly linked not only to technical improvements but also to the working culture and strategic priorities of institutions. Data sharing and access issues, in particular, are prominent, demonstrating that a lack of institutional collaboration and transparency is among the most critical obstacles to biodiversity conservation. Furthermore, the disregard for environmental quality in material choices reveals that short-term cost overlooks long-term ecological risks. In this context, the findings demonstrate that success in biodiversity conservation requires much more than technical solutions: institutional transformation, interoperable data infrastructures, and the integration of an ecological perspective into decision-making processes.

4.2 Strategies applied for biodiversity-responsive electricity supply

This section analyzes responses to strategies implemented across the entire field and specific to urban areas to protect biodiversity during the survey's work processes. The question asks respondents to make an assessment based on their own practices, independent of technical or statistical data. Therefore, it is possible to identify

strategies that are either mentioned in the literature or implemented differently than those in the literature.

4.2.1 Strategies applied in the field withput rural-urban segregation

The data in the table illustrates the strategies employees implement to protect biodiversity. An examination of the responses reveals that nature-based and pipeline-based solutions are the most frequently preferred, followed by institutional policies, land analyses, and collaborative activities. Overall, the strategies largely focus on field-applicable solutions, while data- and planning-based strategies and collaborative activities are less frequently mentioned. This highlights the institution's strengths as well as areas for improvement.

Table 4.9 Most frequently applied strategies for biodiversity conservation

Content group	Sub-groups	Frequency of mention	Percentage
Ecological Planning	Nature-Based Solutions	26	**31%**
	Developing A Bird Protection Plan	13	
	Considering Species and The Environment in Planning	3	
	Planning Based On Land Types	1	
	Use of GIS	7	
Technical/Operational Powerline Management	Powerline Isolation	27	**29%**
	Tree Pruning And Detection	6	
	Creating Corridors	5	
	Moving Lines to The Roadside to Avoid Cutting Down Trees	3	
	Fire Prevention Facilites	4	
Emission Management	Reducing CO_2 Emissions	4	**15%**
	Reducing SF_6 Emissons	7	
	Use of Electric Vehicles	10	
	Use of Renewable Resources	2	
	Reducing Energy Loss	1	

(Table 4.9 continued)

Content group	Sub-groups	Frequency of mention	Percentage
Materials and Waste Management	Purchasing Harmless Products	4	**13%**
	Using Harmless Equipment	1	
	Waste Management	15	
	Product and Service Purchasing	1	
Governance	Including Biodiversity in The Vision and Mission	3	**7%**
	Existence of A Sustainability Team	2	
	Working Staff Training	1	
	Collaborating With A Nature Association	5	
Compliance with Standards	Adherence to International and Creditor Standards	6	**7%**
	Adherence to The Standards of The Sustainability Committee	2	
	Conducting An Environmental İmpact Assessment (EIA)	3	
TOTAL		**162**	**100%**

Source: Output of Content Analyses

The results in the table show that Ecological Planning is the most repeated strategy group. Nearly one-third of staffs (31%) mentioned strategies such as nature-based solutions (26 times) and preparing bird protection plans (13 times). This compatibles with discussions in the literature that nature-based solutions are effective tools for protecting biodiversity and reducing the environmental impact of energy infrastructure (Kiesecker & Naugle, 2017; Moreira, 2019). Furthermore, the use of GIS (7 times) and planning based on land types (3 times) were also prominent under this category. This result supports studies that emphasized the importance of integration of spatial data in balancing electricity energy supply and biodiversity conservation (Soares et al., 2018; Guil et al., 2022).

Technical/Operational Powerline Management strategies is in second place with 28%. Working staffs specifically mentioned practices such as powerline isolation

(27 times), tree pruning (6 times), creating corridors (5 times), and fire prevention facilities (4 times). These results confirm studies showing that powerline isolation and proper management reduce risks such as bird strikes and habitat fragmentation, and demonstrate that the most common technical solution used by these companies in the electrical infrastructure to protect biodiversity is related to power lines (Guil et al., 2022; Katovich, 2024). Similarly, the importance of planning power lines so as not to prevent the migratory movements of species parallels approaches that aim to maintain ecological connectivity (Moreira et al., 2019).

Emissions Management strategies ranked third with 15%. The most prominent practices in this category were electric vehicle use (10 times), reducing CO_2 and SF_6 emissions (11 times in total), renewable energy use (2 times), and reducing energy loss (1 time). These findings reveal that electricity supply companies shape their sustainability goals not only through biodiversity but also through carbon footprint and climate-friendly technologies (Soares et al., 2018; Gallo et al., 2022).

Material and Waste Management also played a significant role (13.0%). Participants particularly highlighted waste management (15 times). The use of harmless products and equipment (6 times) and the consideration of environmental criteria in product and service purchases (1 time) were also mentioned. These results are consistent with the literature emphasizing the importance of the life cycle assessment (LCA) approach in material use (Gallo et al., 2022; Guil et al., 2022).

Although at lower rates, Governance (7%) and Compliance with Standards (7%) strategies were also marked. Within the scope of governance, integrating biodiversity into the vision and mission (3 times) and collaborating with nature associations (2 times) were mentioned. These findings are paralell with studies that emphasized the criticality of corporate governance for long-term sustainability success (Soares et al., 2018; Detritus, 2022). Within the scope of compliance with standards, adherence to international criteria (six times) and the implementation of environmental impact assessment (EIA) processes (three times) were highlighted.

This finding supports the role of environmental management systems and regulations in guiding company practices (Moreira, 2019; Soares et al., 2018).

Overall, the results show that nature-based solutions and technical pipeline management strategies are at the forefront, while corporate-level strategies such as governance and compliance with standards are relatively less frequently mentioned. This situation reveals that practical solutions to reduce the direct impacts of field operations are more adopted by employees, but as emphasized in the literature (Kiesecker & Naugle, 2017; Soares et al., 2018; Moreira, 2019), managerial integration and stakeholder collaborations need to be strengthened for long-term success. These findings reveal that companies' approaches to biodiversity conservation remain largely operational and reactive. Instead of integrating it into corporate vision and strategic planning, the focus is largely on mitigating immediate risks on the ground. This suggests that biodiversity is perceived as a technical issue, rather than a priority governance issue within corporate culture and long-term investments. For operational practices to yield lasting and systemic results, leadership commitment, integration into company missions, and strengthening the institutional dimension through cross-sector collaboration are critical.

4.2.2 Strategies applied specifically in the urban areas

The responses given to the urban area strategies in the survey were similarly subjected to content analysis and the frequency of repetition of the responses is given below.

Table 4.10 Most frequently applied strategies for biodiversity conservation in urban areas

Content group	Sub-groups	Frequency of mention	Percentage
Urban green infrastructure and nature-based solutions	Green roof	2	**24%**
	Vertical garden	3	

(Table 4.10 continued)

Content group	Sub-groups	Frequency of mention	Percentage
Urban green infrastructure and nature-based solutions	Biological corridors	3	**24%**
	Integration of ecological infrastructure	1	
	Creation of green spaces that mimic natural habitats	3	
Urban Powerlines and risk reduction	Use of underground lines and cables	7	**24%**
	Relocation of lines to the roadside	1	
	Tree pruning	1	
	Fire prevention	1	
	Low-interaction interventions	1	
	Transformer load monitoring	1	
Urban planning	Planning based on land types	1	**22%**
	Prioritization based on population density	4	
	Bird protection plan	6	
Emission management	Use of electric vehicles	3	**12%**
	Reducing CO_2 Emissions	1	
	Reducing SF_6 Emissons	1	
	Use of LED luminaires	1	
Materials and waste Management	Use of harmless products	1	**10%**
	Waste management	4	
Governance	Collaboration with other institutions and organizations	2	**8%**
	Remote management	2	
TOTAL		**50**	**100%**

(Table 4.10 continued)

Source: Output of Content Analyses

As seen in the table above, the most repeated strategy groups are urban green infrastructure and nature-based solutions, and urban powerlines and risk reduction (24% each). The frequent mention of practices such as green roofs, vertical gardens, biological corridors, and ecological infrastructure integration demonstrates that nature-based solutions play a critical role in reducing biodiversity loss in cities.

These findings are parallel with studies that emphasized the importance of integrated governance and urban green infrastructure in preserving ecosystem services (Miroshnyk et al., 2022). Within the context of urban powerlines and risk reduction, the use of underground cables, fire prevention measures, and low-interaction interventions are significant. These strategies are parallel to efforts to reduce the impacts of energy infrastructure on habitat fragmentation and bird mortality. Various studies have shown that power lines cause both bird mortality and significant ecological pressures on species' migration routes (Guil et al., 2022; Katovich, 2023; Gilad et al., 2024). Furthermore, Richardson et al. (2017) emphasizes the need for proactive measures to mitigate the impacts of land management strategies on biodiversity.

Urban planning strategies came in third place, with roughly one in five (22%). This finding parallel with literature specifically demonstrating the pressures of energy infrastructure on bird populations (Kaługa et al., 2011; Hollmen et al., 2007). Furthermore, planning based on land type and prioritization based on population density demonstrate the need to reduce the pressures of rapid urbanization on protected areas (Aticho et al., 2023; Syeban & Appiah-Opoku, 2024).

The fourth strategy category highlighted, at 12%, was emissions management strategies, encompassing particularly the use of electric vehicles and the reduction of greenhouse gas emissions. Participants' mention of this issue shows that environmental responsibilities are increasingly being addressed in the energy sector (Tomsana et al., 2020; Ajayi et al., 2022). Furthermore, studies examining the direct impacts of climate change on agricultural suitability and biodiversity also demonstrate that reducing emissions is fundamental to sustainability (Appelt et al., 2023).

Material and waste management, ranked fifth, with 10% of respondents. This included mentions of harmless product use and waste management strategies. This finding is parallel with studies that demonstrated the environmental impacts of

strategic materials used in energy infrastructure should be carefully considered throughout their lifecycle (Gallo et al., 2022). Furthermore, the risk posed to biodiversity by mining waste and heavy metals on a global scale demonstrates that this issue is not unique to the electricity energy supply firms (Aska et al., 2023).

Finally, governance strategies were mentioned less frequently, at 8%. Participants particularly emphasized the need for inter-institutional collaboration and remote management. These findings are consistent with studies that demonstrated the impact of past management practices on current biodiversity in conservation corridors (Theron et al., 2021) and with research emphasizing the importance of compliance with international standards (McCarthy et al., 2021). This also directly correlates with the literature that indicated the institutional collaboration in data management and sharing is critical for sustainability (Costello & Wieczorek, 2014; Chamanara & König-Ries, 2014).

These findings reveal that nature-based solutions and green infrastructure are the most frequently cited by participants at the urban scale. However, these practices appear to be largely implemented locally and in a fragmented manner. While initiatives such as green roofs, vertical gardens, or small-scale ecological corridors may provide short-term benefits, their long-term impact is limited if not supported by a holistic conservation strategy. While companies prioritize practical solutions to mitigate risks on the ground, they fail to develop a comprehensive vision centered on sustainability at the corporate level. This demonstrates that biodiversity is still perceived as a secondary element in urban planning and energy infrastructure management, often treated as a technical issue to be addressed. However, for long-term conservation, nature-based solutions should not be limited to local projects but should be integrated into strategic planning processes. Rapidly increasing energy demand in cities increases pressure on protected areas, while fragmented practices are insufficient to alleviate this pressure. Therefore, biodiversity must be addressed not only at the technical and operational levels but also within the framework of corporate governance. The findings clearly demonstrate that the key need is to

strengthen inter-institutional collaboration, strategic integration, and governance mechanisms. Only then can existing practices be systematically structured to create large-scale ecological benefits and mitigate the long-term negative impacts of energy infrastructure on biodiversity.

4.3 Fundamental needs of biodiversity-responsive electricity supply

This section analyzes the responses to the survey question, "Considering all these challenges and strategies, what do you think is the most fundamental need for increasing your institution's capacity to protect biodiversity?" The question asks participants to make an assessment based on their own experiences and observations, independent of technical or statistical data. Therefore, it is possible to identify important elements related to field experience, organizational culture, and operational processes that may not be revealed in technical analyses. Analyses based solely on technical data may not fully reflect the institutional, cultural, or communication barriers employees face during implementation. Content analysis of open-ended responses goes beyond numerical findings and provides a clearer picture of these barriers and needs.

The 132 responses collected were analyzed using content analysis. First, all responses were read, grouped under similar themes, and "content categories" were created for each group. Each category was defined as sub-themes within itself. During the coding process, repetitive or similar expressions were combined under the same category, and category names were selected to best reflect the meaning of the responses. In the final stage, the frequency (number of times it was repeated) and percentage of total responses were calculated for each subtheme.

Table 4.11 Most requested fundamental needs for biodiversity-responsive electricity supply

Content Groups	Sub-Groups	Frequency of Mentions	Percentage
Need for Data and Analysis	Access to Data	64	**48,5%**
	Conducting Impact Analysis		
	Effective Use of Technology		
	Standardization		
	Systematic Process		
	Use of GIS		
	Developing Long-Term, High-Impact Strategies		
Farkındalık	Awareness	31	**23,5%**
Policy, Audit, and Financial and Human Resources	Supporting Legislation	25	**18,9%**
	Audit		
	Regulation		
	Budget		
Operational and Technical Interventions	Reducing Hazardous Waste Use	8	**6,1%**
	Changes in İnfrastructure Characteristics		
	Changes in Equipment Characteristics		
	Tree Pruning		
Institutional Collaboration	Professional Collaboration	4	**3,0%**
Total		**132**	**100%**

(Table 4.11 continued)

Source: Output of Content Analyses

According to the analysis results, the most frequently expressed need was gathered under the "Need for Data and Analysis" category (n=64, 48.5%). Participants emphasized subheadings such as access to data, conducting impact analyses, effective use of technology, standardization, establishing systematic processes, expanding the use of GIS, and developing long-term, high-impact strategies. This finding demonstrates that to increase technical capacity, not only existing data but also the stages of processing, sharing, and integrating data into decision-making

processes should be strengthened. Furthermore, the high rate in this category reveals that the lack of data is perceived as an obstacle not only at the technical but also at the strategic level, highlighting the impact of the lack of systematic process management revealed by the technical analysis. Participants mentioned the lack of data sharing and GIS use; as stated by Raza et al. (2024), this demonstrates the criticality of GIS and remote sensing integration for decision support processes in monitoring land use patterns. Therefore, participants' emphasis on data and GIS-focused needs directly points to a necessity to ensure that planning processes are grounded in science. The second-ranked category, Awareness (n=31, 23.5%), indicates that the knowledge and sensitivity of working staff on biodiversity within the organization needs to be increased. While some participants directly used the term "awareness," others stated that they lacked a clear understanding on this issue ("don't know"). This demonstrates that the feasibility of technical processes is largely related to corporate culture and working staffs' awareness. Moreira (2019) reveals that energy-biodiversity compromises can be strengthened not only through technical data but also through employee awareness within the organization and the level of communication between stakeholders. Similarly, Soares et al. (2018) argue that technical capacity in field applications can only be effective if employees have sufficient awareness of the issue, and therefore, institutional capacity building programs are critical. Participants' emphasis on the need for awareness aligns with these findings, revealing the cultural and behavioral dimensions of implementation success. The Policy, Audit, and Financial/Human Resources category (n=25, 18.9%) covers structural factors such as supportive legislation, effective oversight mechanisms, appropriate regulations, and adequate budget allocation. Kiesecker & Naugle (2017) argue that policy frameworks need to be restructured to align nature conservation goals with energy infrastructure investments. Furthermore, They also argue that these efforts risk remaining theoretical unless supported by adequate budgetary and administrative resources. Therefore, participants' emphasis in this area reflects the necessity of strengthening implementation through legislative and resource support.

The Operational and Technical Interventions category (n=8, 6.1%), mentioned at lower rates, includes direct field-related recommendations such as reducing hazardous waste use, modifying infrastructure features, equipment improvements, and tree pruning. The low frequency of this category suggests that technical solutions are prioritized less than institutional and data-based approaches.

Finally, the Institutional Collaboration category (n=4, 3%) suggests the need for increased professional collaboration. This low rate indicates that while there is awareness of the importance of collaboration, it lags behind other categories in the priority ranking. However, Kiesecker & Naugle (2017) state that technical interventions alone do not ensure long-term conservation success; their impact will be limited unless supported by institutional coordination and data-based planning. Therefore, these needs, although expressed at a low rate, demonstrate the need to integrate field actions into the strategic framework.

Overall, these findings reveal that data access, data sharing, and GIS integration are the most critical needs for increasing technical capacity. However, the results also clearly demonstrate that simply developing the technical infrastructure is not sufficient. Employee awareness and organizational culture are at least as important as technical solutions for the effective use of data and the applicability of processes. The high level of data and awareness gaps expressed by participants suggests that the main challenge in the biodiversity conservation process is not simply accessing information, but circulating this information within the institution and integrating it into decision-making mechanisms.

Furthermore, the findings demonstrate that policy, auditing, and resource management, while less relevant, are critical to the success of the process. Technical solutions developed without legal regulations, budget support, and institutional collaboration will not be sustainable. The low expression of inter-institutional collaboration, in particular, is a striking indicator of weakness in this area. However, the literature and the results of this study demonstrate that technical interventions

alone do not ensure long-term success and must be embedded within a strategic framework and institutional coordination. In this context, the qualitative findings of the study demonstrate that biodiversity conservation is not limited to technical measures on the ground; it also requires strong data management, employee awareness, an effective legal framework, and trust-based collaboration among institutions. In other words, conservation success is not limited to technical solutions; it is directly related to how institutions operate, what values they prioritize, and how they integrate data into decision-making processes. Therefore, to enhance biodiversity conservation capacity, it is essential to address both technical and institutional dimensions together and develop an integrated approach.

Additionally, the table below shows the frequency of responses to the same 147 respondents asking, "What data do you use in your business processes?" An examination of the types of data used and their frequency of use within this framework reveals that the current situation aligns with the findings discussed above.

Table 4.12 Most frequently used data sets in electricity supply

Data sets	**Data type**	**Frequency of mention**	**Percentage**	**Group Percentage**
Network inventory and design data	Type of materials used in electrical infrastructure (copper, aluminum, neodymium, etc.)	136	8.5%	**40%**
	Technical structural data such as pole type, phase positions, and insulation status	126	7.9%	
	Number of converters and transformers	126	7.9%	
	Design characteristics of electrical lines (phase position, insulation)	125	7.8%	
	Infrastructure data such as current network length, energy amount, voltage level, and number of connections	123	7.7%	
Spatial ecological data	Spatial data of the electrical grid for planned infrastructure projects (location, length, and area of influence)	125	7.8%	**32%**
	Location of lines and surrounding habitat structure	123	7.7%	
	Land use and cover data (LULC)	85	5.3%	
	Satellite imagery (OLI, etc.)	43	2.7%	

(Table 4.12 continued)

Data sets	Data type	Frequency of mention	Percentage	Group Percentage
Spatial ecological data	Classified raster layers (forest, bare land, agriculture, water, urban)	42	2.6%	**32%**
	Bird migration routes	29	1.8%	
	Time-dependent change data (e.g., 2013–2021 NDVI)	20	1.2%	
	Biodiversity indicators (fauna/flora density, habitat quality)	16	1%	
	Global bird mortality data (especially for raptors/eagles)	13	0.8%	
	Spatial planning data for blue-green infrastructure	11	0.7%	
	Landscape quality indicators (habitat integrity, transitivity)	9	0.6%	
Environmental impact and risk data	Fire incidents	65	4%	**16%**
	Oil spills	58	3.6%	
	Carbon and greenhouse gas (CO_2, SF_6) emissions	54	3.4%	
	Species-based mortality rates from bird strikes or electrocution	51	3.2%	
	Hazardous chemical use	32	2%	
Operational performance and service data	Power losses	91	5.7%	**12%**
	Service quality indicators (outage duration, satisfaction)	46	2.9%	
	Monitoring results of infrastructure or events and post-implementation feedback data	31	1.9%	
	Field observation protocols, sampling designs used	16	1%	
	Societal benefit measures (recreation, water retention, climate adaptation)	9	0.6%	
TOTAL		**1605**		**100%**

(Table 4.12 continued)

Source: Output of Content Analyses

Looking at the results from content analyses, it appears that two-fifths of the data groups most frequently used by companies in their daily business processes are network inventory and design data, such as material type, pole/line characteristics, transformer/converter information, voltage-length-number of connections. Spatial

ecological data ranks second (32%), with "line location and surrounding habitat structure," land use/cover data (LULC), and satellite imagery prominent in this group. In contrast, biodiversity indicators, bird migration routes, time series, and blue-green infrastructure plan layers are used at a very low rate (between 1-3%). Data on environmental impacts and risks such as fire, leakage, CO_2/SF_6 emissions, and bird strike rates (16%), as well as operational performance data such as outage duration, customer satisfaction, field observation protocols, etc. (12%), are used to a more limited extent. This distribution demonstrates the lack of systematic impact analysis based on ecological indicators. It also demonstrates the lack of holistic planning. A similar situation is evident in the general and urban strategies discussed earlier. These strategies often consist of fragmented solutions, such as green roofs and vertical gardens. Furthermore, technical measures aimed solely at reducing line risks are also included in this limited approach. Indeed, in the "fundamental needs" table (see Table 4.11), the need for data and analysis, such as access to data, standardization, use of GIS, establishment of systematic processes, and development of long-term, high-impact strategies, ranks far and away first, at 48.5%.

These findings reveal that companies primarily focus on grid inventory and design data in their data use, while ecological indicators remain quite limited. This table demonstrates that biodiversity is still viewed as a secondary element in internal decision-making, alongside technical infrastructure. The fragmented nature of existing data, the use of disparate standards, and the failure to fully integrate regular impact analyses into business processes severely limit the impact of conservation efforts.

The results demonstrate that biodiversity-sensitive planning is directly related not only to technical improvements but also to how data is managed and incorporated into decision-making processes. In this context, establishing regularly shared, standardized, and GIS-based data management systems is a critical need. Such an infrastructure will enable a more holistic assessment of energy-biodiversity-land

interactions, ensure comparability across different sectors, and transform the currently fragmented solutions into more meaningful strategies.

Furthermore, the findings demonstrate that organizations should address their environmental responsibilities not only through reporting but also through regular measurement and management processes. At this point, it becomes clear that data management is not merely a technical task but also a fundamental governance issue in terms of transparency, corporate accountability, and long-term sustainability. In other words, the fundamental need for biodiversity-sensitive energy planning is not so much how institutions collect and use data, but rather the extent to which they integrate it into decision-making processes. Therefore, the findings clearly demonstrate that institutional transformation and the strengthening of a data-driven culture are essential for sustainable success.

CHAPTER 5

CONCLUSION

This thesis examines the challenges, strategies, and data dimensions of biodiversity conservation in electricity supply processes by combining literature review with field-based evidence from four major companies in Türkiye. The findings clearly show that biodiversity protection cannot be achieved through isolated measures. Instead, it requires systematic data governance, integration of ecological indicators, and planning approaches that address both technical and environmental needs.

A survey of 147 employees revealed that systematic sharing of biodiversity data is the most significant predictor of perceived success in biodiversity conservation. This statistical evidence confirms a long-standing debate in the literature: fragmented, outdated, and dispersed data streams undermine conservation outcomes (Allard and Aydınoğlu, 2012; Anderson et al., 2020). However, the thesis goes beyond the literature by quantitatively demonstrating the gravity of this challenge and demonstrating that data management is not merely a background issue but a key driver of success in biodiversity-sensitive energy supply.

Urban infrastructure strategies have also been a significant area of research. While green roofs, vertical gardens, and ecological corridors, frequently mentioned in the study, are beneficial for urban biodiversity, they are not sufficient on their own. Such practices are often visual or symbolic, failing to reflect species diversity and ecological processes. This thesis has demonstrated that direct grid-related risks, such as underground cabling, low-interaction designs, and rerouting of power lines, are at least as significant as green infrastructure at the urban scale. This approach

contributes to the literature by emphasizing the need to integrate direct threats related to the energy grid into urban planning.

Another significant contribution comes from the dataset analysis based on field applications. The most frequently used data in companies is grid inventory data such as transformer, line, and voltage information. However, ecological data such as bird migration routes, species indicators, and blue-green infrastructure layers are rarely reflected in decision-making processes. This suggests that institutions prioritize technical and regulatory data, while ecological data remains secondary. This demonstrates that biodiversity is still treated as a "technical sideline," while the real need lies in integrating data into decision-making mechanisms and conducting multi-dimensional impact analyses.

When all the findings are considered together, it becomes clear that sustainable energy infrastructure planning should be addressed not only through efficiency and technical performance, but also through ecological values and a strong data governance framework. Only with this infrastructure will improvements in legal regulations, efficiency, and environmental performance become meaningful.

Importantly, these results also resonate with broader international discussions. OECD (2024) highlights that biodiversity-sensitive energy planning requires a mix of regulatory, economic, information-based, and voluntary policy instruments. The report stresses the need for systematic post-construction monitoring, transparent data-sharing obligations, and robust due diligence frameworks to ensure accountability. Furthermore, it underlines that circular economy measures—such as life cycle assessments, material recycling, and resource efficiency—must be systematically integrated into energy infrastructure. These insights strengthen the thesis findings by showing that data management and institutional practices at the company level can only become effective when supported by coherent governance mechanisms and multi-level policy frameworks.

The overall contribution of this study can be summarized under three main headings. First, it establishes data management, supported by statistical validation, as a key determinant of biodiversity-sensitive energy supply. Second, it develops an integrated perspective on urban infrastructure by addressing not only green infrastructure but also the risks of the electricity grid. Third, it offers practical guidance regarding gaps between ecological and technical data by presenting an analysis of the dataset based on institutional practice.

In view of these findings, the following recommendations are made:

5.1 Practical Recommendations

- Biodiversity data should be collected on a centralized and interoperable platform. This platform should allow for the integration of spatial layers, particularly habitat types, migration routes, Key Biodiversity Areas (KBA), and Important Bird Areas (IBA), into power grid inventories.
- Investment should be made in GIS (Geographic Information Systems)-based decision support systems that integrate ecological, technical, and legal data. This allows planners to more clearly visualize biodiversity risks during site selection and design.
- To ensure traceability and reusability, biodiversity data used in energy planning systems should be organized in accordance with the FAIR principles (Available, Accessible, Interoperable, Reusable).
- The right biodiversity modules should be integrated into planning processes. This allows for more comprehensive environmental impact assessments, including species-specific and spatially detailed risk analyses.
- Collaboration should be encouraged between GIS, maintenance, sustainability, and investment teams. This can reduce the problem of institutional fragmentation. Biodiversity-focused training programs should

be organized for technical staff, project managers and spatial analysis experts for capacity building.

- Policy-makers should strengthen monitoring obligations, data transparency requirements, and due diligence standards for energy companies, in line with international recommendations such as OECD (2024).
- Circular economy approaches, including systematic life cycle assessments, recycling of critical materials, and efficiency in resource use, should be prioritized to reduce the long-term environmental burden of energy infrastructure.

5.2 Advancements in Practice and Knowledge

This thesis contributes to both theoretical and applied knowledge on the relationship between energy infrastructure and biodiversity. By systematically revealing operational gaps encountered in the electricity supply sector in Türkiye, it allows for the validation of strategic frameworks highlighted in the literature with field evidence. The survey results and dataset analysis reveal that GIS is central to identifying mismatches between ecological and technical data. In this way, the thesis demonstrates that GIS functions not only as a technical instrument but also as a strategic approach for biodiversity-responsive energy planning. This emphasis adds a new dimension to discussions on data-driven ecological governance and highlights the strategic role of GIS at both academic and practical levels.

5.3 Suggestions for Future Research

This study offers several recommendations for future research:

- The institutional perspective presented here could be enriched by comparative studies involving regulatory agencies or conservation-focused NGOs.
- Detailed case studies of how biodiversity data is or is not used in specific energy infrastructure projects could provide deeper insights into institutional behavior.
- Developing and testing GIS-based dashboards or prototypes that map threats to biodiversity along energy corridors could provide a strong foundation for applied research.
- Long-term monitoring of biodiversity-integrated projects could reveal whether these projects improve over time after implementation of training, regulations, or tools.

In short, biodiversity-sensitive energy supply planning is not merely a technical issue; it is also a system-related issue. By reducing data fragmentation, investing in spatial decision-support tools, and strengthening institutional capacity, energy infrastructure systems can become biodiversity-responsive energy supply systems.

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APPENDICES

A. Process and Data-Based Feedback Survey for Biodiversity Protection in the Electric Energy Sector

Bu anket, yüksek lisans tez çalışması kapsamında enerji arzı süreçlerinde biyoçeşitliliğin korunmasına yönelik iş süreçleri, veri kullanımı ve karşılaşılan zorlukların anlaşılmasını amaçlamaktadır.
Anket, yalnızca kurumsal deneyimlere yönelik genel eğilimleri analiz etmeye yöneliktir.
Hiçbir kişisel veri (ad, soyad, iletişim bilgisi vb.) toplanmamaktadır.
Tüm yanıtlar anonim olarak değerlendirilecek ve yalnızca akademik amaçlarla kullanılacaktır.
Katılım tamamen gönüllüdür.

Demografik Bilgiler

Yaşınız

Cinsiyetiniz

Hangi birimde görev alıyorsunuz?

Şirkette kaç yıldır çalışıyorsunuz?

Çalıştığınız kurumun, enerji arzı sağlanan alanlarda biyoçeşitliliği koruma konusundaki uygulamalarını genel olarak ne düzeyde başarılı buluyorsunuz?

(Likert ölçeği: 1 – Hiç katılmıyorum, 7 – Tamamen katılıyorum)

Biyoçeşitliliği Korumayı Sağlarken Yaşanan Zorluklar

(Likert ölçeği: 1 – Hiç katılmıyorum, 7 – Tamamen katılıyorum)

Bu bölümde biyoçeşitliliği korumayı sağlarken süreçte yaşanan zorluklar belirtilmiştir. Her bir değişkenin iş süreçlerinizde biyoçeşitliliği sağlarken ne kadar zorluk yarattığını derecelendirin. (1- En Az, 7- En Çok)

- Çevresel mevzuatların belirsiz olması ve yerel-ulusal-uluslararası düzenlemeler arasında tutarsızlık bulunması
- Çevresel yatırımların finansal olarak önceliklendirilmemesi ve maliyet kaygılarının çevreye tercih edilmesi
- Yeni teknolojilere ve doğa dostu yaklaşımlara kurumsal uyum kapasitesinin yetersiz olması
- Kurumsal ve teknik birimlerin çevresel etkiler ve yükümlülükler konusunda farkındalık eksikliği yaşaması
- Korunan alanlar ve biyoçeşitlilik önceliklerinin enerji altyapı planlamalarına entegre edilmemesi
- Çevresel etkilerin yatırım, planlama ve karar verme süreçlerinde maliyet-fayda analizlerine dahil edilmemesi
- Doğa temelli çözümlerin yatırım planlarında sistematik olarak dikkate alınmaması
- Elektrik altyapısının doğa temelli ve çevre duyarlı ilkelerle uyumlu olmaması
- Yaşam döngüsü analizlerinin (LCA) elektrik altyapısı özelinde yapılmaması veya yetersiz uygulanması
- Geri dönüştürülmüş ve çevre dostu malzeme kullanımının sınırlı olması

- Altyapı-doğa etkileşimlerinin izlenememesi ve uzun dönemli çevresel etkilerin takip edilememesi
- Kurum içi ve kurumlar arası veri paylaşımının sistematik olmaması
- Biyoçeşitlilik verilerinin eksik, güncel olmaması ve standartlaştırılmamış olması

İş Süreçlerinde Kullanılan Veriler

Aşağıda belirtilen verilerin hangilerini iş süreçlerinizde kullanıyorsunuz?

- Elektrik altyapısında kullanılan malzemelerin türü (bakır, alüminyum, neodimyum vb.)
- Elektrik hatlarının tasarım özellikleri (faz konumu, yalıtım)
- Hatların konum bilgisi ve çevresindeki habitat yapısı
- Direk tipi, faz konumları, yalıtım durumu gibi teknik yapı verileri
- Planlanan altyapı projelerine ait elektrik şebekesinin mekânsal verileri (konum, uzunluk, etki alanı)
- Mevcut ağ uzunluğu, enerji miktarı, gerilim seviyesi, bağlantı sayısı gibi altyapı verileri
- Dönüştürücü ve trafo sayısı
- Güç kayıpları
- Kuş çarpması ya da elektrik çarpması kaynaklı tür bazlı ölüm oranları
- Yangın olayları
- Yağ sızıntıları
- Karbon ve sera gazı (CO_2, SF_6) emisyonları
- Tehlikeli kimyasal kullanımı

- Altyapı ya da olayların izleme sonuçları ve uygulama sonrası geri bildirim verileri
- Arazi kullanım ve örtü verileri (LULC)
- Sınıflandırılmış raster katmanları (orman, çıplak toprak, tarım, su, kent)
- Uydu görüntüleri (OLI vb.)
- Zamana bağlı değişim verileri (ör. 2013–2021 NDVI)
- Biyoçeşitlilik göstergeleri (fauna/flora yoğunluğu, habitat kalitesi)
- Küresel kuş ölüm verileri (özellikle yırtıcılar/kartallar için)
- Kuş göç rotaları
- Peyzaj kalitesi göstergeleri (habitat bütünlüğü, geçişlilik)
- Mavi-yeşil altyapıya dair mekânsal planlama verileri
- Toplumsal fayda ölçütleri (rekreasyon, su tutma, iklim uyumu)
- Hizmet kalitesi göstergeleri (kesinti süresi, memnuniyet)
- Saha gözlem protokolleri, kullanılan örnekleme tasarımları

Verilerle İlgili Zorluklar

Bu bölümde biyoçeşitliliği korumayı sağlarken kullanılan verilerle ilgili zorluklar belirtilmiştir. Her bir değişkenin ne kadar zorluk yarattığını derecelendirin. (1- En Az, 7- En Çok)

Aşağıda belirtilen veri ile ilgili değişkenler iş süreçlerinizde biyoçeşitliliği korumayı sağlarken ne kadar zorluk yaratıyor? Derecelendirin.

- Veri Kalitesi ve Güvenilirliği Sorunları:

Eksik, hatalı veya düşük kaliteli veri,

Kalite kontrol eksikliği,

Zaman serisi verilerde standardizasyon eksikliği,

Taksonomik belirsizlikler

- Veri Erişimi, Paylaşımı ve Açıklığı:

Verilere erişim kısıtlılığı,

Veri sağlayıcılar ile kullanıcılar arası geri bildirim mekanizmalarının eksikliği,

Verilerde nesnel bir tanımlama sisteminin olmaması (örneğin sabit tür ID'leri)

- Veri Uyumu ve Standardizasyon Sorunları:

Veri formatlarının ve içerik yapılarının farklılığı,

Sensör verileriyle saha verilerinin uyumsuzluğu,

Ulusal ve uluslararası veri sistemleri arasında tutarsızlık

- Veri Kapsayıcılığı ve Temsiliyeti:

Biyoçeşitlilik verilerinin coğrafi ve tematik kapsamının sınırlı olması,

Geleneksel bilgi sistemlerinin dışlanması

- Veri Altyapısı ve Teknolojik Yetersizlikler:

Uzun vadeli veri depolama sistemlerinin eksikliği,

Sensör teknolojilerinin sınırlılıkları,

Yüzeye yakın sensörlerin (ör. hiperspektral, lidar) yetersiz kullanımı

- Veri Toplama ve Yönetim Süreçlerine İlişkin Sorunlar:

Sistematik veri yönetim planlarının olmaması,

Fon yetersizliği ve altyapı eksikliği,

Kamu veri portallarında kullanıcı katkılarının işlenmemesi

- Veri ile Uygulama Arasındaki Kopukluk:

Koruma planlarına veri entegrasyonunun zayıflığı,

Karar destek sistemlerinin veri zayıflığı nedeniyle sınırlı çalışması

Aşağıda yer alan soruları iş süreçlerinizi değerlendirerek cevaplayınız.

- Biyoçeşitliliği korumak için iş süreçlerinizde hangi stratejiler uygulanıyor?
- İş süreçlerinizde kentsel mekanda biyoçeşitliliği korumak için kırsal mekandan ayrılan hangi stratejiler uygulanıyor? Varsa bu strateji farkları nelerdir?
- Tüm bu zorlukları ve stratejileri göz önünde bulundurduğunuzda, sizce kurumunuzun biyoçeşitliliği koruma kapasitesini artırmak için en temel ihtiyaç nedir?

B. Literature Review Base Table

Keyword	Author/s	Article Title	Research Theme	Challenging Issues / Research Questions	Contribution to my own thesis	What are the variables in biodiversity conservation?
Biodiversity	Chamanara, J., & König-Ries, B. (2014)	A conceptual model for data management in the field of ecology	Data management in ecology, Data integration	How to integrate diverse environmental data types for better ecosystem management	Processing biodiversity and energy infrastructure data, integrating spatial biodiversity data into GIS-based applications	
environmental impact AND electricity distribution	Gallo, M., Moreschi, L., & Del Borghi, A. (2022)	A Critical Environmental Analysis of Strategic Materials Towards Energy Transition	Energy transition, Strategic materials, Environmental impact	What are the environmental impacts of using strategic materials for energy transition, and how can these be mitigated?	Linking energy transition to biodiversity conservation, environmental impacts of materials used in energy infrastructure	Energy transition, Strategic material use, Environmental sustainability
biodiversity AND power lines AND electricity	Richardson, M. L., Wilson, B. A., Aiuto, D. A., Crosby, J. E., Alonso, A., Dallmeier, F., & Golinski, G. K. (2017)	A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation	Energy infrastructure, Biodiversity conservation, Environmental impacts	What are the direct and indirect impacts of pipelines and power lines on biodiversity? How can these impacts be mitigated effectively?	Impact of energy infrastructure on biodiversity, potential mitigation strategies	Energy infrastructure, Biodiversity conservation, Mitigation strategies
Biodiversity	Gadelha, L. M., de Siracusa, P. C., Dalcin, E. C., da Silva, L. A., Augusto, D. A., Krempser, E., … & de Siqueira, M. F. (2020)	A survey of biodiversity informatics: Concepts, practices, and challenges	Biodiversity informatics, Data management, Conservation technology	What are the concepts and practices in biodiversity informatics, and what are the challenges in data management and sharing for biodiversity conservation?	Importance of data management systems and IT tools in supporting biodiversity conservation	Data standardization, Data accessibility, Data integration
Ecological network AND grid infrastructure	Gould, Z., Day, S., Reichard, G., Shealy, T., & Saad, W. (2023)	A Transdisciplinary Blueprint for Energy Markets Modeled after Mycorrhizal Networks	Energy markets, Mycorrhizal networks, Ecosystem services	How can energy markets be modeled using mycorrhizal networks to improve system adaptability and sustainability?	An ecological approach to energy system design, demonstrating how biodiversity principles can enhance energy infrastructure planning and resilience	Biodiversity, Resilience, Energy systems, Ecosystem-based modeling
environmental impact AND electricity distribution	Tomsana, A., Itoba-Tombo, E. F., & Human, I. S. (2020)	An analysis of environmental obligations and liabilities of an electricity distribution company to improve sustainable development	Environmental obligations, Electricity distribution, Sustainability	How do environmental obligations affect the sustainability practices of electricity distribution companies, and what role do liabilities play in promoting sustainable development?	Regulatory aspects of electricity distribution and the environmental impacts of such infrastructure, integrating biodiversity conservation into energy planning	Environmental liabilities, Sustainable practices, Corporate governance

Keyword	Author/s	Article Title	Research Theme	Challenging Issues / Research Questions	Contribution to my own thesis	What are the variables in biodiversity conservation?
Biodiversity	Costello, M. J., & Wieczorek, J. (2014)	Best practice for biodiversity data management and publication	Biodiversity data management, Data publication, Data standards	What are the best practices for managing and publishing biodiversity data, and how can these practices improve the efficiency of conservation efforts?	Impact of energy infrastructure on biodiversity, data management and interoperability are critical when integrating data systems for biodiversity conservation in energy planning	Data standards, Data quality, Interoperability
environmental impact AND electricity distribution	Gilad, D., May, R., Stokke, B. G., & Verones, F. (2024)	Between the lines: Life cycle impact assessment models of collision and electrocution impacts of power lines on bird diversity in Norway	Energy infrastructure, Bird conservation, Impact assessment	What are the life cycle impacts of power lines on bird diversity in Norway, particularly focusing on collision and electrocution?	Impact of energy infrastructure on biodiversity and conservation strategies that can mitigate these impacts	Biodiversity loss, Energy infrastructure impacts, Conservation strategies
Biodiversity	Chamanara, J., Gaikwad, J., Gerlach, R., Algergawy, A., Ostrowski, A., & König-Ries, B. (2021)	BEXIS2: A FAIR-aligned data management system for biodiversity, ecology and environmental data	Data management systems, FAIR principles, Biodiversity data systems, Ecology data integration	How can FAIR principles (Findability, Accessibility, Interoperability, and Reusability) be applied to biodiversity and ecological data management, and what challenges exist in aligning these principles with biodiversity conservation?	Importance of data systems and interoperability in biodiversity conservation, environmental impacts of energy infrastructure on biodiversity	Data standardization, Open data access, Data interoperability
Biodiversity	Varshney, K., MacKinnon, M., Zari, M. P., Shanahan, D., Woolley, C., Freeman, C., & van Heezik, Y. (2024)	Biodiverse residential development: A review of New Zealand policies and strategies for urban biodiversity	Urban biodiversity, Residential development, Sustainable cities, Conservation policies	How can residential development in New Zealand be aligned with biodiversity conservation goals, and what are the challenges in implementing urban biodiversity strategies?	How urban development can impact biodiversity, assessing the environmental impacts of energy infrastructure in urban environments The need for sustainable planning practices that can be implemented	Biodiversity conservation, Urban planning, Sustainable development
Biodiversity conservation AND Biodiversity areas	He, X., & Wei, H. (2023)	Biodiversity and ecosystem services: Complementary approach for catchment protection and land use in northeastern Poland	Catchment protection, Ecosystem services	How can land use planning and catchment management contribute to ecosystem service preservation?	Ecosystem service assessment applicable to energy infrastructure planning to understand ecosystem impacts	
Biodiversity conservation AND Biodiversity areas	Sokół, M., & Łaska, G. (2024)	Biodiversity conservation and ecological value of protected areas: a review of current situation and future prospects	Protected areas, Biodiversity conservation	How effective are protected areas in conserving biodiversity?	Impact of energy infrastructure in protected areas on biodiversity	
Biodiversity conservation AND Biodiversity areas	Aska, B., Franks, D. M., Stringer, M., & Sonter, L. J. (2023)	Biodiversity conservation threatened by global mining wastes	Mining impacts on biodiversity	What are the effects of mining waste on biodiversity?	Energy infrastructure and its impact on biodiversity in relation to mining waste	Key variables include mining waste, pollution, habitat fragmentation, and ecosystem degradation.

Keyword	Author/s	Article Title	Research Theme	Challenging Issues / Research Questions	Contribution to my own thesis	What are the variables in biodiversity conservation?
GIS AND biodiversity	Weiskopf, S. R., Isbell, F., Arce-Plata, M. I., et al. (2024)	Biodiversity loss reduces global terrestrial carbon storage	Biodiversity conservation, Carbon storage, Climate change	How does biodiversity loss affect the global terrestrial carbon storage, and what are the implications for climate change mitigation?	The link between biodiversity conservation and climate change, the impact of energy infrastructure on both biodiversity and carbon storage	Biodiversity loss, Carbon flux, Ecosystem degradation
environmental impact AND electricity distribution	Guil, F., & Pérez-García, J. M. (2022)	Bird electrocution on power lines: Spatial gaps and identification of driving factors at global scales	Bird electrocution, Energy infrastructure, Biodiversity conservation	What are the global spatial gaps in data regarding bird electrocution on power lines, and what are the driving factors behind it?	Impact of energy infrastructure on biodiversity and electrocution mitigation strategies applicable to energy projects and biodiversity conservation	Biodiversity loss, Energy infrastructure, Electrocution risks
Species distribution modeling AND remote sensing	Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., … Zhu, Z. (2014)	Bringing an ecological view of change to Landsat-based remote sensing	Remote sensing, Ecological change, Land cover change, Biodiversity conservation	How can Landsat-based remote sensing be used to detect ecological changes such as land cover change, and how does this impact biodiversity conservation?	Assessing the impact of remote sensing on energy infrastructure and other land-use changes on biodiversity	Land cover change, Biodiversity loss, Ecological change detection
energy transition AND biodiversity	Ponitka, J., & Boettner, S. (2020)	Challenges of future energy landscapes in Germany — a nature conservation perspective	Energy transition, Nature conservation, Energy infrastructure	How can energy landscapes in Germany be managed to minimize the negative impacts on nature conservation and biodiversity?	The balance between energy infrastructure development and biodiversity conservation	Energy infrastructure, Biodiversity conservation, Land use change
Biodiversity conservation AND Biodiversity areas	Appelt, J. L., Saphangthong, T., Malek, Ž., Verburg, P. H., & van Vliet, J. (2023)	Climate change impacts on tree crop suitability in Southeast Asia	Climate change effects on agriculture	How does climate change affect the suitability of tree crops in Southeast Asia?	Integrating biodiversity concerns into energy infrastructure planning and land use	Agricultural sustainability, Climate adaptation, Biodiversity in farming systems
environmental impact AND electricity distribution	Weber, J., Steinkamp, T., & Reichenbach, M. (2023)	Competing for space? A multi-criteria scenario framework intended to model the energy–biodiversity–land nexus for regional renewable energy planning based on a German case study	Energy planning, Biodiversity conservation, Land use management	How can a multi-criteria scenario framework be used to balance energy infrastructure development with biodiversity conservation and land use?	Impacts of energy infrastructure on wildlife and biodiversity conservation	Biodiversity, Energy infrastructure, Land use change
Species distribution modeling AND remote sensing	Middleton, A. D., Sawyer, H., Merkle, J. A., Kauffman, M. J., Cole, E. K., Dewey, S. R., Gude, J. A., Gustine, D. D., McWhirter, D. E., Proffitt, K. M., & White, P. (2019)	Conserving transboundary wildlife migrations: recent insights from the Greater Yellowstone Ecosystem	Wildlife migration, Transboundary conservation, Ecosystem connectivity	How can transboundary wildlife migrations be effectively conserved, and what role does landscape connectivity play in these efforts?	Integrating biodiversity into urban infrastructure planning, particularly energy infrastructure projects in urban areas	Migration corridors, Ecosystem fragmentation, Conservation strategies

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environmental impact AND electricity distribution	Wu, Y., Azmi, A., Ibrahim, R., Ghafar, A. A., & Salih, S. A. (2024)	Creating a sustainable urban ecosystem: the Azheke village model	Sustainable urban ecosystems, Ecological urbanism, Urban planning	How can urban ecosystems be made more sustainable and integrated with biodiversity conservation?	The role of supply chains and certification systems in reducing the negative environmental impacts of agriculture	Biodiversity integration, Urban sustainability, Green infrastructure
key biodiversity areas AND remote sensing	VanderWilde, C. P., Newell, J. P., Gounaridis, D., & Goldstein, B. P. (2023)	Deforestation, certification, and transnational palm oil supply chains: Linking Guatemala to global consumer markets	Deforestation, Palm oil supply chains, Certification systems, Sustainability	How does deforestation driven by palm oil production affect biodiversity in Guatemala, and how can certification systems help reduce these impacts?	Energy The environmental impacts of infrastructure on biodiversity, the impact of external factors (such as environmental conditions) on utility operations	Deforestation, Biodiversity loss, Sustainable certification systems
environmental impact AND electricity distribution	Leme, R. C., Paiva, A. P., Steele Santos, P. E., Balestrassi, P. P., & Galvão, L. de. (2014)	Design of experiments applied to environmental variables analysis in electricity utilities efficiency: The Brazilian case	Energy efficiency, Environmental variables, Electricity utilities	How do environmental variables influence the efficiency of electricity utilities in Brazil?	Integrating energy development with biodiversity conservation in energy infrastructure planning	Energy efficiency, Environmental impacts, Energy infrastructure
biodiversity conservation AND energy sector	Kiesecker, J. M., Baruch-Mordo, S., Baumgarten, L., Cameron, D. R., Cardenas Lopez, J. J., Crane, L., Evans, J. S., Fargione, J., & Naugle, D. E. (2017)	Energy Sprawl Solutions: Balancing Global Development and Conservation	Energy sprawl, Conservation, Sustainable development	How can global development and biodiversity conservation be balanced, particularly with respect to energy infrastructure?		Energy sprawl, Land use planning, Biodiversity loss
Biodiversity	Urbano, F., Viterbi, R., Pedrotti, L., Vettorazzo, E., Movalli, C., & Corlatti, L. (2023)	Enhancing biodiversity conservation and monitoring in protected areas through efficient data management	Biodiversity conservation, Data management, Protected areas, Monitoring systems	How can data management systems enhance biodiversity conservation efforts in protected areas, and what are the challenges in implementing these systems effectively?	The impacts of energy infrastructure on ecosystem health in protected areas, the role of data management systems in improving biodiversity monitoring	Data integration, Ecosystem health monitoring, Real-time data analysis
Species distribution modeling AND remote sensing	Shiklomanov, A. N., Bradley, B. A., Dahlin, K. M., M Fox, A., Gough, C. M., Hoffman, F. M., M Middleton, E., Serbin, S. P., Smallman, L., & Smith, W. K. (2019)	Enhancing global change experiments through integration of remote-sensing techniques	Global change, Remote sensing, Environmental monitoring, Climate change	How can remote sensing techniques improve the effectiveness of global change experiments, particularly in monitoring biodiversity and ecosystem changes?	How remote sensing can be used to assess the impacts of energy infrastructure and climate change on biodiversity and ecosystems	Biodiversity conservation, Climate change impacts, Ecosystem monitoring
Species distribution modeling AND remote sensing	Dickie, M., Serrouya, R., DeMars, C., Cranston, J., & Boutin, S. (2017)	Evaluating functional recovery of habitat for threatened woodland caribou	Wildlife conservation, Habitat recovery, Caribou, Ecosystem restoration	How does functional recovery of habitats contribute to the conservation of threatened woodland caribou, and what are the key factors influencing recovery success?	The importance of habitat restoration and wildlife protection that can inform strategies for biodiversity conservation in the context of energy infrastructure development	Caribou populations, Habitat recovery success, Land use impacts

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Ecological network AND grid infrastructure	Bussotti, F., Papitto, G., Di Martino, D., Cocciufa, C., Cindolo, C., Cenni, E., Bettini, D., Iacopetti, G., Ghelardini, L., Moricca, S., Panzavolta, T., Bracalini, M., & Pollastrini, M. (2024)	Extreme climatic events, biotic interactions and species-specific responses drive tree crown defoliation and mortality in Italian forests	Climate change, Forest ecosystems, Biodiversity conservation	How do extreme climatic events and biotic interactions affect tree health and mortality in Italian forests?	The impact of climate change and biotic factors on forests and biodiversity, the impact of energy infrastructure on ecosystems	Biodiversity conservation, Forest ecosystems, Climate impact on species
Biodiversity conservation AND Biodiversity areas	Yang, R., Dong, X., Xu, S., Wang, K., Li, X., Xiao, W., & Ye, Y. (2024)	Fragmentation of Key Biodiversity Areas highlights attention to human disturbance patterns	Human impact on biodiversity	How does human disturbance affect the fragmentation of Key Biodiversity Areas (KBAs)?	The impact of human activity (including energy infrastructure) on protected areas and biodiversity	Protected areas, Human impact, Biodiversity conservation
Biodiversity conservation AND Biodiversity areas	Miroshnyk, N. V., Likhanov, A. F., Grabovska, T. O., Teslenko, I. K., & Roubík, H. (2022)	Green infrastructure and relationship with urbanization – Importance and necessity of integrated governance	Urbanization, Green Infrastructure, Biodiversity conservation	How can green infrastructure be integrated into urban planning for biodiversity conservation?	Integrating biodiversity into energy infrastructure development	Urban sustainability, Green infrastructure, Biodiversity conservation
Biodiversity	Wierucka, K., Hatten, C. E., Murphy, D., Allcock, J. A., Andersson, A. A., Bojan, J. W., Kong, T. C., Kwok, J. K., Lam, J. Y., Ma, C. H., Phalke, S., Tilley, H. B., Wang, R. S., Wang, Y., Webster, S. J., Mumby, H. S., & Dingle, C. (2023)	Human-wildlife interactions in urban Asia	Human-wildlife conflicts, Urban ecology, Biodiversity conservation, Urban development	How do human-wildlife interactions in urban Asia affect biodiversity, and what are the primary challenges in managing these interactions?	The relationship between urbanization and biodiversity conservation, and how changes in energy infrastructure and land use can affect human-wildlife interactions	Human-wildlife interactions, Urban wildlife management, Biodiversity in cities
key biodiversity areas AND remote sensing	Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators	Conservation corridors, Remote sensing, Bioindicators, Biodiversity monitoring	How do managerial legacies within conservation corridors affect biodiversity and can grasshoppers be used as bioindicators of these effects?		Biodiversity conservation, Remote sensing applications, Bioindicators
Biodiversity conservation AND Biodiversity areas	Dong, X., Gong, J., Zhang, W., Zhang, S., Hu, Y., Yang, G., Yan, C., & Li, F. Y. (2024)	Importance of including Key Biodiversity Areas in China's conservation area-based network	Conservation policies, Biodiversity hotspots, Protected areas	What is the importance of Key Biodiversity Areas (KBAs) in China's conservation strategy?	Bioindicators and remote sensing methods for assessing the impact of land use and management practices on biodiversity, including how these methods can be used to assess the impacts of energy infrastructure on ecosystems.	Biodiversity conservation, Ecological networks, Sustainability
environmental impact AND electricity distribution	Ajayi, V., Anaya, K., & Pollitt, M. (2022)	Incentive regulation, productivity growth and environmental effects: the case of electricity networks in Great Britain	Energy regulation, Productivity growth, Environmental impact	How do incentive regulations affect the productivity of electricity networks in Great Britain, and what are the environmental effects?	The relationship between protected areas and energy infrastructure.	Regulatory frameworks, Energy efficiency, Environmental impacts

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environmental impact AND infrastructure AND biodiversity	Raza, A., Syed, N. R., Fahmeed, R., Acharki, S., Aljohani, T. H., Hussain, S., Zubair, M., Zahra, S. M., Islam, A. R., Almohamad, H., & Abdo, H. G. (2024)	Investigation of changes in land use: land cover using principal component analysis and supervised classification from OLI satellite data – a case study of underdeveloped regions, Pakistan	Land use change, Satellite imagery, Remote sensing, Biodiversity	How can satellite data and principal component analysis (PCA) be used to detect land use changes and land cover changes in underdeveloped regions like Pakistan?	The role of regulation in managing energy infrastructure and how such frameworks can minimize negative impacts on biodiversity.	Land use change, Biodiversity conservation, Remote sensing applications
environmental impact AND infrastructure AND biodiversity	Hoffman, K. N. (2023)	Justifying Nature-Based Solutions	Nature-based solutions, Environmental management, Biodiversity conservation	What is the role of nature-based solutions (NBS) in mitigating environmental challenges like climate change, biodiversity loss, and ecosystem degradation?	Remote sensing techniques for analyzing land use changes that can be implemented in the impact of energy infrastructure and biodiversity conservation.	Nature-based solutions, Ecosystem services, Biodiversity
environmental impact AND electricity distribution	Turconi, R., Simonsen, C. G., Byriel, I. P., & Astrup, T. (2013)	Life cycle assessment of the Danish electricity distribution network	Life cycle assessment (LCA), Energy infrastructure, Environmental impacts	What are the environmental impacts associated with the life cycle of the Danish electricity distribution network?	Integrating nature-based solutions into energy infrastructure planning.	Carbon footprint, Environmental impact, Energy efficiency
biodiversity conservation AND energy sector	Moreira, F. (2019)	Love me, love me not: Perceptions on the links between the energy sector and biodiversity conservation	Energy sector, Biodiversity conservation, Sustainable development, Stakeholder perceptions	How do stakeholders in the energy sector perceive the links between energy development and biodiversity conservation, and what are the barriers to better integration?	Using the LCA approach to assess the impact of energy systems on biodiversity.	Policy integration, Stakeholder perception, Economic incentives
Species distribution modeling AND remote sensing	Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	Mapping behavioral landscapes for animal movement: a finite mixture modeling approach	Animal movement, Behavioral landscapes, Ecology modeling, Biodiversity conservation	How can finite mixture modeling be used to map behavioral landscapes for animal movement, and what are the implications for biodiversity conservation?	The relationship between energy development and biodiversity conservation, and the obstacles to integrating energy infrastructure with biodiversity management.	Animal movement patterns, Behavioral landscapes, Ecological corridors, Habitat fragmentation
environmental impact AND infrastructure AND biodiversity	Cunha, J. S., Fonsêca, N. C., Vieira de Lima, C. R., Santos, J. G., Pereira, H. de, Bezerra, B. M., & Lins-e-Silva, A. C. (2024)	Minor loss or huge threat? Assessment of potential infrastructure projects reveals drastic landscape degradation in the Atlantic forest	Infrastructure development, Landscape degradation, Biodiversity conservation	How do infrastructure projects (such as roads, dams, and power lines) affect landscape degradation and biodiversity in the Atlantic Forest?	Mapping animal movement patterns that can be useful for assessing the impacts of energy infrastructure on wildlife and ecosystem connectivity.	Landscape degradation, Biodiversity loss, Infrastructure impacts
key biodiversity areas AND remote sensing	McCarthy, C., Banfill, J., & Hoshino, B. (2021)	National parks, protected areas and biodiversity conservation in North Korea: opportunities for international collaboration	Biodiversity conservation, Protected areas, International collaboration	How can international collaboration improve biodiversity conservation in North Korea's national parks and protected areas?	The impacts of energy infrastructure on natural ecosystems.	Protected areas, National parks, Conservation policy, International support
Biodiversity conservation AND Biodiversity areas	Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Nature-based climate solutions for expanding the global protected area network	Climate change, Nature-based solutions, Protected areas	How can nature-based solutions (NbS) help expand global protected areas to address climate change?	The role of cooperation and policy frameworks in biodiversity conservation.	Climate change mitigation, Biodiversity conservation, Protected area management

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key biodiversity areas AND remote sensing	Aticho, A., Beyene, A., Zelelew, S. A., Nigussie, A., Gutema, T. M., Bakkestuen, V., & Chala, D. (2023a)	Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma	Urbanization, Nature conservation, Sustainable development	What are the impacts of urbanization on nature conservation in fast-growing cities like Jimma, and how can urban planning integrate biodiversity conservation?	Using NbS to mitigate the impacts of energy infrastructure on biodiversity.	Urban expansion, Land use change, Biodiversity loss
GIS AND biodiversity	Gabi, A. U., & Abdullah, N. M. (2024)	Optimizing Biodiversity Conservation in Sundaland through Advanced Geospatial Techniques and Remote Sensing Technologies	Biodiversity conservation, Geospatial techniques, Remote sensing	How can advanced geospatial techniques and remote sensing technologies be used to improve biodiversity conservation efforts in Sundaland?	The importance of integrating nature conservation into urban planning, the role of energy infrastructure in the Environmental impacts on biodiversity	Biodiversity conservation, Ecosystem mapping, Habitat loss, Land use change
Biodiversity	Anderson, R. P., Araújo, M. B., Guisan, A., Lobo, J. M., Martínez-Meyer, E., Peterson, A. T., & Soberón, J. M. (2020)	Optimizing biodiversity informatics to improve information flow, data quality, and utility for science and society	Biodiversity informatics, Data management, Information flow, Data quality, Conservation technology	How can biodiversity informatics be optimized to improve data flow, data quality, and utility for both scientific research and conservation practices?	Assessing the impact of changes in energy infrastructure and land use on biodiversity conservation using remote sensing	Data accessibility, Data integration, Standardization
Species distribution modeling AND remote sensing	Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	Patterns of diversity along a habitat size gradient in a biodiversity hotspot	Biodiversity patterns, Habitat size, Conservation hotspots	How does habitat size affect species diversity in a biodiversity hotspot, and what implications does this have for conservation strategies?	The importance of data management systems for biodiversity, integrating energy infrastructure with biodiversity conservation efforts through optimized data systems	Biodiversity hotspots, Fragmentation, Conservation strategies
Species distribution modeling AND remote sensing	Benson, B. J., Bond, B. J., Hamilton, M. P., Monson, R. K., & Han, R. (2009)	Perspectives on next-generation technology for environmental sensor networks	Environmental monitoring, Sensor technology, Data networks, Biodiversity conservation	How can next-generation sensor technologies improve the efficiency and accuracy of environmental monitoring, especially in relation to biodiversity conservation?	The importance of habitat size and fragmentation in biodiversity conservation	Real-time monitoring, IoT sensors, Biodiversity data
energy transition AND biodiversity	Ellwanger, J. H., Fearnside, P. M., Ziliotto, M., & Chies, J. A. (2024)	Pollution-Related Biodiversity Loss in Brazil: More Actions Required	Pollution, Biodiversity loss, Environmental policy	How does pollution contribute to biodiversity loss in Brazil, and what actions can be taken to mitigate this issue?	The role of sensor networks and remote sensing technologies in improving biodiversity monitoring, and how these technologies can be integrated into energy infrastructure planning to minimize impacts on ecosystems	Pollution, Biodiversity conservation, Ecosystem restoration
Biodiversity conservation AND Biodiversity areas	Kraus, D., Enns, A., Hebb, A., Murphy, S., Drake, D. A., & Bennett, B. (2022)	Prioritizing nationally endemic species for conservation	Endemic species, Conservation priorities, Species distribution	How should endemic species be prioritized for conservation in relation to other species?	How pollution affects biodiversity, and how these impacts can be mitigated when considering the impacts of energy infrastructure	Endemic species, Conservation priorities, Habitat protection

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environmental impact AND infrastructure AND biodiversity	Katovich, E. (2023)	Quantifying the Effects of Energy Infrastructure on Bird Populations and Biodiversity	Energy infrastructure, Bird populations, Biodiversity conservation, Environmental impact	How does energy infrastructure (e.g., power lines, wind turbines, power plants) affect bird populations and overall biodiversity?	Species prioritization, particularly because energy infrastructure impacts endemic species	Bird mortality, Habitat fragmentation, Energy infrastructure impacts
Biodiversity	Ball-Damerow, J. E., Brenskelle, L., Barve, N., Soltis, P. S., Sierwald, P., Bieler, R., LaFrance, R., Ariño, A. H., & Guralnick, R. (2019)	Research applications of primary biodiversity databases in the digital age	Biodiversity data management, Primary biodiversity databases, Data sharing, Digital tools in conservation	What are the applications of primary biodiversity databases in the digital age, and how can they support biodiversity conservation and research?	The impact of energy infrastructure on biodiversity, and how biodiversity conservation can be integrated into energy planning	Data interoperability, Data standardization, Global collaboration
environmental impact AND electricity distribution	Soares, N., Martins, A. G., Carvalho, A. L., Caldeira, C., Du, C., Castanheira, Rodrigues, E., Oliveira, G., Pereira, G. I., Bastos, J., Ferreira, J. P., Ribeiro, L. A., Figueiredo, N. C., Šahović, N., Miguel, P., & Garcia, R. (2018)	The challenging paradigm of interrelated energy systems towards a more sustainable future	Energy systems integration, Sustainability, Energy transition	How can interrelated energy systems be integrated to create more sustainable and efficient energy networks while minimizing negative environmental impacts?	The role of data systems in biodiversity conservation, and the importance of standardization and data sharing as a basis for assessing the environmental impacts of energy infrastructure	Energy transition, Sustainability, Environmental impacts, Biodiversity conservation
Biodiversity conservation AND Biodiversity areas	Peck, M. R., Desselas, M., Bonilla-Bedoya, S., Redín, G., & Durango-Cordero, J. (2024)	The conflict between Rights of Nature and mining in Ecuador: Implications of the Los Cedros Cloud Forest case for biodiversity conservation	The role of legal frameworks (e.g., Rights of Nature) in protecting biodiversity against mining.	How do legal frameworks like the Rights of Nature conflict with mining practices in terms of biodiversity protection?	The integration of energy systems to minimize environmental impacts when planning for energy infrastructure and biodiversity conservation	Biodiversity conservation, Legal frameworks, Environmental degradation, Mining impacts
biodiversity AND power lines AND electricity	Farias, A. T., Hamilton, S. E., Pires, L. B., Canale, G. R., Santos, R. R., & Presotto, A. (2024)	The Impact of Land Conversion on Primate Habitats: Refining the Extent of Occurrence Data	Land conversion, Primate habitats, Species distribution	How does land conversion affect primate habitats and the accuracy of species distribution data?	Legal frameworks to protect biodiversity How accurate species occurrence data can be used to assess the impacts of energy projects on biodiversity	Habitat loss, Primate conservation, Species modeling
Species distribution modeling AND remote sensing	Crowl, T. A., Crist, T. O., Parmenter, R. R., Belovsky, G., & Lugo, A. E. (2008)	The spread of invasive species and infectious disease as drivers of ecosystem change	Invasive species, Ecosystem change, Biodiversity loss, Infectious disease	How do invasive species and infectious diseases act as drivers of ecosystem change, and what are the consequences for biodiversity conservation?	The role of invasive species and diseases in ecosystem degradation, a key factor in assessing the impact of energy infrastructure on biodiversity and ecosystem stability	Ecosystem disruption, Biodiversity decline, Invasive species impact
Species distribution modeling AND remote sensing	Huston, M. A. (2005)	The three phases of land-use change: Implications for biodiversity	Land-use change, Biodiversity loss, Ecosystem degradation	How do the three phases of land-use change (conversion, consolidation, and abandonment) affect biodiversity? What are the long-term impacts of these phases on species richness and ecosystem function?	The impact of land-use change on biodiversity, which can be directly applied to assessing how energy infrastructure and land development affect ecosystems and species conservation	Habitat fragmentation, Biodiversity loss, Ecosystem resilience

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Biodiversity	Enke, N., Thessen, A., Bach, K., Bendix, J., Seeger, B., & Gemeinholzer, B. (2012)	The user's view on biodiversity data sharing: Investigating facts of acceptance and requirements to realize a sustainable use of research data	Biodiversity data sharing, Research data management, Sustainable use of data, Data interoperability	What are the user views on biodiversity data sharing, and what are the requirements to ensure the sustainable use of research data?	The need for effective data systems to support biodiversity monitoring, which can be applied to energy infrastructure planning to minimize environmental impacts on ecosystems and species	Data standardization, Open data platforms, Data privacy concerns
biodiversity AND power lines AND electricity	Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	The value of open power line habitat in conservation of ground beetles associated with mires	Power line corridors, Conservation, Ground beetles, Mires	How do open power line corridors impact the conservation of ground beetles in mires?	The role of energy infrastructure (e.g., power lines) in habitat conservation and biodiversity conservation, particularly in fragmented landscapes	Biodiversity conservation, Energy infrastructure, Habitat value
biodiversity conservation AND urban infrastructure	Syaban, A. S., & Appiah-Opoku, S. (2024)	Unveiling the Complexities of Land Use Transition in Indonesia's New Capital City IKN Nusantara: A Multidimensional Conflict Analysis	Land use transition, Urban development, Sustainability	What are the impacts of land use transitions in Indonesia's new capital on biodiversity and sustainable development?	The impact of land-use change on biodiversity conservation, particularly in the context of urban development and potential energy infrastructure projects	Urban sustainability, Biodiversity conservation, Ecosystem services
GIS AND biodiversity	Kalfas, D., Kalogiannidis, S., Chatzitheodoridis, F., & Toska, E. (2023)	Urbanization and Land Use Planning for Achieving the Sustainable Development Goals (SDGs): A Case Study of Greece	Urbanization, Land use planning, Sustainable Development Goals (SDGs)	How can urbanization and land use planning contribute to achieving the Sustainable Development Goals (SDGs), with a specific focus on biodiversity conservation?	How land-use planning and urban development can be aligned with biodiversity conservation, particularly considering the impact of energy infrastructure on biodiversity	Sustainable development, Urbanization impacts, Biodiversity conservation, Land use policies
Species distribution modeling AND remote sensing	Lorang, M. S., Whited, D. C., Hauer, F. R., Kimball, J. S., & Stanford, J. A. (2005)	Using airborne multispectral imagery to evaluate geomorphic work across floodplains of gravel-bed rivers	Geomorphology, Floodplains, Remote sensing, Ecosystem dynamics	How can airborne multispectral imagery be used to assess the geomorphic processes and ecosystem dynamics in gravel-bed rivers, and how do these processes impact biodiversity in floodplain environments?	The impact of remote sensing on the impact of land-use and energy infrastructure on ecosystem dynamics and biodiversity impacts	Floodplain dynamics, Sediment transport, River ecosystems, Biodiversity impacts
biodiversity conservation AND urban infrastructure	Burgin, S. (2016)	What about biodiversity? Redefining urban sustainable management to incorporate endemic fauna with particular reference to Australia	Urban sustainability, Endemic species, Biodiversity conservation	How can endemic fauna be incorporated into urban sustainability models to improve biodiversity conservation?	energy infrastructure and how it interacts with biodiversity in urban environments	Biodiversity conservation, Urban sustainability, Endemic species management

C. Challenges Mentioned in Literature

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Gallo, M., Moreschi, L., & Del Borghi, A. (2022)	A Critical Environmental Analysis of Strategic Materials Towards Energy Transition	The extraction, refining, and production processes of strategic raw materials for the energy transition lead to environmental impacts such as habitat destruction, biodiversity loss, and forest destruction.	Inadequate recycled material rates
		The use of metals with high environmental risks (e.g., platinum, iridium, indium, dysprosium) in areas directly dependent on nature causes conflicts between sustainable energy infrastructures and biodiversity.	High-risk material use
		Insufficient recycled material rates in LCA (Life Cycle Assessment) analyses make it difficult to reduce the environmental impacts of these materials.	Deforestation
Tomsana, A., Itoba-Tombo, E. F., & Human, I. S. (2020)	An Analysis of Environmental Obligations and Liabilities of an Electricity Distribution Company to Improve Sustainable Development	Bird strikes and electrocutions, in particular, result in the deaths of protected bird species and create serious environmental liabilities for companies.	Animal deaths from electrocution
		Animal deaths (e.g., giraffes, wild animals) increase due to the lack of insulation of conductors or inadequate infrastructure, leading to biodiversity loss.	Under-reporting of environmental events
		Velvet fires cause the collapse of power poles and have irreversible effects on both flora and fauna.	Lack of awareness of company employees regarding their environmental responsibilities
		Underreporting of environmental incidents and company employees' inadequate knowledge of their environmental responsibilities threaten sustainable development goals.	Differences between local and national legislation
		Differences between local and national legislation complicate responsibilities.	Regulations fail to consider regional differences
Gilad, D., May, R., Stokke, B. G., & Verones, F. (2024)	Between the Lines: Life Cycle Impact Assessment Models of Collision and Electrocution Impacts of Power Lines on Bird Diversity in Norway	Bird strikes and electrocutions from power lines pose serious threats to bird diversity in Norway. These strikes are particularly prevalent at night and during foggy weather, with topography and line visibility playing a critical role.	Bird deaths from electrocution
		Complex species behavior and migration routes increase the difficulty of environmental impact analyses.	Difficulty of environmental impact analyses due to complex species behavior and migration routes
		It has been noted that existing life cycle assessment models underrepresent bird mortality and therefore offer limited contribution to policy-making.	Data insufficiency for life-cycle assessment models
		Uncertainty in ecological impact modeling complicates the assessment of biodiversity risks.	

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Guil, F., & Pérez-García, J. M. (2022)	Bird electrocution on power lines: Spatial gaps and identification of driving factors at global scales	Bird mortality from power lines poses a serious threat, particularly to endangered birds of prey and eagles.	Animal deaths from electrocution
		Spatial imbalance of research: While most studies have been conducted in developed countries (especially Europe and North America), systematic data is lacking in regions such as South America, Africa, and Oceania.	Research conducted primarily in developed countries such as Europe and North America
		Overlooking pole design factors: Contrary to expectations, technical features such as pole design have little impact on overall mortality rates, complicating the process of developing preventative designs.	Pole designs lack collision-prevention technical features
		Unstandardized data collection methods: The lack of standard protocols for data collection on bird mortality makes global comparisons and the identification of risk areas difficult.	Unstandardized data collection methods
		The impact of socioeconomic and climatic variables: The expansion of energy infrastructure, particularly in developing countries, is leading to the emergence of new mortality in high-risk areas.	Expansion of energy infrastructure in developing countries
		Inadequate regional migratory bird protection measures: Measures taken solely in a specific region to protect migratory species are ineffective, raising the issue of a lack of international cooperation.	Measures taken for migratory species are taken locally
Leme, R. C., Paiva, A. P., Steele Santos, P. E., Balestrassi, P. P., & Galvão, L. de. (2014)	Design of experiments applied to environmental variables analysis in electricity utilities efficiency: The Brazilian case	Environmental variables (e.g., weather, population density, wage differentials) have a direct impact on the efficiency of energy infrastructure. While these factors do not directly affect biodiversity, they can have indirect environmental consequences by influencing infrastructure decisions.	
		In large and heterogeneous countries like Brazil, modeling the impact of environmental variables to increase infrastructure efficiency becomes difficult, which can lead to the failure to develop well-positioned, environmentally sound plans.	Modeling difficulties due to the large and heterogeneous nature of biodiversity data
		Model errors in data analysis can mislead biodiversity conservation strategies.	Model errors in data analysis
		Regulations that fail to consider regional differences make it difficult to take action against infrastructure investments that threaten biodiversity.	Regulations fail to consider regional differences

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Ajayi, V., Anaya, K., & Pollitt, M. (2022)	Incentive regulation, productivity growth and environmental effects: the case of electricity networks in Great Britain	Incentive mechanisms focused on efficiency improvements that are not sufficiently integrated with environmental objectives can subordinate the environmental sustainability of energy infrastructure.	Incentive mechanisms focused on efficiency improvements are not sufficiently integrated with environmental objectives
		If emissions reduction targets (especially carbon and SF6) are overlooked in cost-benefit analyses of grid investments, environmentally detrimental decisions can be made.	Emission reduction targets overlooked in cost-benefit analyses of grid investments Impact
		Focusing solely on cost reduction may not encourage investments aimed at protecting biodiversity.	
		Failure to include quality and environmental impacts in efficiency criteria leads to the marginalization of environmentally friendly solutions in planning processes.	Failure to include quality and environmental impacts in efficiency criteria
Turconi, R., Simonsen, C. G., Byriel, I. P., & Astrup, T. (2013)	Life cycle assessment of the Danish electricity distribution network	The environmental impacts of electricity distribution infrastructure are often neglected in LCA analyses, while the infrastructure itself (especially cables, poles, and transformer substations) has a significant environmental footprint.	Failure to include electricity distribution infrastructure in LCA analyses
		Underground cables have a higher environmental impact than overhead cables, and this impact is particularly exacerbated when not recycled.	
		The materials used in infrastructure (copper, aluminum) contribute to environmental impacts such as metal depletion and freshwater eutrophication.	Materials used in infrastructure
		These impacts are projected to increase in the future because the transition to renewable energy and distributed generation systems increases the need for electricity distribution infrastructure, meaning that more natural areas will be converted into infrastructure.	Increased need for electricity distribution infrastructure
		Electricity losses are a significant source of environmental impact at both the transmission and distribution levels.	Electricity losses

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Soares, N., Martins, A. G., Carvalho, A. L., Caldeira, C., Du, C., Castanheira, Rodrigues, E., Oliveira, G., Pereira, G. I., Bastos, J., Ferreira, J. P., Ribeiro, L. A., Figueiredo, N. C., Šahović, N., Miguel, P., & Garcia, R. (2018)	The challenging paradigm of interrelated energy systems towards a more sustainable future	Distribution system operators (DSOs) have limited capacity to adapt to new technologies, which can lead to a failure to integrate renewables and undermine environmental sustainability goals.	Limited capacity of distribution companies to adapt to new technologies
		The traditional structure of energy distribution infrastructure is incompatible with distributed generation, electric vehicles, and energy storage systems, which can lead to natural areas being overwhelmed by the increasing demands on energy infrastructure.	Pressure on natural areas due to increasing energy infrastructure demands
		Lack of data management and transparency prevents the analysis necessary for system resilience and biodiversity conservation.	Inability to perform analyses necessary for system flexibility and biodiversity protection due to lack of data management and transparency
		Administrative, technological, and organizational transformation requirements make it difficult for distribution companies to develop environmentally friendly strategies.	Difficulty for distribution companies to develop environmentally friendly strategies due to administrative, technological, and organizational transformation requirements
		There is a conflict between sustainability goals and economic pressures. This conflict can lead to environmental priorities being overlooked.	Conflict between sustainability goals and economic pressures
Raza, A., Syed, N. R., Fahmeed, R., Acharki, S., Aljohani, T. H., Hussain, S., Zubair, M., Zahra, S. M., Islam, A. R., Almohamad, H., & Abdo, H. G. (2024)	Investigation of changes in land use: land cover using principal component analysis and supervised classification from operational land imager satellite data – a case study of underdeveloped regions, Pakistan	Urbanization and agricultural expansion lead to the loss of natural areas and the decline of biodiversity.	Destruction of natural areas due to urbanization and agricultural development
		Depletion of water resources and extreme events (floods, heat waves) related to climate change threaten ecosystems in areas where energy production and infrastructure are located.	
		Biodiversity loss increases with land cover changes; Natural habitats are being replaced by agricultural or residential areas.	Loss of biodiversity due to land cover change
		Political conflicts and unplanned land use complicate sustainable planning, reducing the effectiveness of conservation strategies.	Reduced effectiveness of conservation strategies due to unplanned land use
		Lack of data, especially in rural and underdeveloped areas, makes monitoring ecosystem changes difficult and hinders the planning of appropriate interventions.	Difficulty in assessing ecosystem changes and accurate intervention planning due to lack of data

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Hoffman, K. N. (2023)	Justifying nature-based solutions	Although nature-based solutions (NbS) are presented as biodiversity-friendly, it has been noted that some artificial analogues (e.g., concrete infrastructures) offer functionally similar contributions and therefore may not always be ecologically superior.	
		The impact of green-blue infrastructures varies depending on the local context; their contribution to biodiversity is often hypothetical and may not always provide measurable benefits.	The impact of green-blue infrastructures remains hypothetical due to the lack of concrete metrics
		Justifications based on aesthetic contribution may fall short of measurable protection of ecological integrity.	
		Policymakers' preference for NbS may remain symbolic in the absence of concrete criteria, and infrastructure projects may be justified by "visual naturalness" rather than biodiversity.	
Cunha, J. S., Fonsêca, N. C., Vieira de Lima, C. R., Santos, J. G., Pereira, H. de, Bezerra, B. M., & Lins-e-Silva, A. C. (2024)	Minor loss or huge threat? Assessment of potential infrastructure projects reveals drastic landscape degradation in the Atlantic forest	Urbanization and transportation projects lead to fragmentation and biodiversity loss in protected forest areas.	Destruction of protected areas due to urbanization and transportation projects
		The implementation of planned projects (e.g., the Metropolitan Road Belt, the Military Training School) reduces habitat connectivity by 51% and significantly degrades forest quality.	Degradation of biodiversity due to fragmentation of forests The isolation of their populations and the risk of extinction.
		Forest fragmentation hinders the mobility of species within forests, such as birds, leading to the isolation of populations and the risk of extinction.	The long time it takes for degraded habitats to recover.
		Compensation strategies (e.g., reforestation) are not sufficiently effective; degraded habitats can take decades to recover.	Inadequate environmental impact assessments.
		Environmental impact assessments are inadequate, and scientific findings are not considered in decision-making processes.	
Katovich, E. (2023)	Quantifying the Effects of Energy Infrastructure on Bird Populations and Biodiversity	The impact of energy infrastructure on birds is significant: Habitat loss, noise pollution, light pollution, and magnetic field changes negatively affect birds' navigation, migration, and breeding.	The impact of habitat loss, noise pollution, light pollution, and magnetic field changes on birds.
		Noise and light pollution disrupt the behavioral and physiological adaptation of bird species, reducing species diversity and threatening local populations.	The difficulty of modeling complex interactions.
		Traditional environmental impact analyses do not fully reflect these impacts; This leads to the systematic underestimation of biodiversity impacts in infrastructure decisions.	The systematic neglect of biodiversity impacts in infrastructure decisions due to the use of traditional environmental impact analyses.
		Modeling complex interactions (e.g., the combined impact of roads and power lines) is difficult, leading to inadequate multifactorial planning.	

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Syaban, A. S., & Appiah-Opoku, S. (2024)	Unveiling the Complexities of Land Use Transition in Indonesia's New Capital City IKN Nusantara	The rapid transformation of natural habitats and forests is causing biodiversity loss.	The destruction of natural areas by urbanization processes.
		Planned urbanization processes threaten local people's livelihoods, cultural ties, and ecosystem services.	Multidimensional conflicts: Serious social, economic, and environmental conflicts regarding land allocation, resource use, and environmental degradation.
		Multidimensional conflicts: Serious social, economic, and environmental conflicts arise over land allocation, resource use, and environmental degradation.	Lack of inclusive governance due to lack of community involvement
		Lack of inclusive governance, lack of community involvement, and unequal distribution of benefits lead to social unrest.	
		Pressure on protected areas results in forest fragmentation and species displacement.	
Burgin, S. (2016)	What about biodiversity? Redefining urban sustainable management to incorporate endemic fauna with particular reference to Australia	Neglecting biodiversity planning in cities leads to the loss of endemic species (e.g., small bird species), in particular.	Loss of endemic species due to neglected biodiversity planning
		The unplanned and aesthetically motivated use of green infrastructure disrupts natural population balances, leading to biotic homogenization.	Neglect of ecological services due to aesthetic approaches
		Overpopulating species (e.g., parrots) reduce the habitats of endemic and less competitive species, reducing biodiversity.	Biotic homogenization due to aesthetically focused green infrastructure
		Increasing alien species invasion with urbanization complicates the ecological adaptation of native species and threatens species diversity.	Disruption of the ecological harmony of native species due to the invasion of alien species
		Considering biodiversity solely through aesthetic value in sustainable urban planning overlooks functional ecological services.	Reduction of habitats of endemic species due to overpopulation
Sokół, M., & Łaska, G. (2024)	Biodiversity and ecosystem services: Complementary approach for catchment protection and land use in northeastern Poland	Increasing land use density in urban areas leads to a combined decline in biodiversity and ecosystem services.	Decrease in biodiversity and ecosystem services due to increased land use intensity
		While nearby urban centers have lower biodiversity due to higher construction density, the edge areas of river valleys hold higher conservation potential.	Low biodiversity due to dense urban development
		When biodiversity is evaluated solely through the services provided (e.g., food production), regulatory and cultural ecosystem services are overlooked, leading to the weakening of holistic conservation strategies.	Failure to integrate nature conservation and infrastructure planning due to lack of data-based multi-criteria analysis
		The failure to integrate protected areas into spatial planning complicates optimal land-use decisions.	Undermining optimal land use due to the lack of integration of protected areas into spatial planning
		The lack of data-based multi-criteria analysis hinders the integration of nature conservation and infrastructure planning processes.	High conservation potential in the edge regions of river valleys
			Neglect of regulatory and cultural services due to a focus solely on provided services

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He, X., & Wei, H. (2023)	Biodiversity conservation and ecological value of protected areas: A review of current situation and future prospects	The limited area coverage and uneven spatial distribution of protected areas hinder the effective conservation of biodiversity.	Ineffective biodiversity protection due to the limited coverage and uneven distribution of protected areas
		Climate change and anthropogenic pressures are causing species within protected areas to abandon their habitats.	Weakening of conservation policies due to insufficient efforts to economize natural values
		Due to what is known as the "leakage effect," human activities around protected areas are increasing, reducing the effectiveness of conservation.	Climate change and human Species abandon their habitats due to pressure from mining, tourism, and infrastructure
		Pressure from mining, tourism, and infrastructure activities in protected areas exacerbates threats to biodiversity.	Increased threats to biodiversity in protected areas due to mining, tourism, and infrastructure
		The limited efforts to economize on natural values weakens conservation policies.	Increased human activities around protected areas due to seepage
Aska, B., Franks, D. M., Stringer, M., & Sonter, L. J. (2023)	Biodiversity conservation threatened by global mining wastes	The overlap of mining waste (especially tailings dams) with protected areas, KBAs, and pristine ecosystems directly causes habitat loss and pollution.	Habitat loss and pollution due to mining tailings overlapping protected areas and intact ecosystems
		Tailings dam structures have a high risk of failure, which can lead to biodiversity loss across hundreds of kilometers.	Increased biodiversity threat due to the increase in mining facilities in developing countries due to weak governance
		Most tailings dams are classified as “low risk” by methods that do not assess environmental impacts, thus ignoring real threats to nature.	Large-scale biodiversity loss due to the high risk of tailings dam failure
		Insufficient transparency and lack of standardization hinder the assessment of the environmental impacts of these infrastructures.	Impaired assessment of environmental impacts due to lack of transparency and standardization
		The proliferation of these facilities in developing countries poses a greater threat to biodiversity due to weak governance structures.	Underestimated threats due to low-risk classifications without environmental impact assessment
Appelt, J. L., Saphangthong, T., Malek, Ž., Verburg, P. H., & van Vliet, J. (2023)	Climate change impacts on tree crop suitability in Southeast Asia	The displacement of agricultural lands due to climate change puts pressure on areas with high biodiversity (e.g., KBAs).	Pressure on areas with high biodiversity due to the displacement of agricultural land
		Rainfall and temperature changes reduce the suitability of existing agricultural lands and create the need to open new areas for agriculture.	Increased pressure around protected areas due to the spread of commercial crops (e.g., palm oil, rubber)
		The loss of livelihoods for smallholder farmers can increase land pressure in biodiversity-rich areas.	Reduced suitability of existing agricultural land due to changes in rainfall and temperature
		New agricultural lands are often located in forest areas, resulting in habitat loss and species displacement.	Habitat loss and species displacement due to the opening of new agricultural lands in forested areas
		The commercial expansion of crops such as palm oil and rubber directly puts pressure on the periphery of protected areas.	Increased land pressure on valuable ecosystem areas due to smallholder farmers experiencing livelihood losses

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Yang, R., Dong, X., Xu, S., Wang, K., Li, X., Xiao, W., & Ye, Y. (2024)	Fragmentation of Key Biodiversity Areas highlights attention to human disturbance patterns	62% of KBAs worldwide are classified as human-threatened areas, indicating intense human impact on these habitats.	The development of KBAs Intense habitat degradation due to 62% of KBAs being classified as human-threatened areas
		57% of KBAs are fragmented and fragmented, reducing habitat connectivity and complicating species transition.	Inability to develop effective conservation strategies due to failure to consider spatial degradation patterns
		Agricultural and urban development activities cause habitat degradation in one-quarter of terrestrial KBAs.	Decreased habitat connectivity and species migrations due to the fragmentation of 57% of KBAs
		The increase in the number of protected areas does not reduce human impact (Human Footprint Index) on KBAs, highlighting the inadequacy of conservation systems.	Inadequate protection systems due to the continued decline of human impacts on KBAs despite the increase in the number of protected areas
		Because spatial patterns of degradation are not considered in conservation plans, effective intervention and prioritization strategies cannot be developed.	Habitat degradation in one-quarter of terrestrial KBAs due to agriculture and urban development
Miroshnyk, N. V., Likhanov, A. F., Grabovska, T. O., Teslenko, I. K., & Roubík, H. (2022)	Green infrastructure and relationship with urbanization – Importance and necessity of integrated governance	Rapid urbanization reduces the area, structure, and quality of green infrastructure that provides ecosystem services.	Reduction in the area, structure, and quality of green infrastructure due to rapid urbanization
		Anthropogenic pressure on park ecosystems weakens species diversity, canopy density, and habitat integrity.	Increasing threats to endemic species due to invasive species and urban degradation
		The lack of governance to protect and maintain the functions of green spaces in urban ecosystems creates policy gaps that threaten biodiversity.	Weakening species diversity and habitat integrity in park ecosystems due to anthropogenic pressure
		Difficulty in data collection prevents decision-makers from accessing reliable information about the status of green infrastructure.	Difficulties in data collection make decision-makers unable to access reliable information about green infrastructure
		Widespread invasive species and urbanization-related degradation pose a serious threat to endemic species.	Political gaps in green space conservation due to lack of governance
Dong, X., Gong, J., Zhang, W., Zhang, S., Hu, Y., Yang, G., Yan, C., & Li, F. Y. (2024)	Importance of including Key Biodiversity Areas in China's conservation area-based network	The current conservation network in China does not adequately cover KBAs, reducing the representativeness of biodiversity.	Reduced biodiversity representation due to the inadequacy of the existing protection network in KBAs
		The risks of population density, land conversion, and climate change are quite high in areas designated for conservation area expansion.	Social unsustainability of conservation goals due to lack of local community participation
		Focusing solely on quantitative targets in conservation area selection can compromise effectiveness.	High population density in designated protected areas, land conversion, and climate change Risk
		Climate change-induced ecosystem and species distribution changes can render existing conservation boundaries dysfunctional.	Changes in ecosystem and species distribution due to climate change render conservation boundaries dysfunctional
		Inadequate participation of local communities can lead to the social unsustainability of conservation targets.	Reduced effectiveness due to a focus on quantitative targets in protected area selection

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Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Nature-based climate solutions for expanding the global protected area network	A lack of resources for the expansion of protected areas hinders the implementation of effective conservation plans in many countries.	Inability to expand protected areas in many countries due to a lack of resources
		Financial resources such as voluntary carbon markets are underutilized, and opportunities for nature-based solutions are being missed.	Hindering species migrations and adaptation to climate change due to a lack of connectivity and functionality in protected areas
		The fact that carbon credits do not always directly protect biodiversity can lead to biodiversity loss in carbon-focused projects.	Missed opportunities for nature-based solutions due to inadequate use of voluntary carbon markets
		Only 33% of protected areas are protected outside the existing protection network, and strategic planning to increase this rate is lacking.	Lack of strategic planning, as only 33% of KBAs can be protected outside the current conservation network
		The low connectivity and functionality of protected areas poses obstacles to species migration and adaptation to climate change.	Biodiversity losses in carbon-focused projects, as carbon credits do not directly protect biodiversity
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma	Rapid urbanization threatens natural habitats, and forests, grasslands, and wetlands are rapidly declining.	Rapid depletion of natural habitats (forests, grasslands, wetlands) due to rapid urbanization
		Unplanned urban growth complicates the implementation of conservation strategies; ecosystems are particularly damaged by rural-urban migration and population pressure.	Inadequate integration of biodiversity priority areas into urban plans
		According to long-term projections, forests are expected to decline by 42%, wetlands by 40%, and open water areas by 81% within 50 years.	Difficulty implementing conservation strategies due to unplanned urban growth
		Urbanization without adequate data and planning leads to the loss of priority areas for biodiversity.	Loss of biodiversity priority areas due to a lack of data and planning
		Despite the identification of priority biodiversity areas, their integration into urban plans remains inadequate.	Damage to ecosystems due to rural-urban migration and population pressure
			Long-term projections predict a significant decline in forest, wetland, and water areas.
Kraus, D., Enns, A., Hebb, A., Murphy, S., Drake, D. A., & Bennett, B. (2022)	Prioritizing nationally endemic species for conservation	Because spatial monitoring of endemic species at the national level is difficult, species at risk due to pressures such as energy infrastructure cannot be identified.	The difficulty of spatially monitoring endemic species, coupled with pressures on energy infrastructure, leads to the inability to identify species at risk.
		Because conservation strategies are often based on international prioritization lists, local endemic species can be overlooked.	The risk that existing protected areas will be unable to protect endemic species in the future due to habitat shifts related to climate change.
		The habitats of endemic species are often not considered in the site selection processes for energy projects.	The neglect of local endemic species due to the reliance on international prioritization of conservation strategies.
		Lack of data and low conservation capacity leave the habitats of endemic species at risk in many countries.	The endemic species' habitats remain at risk due to a lack of data and low conservation capacity.
		Habitat shifts due to climate change indicate that existing protected areas will not be able to protect endemic species in the future.	The failure to consider the habitats of endemic species in the location selection of energy projects.

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Peck, M. R., Desselas, M., Bonilla-Bedoya, S., Redín, G., & Durango-Cordero, J. (2024)	The conflict between Rights of Nature and mining in Ecuador: Implications of the Los Cedros Cloud Forest case for biodiversity conservation	Conflicts between nature rights and economic activities (e.g., mining) threaten ecosystem integrity.	Ecosystem integrity is threatened due to conflicts between nature rights and economic activities.
		Even in legally protected areas, mining permits are issued, causing habitat destruction in areas of high biodiversity value.	Conservation efforts are hampered by the tension between nature rights and economic growth targets.
		Legislative gaps and conflicts of interest lead to the implementation of projects that harm nature within protected areas.	Habitat destruction in biodiversity-valued areas due to the issuance of mining licenses in legally protected areas.
		Even when judicial decisions favor conservation, there are serious shortcomings in their implementation.	Ineffective protection decisions due to deficiencies in the implementation of judicial decisions.
		The tension between the legal definition of nature's rights and economic growth objectives hinders conservation efforts.	The implementation of environmentally damaging projects in protected areas due to legislative gaps and conflicts of interest.
Kiesecker, J. M., Baruch-Mordo, S., Baumgarten, L., Cameron, D. R., Cardenas Lopez, J. J., Crane, L., Evans, J. S., Fargione, J., & Naugle, D. E. (2017)	Energy Sprawl Solutions: Balancing Global Development and Conservation	Even renewable energy projects occupy large areas, creating habitat fragmentation and land-use pressures.	Habitat fragmentation and land use disruption due to the large footprint of renewable energy projects. Pressure
		Transmission lines and energy infrastructure fragment habitats, disrupt migration routes, and facilitate the spread of invasive species.	A lack of data-based spatial planning hinders environmentally friendly energy planning.
		Energy projects are rapidly expanding in protected areas in developing countries, but legal protections are often inadequate.	Transmission lines and energy infrastructure fragment habitats, disrupt migration routes, and facilitate the spread of invasive species.
		Current environmental impact assessment systems are often narrow-scale and sectoral, ignoring cumulative impacts.	Biodiversity compensation mechanisms are ineffective and used as public relations tools.
		Biodiversity offset mechanisms are not always effective and are often viewed as mere public relations tools.	Insufficient legal protection due to the increasing number of energy projects in protected areas in developing countries.
		The lack of data-based spatial planning poses a major obstacle to environmentally friendly energy planning.	Cumulative impacts are overlooked due to the narrow-scale and sectoral nature of environmental impact assessment systems.
Moreira, F. (2019)	Love me, love me not: Perceptions on the links between the energy sector and biodiversity conservation	There is a lack of compatibility between the energy sector and nature conservation policies (e.g., Natura 2000, EU Nature Directives).	Incompatibility between the energy sector and nature conservation policies.
		Energy sector stakeholders perceive conservation policies as costly and complex, making collaboration difficult.	Protected areas are not protected against energy projects due to the lack of integration between energy and conservation policies.
		Lack of scientific knowledge and limited implementation capacity are significant problems in impact assessment.	Cooperation with energy sector stakeholders is difficult due to the perceived cost and complexity of conservation policies.
		The uncertainty of impact assessment and compensation processes can lead to the systematic underestimation of environmental impacts in energy investments.	Environmental impacts are overlooked due to uncertainty in impact assessment and compensation processes.
		The lack of integration of energy policies with conservation policies makes it difficult to protect protected areas from energy projects.	Problems in assessing impacts due to a lack of scientific knowledge and limited implementation capacity

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Allard, S., & Aydınoğlu, A. U. (2012)	Environmental Researchers' Data Practices: An Exploratory Study in Turkey	Environmental data is mostly stored on personal computers, preventing sustainable data management.	Inability to ensure sustainable data management due to environmental data being stored on personal computers
		Data sharing is low, fueled by socio-cultural factors and academic incentive systems.	Inability to implement data management in practice due to awareness being limited to academic circles
		Standard data archiving, access, and sharing infrastructure are lacking, making it difficult to monitor the impacts of energy infrastructure on nature.	Limited information flow due to low data sharing; This situation is fueled by socio-cultural factors and academic incentive systems.
		Because interdisciplinary data integration is lacking, information for use in conservation planning remains fragmented and unreliable.	Information remains fragmented and unreliable in conservation planning due to a lack of interdisciplinary data integration.
		Awareness of data management is limited to academic circles and is not implemented in practice.	Monitoring the impacts of energy infrastructure on nature becomes difficult due to a lack of standard data archiving, access, and sharing infrastructure.
Jetz, W., McGeoch, M. A., Guralnick, R., Ferrier, S., Beck, J., Costello, M. J., Fernandez, M., Geller, G. N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F. E., Pereira, H. M., Regan, E. C., Schmeller, D. S., & Turak, E. (2019)	Essential biodiversity variables for mapping and monitoring species populations	The lack of standard, continuous, and reliable data on species distribution and abundance at the global level limits conservation decisions.	Conservation decisions are limited due to a lack of standard, continuous, and reliable data on species distribution and abundance.
		Raw data is patchy, incomplete, and heterogeneous, making spatial planning difficult.	Inadequacy of the existing data infrastructure due to the need for model-based data integration.
		The temporal and geographical inconsistency of data reduces the effectiveness of conservation strategies.	Spatial planning becomes difficult due to the irregular, incomplete, and heterogeneous nature of raw data.
		Most observational data only provides information about the presence of biodiversity data, not enough to monitor the risk of absence or loss.	Inability to monitor the risk of extinction and loss due to observational data providing only presence information.
		Model-based data integration is needed, but this approach has not yet become widespread.	Reduced effectiveness of conservation strategies due to temporal and geographical inconsistency of data.
Gadelha, L. M., de Siracusa, P. C., Dalcin, E. C., da Silva, L. A., Augusto, D. A., Krempser, E., … & de Siqueira, M. F. (2020)	A Survey of Biodiversity Informatics: Concepts, Practices, and Challenges	The fragmented, scattered, and non-standard formats of biodiversity data complicate the integration of spatial analyses with energy infrastructure.	Difficulty in integrating spatial analyses with energy infrastructure due to the fragmented, dispersed, and non-standard formats of biodiversity data.
		Technical incompatibilities arise when different data types (observations, DNA data, model outputs) are used together.	Sustainable infrastructure planning becomes difficult due to the inadequate integration of biodiversity data infrastructures with the energy sector.
		Uncertainties regarding data ownership, privacy, and access policies prevent the publication of data in an open-access format.	Technical incompatibilities arise when using different data types together.
		The lack of global data sharing platforms reduces the effectiveness of decision support systems.	Decision support systems are inadequate due to a lack of global data sharing platforms. Decreased effectiveness
		The inadequate integration of biodiversity data infrastructures with the energy sector complicates sustainable infrastructure planning.	Inability to publish data openly due to uncertainties in data ownership, privacy, and access policies

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Chamanara, J., & König-Ries, B. (2014)	A Conceptual Model for Data Management in the Field of Ecology	The lack of common understanding and structure throughout the data lifecycle limits the reusability of ecological data.	Limited reusability of ecological data due to lack of common understanding and structure in the data lifecycle
		The lack of interdisciplinary collaboration on data modeling and integration makes energy-biodiversity analyses technically complex.	Loss of meaning in data sharing due to weak data semantics and ontology support
		The inability of traditional ecological data structures to cope with multidimensional (time-space-species) structures hinders scalable analyses.	Technical complexity of energy-biodiversity analyses due to lack of interdisciplinary collaboration
		Solutions such as the BExIS system have not yet become widespread and have not found application in sectors such as energy infrastructure.	Lack of widespread adoption of systems such as BExIS and their use in the energy infrastructure sector
		Weak data semantics and ontology support lead to a loss of meaning in data sharing.	Hindered scalable analyses due to the inability of traditional ecological data structures to cope with multidimensional data
Costello, M. J., & Wieczorek, J. (2014)	Best Practice for Biodiversity Data Management and Publication	The lack of a data publication culture creates significant gaps, particularly in species distribution and ecosystem monitoring data.	Large gaps in species distribution and ecosystem monitoring data due to a lack of a data publication culture
		The lack of metadata hinders the understandability and reuse of datasets.	Limiting data integration in decision support systems due to non-compliance with data standards (e.g., Darwin Core, GBIF)
		The lack of open access and long-term archiving of data hinders the monitoring of the environmental impacts of energy projects.	Difficulty in understanding and reusing datasets due to a lack of metadata
		The presentation of most research data only in publication outputs results in structures unsuitable for spatial analysis.	Developing data structures unsuitable for spatial analysis due to the presentation of research data only in publication outputs
		Lack of compliance with standards (e.g., Darwin Core, GBIF compliance) limits data integration in decision support systems.	Inability to monitor the environmental impacts of energy projects due to the lack of open access and long-term archiving of data
Chamanara, J., Gaikwad, J., Gerlach, R., Algergawy, A., Ostrowski, A., & König-Ries, B. (2021)	BEXIS2: A FAIR-Aligned Data Management System for Biodiversity, Ecology and Environmental Data	Lack of compliance with FAIR principles in biodiversity data management limits the availability, accessibility, and reusability of data.	Limiting the availability, accessibility, and reusability of biodiversity data due to a lack of compliance with FAIR principles
		Deficiencies in the data lifecycle in research projects hinder systematic data analysis in sectors such as energy infrastructure.	Difficulty in accessing and using biodiversity data for field workers and energy sector experts due to data management competence being limited to technical knowledge
		The lack of modular systems for data modeling, version control, sharing, and monitoring hinders traceability at an institutional scale.	Deficiencies in data lifecycles hinder systematic data analysis in sectors such as energy infrastructure
		Structural challenges in managing multiple data types (observation, measurement, simulation) hinder direct integration into decision-making systems.	Structural challenges in managing multiple data types hinder direct integration into decision support systems
		Data management competence limited to technical knowledge creates access and usage difficulties for field workers and energy sector experts.	Difficulty in institutional traceability in data modeling, version control, sharing, and monitoring due to a lack of modular systems

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Enke, N., Thessen, A., Bach, K., Bendix, J., Seeger, B., & Gemeinholzer, B. (2012)	The user's view on biodiversity data sharing	Social concerns about data sharing (e.g., fear of losing control over data, concerns about insufficient citations) hinder data sharing.	Social concerns (loss of control, lack of citation) Concerns about data sharing are hindered.
		User-unfriendly interfaces make entering data into online databases time-consuming and complex, reducing participation.	Lack of training and data management plans make reuse of scientific data and integration into spatial planning difficult.
		The inadequacy of long-term data storage infrastructures threatens data sustainability.	Unfriendly interfaces make data entry time-consuming and complex, leading to decreased participation.
		Lack of motivation leads to insufficient incentives for data providers to share data.	Lack of motivation makes data providers less incentivized to share data.
		Lack of training and data management plans hinder the reuse and integration of scientific studies into spatial planning.	Data sustainability is threatened due to inadequate long-term data storage infrastructures.
Urbano, F., Viterbi, R., Pedrotti, L., Vettorazzo, E., Movalli, C., & Corlatti, L. (2023)	Enhancing biodiversity conservation and monitoring in protected areas	Weak data management in protected areas limits the reuse of long-term monitoring data.	Poor data management in protected areas limits the reuse of long-term monitoring data.
		Incompatibility of protocols and data formats across different protected areas complicates data integration.	Lack of technical knowledge (e.g., SQL, GIS tools) hinders field personnel from effectively using data.
		A lack of resources for digitizing and verifying data means that only a limited portion of the available information can be analyzed.	Incompatibility of protocols and data formats across protected areas makes data integration difficult.
		Lack of quality control and incomplete documentation in historical data reduce the reliability of data for use in decision support systems.	Lack of quality control and documentation in historical data reduces data reliability for decision support systems.
		Lack of technical knowledge (e.g., SQL, GIS tools) hinders field personnel's ability to effectively use data.	Lack of resources for digitization and verification results in the analysis of only a limited portion of existing information.
Anderson, R. P., Araújo, M. B., Guisan, A., Lobo, J. M., Martínez-Meyer, E., Peterson, A. T., & Soberón, J. M. (2020)	Optimizing biodiversity informatics to improve information flow, data quality, and utility for science and society	Much primary biodiversity data is provided with low quality and incomplete metadata, weakening decision-making processes.	Decision-making processes are weakened due to the provision of low-quality and incomplete metadata for primary biodiversity data.
		Feedback mechanisms between data users and providers are lacking, preventing the correction of inaccurate data.	Limited data quality and system integration due to insufficient funder investment in systems.
		The lack of widespread use of fixed, unique identifier (ID) systems makes data tracking difficult.	Inadequate feedback mechanisms hinder the correction of inaccurate data.
		Inadequate processing of user contributions on public data portals results in slow data curation processes.	Inadequate processing of user contributions on public data portals slows down data curation processes.
		Insufficient investment by funders in these systems limits quality improvements and system integration.	Data tracking is difficult due to the lack of widespread use of fixed and unique identifier systems.

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Ball-Damerow, J. E., Brenskelle, L., Barve, N., Soltis, P. S., Sierwald, P., Bieler, R., LaFrance, R., Ariño, A. H., & Guralnick, R. (2019)	Research applications of primary biodiversity databases in the digital age	Only 10% of global biological data collections are digital, limiting spatial decision support analyses.	Spatial decision support analyses are limited due to the fact that only 10% of global biological data collections are digital.
		Geographic coordinates and sampling errors are frequently missing or inaccurate, particularly in data collected over extended time intervals.	Proper attribution of open-access datasets hinders traceability and reusability.
		Taxonomic misidentifications are common (5–60%), which can lead to flawed distribution and diversity analyses.	Long-term data accuracy is problematic due to frequent geographic coordinate and sampling errors.
		Data quality checks are skipped in many studies, leading to errors, particularly in species number and diversity estimates.	Inaccuracies in species number and diversity estimates due to omission of data quality checks.
		Lack of proper attribution of open-access datasets hinders data traceability and reusability.	Common taxonomic misidentifications (5–60%) lead to inaccurate distribution and diversity analyses.
Huvenne, V. A. I., Bett, B. J., Masson, D. G., Le Bas, T. P., & Wheeler, A. J. (2016)	Effectiveness of a deep-sea cold-water coral Marine Protected Area	Deep-sea coral ecosystems have a very low capacity to recover; no recovery has been observed in degraded areas for eight years.	Long-term coral ecosystems are vulnerable to low recovery capacity due to long-term Habitat degradation
		The impact of infrastructural activities such as trawling is long-lasting, and habitats may not recover for decades.	Failure to restore habitats due to long-term impacts of infrastructural activities such as trawling
		Even in protected areas, illegal entry and encroachment can occur, undermining the reliability of conservation measures.	Weakening the reliability of conservation measures due to illegal entries and violations in protected areas
		Differences in bathymetry and currents mean that conservation strategies cannot be applied uniformly across regions.	Uneven application of conservation strategies across regions due to bathymetry and current differences
		Deep-sea monitoring is costly and technically challenging, resulting in scarce long-term monitoring data.	Inadequacy of long-term data due to high deep-sea monitoring costs
Hughes, K. A., & Pertierra, L. R. (2016)	Evaluation of non-native species policy development and implementation within the Antarctic Treaty area	Policy development against invasive species is slow, and implementation lacks uniformity and standards.	Slow policy development and lack of implementation standards against invasive species
		The lack of data-based systematic monitoring delays the detection of invasive species and response processes.	Delayed detection and response processes for invasive species due to a lack of data-based systematic monitoring
		The spread of microinvertebrate species around research stations cannot be prevented, putting native species at risk.	Threatening native species due to the inability to prevent the spread of microinvertebrate species around research stations
		Biological reservoirs such as seed banks make it difficult to completely eliminate plant invasions.	Inability to completely eliminate plant invasions due to biological reservoirs such as seed banks
		A lack of international cooperation leads to inequalities in policy implementation.	Inequities in policy implementation due to lack of international cooperation

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van Strien, A. J., Meyling, A. W., Herder, J. E., Hollander, H., Kalkman, V. J., Poot, M. J. M., Turnhout, S., van der Hoorn, B., van Strien-van Liempt, W. T. F. H., van Swaay, C. A. M., van Turnhout, C. A. M., Verweij, R. J. T., & Oerlemans, N. J. (2016)	Modest recovery of biodiversity in a western European country	Significant declines in species in agricultural and semi-natural open areas have been observed; this decline is particularly related to nitrogen deposition and agricultural intensification.	Negative impacts of nitrogen deposition and agricultural intensification on biodiversity due to a decrease in species in agricultural and semi-natural open areas
		Biodiversity trends vary significantly across habitat types, making single policy solutions ineffective.	Ineffectiveness of single policy solutions due to differing biodiversity trends across habitat types
		Improvements in chemical quality alone are not sufficient; habitat restoration is necessary.	Demand for habitat restoration due to insufficient chemical quality improvements alone need
		While some habitats have improved with conservation measures, biodiversity losses continue, particularly in agricultural areas.	Despite some habitat improvements, biodiversity losses in agricultural areas continue.
		Methodological shortcomings in the interpretation of biodiversity indicators can lead to overlooked trends in some species.	Inaccurate monitoring of trends due to methodological shortcomings in interpreting biodiversity indicators.
Bussotti, F., Papitto, G., Di Martino, D., Cocciufa, C., Cindolo, C., Cenni, E., Bettini, D., Iacopetti, G., Ghelardini, L., Moricca, S., Panzavolta, T., Bracalini, M., & Pollastrini, M. (2024)	Extreme climatic events, biotic interactions and species-specific responses drive tree crown defoliation and mortality in Italian forests	Extreme climate events (heat waves, droughts) and biotic interactions (e.g., insect outbreaks, fungal diseases) accelerate tree defoliation and mortality.	Increased rates of tree defoliation and mortality due to extreme climate events and biotic interactions.
		Species- and region-specific responses increase the heterogeneity of impacts on forest health and complicate the development of universal solutions.	Heterogeneity of forest health impacts due to species- and region-specific responses.
		Observed defoliation trends have increased significantly, particularly after 2010, indicating an intensification of climate change impacts.	Intensification of climate change impacts due to defoliation trends that became more pronounced after 2010.
		Because the network density of forest monitoring infrastructure in Italy is low, some ecological conditions are underrepresented.	Inadequate representation of ecological conditions due to low network density of monitoring infrastructure in Italy.
		Trees exposed to climate stress subsequently become vulnerable to pathogens such as fungi, increasing secondary causes of mortality.	Increased risks of secondary mortality due to climate-stressed trees becoming vulnerable to pathogens such as fungi.

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McCarthy, C., Banfill, J., & Hoshino, B. (2021)	National parks, protected areas and biodiversity conservation in North Korea: opportunities for international collaboration	Protected areas in North Korea are experiencing significant tree loss and habitat fragmentation, threatening biodiversity.	Increasing threats to biodiversity due to severe tree loss and habitat fragmentation in protected areas in North Korea.
		Management capacity and effectiveness are weak, and the existing protected area network does not provide adequate protection against these threats.	Weak management capacity prevents the existing protection network from providing adequate protection against threats.
		Human activities (logging, agricultural expansion, natural disasters) have caused significant damage even in protected areas.	Serious damage to protected areas due to human activities.
		A lack of international data sharing and monitoring makes it difficult to understand the scale of biodiversity loss.	Inability to understand the scale of biodiversity loss due to lack of international data sharing and monitoring.
		Conservation activities have become politicized, leading to problems with the stability and sustainability of local practices.	Politicization of conservation activities. Stability and sustainability issues in local practices
Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators	Past management practices within corridors have lasting impacts on current biodiversity. This impact is particularly shaped by fire regimes and the presence of invasive species.	Current biodiversity is shaped by fire regimes and invasive species due to the lasting effects of past management practices in corridors
		A lack of long-term monitoring makes it difficult to assess the effectiveness of corridors, making planning processes inefficient.	Inability to assess the effectiveness of corridors and ineffective planning due to lack of long-term monitoring
		Invasive species (e.g., Rubus cuneifolius) reduce the diversity of native herbivore and pollinator species, thus threatening biodiversity in managed corridors even without energy infrastructure.	Biodiversity is threatened in managed corridors due to invasive species (e.g., Rubus cuneifolius) reducing the diversity of native herbivores and pollinators
		Infrastructure integration of satellite imagery and NDVI-based monitoring systems is lacking. However, these systems can be effective in detecting biodiversity changes early.	Lack of infrastructure integration of satellite imagery and NDVI-based monitoring systems
		Without proper management, these corridors, which could serve as buffer zones for energy supply, become dysfunctional.	Corridors that serve as buffer zones for energy supply become dysfunctional when not properly managed
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma	Rapid urbanization has caused significant habitat loss in forests (39%), grasslands (20%), and wetlands (28%).	Significant habitat loss in forests (39%), grasslands (20%), and wetlands (28%) due to rapid urbanization
		Because nature conservation is not considered in urban planning, high-priority areas such as KBAs have come under pressure from construction.	Nature conservation is not considered in urban planning, leading to the development pressure in KBAs
		Insufficient data, lack of planning, and lack of strategy prevent early action against habitat transformation.	Inability to take early precautions against habitat conversion due to lack of data, planning, and strategies
		Projections for the next 50 years predict a 40% decline in wetlands and 42% in forests.	Expected decline of 40% in wetlands and 42% in forests according to 50-year projections
		The lack of appropriate policy and spatial decision-support tools relegates nature conservation to the background as energy infrastructure expands.	Nature conservation takes a back seat to energy infrastructure due to a lack of policy and spatial decision support tools.

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Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators	Past management practices of corridors have a lasting impact on present-day biodiversity; management of flammable grasses and invasive species are particularly decisive.	Current biodiversity is permanently affected due to past corridor management practices.
		Invasive plants such as Rubus cuneifolius prevent the survival of endemic species and reduce habitat quality.	Invasive plants such as Rubus cuneifolius have caused shrinkage of endemic species' habitats and a decline in habitat quality.
		Inadequate fire regimes reduce habitat heterogeneity and negatively impact species diversity.	Decreased habitat heterogeneity and species diversity due to inadequate fire regimes
		Because continuous monitoring is lacking, declines in habitat quality cannot be detected in a timely manner, reducing the functionality of corridors.	Failure to timely detect declines in habitat quality due to a lack of continuous monitoring
		Integration of field data with satellite imagery (NDVI) is insufficient, but this method is effective for monitoring habitat changes.	Inadequate integration of field data with NDVI satellite imagery
Huston, M. A. (2005)	The Three Phases of Land-Use Change: Implications for Biodiversity	The three phases of land use change (agriculture, industry, and the knowledge economy) each affect different habitats and species at different periods.	Variation of seasonal habitat and species impacts due to three phases of land-use change (agriculture, industry, and the knowledge economy)
		As population density in areas where energy infrastructure is located generally shifts to fertile and highly biologically productive areas, biodiversity-rich areas are under pressure.	Pressure on areas with high biological productivity in regions with energy infrastructure
		Areas that were under-impacted during the agricultural and industrial eras are being destroyed by development pressures in the knowledge economy era.	Destruction of under-impacted areas due to development pressures in the knowledge economy era
		Increasing recreational and secondary housing development in rural-urban transition zones fragments natural habitats.	Habitat fragmentation due to recreational and second-home development in rural-urban transition zones
		Long-term land use policies overlook the temporal impacts on biodiversity, leading to errors in decision-making.	Overlooking temporal impacts on biodiversity in long-term land-use policies
Lorang, M. S., Whited, D. C., Hauer, F. R., Kimball, J. S., & Stanford, J. A. (2005)	Using airborne multispectral imagery to evaluate geomorphic work across floodplains of gravel-bed rivers	Energy infrastructures (dams, stream reclamation, fill areas) disrupt natural processes (e.g., avulsion and sediment transport) in river floodplains.	Energy infrastructures such as dams, stream rehabilitation, and embankments disrupt natural processes in river floodplains
		Because floodplain habitats are complex and dynamic, permanent development in these areas poses a threat to biodiversity.	Threats to biodiversity due to permanent construction in floodplain habitats
		Failure to integrate multispectral imaging systems into conservation planning hinders strategic restoration practices.	Failure to integrate multispectral imaging systems into conservation planning
		Species that rely on frequent flooding and water diversion are losing their habitats due to energy projects.	Habitat loss due to energy projects for species that require frequent flooding
		Riparian development projects reduce habitat diversity and disrupt biological connectivity.	Reduction of habitat diversity due to riverside development projects and the breakdown of biological connectivity

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Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	Mapping behavioral landscapes for animal movement: a finite mixture modeling approach	Urban sprawl alters the movement patterns of mammalian predators (e.g., bobcats), reducing habitat connectivity (functional connectivity).	Changing movement patterns of mammalian predators and decreasing habitat connectivity due to urban sprawl
		Animals alter their movements at urban edges, either paralleling or moving away from urban areas, suggesting that overlapping routes with energy infrastructure can be problematic.	Changing animal movements at urban boundaries create problems with routes overlapping with energy infrastructure
		Individuals near urban areas exhibit varying behavioral responses, complicating species-based conservation plans.	Complicated species-based planning due to differing behavioral responses of individuals living near urban areas
		While behavioral landscape maps are essential for understanding species' habitat preferences and risk areas, such data are still not widely used.	Lack of widespread use of behavioral landscape maps
		Decision support systems based on spatial analysis of movement data are still not widely available.	Lack of widespread use of decision support systems based on movement data
Benson, B. J., Bond, B. J., Hamilton, M. P., Monson, R. K., & Han, R. (2009)	Perspectives on next-generation technology for environmental sensor networks	he lack of widespread availability of real-time data collection systems complicates habitat monitoring and early response processes.	Difficulty in habitat monitoring and early intervention due to the lack of widespread real-time data collection systems
		The limited temporal and spatial resolution of traditional sensor technologies prevents them from adequately capturing the dynamics of habitat degradation.	Inadequate monitoring of habitat degradation due to the limited resolution of traditional sensor technologies
		The lack of data management and communication protocols limits the integration of biodiversity monitoring with sectors such as energy infrastructure.	Inability to integrate biodiversity monitoring with the energy sector due to the lack of data management and communication protocols
		The lack of energy resources in remote areas limits sensor deployment and long-term monitoring.	Limited sensor deployment and monitoring capabilities in remote areas due to a lack of energy resources
		The lack of interdisciplinary training limits the effective use of environmental monitoring networks.	Limited effective use of environmental monitoring networks due to a lack of interdisciplinary training
Crowl, T. A., Crist, T. O., Parmenter, R. R., Belovsky, G., & Lugo, A. E. (2008)	The spread of invasive species and infectious disease as drivers of ecosystem change	Global connectedness causes the faster spread of invasive species and diseases, which in turn threatens native species.	Faster spread of invasive species and diseases due to global interconnectedness
		Energy and transportation infrastructures serve as vectors for the spread of these organisms.	Energy and transportation infrastructures serve as vectors for the spread of invasive organisms
		Land use and climate change exacerbate the impacts of invasive species, leading to significant changes in biodiversity and ecosystem services.	Increased impacts of invasive species due to land use and climate change
		The lack of monitoring and data integration at the continental level hinders the early detection of invasive species and response planning.	Continents Lack of inter-regional monitoring and data integration results in the inability to early detect invasive species and facilitate response planning.
		The fragmented and disorganized nature of monitoring systems precludes the effective use of decision support systems.	Decision support systems cannot be used effectively due to fragmented and disorganized monitoring systems.

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Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	Patterns of diversity along a habitat size gradient in a biodiversity hotspot	As habitat size shrinks, species diversity decreases, and this effect is particularly pronounced in medium- and large-sized mammals.	As habitat size shrinks, species diversity in medium- and large-sized mammals decreases.
		In fragmented habitats, the spread of invasive species increases, and smaller fragments are more vulnerable to invasion.	Increased spread of invasive species in fragmented habitats, making small fragments more vulnerable to invasion.
		Isolation and small-area effects hinder species survival and migration, reducing habitat connectivity.	Isolation and small-area effects make migration and survival of species more difficult.
		Edge effects also affect the interior of habitats, causing changes in microclimate and species composition.	Edge effects cause changes in microclimate and species composition in habitat interiors.
		Monitoring studies often generalize without considering land size, reducing the effectiveness of conservation measures.	Reduced effectiveness of conservation measures due to generalizations made without considering land size.
Dickie, M., Serrouya, R., DeMars, C., Cranston, J., & Boutin, S. (2017)	Evaluating functional recovery of habitat for threatened woodland caribou	Linear transitions caused by energy infrastructure (e.g., pipelines, roads) increase the speed of wolf movement and increase caribou predation rates.	Linear transitions related to energy infrastructure (e.g., pipelines, roads) increase the speed of movement of wolves, increasing hunting pressure (caribou).
		Because natural vegetation regeneration is very slow, habitats can take years to functionally recover.	Delayed habitat recovery due to the very slow regeneration of natural vegetation.
		Restoration based solely on structural similarity (plant height) may yield inadequate conservation outcomes.	Restoration based solely on structural similarity (plant height) leads to inadequate conservation outcomes.
		A multi-criteria assessment (ecological process + vegetation structure) is required for a habitat to be considered "recovered."	Multi-criteria assessment (ecological process + vegetation structure) is needed to accept that habitat has recovered.
		Because the impacts of energy projects are widespread, small-scale restoration efforts are insufficient.	Small-scale restoration is inadequate due to the widespread impact of energy projects.

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Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., … Zhu, Z. (2014)	Bringing an ecological view of change to Landsat-based remote sensing	Traditional remote sensing methods cannot fully reflect ecological processes. This leads to an underestimation of the impacts of land use changes on biodiversity.	Traditional remote sensing methods cannot reflect ecological processes.
		Data resolution (time-space) and accessibility limitations make it difficult to monitor the impacts of large-scale projects such as energy infrastructure.	Data resolution and access limitations make energy projects less effective. Inability to monitor the effects of migratory species
		Inadequate modeling of long-term changes and recovery processes (e.g., post-fire recovery) renders conservation strategies incomplete.	Inadequate modeling of processes such as post-fire recovery results in inadequate protection strategies
		When change is considered solely as a "before-after" comparison, process dynamics (e.g., chronic stress, subsequent growth) are overlooked.	Analyses based solely on "before-after" comparisons ignore process dynamics
		Systems used to monitor land cover dynamics are susceptible to errors such as cloud cover and atmospheric influences, which can lead to misinterpretations of the environmental impacts of energy projects.	Incorrect interpretation of land cover changes due to cloud and atmospheric effects in remote sensing
Middleton, A. D., Sawyer, H., Merkle, J. A., Kauffman, M. J., Cole, E. K., Dewey, S. R., Gude, J. A., Gustine, D. D., McWhirter, D. E., Proffitt, K. M., & White, P. (2019)	Conserving transboundary wildlife migrations: recent insights from the Greater Yellowstone Ecosystem	Habitats used by migratory species are widespread and often dispersed across different ownership and management boundaries.	Habitats of migratory species expand over large areas and cross management boundaries
		Energy development projects and roads lead to behavioral changes and nutritional losses along migration corridors.	Behavioral changes and nutritional losses occur in migration corridors due to energy projects and roads
		Because migration routes are learned behaviors passed down from generation to generation, once disrupted, they can be difficult to regain.	Recovery becomes difficult when migration routes are disrupted because they are behaviors passed down from generation to generation
		Inadequate corridor mapping and low levels of intergovernmental coordination complicate the conservation of migratory species.	Inadequate corridor mapping and lack of coordination between governments make it difficult to protect migratory species
		Energy development, settlement expansion, and interventions such as fencing systems can create bottlenecks in migration routes, leading to population declines.	Bottlenecks develop in migration routes due to interventions such as energy development, settlement, and fencing systems

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Shiklomanov, A. N., Bradley, B. A., Dahlin, K. M., M Fox, A., Gough, C. M., Hoffman, F. M., M Middleton, E., Serbin, S. P., Smallman, L., & Smith, W. K. (2019)	Enhancing global change experiments through integration of remote-sensing techniques	Global change experiments are spatially and temporally limited, making it difficult to measure the long-term impacts of energy infrastructures.	Inability to measure long-term impacts of energy infrastructure due to the spatial and temporal limitations of global change experiments
		The underutilization of near-surface remote sensing techniques (e.g., thermal, hyperspectral, and laser scanners) hinders the timely measurement of habitat recovery and ecosystem responses.	Insufficient use of near-surface remote sensing techniques such as thermal, hyperspectral, and laser scanners
		Remote sensing techniques are often neglected in land selection and assessment of the representativeness of experimental sites.	The neglect of remote sensing techniques in representativeness analyses of experimental sites.
		Because the integration of sensor data with field observations is incomplete, decision support systems must operate with limited information.	Decision support systems operate with limited information due to the lack of integration of sensor data with field observations.
		Managing data diversity and sensor outputs is complex, delaying the widespread implementation of systems.	The complexity of managing data and sensor outputs delays the widespread deployment of systems.
Richardson, M. L., Wilson, B. A., Aiuto, D. A., Crosby, J. E., Alonso, A., Dallmeier, F., & Golinski, G. K. (2017)	A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation	Habitat loss and disruption of ecosystem connectivity are common during both construction and operation.	Habitat loss and ecosystem disruption during construction and operation.
		Bird collisions and electrocution are common threats to biodiversity, particularly along power lines.	Bird collisions and electrocution pose widespread biodiversity threats along power lines.
		Continuous vegetation pruning alters habitat structure and prevents the survival of some species.	The constant pruning of vegetation disrupts habitat structure and hinders the survival of some species.
		Due to a lack of baseline data, the extent of impacts is often unknown, and monitoring systems are inadequate.	The lack of baseline data results in an unknown magnitude of impacts and inadequate monitoring systems.
		Mitigation strategies are often proposed only theoretically and are not scientifically tested.	Mitigation strategies remain theoretical and have not been scientifically tested.
		Diversity and functionality are not considered in bioindicator selection, which hinders a holistic understanding of impacts.	The lack of consideration of diversity and functionality in bioindicator selection results in a lack of holistic understanding of impacts.
Ponitka, J., & Boettner, S. (2020)	Challenges of future energy landscapes in Germany — a nature conservation perspective	Renewable energy systems require high land requirements, which increases habitat loss and fragmentation.	The high land demand of renewable energy systems increases habitat loss and fragmentation.
		The visual, functional, and ecological qualities of the landscape are degraded, directly impacting species' habitats.	The degradation of visual, functional, and ecological qualities of landscapes negatively impacts species' habitats.
		Complex legal and administrative regulations make it difficult to balance energy projects with nature conservation.	Complex legal and administrative regulations make it difficult to balance energy projects with nature conservation.
		The risk of collision with wind turbines for bird and bat species is a widespread and yet poorly resolved problem.	The risk of collisions with wind turbines is widespread among bird and bat species. and the failure to develop solutions
		Failure to consider conservation priorities in regional planning leads to poor decisions regarding biodiversity.	Weak biodiversity decisions due to a failure to consider conservation priorities in regional planning

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Farias, A. T., Hamilton, S. E., Pires, L. B., Canale, G. R., Santos, R. R., & Presotto, A. (2024)	The Impact of Land Conversion on Primate Habitats: Refining the Extent of Occurrence Data for Four Capuchin Species in North and Northeastern Brazil	IUCN scoping data (EOO) are outdated because habitat loss is rapidly accelerating.	Failure to reflect rapidly accelerating habitat loss due to outdated IUCN scoping data (EOO)
		Agriculture, mining, and urbanization have caused significant loss of habitats for primate species (e.g., a 77% loss of ERR for S. flavius).	Significant EOO (77%) loss of habitats for primate species due to agriculture, mining, and urbanization
		Even protected areas are affected by habitat conversion, demonstrating that their legal protection status remains inadequate.	Inadequate legal protection status due to habitat conversion even in protected areas
		ERR calculations often overlook actual habitat suitability, rendering species conservation plans ineffective.	Ineffective conservation plans due to failure to consider actual habitat suitability in EOO calculations
		A lack of analyses using high-resolution land cover data can lead to risky decisions in energy and infrastructure planning.	Risky energy and infrastructure planning due to the lack of high-resolution land cover data
Guil, F., & Pérez-García, J. M. (2022)	Bird electrocution on power lines: Spatial gaps and identification of driving factors at global scales	Global data imbalance: While electrocution studies are largely concentrated in Europe and North America, significant data gaps exist in high-risk regions such as South America, Africa, and Asia. This leads to spatial inequality shaping global conservation strategies.	Serious data gaps in South America, Africa, and Asia due to global imbalances in electrocution data
		Inadequate monitoring systems: Many regions lack systematic monitoring and recording systems for bird strikes. This leads to insufficient consideration of environmental impacts in the planning phase of energy infrastructure projects.	Lack of systematic bird strike monitoring systems in many regions, leading to inadequate assessment of impacts
		Infrastructure design uncertainties: The impact of technical factors such as pole design varies regionally, and the mechanisms underlying the risk of strikes are not fully understood. This can lead to the ineffectiveness of uniform technical measures.	Ineffective measures due to regional variations in technical factors such as pole design
		Lack of transboundary protection for migratory species: Local measures taken along migratory bird routes are often inadequate.	Inadequate local measures due to lack of transboundary protection for migratory species
		Inadequate reporting and lack of standard protocols: Data collection methods for electrocution events are inconsistent across countries and regions, making it difficult to conduct comparable analyses and develop effective preventative measures.	Difficulty in analysis and development of measures due to lack of standard protocols and inconsistent reporting of electrocution events

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Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	The value of open power line habitat in conservation of ground beetles (Coleoptera: Carabidae) associated with mires	Loss of natural habitat characteristics: The drainage of moist natural habitats such as mires (peat bogs) eliminates the habitat of rare and specialist insect species. This leads to the loss of species that prefer humid microclimates.	Depletion of habitats for rare and specialist species due to the drying of moist natural habitats (e.g., mires)
		Open spaces created under power lines have limited conservation value: Although thought to provide open habitat, the open spaces created in areas crossed by power lines have been found to benefit only a few common species and provide inadequate conditions for mire specialist species.	Limited conservation value of open spaces created under power lines
		Increased species richness can be misleading: Species diversity increases after drainage, but this increase is due to widespread and generalist species. High-conservation, endemic, or vulnerable species have little chance of surviving in these environments.	Low conservation value due to increased species richness after drainage resulting from widespread and generalist species
		Limited coverage of biodiversity monitoring systems: While more advanced monitoring systems (e.g., NMDS and plant-community comparisons) are necessary to analyze the habitat responses of insect species, ecological modeling at this level is rarely used in energy infrastructure planning.	Limited analysis of detailed ecological responses due to limited biodiversity monitoring systems
		Management deficiencies and irregularities cause significant changes in the habitat quality of areas under power lines. For example, years of neglect in some areas can lead to uncontrolled vegetation growth and habitat deforestation, thus diminishing the open habitat character.	Significant changes in habitat quality due to management deficiencies in areas under power lines
		The presence of open spaces alone is not sufficient: While this study shows that open habitats benefit some species (e.g., Cicindela campestris), the humid microclimate and unique vegetation structure beyond the open spaces are also necessary for the survival of mire-specific species.	Openness alone is not sufficient; For example, mire species require humid microclimates and unique plant structures.

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Ellwanger, J. H., Fearnside, P. M., Ziliotto, M., & Chies, J. A. (2024)	Pollution-Related Biodiversity Loss in Brazil: More Actions Required	Oil extraction and transportation pose a significant risk to ecosystems in the Amazon: Deepwater Horizon-like deep-sea oil extraction, particularly in the Amazon River estuary, suggests the potential for disasters similar to the Deepwater Horizon. This could have irreversible consequences for both terrestrial and aquatic biodiversity.	The risk of irreversible damage to terrestrial and aquatic biodiversity due to oil extraction in the Amazon.
		Pollution has multifaceted and widespread impacts: Different pollutants, such as mercury (especially from illegal gold mining), CO_2 (from deforestation and fires), plastics, fertilizers, sewage, pesticides, and heavy metals, are contributing to biodiversity losses across all Brazilian biogeographic regions.	Widespread biodiversity losses across biogeographic regions due to pollutants such as mercury, CO_2, pesticides, plastics, and heavy metals.
		Pollution types linked to the energy sector particularly impact sensitive ecosystems: For example, mining and oil extraction directly lead to habitat loss, community disruption, decline in species richness, and reduced microbial diversity in both terrestrial and marine systems.	Mining and oil extraction lead to habitat loss, decreased species richness, and a decline in microbial diversity in sensitive ecosystems.
		Untreated waste discharged into water bodies threatens stream biodiversity, especially in urban and industrial areas. Studies in cities like Manaus indicate that the impact of pollution is as strong as that of deforestation.	Stream biodiversity is threatened by untreated waste from urban and industrial areas.
		Emerging classes of pollutants (e.g., microplastics, pharmaceutical waste, aromatic hydrocarbons) pose new threats not covered by traditional monitoring systems, making assessing the impacts of energy infrastructure more complex.	New classes of pollutants, such as microplastics and pharmaceutical waste, are not detected by traditional monitoring systems.
		Management inefficiencies and policy implementation gaps hinder the control of biodiversity losses due to pollution. For example, coverage of key systems such as wastewater treatment and solid waste management remains low.	Inadequate wastewater and solid waste management results in the inability to control biodiversity losses due to pollution.

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Montgomery, D. C. (2017)	Design and Analysis of Experiments	Incomplete Use of Experimental Design Information in Infrastructure Planning: In energy infrastructure projects, many decisions regarding nature conservation are often made without empirical testing. Systematic experimental approaches (e.g., factorial designs, response surface methods), as described by Montgomery, are rarely used in environmental decision-making processes. This hinders a full understanding of cause-and-effect relationships among habitats.	Failure to utilize experimental design information in energy infrastructure planning.
		Failure to Consider Interactive Factors (e.g., infrastructure type × habitat type): The "factor interaction" analysis emphasized in the book can be critical for testing how energy infrastructure produces different effects under different environmental conditions. However, in practice, such interactive experiments are not conducted in most energy projects.	Failure to analyze the interactions of factors such as infrastructure type and habitat type.
		Insufficient empirical validation of decision support systems: The multi-level, multivariate empirical approaches recommended by Montgomery are rarely applied to outcomes such as habitat degradation threshold, bird strike risk, or flora/fauna diversity, preventing conservation plans from being based on sound empirical foundations.	Lack of empirical validation in decision support systems results in protection plans lacking an empirical basis.
		Local environmental variability is overlooked: The principles of "blocking" and "randomization" emphasized in the book are important for considering the potential for energy projects to have different impacts in different ecological zones. However, most environmental impact assessments do not statistically account for this variability.	Generalization of impact analyses due to failure to assess local environmental variability.
		Weaknesses in repeatability and sampling errors: Most studies analyzing environmental impacts do not adequately consider sampling errors. Without replication and random error estimation, as emphasized by Montgomery, nature conservation strategies cannot be based on reliable data.	Reduced reliability of analyses due to failure to consider repeatability and sampling errors.

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Radulescu, B.-A., & Radulescu, V. (2020)	Environmental Friendly Solution to Combat Massive Developed Vegetation in Natural or Hydropower Lakes	Eutrophication in hydroelectric reservoirs: Twenty-nine hydroelectric reservoirs on the Bistrita River (three of which are RAMSAR and Natura 2000 sites) have become eutrophic over the years due to severe organic and inorganic accumulation. This triggers intense aquatic plant growth, disrupting habitat structure and affecting the water's oxygen balance.	Deterioration of habitat structure and altered oxygen balance due to eutrophication in dam lakes.
		Dense aquatic vegetation threatens habitats for migratory birds and endemic fish species: For example, in Lakes Pangarati, Vaduri, and Reconstructia, vegetation has been observed to cover up to 40% of the area. This prevents bird nesting and causes population collapses in some endemic fish species.	Loss of nesting areas for migratory birds and collapse of endemic fish populations due to the density of aquatic vegetation.
		Interactions between lakes and low current speeds cause a problem experienced in one lake to spread rapidly to others: Nutrient loads (e.g., phosphorus), particularly from lower elevations, lead to algal blooms in the lakes below. This cascading effect renders single solutions inadequate.	The spread of nutrient loads and the formation of chain reaction algal blooms due to interactions between lakes.
		Past control methods have caused environmental damage: Chemical algaecides and herbicides have degraded water quality and threatened ecosystem health. The grass carp (grass-eating fish) solution has failed due to inadequate water temperatures. Approaches such as sediment control and water level lowering have been economically and technically unsustainable.	Degradation of water quality and ecosystem health due to past chemical control methods.
		Mechanical methods (harvesters and rotovators) are effective at limited depths and disturb the sediment, increasing turbidity, which in turn alters photosynthesis rates, leading to uncontrolled growth in the ecosystem.	Mechanical control methods are effective at limited depths and increase turbidity, disrupting photosynthesis.
		Vegetation that blocks light transmission at sufficient depths reduces dissolved oxygen levels, creating anoxic environments for fish and other higher life forms.	Dense vegetation obstructs light transmission, leading to oxygen deficiency (anoxia), creating unsuitable environments for higher life forms.
Plewa, R., Jaworski, T., Gil, W., & Horak, J. (2020)	Establishment and Maintenance of Power Lines Are Important for Insect Diversity in Central Europe	Power lines cause habitat fragmentation.	Habitat fragmentation due to transmission lines
		While they may provide temporary benefits for some insect species, this situation cannot be generalized.	Generalization of impact analyses due to failure to assess local environmental variability.
		Visual and aesthetic landscape value is compromised.	Deterioration of visual and aesthetic landscape value
		Construction and maintenance processes cause natural disturbances.	Construction and maintenance processes cause natural degradation
		Openings under power lines can spread invasive plant species.	Invasive plant spread in open spaces under power lines and suppression of natural succession
		Natural succession is suppressed, and the structure of open spaces becomes artificial.	The artificial nature of the open spaces creates unsuitable habitat for some species

Author/s	Article Title	Challenges mentioned by the author/s	Labeled Challenge Ctaegories
Kaługa, I., Sparks, T. H., & Tryjanowski, P. (2011)	Reducing death by electrocution of the white stork (Ciconia ciconia)	Power lines pose a serious mortality risk for white storks.	Power lines pose a serious mortality risk for species such as white storks
		Juveniles are more susceptible to electroshock.	Young birds are more vulnerable to electroshock
		Power lines disrupt not only the birds but also the transmission of electricity.	Power lines cause interruptions in power transmission due to bird deaths
		Bird protection measures are not initially considered in infrastructure projects.	Failure to consider bird protection measures in the planning phase of energy projects
		Simple technical solutions are not widely implemented.	Lack of widespread use of simple and applicable technical solutions

D. Datas Mentioned in Literature

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Gallo, M., Moreschi, L., & Del Borghi, A. (2022)	A Critical Environmental Analysis of Strategic Materials Towards Energy Transition	Material type used in electrical infrastructure inventories (e.g., copper, aluminum, neodymium)	Type of materials used in electricity infrastructure (copper, aluminum, neodymium, etc.)
		Energy and water consumption data	Impact reports and follow-up notifications regarding infrastructure-related events
		Greenhouse gas emissions	Carbon and greenhouse gas (CO_2, SF_6) emissions
		Use of hazardous chemicals	Use of hazardous chemicals
Tomsana, A., Itoba-Tombo, E. F., & Human, I. S. (2020)	An analysis of environmental obligations and liabilities of an electricity distribution company to improve sustainable development	Species-based mortality rates from bird strikes and electrocutions	Bird collisions or electrocution and related mortality rates
		Fire incidents	Fire incidents
		Oil leaks	Oil leaks
		Geographic location of these incidents	Impact reports and follow-up notifications regarding infrastructure-related events
Gilad, D., May, R., Stokke, B. G., & Verones, F. (2024)	Between the lines: Life cycle impact assessment models of collision and electrocution impacts of power lines on bird diversity in Norway	Species-based mortality rates from bird strikes and electrocutions	Bird collisions or electrocution and related mortality rates
		Design features of power lines (e.g., phase location, insulation)	Design features of power lines (conductor type, insulation)
		Line location information and surrounding habitat structure	Spatial data of planned infrastructure projects (location, length, number of poles, area)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Guil, F., & Pérez-García, J. M. (2022)	Bird electrocution on power lines: Spatial gaps and identification of driving factors at global scales	Global bird mortality data (especially for raptors and eagles)	Global bird mortality data (especially scientific studies/cards)
		Geographic distribution of low-voltage (distribution line <66kV) lines	Classified raster layers (forest, bare soil, agriculture, water, urban)
		Technical structure data such as pole type, phase locations, insulation status	Technical specifications of poles (type, phase conductor, insulation)
		Field observation protocols, sampling designs used	Field observation protocols and sample form templates used
Ajayi, V., Anaya, K., & Pollitt, M. (2022)	Incentive regulation, productivity growth and environmental effects: the case of electricity networks in Great Britain	Environmental outputs such as carbon emissions and SF6	Carbon and greenhouse gas (CO_2, SF_6) emissions
		Service quality indicators (outage duration, customer satisfaction)	Service quality indicators (accessibility, satisfaction, duration of service)
		Technical infrastructure data such as network length, energy quantity, number of connections	Structural characteristics of poles and surrounding environment
Turconi, R., Simonsen, C. G., Byriel, I. P., & Astrup, T. (2013)	Life cycle assessment of the Danish electricity distribution network	Power losses	Power outages
		Voltage levels (50, 10, 0.4 kV)	Current transformer capacity, energy quantity, voltage levels, connection status, and other substructure data
		Technical data of converters and transformers	Transformer age and brand
Raza, A., Syed, N. R., Fahmeed, R., Acharki, S., Aljohani, T. H., Hussain, S., Zubair, M., Zahra, S. M., Islam, A. R., Almohamad, H., & Abdo, H. G. (2024)	Investigation of changes in land use/land cover using principal component analysis and supervised classification from operational land imager satellite data – a case study of underdeveloped regions, Pakistan	Land use and cover (LULC) data	Land use and land cover (LULC)
		Classified raster layers (forest, bare land, agricultural land, water, urban structure)	Classified raster layers (forest, bare soil, agriculture, water, urban)
		Satellite imagery (Operational Land Imager - OLI)	Satellite imagery (OLI etc.)
		Time-dependent change data (sample from 2013 to 2021)	Time-series data (e.g., 2013–2021 NDVI)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Hoffman, K. N. (2023)	Justifying nature-based solutions	Spatial planning data for blue-green infrastructure systems	Blue-green infrastructure spatial planning data
		Project monitoring results and post-implementation feedback data	Impact reports and follow-up notifications regarding infrastructure-related events
		Biodiversity indicators (fauna/flora density, habitat quality, etc.)	Biodiversity indicators (fauna/flora density, habitat quality)
		Social benefit measures (recreation, climate adaptation, water holding capacity)	Social benefit indicators (recreation, aesthetic value, cultural compatibility)
Cunha, J. S., Fonsêca, N. C., Vieira de Lima, C. R., Santos, J. G., Pereira, H. de, Bezerra, B. M., & Lins-e-Silva, A. C. (2024)	Minor loss or huge threat? Assessment of potential infrastructure projects reveals drastic landscape degradation in the Atlantic forest	Landscape quality indicators: forest area ratio, habitat integrity, permeability	Landscape quality indicators (habitat integrity, connectivity)
		Spatial data (location, length, area of influence) of the power grid for planned infrastructure projects	Spatial data of planned infrastructure projects (location, length, number of poles, area)
Katovich, E. (2023)	Quantifying the Effects of Energy Infrastructure on Bird Populations and Biodiversity	Spatial distribution data of bird species (e.g., from sources such as IUCN, eBird)	Bird migration routes
		Protected area boundaries (KBA, IBA, nature conservation areas)	Classified raster layers (forest, bare soil, agriculture, water, urban)
		Detailed geographic data for energy infrastructure (solar, wind, transmission lines)	Spatial data of planned infrastructure projects (location, length, number of poles, area)
		Buffer zone analyses	Blue-green infrastructure spatial planning data
Syaban, A. S., & Appiah-Opoku, S. (2024)	Unveiling the Complexities of Land Use Transition in Indonesia's New Capital City IKN Nusantara: A Multidimensional Conflict Analysis	Land use and cover change data	Blue-green infrastructure spatial planning data
		Location of ecologically sensitive areas	Blue-green infrastructure spatial planning data
		Satellite imagery and LULC classifications	Land use and land cover (LULC)
		Community-based spatial data (local uses, traditional areas)	Classified raster layers (forest, bare soil, agriculture, water, urban)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Burgin, S. (2016)	What about biodiversity? Redefining urban sustainable management to incorporate endemic fauna with particular reference to Australia	Spatial data on endemic fauna species	Blue-green infrastructure spatial planning data
		Land use information obtained from community-based participation	Blue-green infrastructure spatial planning data
		Urbanization and infrastructure expansion maps	Blue-green infrastructure spatial planning data
		Network data for ecological corridors	Blue-green infrastructure spatial planning data
Sokół, M., & Łaska, G. (2024)	Biodiversity and Ecosystem Services: Complementary Approach for Catchment Protection and Land Use in Northeastern Poland	Basin-based land use and ecosystem service data	Blue-green infrastructure spatial planning data
		Flora/fauna distribution maps	Blue-green infrastructure spatial planning data
		Environmental variables such as soil moisture, slope, and flow direction	Blue-green infrastructure spatial planning data
He, X., & Wei, H. (2023)	Biodiversity Conservation and Ecological Value of Protected Areas: A Review of Current Situation and Future Prospects	Location, boundary, and species data for Protected Areas (PAs) and KBAs	Blue-green infrastructure spatial planning data
		Ecological value classifications (ecosystem services, natural capital, habitat quality)	Biodiversity indicators (fauna/flora density, habitat quality)
		Biodiversity change indicators (number of protected species, area change, threatened species)	Biodiversity indicators (fauna/flora density, habitat quality)
Aska, B., Franks, D. M., Stringer, M., & Sonter, L. J. (2023)	Biodiversity conservation threatened by global mining wastes	Hazardous waste generated by mining activities species, abundance, and extent.	Use of hazardous chemicals
		Temporal datasets for impact monitoring	Impact reports and follow-up notifications regarding infrastructure-related events
		Spatial overlap of protected areas and mining activities.	Landscape quality indicators (habitat integrity, connectivity)
Appelt, J. L., Saphangthong, T., Malek, Ž., Verburg, P. H., & van Vliet, J. (2023)	Climate change impacts on tree crop suitability in Southeast Asia	Future climate scenarios (especially temperature and precipitation data).	Impact reports and follow-up notifications regarding infrastructure-related events
		Spatially disaggregated land cover data.	Satellite imagery (OLI etc.)
		Environmental variables such as soil type, slope, and elevation.	Biodiversity indicators (fauna/flora density, habitat quality)
Yang, R., Dong, X., Xu, S., Wang, K., Li, X., Xiao, W., & Ye, Y. (2024)	Fragmentation of Key Biodiversity Areas highlights attention to human disturbance patterns	Key Biodiversity Area (KBA) boundary and attribute data	Blue-green infrastructure spatial planning data
		Land cover data: especially agricultural and residential areas.	Land use and land cover (LULC)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Miroshnyk, N. V., Likhanov, A. F., Grabovska, T. O., Teslenko, I. K., & Roubík, H. (2022)	Green infrastructure and relationship with urbanization – Importance and necessity of integrated governance	Urban sprawl data and land-use change maps.	Impact reports and follow-up notifications regarding infrastructure-related events
Dong, X., Gong, J., Zhang, W., Zhang, S., Hu, Y., Yang, G., Yan, C., & Li, F. Y. (2024)	Importance of including Key Biodiversity Areas in China's conservation area-based network	Spatial boundaries and conservation status of KBAs.	Blue-green infrastructure spatial planning data
		Species threat levels and habitat requirements.	Biodiversity indicators (fauna/flora density, habitat quality)
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Nature-based climate solutions for expanding the global protected area network	Global carbon stock, habitat quality, and biodiversity data.	Biodiversity indicators (fauna/flora density, habitat quality)
		Current status of natural areas outside protected areas.	Landscape quality indicators (habitat integrity, connectivity)
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma	Remote sensing data: Landsat series (1987, 2002, 2020).	Satellite imagery (OLI etc.)
		Biodiversity indicators and urban growth boundaries.	Blue-green infrastructure spatial planning data
		Land-use change data and classifications.	Time-series data (e.g., 2013–2021 NDVI)
		Boundaries of protected areas and their changes over time.	Blue-green infrastructure spatial planning data
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Prioritizing nationally endemic species for conservation	Distribution data and threat status of endemic species.	Biodiversity indicators (fauna/flora density, habitat quality)
		Species abundance and risk indices at the national scale.	Biodiversity indicators (fauna/flora density, habitat quality)
		Threat assessment data for area-based prioritization.	Blue-green infrastructure spatial planning data
Peck, M. R., Desselas, M., Bonilla-Bedoya, S., Redín, G., & Durango-Cordero, J. (2024)	The conflict between Rights of Nature and mining in Ecuador: Implications of the Los Cedros Cloud Forest case for biodiversity conservation	Boundaries of mining licenses and environmental impact potential.	Blue-green infrastructure spatial planning data
		Environmental indicators related to forest cover, water resources, and ecosystem services.	Biodiversity indicators (fauna/flora density, habitat quality)
		Habitat data for species of conservation interest.	Biodiversity indicators (fauna/flora density, habitat quality)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Jetz, W., McGeoch, M. A., Guralnick, R., Ferrier, S., Beck, J., Costello, M. J., Fernandez, M., Geller, G. N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F. E., Pereira, H. M., Regan, E. C., Schmeller, D. S., & Turak, E. (2019)	*Essential biodiversity variables for mapping and monitoring species populations*	Species Distribution (SD EBV)	Blue-green infrastructure spatial planning data
		Species observations across time and space	Blue-green infrastructure spatial planning data
		Species Abundance (SA EBV)	Blue-green infrastructure spatial planning data
		Inventory data (checklist, presence–absence data)	Biodiversity indicators (fauna/flora density, habitat quality)
Kiesecker, J. M., Baruch-Mordo, S., Baumgarten, L., Cameron, D. R., Cardenas Lopez, J. J., Crane, L., Evans, J. S., Fargione, J., & Naugle, D. E. (2017)	nergy Sprawl Solutions: Balancing Global Development and Conservation	Spatial data for protected areas	Blue-green infrastructure spatial planning data
		Land use, habitat quality, and ecosystem services data	Biodiversity indicators (fauna/flora density, habitat quality)
		Information on species' habitat requirements	Biodiversity indicators (fauna/flora density, habitat quality)
Moreira, F. (2019)	*Love me, love me not: Perceptions on the links between the energy sector and biodiversity conservation*	Spatial data for protected areas	Blue-green infrastructure spatial planning data
		Spatial data for energy projects	Spatial data of planned infrastructure projects (location, length, number of poles, area)
Chamanara, J., Gaikwad, J., Gerlach, R., Algergawy, A., Ostrowski, A., & König-Ries, B. (2021)	*BEXIS2: A FAIR-aligned data management system for biodiversity, ecology and environmental data*	Observation-based primary data and detailed metadata (e.g., time, location, project information)	Spatial data of planned infrastructure projects (location, length, number of poles, area)
		Structured data elements such as taxonomic classifications, variable names, and data types	Biodiversity indicators (fauna/flora density, habitat quality)
Costello, M. J., & Wieczorek, J. (2014)	*Best practice for biodiversity data management and publication*	Data records containing information on time, location, taxonomy, and observation method	Biodiversity indicators (fauna/flora density, habitat quality)
Chamanara, J., & König-Ries, B. (2014)	*A conceptual model for data management in the field of ecology*	Data from observations, experiments, modeling, and simulations	Biodiversity indicators (fauna/flora density, habitat quality)
		Time series, spatial data, organism-level measurements	Blue-green infrastructure spatial planning data

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Gadelha, L. M., de Siracusa, P. C., Dalcin, E. C., da Silva, L. A., Augusto, D. A., Krempser, E., ... & de Siqueira, M. F. (2020)	*A survey of biodiversity informatics: Concepts, practices, and challenges*	Taxonomic, genetic, ecological, geographic, and climatic data	Biodiversity indicators (fauna/flora density, habitat quality)
		Species distribution, population trends, and habitat information	Landscape quality indicators (habitat integrity, connectivity)
Urbano, F., Viterbi, R., Pedrotti, L., Vettorazzo, E., Movalli, C., & Corlatti, L. (2023)	*Enhancing biodiversity conservation and monitoring in protected areas through efficient data management*	Species population, habitat, and conservation status information	Landscape quality indicators (habitat integrity, connectivity)
		Metadata to assess data quality (e.g., sampling method, measurement times)	Biodiversity indicators (fauna/flora density, habitat quality)
		Time series for long-term monitoring of species in protected areas	Time-series data (e.g., 2013–2021 NDVI)
		Geographic data on land use and threat factors	Impact reports and follow-up notifications regarding infrastructure-related events
Anderson, R. P., Araújo, M. B., Guisan, A., Lobo, J. M., Martínez-Meyer, E., Peterson, A. T., & Soberón, J. M. (2020)	*Optimizing biodiversity informatics to improve information flow, data quality, and utility for science and society*	Data on biodiversity observations, species distribution, and environmental variables	Biodiversity indicators (fauna/flora density, habitat quality)
		Standardized species and taxonomy data	Biodiversity indicators (fauna/flora density, habitat quality)
Ball-Damerow, J. E., Brenskelle, L., Barve, N., Soltis, P. S., Sierwald, P., Bieler, R., LaFrance, R., Ariño, A. H., & Guralnick, R. (2019)	*Research applications of primary biodiversity databases in the digital age*	Species inventories, distribution information, and conservation status	Biodiversity indicators (fauna/flora density, habitat quality)
		Datasets suitable for analyses such as species number, endemism, and threat level	Biodiversity indicators (fauna/flora density, habitat quality)
		Time- and location-stamped species observation data	Blue-green infrastructure spatial planning data
Enke, N., Thessen, A., Bach, K., Bendix, J., Seeger, B., & Gemeinholzer, B. (2012)	*The user's view on biodiversity data sharing: Investigating facts of acceptance and requirements to realize a sustainable use of research data*	User feedback data collected through surveys	Service quality indicators (accessibility, satisfaction, duration of service)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Huvenne, V. A. I., Bett, B. J., Masson, D. G., Le Bas, T. P., & Wheeler, A. J. (2016)	*Effectiveness of a deep-sea cold-water coral Marine Protected Area*	Habitat structure and species distribution information (especially cold-water corals)	Landscape quality indicators (habitat integrity, connectivity)
		Pre- and post-protection ecosystem status comparisons	Impact reports and follow-up notifications regarding infrastructure-related events
		Long-term biodiversity monitoring data	Impact reports and follow-up notifications regarding infrastructure-related events
Hughes, K. A., & Pertierra, L. R. (2016)	*Evaluation of non-native species policy development and implementation in the UK*	Distribution data on the spread and impacts of invasive species	Blue-green infrastructure spatial planning data
van Strien, A. J., Meyling, A. W., Herder, J. E., Hollander, H., Kalkman, V. J., Poot, M. J. M., Turnhout, S., van der Hoorn, B., van Strien-van Liempt, W. T. F. H., van Swaay, C. A. M., van Turnhout, C. A. M., Verweij, R. J. T., & Oerlemans, N. J. (2016)	*Modest recovery of biodiversity in a Western European country: The Netherlands*	Long-term species monitoring data	Biodiversity indicators (fauna/flora density, habitat quality)
		Habitat area changes and connectivity measurements	Landscape quality indicators (habitat integrity, connectivity)
Bussotti, F., Papitto, G., Di Martino, D., Cocciufa, C., Cindolo, C., Cenni, E., Bettini, D., Iacopetti, G., Ghelardini, L., Moricca, S., Panzavolta, T., Bracalini, M., & Pollastrini, M. (2024)	*Extreme climatic events, biotic interactions and species-specific responses drive tree crown defoliation and mortality in Italian forests*	Species-specific defoliation (leaf loss) and mortality data	Biodiversity indicators (fauna/flora density, habitat quality)
		Environmental parameters such as soil moisture, water stress, and leaf area index	Biodiversity indicators (fauna/flora density, habitat quality)
		Climatic variables (temperature, drought, precipitation anomalies)	Biodiversity indicators (fauna/flora density, habitat quality)
		Long-term forest monitoring data on species distribution and health	Blue-green infrastructure spatial planning data
Gould, Z., Day, S., Reichard, G., Shealy, T., & Saad, W. (2023)	*A Transdisciplinary Blueprint for Energy Markets Modeled after Mycorrhizal Networks*	Spatial organization of energy infrastructure	Spatial data of planned infrastructure projects (location, length, number of poles, area)
		Geographic distribution of energy demands and overlap with natural areas	Spatial data of planned infrastructure projects (location, length, number of poles, area)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., ... Zhu, Z. (2014)	*Bringing an ecological view of change to Landsat-based remote sensing*	Habitat change data monitored with Landsat time-series data	Satellite imagery (OLI etc.)
		Past and present land use information for the area	Time-series data (e.g., 2013–2021 NDVI)
Shiklomanov, A. N., Bradley, B. A., Dahlin, K. M., M Fox, A., Gough, C. M., Hoffman, F. M., M Middleton, E., Serbin, S. P., Smallman, L., & Smith, W. K. (2019)	*Enhancing global change experiments through integration of remote-sensing techniques*	Biophysical variables such as vegetation, carbon flux, and soil moisture	Biodiversity indicators (fauna/flora density, habitat quality)
Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	*Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators*	Bioindicator species (e.g., locusts) distribution and abundance data	Biodiversity indicators (fauna/flora density, habitat quality)
		Pre- and post-intervention corridor monitoring data	Time-series data (e.g., 2013–2021 NDVI)
		Images of habitat quality using remote sensing	Satellite imagery (OLI etc.)
Huston, M. A. (2005)	*The three phases of land-use change: Implications for biodiversity*	Temporal cycles of land use change (disturbance, conversion, restoration)	Time-series data (e.g., 2013–2021 NDVI)
		Surface cover transformation and land dominance data	Time-series data (e.g., 2013–2021 NDVI)
		Species composition and abundance changes	Biodiversity indicators (fauna/flora density, habitat quality)

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Crowl, T. A., Crist, T. O., Parmenter, R. R., Belovsky, G., & Lugo, A. E. (2008)	*The spread of invasive species and infectious disease as drivers of ecosystem change*	Dispersal pathways of invasive species and pathogens (geographic source and destination data)	Blue-green infrastructure spatial planning data
		Human activities (ports, roads, energy infrastructure) and biological interference points	Impact reports and follow-up notifications regarding infrastructure-related events
		Species interactions (predator-prey, competition, symbiosis, etc.)	Biodiversity indicators (fauna/flora density, habitat quality)
Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	*Patterns of diversity along a habitat size gradient in a biodiversity hotspot*	Habitat area sizes and geographic locations	Biodiversity indicators (fauna/flora density, habitat quality)
		Species ecological niche characteristics and land use data	Biodiversity indicators (fauna/flora density, habitat quality)
		Species diversity, evenness, and endemism data	Biodiversity indicators (fauna/flora density, habitat quality)
		Level of fragmentation and connectivity among habitats	Biodiversity indicators (fauna/flora density, habitat quality)
		Habitat edge effects, degree of degradation, and human interaction data	Landscape quality indicators (habitat integrity, connectivity)
Dickie, M., Serrouya, R., DeMars, C., Cranston, J., & Boutin, S. (2017)	*Evaluating functional recovery of habitat for threatened woodland caribou*	Habitat quality (cover, vegetation, land use change) data	Blue-green infrastructure spatial planning data
		Post-intervention species-habitat interaction times	Impact reports and follow-up notifications regarding infrastructure-related events
		Restoration intervention timing and species response data	Impact reports and follow-up notifications regarding infrastructure-related events
		Habitat fragmentation and road density data	Blue-green infrastructure spatial planning data
		Species mobility data (GPS-tracked caribou populations)	Blue-green infrastructure spatial planning data
Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	*Mapping behavioral landscapes for animal movement: A finite mixture modeling approach*	GPS Animal movement routes derived from data	Blue-green infrastructure spatial planning data
		Behavior-based habitat use data for spatial modeling	Blue-green infrastructure spatial planning data
		Behavior classifications (e.g., feeding, resting, browsing)	Biodiversity indicators (fauna/flora density, habitat quality)
		Landscape structure, land cover, and human impact layers	Impact reports and follow-up notifications regarding infrastructure-related events

Author/s	Article Title	Data mentioned by the author/s	Labeled Data Categories
Lorang, M. S., Whited, D. C., Hauer, F. R., Kimball, J. S., & Stanford, J. A. (2005)	*Using airborne multispectral imagery to evaluate geomorphic work across floodplains of gravel-bed rivers*	Flood plain structure and watercourse data obtained from multispectral imagery	Satellite imagery (OLI etc.)
		Vegetation, soil moisture, and microtopographic structures	Biodiversity indicators (fauna/flora density, habitat quality)
		Geographically time-series sediment movement and channel change data	Time-series data (e.g., 2013–2021 NDVI)
Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	*The value of open power line habitat in conservation of ground beetles (Coleoptera: Carabidae) associated with mires*	Habitat types and structural features (e.g., open space, moist habitat) where power lines pass	Blue-green infrastructure spatial planning data
		Species-based distribution data on ground-level fauna, especially ground insects	Blue-green infrastructure spatial planning data
		Monitoring data on habitat connectivity and the contribution of open spaces to biodiversity	Landscape quality indicators (habitat integrity, connectivity)
		Records on management interventions (cutting, pruning, spraying, etc.) performed around the power line	Type of materials used in electricity infrastructure (copper, aluminum, neodymium, etc.)
		Spatial data of the lines (geometrically accurate GIS-based data)	Type of materials used in electricity infrastructure (copper, aluminum, neodymium, etc.)

E. Data-Related Challenges Mentioned in Literature

Author/s	Article Title	Challenges Related to Data Used
Gallo, M., Moreschi, L., & Del Borghi, A. (2022)	A Critical Environmental Analysis of Strategic Materials Towards Energy Transition	Inconsistency of LCA data across sources (e.g., lack of a lower limit for water use)
		High environmental impacts and data uncertainties for some strategic materials (e.g., iridium, platinum)
		Lack of recycling data, especially for critical metals
		Failure to integrate this LCA data into sustainable planning of grid infrastructure
Tomsana, A., Itoba-Tombo, E. F., & Human, I. S. (2020)	An analysis of environmental obligations and liabilities of an electricity distribution company to improve sustainable development	Non- or under-reporting of events
		Lack of spatial mapping of events, making it difficult to clarify responsibilities
		Inadequate use of environmental management systems, resulting in inability to monitor environmental performance
		Lack of institutional capacity (e.g., awareness of local legislation)
Gilad, D., May, R., Stokke, B. G., & Verones, F. (2024)	Between the lines: Life cycle impact assessment models of collision and electrocution impacts of power lines on bird diversity in Norway	Insufficient consideration of species-based behavioral differences in impact assessment models
		Difficulties in directly measuring biodiversity loss in life cycle models
		Measured impacts are often localized, making general policy development difficult
Guil, F., & Pérez-García, J. M. (2022)	Bird electrocution on power lines: Spatial gaps and identification of driving factors at global scales	Lack of data and unpublished studies in developing countries
		Low data comparability due to lack of standard protocols
		Availability of technical construction information Lack of data
		Large gaps in spatial representation (e.g., little to no data in Africa, South America, and Oceania)
Ajayi, V., Anaya, K., & Pollitt, M. (2022)	Incentive regulation, productivity growth and environmental effects: the case of electricity networks in Great Britain	Difficulty linking environmental outcomes to efficiency (e.g., carbon reduction may appear as a decrease in efficiency even though it improves quality)
		Current regulatory regimes (such as RIIO) contain numerous incentives, making data disaggregation and interpretation difficult.
		Focusing solely on financial outcomes in efficiency measurement can obscure environmental contributions.

Author/s	Article Title	Challenges Related to Data Used
Turconi, R., Simonsen, C. G., Byriel, I. P., & Astrup, T. (2013)	Life cycle assessment of the Danish electricity distribution network	Lack of original LCA data on grid infrastructure
		Environmental burdens of new systems such as underground cables are poorly documented (especially post-recycling effects).
		Most existing LCA studies focus solely on electricity generation; The effects of distribution are overlooked.
Raza, A., Syed, N. R., Fahmeed, R., Acharki, S., Aljohani, T. H., Hussain, S., Zubair, M., Zahra, S. M., Islam, A. R., Almohamad, H., & Abdo, H. G. (2024)	Investigation of changes in land use/land cover using principal component analysis and supervised classification from operational land imager satellite data – a case study of underdeveloped regions, Pakistan	Data quality and cloud cover in remote sensing-based classifications.
		Lack of sufficient generic data to relate changing land cover to biodiversity.
		Specialized techniques such as PCA require specialized analysis capacity in underdeveloped regions.
		Accuracy issues when field data collection is not available for ground-justifying satellite data.
Hoffman, K. N. (2023)	Justifying nature-based solutions	Lack of concrete, long-term data on the effectiveness of blue-green infrastructures.
		Risk of misidentifying “green” infrastructure in non-biodiversity-focused applications.
		Lack of sufficient comparative data to prioritize the benefits of nature-based solutions over other strategies.
		Lack of quantification of ecological benefits reduces project defensibility.
Cunha, J. S., Fonsêca, N. C., Vieira de Lima, C. R., Santos, J. G., Pereira, H. de, Bezerra, B. M., & Lins-e-Silva, A. C. (2024)	Minor loss or huge threat? Assessment of potential infrastructure projects reveals drastic landscape degradation in the Atlantic forest	Impact assessment approaches used for energy and transportation projects are inadequate.
		Lack of data can underestimate the potential degradation of natural landscapes during planning.
		Lack of cumulative impact analysis obscures the combined impacts of individual projects.
Katovich, E. (2023)	Quantifying the Effects of Energy Infrastructure on Bird Populations and Biodiversity	The varying impacts of energy infrastructures on species across their impact areas make generalizations difficult.
		The extent of impact on species is shaped not only by physical proximity but also by behavioral responses, making it difficult to collect such data.
		Long-term monitoring data on the impacts of solar and wind power plants is insufficient.
		The diverse habitat needs of birds necessitate separate analyses for each project.

Author/s	Article Title	Challenges Related to Data Used
Syaban, A. S., & Appiah-Opoku, S. (2024)	Unveiling the Complexities of Land Use Transition in Indonesia's New Capital City IKN Nusantara: A Multidimensional Conflict Analysis	Current decision support models used in infrastructure projects fail to adequately integrate ecological values.
		The lack of multidisciplinary and multi-scale data integration for complex land-use transitions complicates analyses.
		Lack of data sharing leads to communication gaps between local actors and central government.
		Inadequate up-to-date mapping and monitoring systems hinder the prediction of environmental impacts.
Burgin, S. (2016)	What about biodiversity? Redefining urban sustainable management to incorporate endemic fauna with particular reference to Australia	Urban planning systems lack the data infrastructure to consider the needs of endemic species.
		The fact that suitable habitats remain in fragmented or inaccessible areas limits restoration efforts.
		The inability to spatially model species-ecosystem relationships complicates the integration of biodiversity into urban design.
		The lack of concrete indicators of biodiversity in planning results in ineffective strategies.
Sokół, M., & Łaska, G. (2024)	Biodiversity and Ecosystem Services: Complementary Approach for Catchment Protection and Land Use in Northeastern Poland	The difficulty of integrating multi-scale data for integrating ecosystem services into planning.
		The incompatibility of habitat mosaics supporting species diversity with planning decisions and their loss under planning pressure.
		Lack of access by local decision-makers to maps supported by ecological data.
		A lack of measurability exists in expressing the value of conservation services.
He, X., & Wei, H. (2023)	Biodiversity Conservation and Ecological Value of Protected Areas: A Review of Current Situation and Future Prospects	A lack of a common methodology for calculating and monitoring ecological values in PA systems.
		There is a lack of data and definitional uncertainty regarding the reflection of ecosystem values in decision-making processes.
		Gaps exist in the integration of important areas such as KBAs into the existing PA system.
Aska, B., Franks, D. M., Stringer, M., & Sonter, L. J. (2023)	Biodiversity conservation threatened by global mining wastes	A lack of up-to-date, transparent, and reliable data on mining activities in developing countries.
		A lack of international data sharing, accountability assignment, and monitoring mechanisms in management systems.
		Inability to detect habitat-level impacts due to low spatial resolution of the data.
		Overlap of waste areas with ecosystems requiring protection, and inability to systematically analyze the impacts of these overlaps.

Author/s	Article Title	Challenges Related to Data Used
Appelt, J. L., Saphangthong, T., Malek, Ž., Verburg, P. H., & van Vliet, J. (2023)	Climate change impacts on tree crop suitability in Southeast Asia	Lack of accuracy in climate change projections at the regional level.
		Lack of communication between policymakers and scientific models.
		Lack of locally based data, particularly failure to account for microclimate differences.
		Model uncertainties in identifying potential habitats for different species.
Yang, R., Dong, X., Xu, S., Wang, K., Li, X., Xiao, W., & Ye, Y. (2024)	Fragmentation of Key Biodiversity Areas highlights attention to human disturbance patterns	Inadequate mapping of human impacts that put pressure on KBAs.
		Methodological limitations in obtaining consistent and detailed human pressure data at the global scale.
		Inadequacy of current protection statuses in reducing HFI values.
		Loss of habitat connectivity and patching effects (decreased mean patch size and increased perimeter-area ratio).
Miroshnyk, N. V., Likhanov, A. F., Grabovska, T. O., Teslenko, I. K., & Roubík, H. (2022)	Green infrastructure and relationship with urbanization – Importance and necessity of integrated governance	Lack of integrated datasets between green infrastructure and biodiversity in urban planning.
		Economic priorities and data-based decision-making challenges faced during policy implementation.
		Lack of coordination in planning due to dispersed duties and authorities between local and central governments.
		Lack of databases for the long-term protection of urban green infrastructure.
Dong, X., Gong, J., Zhang, W., Zhang, S., Hu, Y., Yang, G., Yan, C., & Li, F. Y. (2024)	Importance of including Key Biodiversity Areas in China's conservation area-based network	The protected area system's inadequate coverage of existing KBAs.
		Lack of data clarity and lack of strategic integration.
		Planning gaps due to neglecting ecosystem services and biodiversity.
		KBAs' lack of overlap with areas that should be ecologically representative.
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	Nature-based climate solutions for expanding the global protected area network	Decision-makers' failure to consider climate and biodiversity objectives together.
		Misplacement of carbon-focused protected areas due to a lack of data.
		Nature-based solutions are evaluated by reducing them to short-term climate targets.
		Exclusion of local communities from the data and disregard of local knowledge systems.

Author/s	Article Title	Challenges Related to Data Used
Aticho, A., Beyene, A., Zelelew, S. A., Nigussie, A., Gutema, T. M., Bakkestuen, V., & Chala, D. (2023a)	Observed and projected changes in urbanization and nature conservation in a typical fast growing city of Ethiopia, Jimma	Fragmentation of protected areas due to rapid urban growth.
		Insufficient data resolution and methodological limitations in spatial analysis of urban sprawl.
		The exclusion of nature conservation priorities from land-use planning.
		Lack of long-term monitoring systems.
Kraus, D., Enns, A., Hebb, A., Murphy, S., Drake, D. A., & Bennett, B. (2022)	Prioritizing nationally endemic species for conservation	Lack of systematic conservation plans for endemic species at the national level.
		Problems with data openness and explainability in conservation prioritization.
		Lack of sufficient distribution data for species.
		Uncertainty in setting conservation priorities due to the lack of use of decision support systems.
Peck, M. R., Desselas, M., Bonilla-Bedoya, S., Redín, G., & Durango-Cordero, J. (2024)	The conflict between Rights of Nature and mining in Ecuador: Implications of the Los Cedros Cloud Forest case for biodiversity conservation	Serious gaps in implementation despite constitutional recognition of legal rights to nature.
		Incompatibility between rights-based approaches and economic interests.
		Inadequate and lack of transparency in environmental impact assessments for mining projects.
		Limited access to and participation in data by indigenous people and local communities.
Allard, S., & Aydınoğlu, A. U. (2012)	*Environmental Researchers' Data Practices: An Exploratory Study in Turkey*	Weak data sharing culture.
		Legal uncertainties and ethical concerns hinder data sharing.
		Lack of sharing platforms and inadequate existing systems.
		Insufficient metadata entry and data quality issues.
		Lack of data standardization and lack of open access infrastructure.

Author/s	Article Title	Challenges Related to Data Used
Jetz, W., McGeoch, M. A., Guralnick, R., Ferrier, S., Beck, J., Costello, M. J., Fernandez, M., Geller, G. N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F. E., Pereira, H. M., Regan, E. C., Schmeller, D. S., & Turak, E. (2019)	*Essential biodiversity variables for mapping and monitoring species populations*	Data is spatially, temporally, and taxonomically heterogeneous and incomplete.
		Incompatibility of data collection practices restricted by national boundaries with global decision support systems
		Infrequent and unreliable collection of absence data
		Limited community incentives for data sharing
		Lack of sampling protocols for citizen science data
		Inadequate standard data and metadata infrastructures (e.g., Humboldt Core is not yet widespread)
Kiesecker, J. M., Baruch-Mordo, S., Baumgarten, L., Cameron, D. R., Cardenas Lopez, J. J., Crane, L., Evans, J. S., Fargione, J., & Naugle, D. E. (2017)	nergy Sprawl Solutions: Balancing Global Development and Conservation	Inability to predict development pressures spatially
		Inability to link species-level data to spatial planning
		Failure to consider biodiversity data in planning processes
		Lack of integration of conservation plans with national policies
		Inadequate monitoring of conservation offsets (compensation mechanisms)
Moreira, F. (2019)	*Love me, love me not: Perceptions on the links between the energy sector and biodiversity conservation*	Lack of a sense of responsibility for biodiversity within the energy sector
		Inadequate implementation of species protection guidelines
		Lack of coordination and data sharing among institutions
		Failure to consider nature conservation legislation in energy infrastructure planning
Chamanara, J., Gaikwad, J., Gerlach, R., Algergawy, A., Ostrowski, A., & König-Ries, B. (2021)	*BEXIS2: A FAIR-aligned data management system for biodiversity, ecology and environmental data*	Data are heterogeneous, fragmented, and poorly reusable
		Lack of flexible, sustainable systems capable of managing the data lifecycle
		Lack of metadata entry and versioning Lack of tracking
		Data not compliant with FAIR (Findable, Accessible, Interoperable, Reusable) principles

Author/s	Article Title	Challenges Related to Data Used
Costello, M. J., & Wieczorek, J. (2014)	*Best practice for biodiversity data management and publication*	Data records incomplete, inaccurate, or conflicting
		Difficulties in sharing due to copyright and usage restrictions
		Published data contains insufficient metadata for reuse
		Lack of data management knowledge among publishers and researchers
Chamanara, J., & König-Ries, B. (2014)	*A conceptual model for data management in the field of ecology*	Inability to establish a consistent management model due to the inherent diversity of ecological data
		Lack of data systems that can be customized to user needs
		Lack of contextual information to ensure interpretability of datasets
		Lack of integrated systems for storage, access, and version tracking
Gadelha, L. M., de Siracusa, P. C., Dalcin, E. C., da Silva, L. A., Augusto, D. A., Krempser, E., ... & de Siqueira, M. F. (2020)	*A survey of biodiversity informatics: Concepts, practices, and challenges*	Lack of standardization and data incompatibility in biodiversity data
		User interfaces not accessible to non-technical users
		Weak interdisciplinary data integration
		Lack of open access and long-term sustainability in data systems
Urbano, F., Viterbi, R., Pedrotti, L., Vettorazzo, E., Movalli, C., & Corlatti, L. (2023)	*Enhancing biodiversity conservation and monitoring in protected areas through efficient data management*	Lack of infrastructure for data collection and management in protected areas
		Lack of systems to ensure the sustainability of biodiversity data
		Inconsistent, fragmented, and outdated databases
		Regional incompatibilities and methodological differences in observation standards
		Institutional barriers and lack of coordination in sharing monitoring data

Author/s	Article Title	Challenges Related to Data Used
Anderson, R. P., Araújo, M. B., Guisan, A., Lobo, J. M., Martínez-Meyer, E., Peterson, A. T., & Soberón, J. M. (2020)	*Optimizing biodiversity informatics to improve information flow, data quality, and utility for science and society*	Inefficient data flow between science and society
		Lack of collaboration and data standardization among institutions
		Incompatibility of content and formats in data from various sources
		User-unfriendly information management infrastructures
		Inadequate data quality assurance mechanisms
Ball-Damerow, J. E., Brenskelle, L., Barve, N., Soltis, P. S., Sierwald, P., Bieler, R., LaFrance, R., Ariño, A. H., & Guralnick, R. (2019)	*Research applications of primary biodiversity databases in the digital age*	Most species data are stored in project-specific formats and for short periods of time
		Lack of integration with global systems and lack of data quality control
		Lack of financial resources for sustainable database management
		Data not categorized appropriately for analyses
		Data not updated or lost access over time
Enke, N., Thessen, A., Bach, K., Bendix, J., Seeger, B., & Gemeinholzer, B. (2012)	*The user's view on biodiversity data sharing: Investigating facts of acceptance and requirements to realize a sustainable use of research data*	Insufficient support for data sharing through scientific awards
		User-unfriendly open data systems and lack of institutional support
		Widespread concerns about data misuse
		Lack of sustainable data management infrastructures
		Lack of metadata and lack of standardization
Huvenne, V. A. I., Bett, B. J., Masson, D. G., Le Bas, T. P., & Wheeler, A. J. (2016)	*Effectiveness of a deep-sea cold-water coral Marine Protected Area*	Deep Technical and logistical challenges of collecting data in marine environments
		Lack of standardization of monitoring protocols and local data gaps
		Lack of long-term and consistent data to assess the impact of protected areas
		Inability to monitor fishing activities and disaggregate cumulative impacts
		Lack of time-series visual/data records for determining habitat changes

Author/s	Article Title	Challenges Related to Data Used
Hughes, K. A., & Pertierra, L. R. (2016)	*Evaluation of non-native species policy development and implementation in the UK*	Incomplete, irregular, and outdated invasive species data
		Uncertainty of distribution estimates due to climate change
		Inadequacy of early warning and monitoring systems for species identification
		Lack of data sharing and coordination among different institutions
		Inability to measure the impact of policy implementation on the ground
van Strien, A. J., Meyling, A. W., Herder, J. E., Hollander, H., Kalkman, V. J., Poot, M. J. M., Turnhout, S., van der Hoorn, B., van Strien-van Liempt, W. T. F. H., van Swaay, C. A. M., van Turnhout, C. A. M., Verweij, R. J. T., & Oerlemans, N. J. (2016)	*Modest recovery of biodiversity in a Western European country: The Netherlands*	Limited effectiveness of conservation measures implemented without ensuring habitat integrity
		Difficulties in evaluating climate, agricultural policies, and land-use changes together
		Length of time required to collect data at the species level
		Incomplete or irregular species monitoring data for some taxonomic groups
		Time lag in measuring the impact of habitat restoration projects
Bussotti, F., Papitto, G., Di Martino, D., Cocciufa, C., Cindolo, C., Cenni, E., Bettini, D., Iacopetti, G., Ghelardini, L., Moricca, S., Panzavolta, T., Bracalini, M., & Pollastrini, M. (2024)	*Extreme climatic events, biotic interactions and species-specific responses drive tree crown defoliation and mortality in Italian forests*	Spatial and temporal inconsistency of data in monitoring species-specific responses
		Lack of coverage of forest health monitoring networks and low-frequency data collection
		Lack of time series long enough to distinguish the effects of extreme climate events
		Lack of data on stress thresholds and adaptive capacity of different species
		Data limitations in accurately modeling biotic interactions (e.g., competition, pest impact)

Author/s	Article Title	Challenges Related to Data Used
Gould, Z., Day, S., Reichard, G., Shealy, T., & Saad, W. (2023)	*A Transdisciplinary Blueprint for Energy Markets Modeled after Mycorrhizal Networks*	Planning existing energy infrastructure without considering ecological functionality
		Methodological uncertainties in incorporating ecological network dynamics into energy infrastructure modeling
		Lack of biomimicry-based data modeling and the challenge of multidisciplinary data integration
		Lack of empirical data in harmonizing energy systems with nature
		Parameter deficiencies in adapting the behavior of natural networks to the energy system
Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., ... Zhu, Z. (2014)	*Bringing an ecological view of change to Landsat-based remote sensing*	Lack of standardization of time-series analysis in processing Landsat data
		Gaps in converting remote sensing data into ecological interpretation
		Interpretation uncertainty in directly relating spectral changes to ecological processes
		Linking surface cover changes to habitat quality Lack of ground truthing data
		The ability to observe degradation and recovery dynamics simultaneously in the same pixel (clutter effect)
Shiklomanov, A. N., Bradley, B. A., Dahlin, K. M., M Fox, A., Gough, C. M., Hoffman, F. M., M Middleton, E., Serbin, S. P., Smallman, L., & Smith, W. K. (2019)	*Enhancing global change experiments through integration of remote-sensing techniques*	Methodological gaps in the integration of large-scale remote sensing data with experimental sites
		Inability to directly measure subsoil or biotic interactions with remote sensing
		The complexity of sensor technologies and high data processing requirements
		Risk of errors in generalizing the dynamics of widely dispersed habitats from individual experimental sites
		Low representativeness of sites leading to incorrect generalizations in experimental analysis

Author/s	Article Title	Challenges Related to Data Used
Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	*Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators*	Inability to monitor the impact of past land use practices on habitat quality within conservation corridors
		Lack of standardized monitoring protocols to assess the effectiveness of interventions
		Lack of long-term and detailed data for bioindicator species
		Inhomogeneity of habitat degradation levels within and between sites
		Analysis limitations in correlating time-series NDVI data with past interventions
Huston, M. A. (2005)	*The three phases of land-use change: Implications for biodiversity*	Lack of long-term monitoring data needed to determine the stage of the degradation process
		The effects of agricultural or urban pressures that inhibit ecological recovery
		Inability to clearly observe the short-term effects of land change on biodiversity
		The necessity of complex analysis due to the existence of multiple land-use phases simultaneously
		Uncertainty of the recovery process and failures of management interventions
Crowl, T. A., Crist, T. O., Parmenter, R. R., Belovsky, G., & Lugo, A. E. (2008)	*The spread of invasive species and infectious disease as drivers of ecosystem change*	The rapid spread of invasive species through human-induced transport and difficulty in monitoring
		Lack of transboundary data sharing and monitoring infrastructure
		Insufficient data to detect disease transmission between aquatic and terrestrial systems
		The difficulty of simultaneously monitoring the factors affecting spread (climate, competition, predation)
		Inability to systematically model interspecies interactions
		Lack of long-term monitoring systems

Author/s	Article Title	Challenges Related to Data Used
Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	*Patterns of diversity along a habitat size gradient in a biodiversity hotspot*	Small habitat fragments under greater invasive species pressure
		Data inadequacy in setting conservation priorities in fragmented areas Inadequacy
		Disappearance of species in fragmented areas (community disassembly)
		Differences in ecological context that reduce the generalizability of observations
		Complexity of the relationship between habitat size and biodiversity
		Inability to monitor environmental variability within habitats
Dickie, M., Serrouya, R., DeMars, C., Cranston, J., & Boutin, S. (2017)	*Evaluating functional recovery of habitat for threatened woodland caribou*	Excessive time lag for ecosystem recovery after restoration (decades)
		Uncertainty about the contribution of artificial increases in habitat quality associated with restoration to functional transformation
		Persistent impact of forest road density and accessibility on species behavior
		Lack of sufficient time-series data to measure the impact of interventions
		Species do not reuse former habitats.
Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	*Mapping behavioral landscapes for animal movement: A finite mixture modeling approach*	Data resolution limitations in geographically interpreting animal behavior.
		Difficulty in measuring the long-term effects of behavioral barriers created by energy infrastructure on migration and mobility.
		Species-specific differences in the classification of behavioral modes.
		Need to model indirect effects rather than directly observe infrastructure effects.
Lorang, M. S., Whited, D. C., Hauer, F. R., Kimball, J. S., & Stanford, J. A. (2005)	*Using airborne multispectral imagery to evaluate geomorphic work across floodplains of gravel-bed rivers*	Existing infrastructure (dams, bridges) alter flood dynamics.
		Lack of integrated datasets to analyze the impact of changing geomorphological structures over time on the distribution of living species.
		Loss of habitat complexity and degradation of fish and wildlife breeding grounds.
		The spatial resolution of multispectral data is not always sufficient.

Author/s	Article Title	Challenges Related to Data Used
Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	*The value of open power line habitat in conservation of ground beetles (Coleoptera: Carabidae) associated with mires*	Lack of standardized power line management practices and their inability to correlate with biological monitoring.
		The potential for energy companies to regularly destroy open spaces with habitat value, and the inability to quantify the impacts of this destruction with data.
		Lack of long-term, spatially comparable data at the species level for microfauna such as ground insects.
		Determining whether open spaces have conservation value. Lack of long-term monitoring to identify potential sources of contamination
		Difficulties in collecting data on the line's impact on microhabitats (e.g., difficult to identify sub-factors affecting the distribution of small species)

F. Strategies Mentioned in Literature

Author/s	Article Title	Strategies
Gallo, M., Moreschi, L., & Del Borghi, A. (2022)	A Critical Environmental Analysis of Strategic Materials Towards Energy Transition	The environmental impacts of critical materials should be monitored throughout their lifecycle (LCA).
		The use of materials such as platinum and iridium, in particular, should be monitored, and alternatives should be evaluated to reduce environmental risks.
		The use of recycled materials should be encouraged.
		Energy and water consumption should be reduced and greenhouse gas emissions minimized in the production processes of strategic materials used in grid infrastructure.
		Material choices should be prioritized based on their environmental impact.
Tomsana, A., Itoba-Tombo, E. F., & Human, I. S. (2020)	An Analysis of Environmental Obligations and Liabilities of an Electricity Distribution Company	Electricity distribution companies should ensure the reporting and mapping of environmental incidents (e.g., bird deaths, fires).
		Liabilities (compensation, repairs) arising from failure to fulfill environmental obligations should be clearly defined and implemented.
		Companies' sustainability performance should be improved by implementing environmental management systems (e.g., ISO 14001).
		Special measures should be taken against biodiversity threats (e.g., insulation or design changes against bird deaths).
		Environmental incidents should be monitored through incident management systems (e.g., SAP EH&S).
Guil, F., & Pérez-García, J. M. (2022)	Bird Electrocution on Power Lines	The lethal effects of power lines on birds cannot be adequately assessed due to a lack of data, especially in developing countries – data sharing should be encouraged.
		Distribution line designs should be modified (insulation, wider conductor spacing, etc.) to reduce bird mortality.
		Technical configurations that reduce the risk of electrocution (e.g., replacing line heads, overhead insulation) should be implemented globally.
		Mortality hotspots should be identified, and preventative planning should be implemented, especially in areas where new power lines are planned.
		Standardized monitoring protocols should be developed.

Author/s	Article Title	Strategies
Gilad, D., May, R., Stokke, B. G., & Verones, F. (2024)	Between the Lines	Collision and electrocution effects should be included in life cycle analyses.
		Separate models should be used for impacts on bird diversity.
		Decision support tools should be developed for infrastructure projects to estimate impacts and model mitigation strategies.
		Targeted mitigation strategies should be implemented for species with conservation priorities.
		The location and height of power lines should be optimized, taking into account the movement and behavioral patterns of bird species.
Soares, N., Martins, A. G., Carvalho, A. L., Caldeira, C., Du, C., Castanheira, Rodrigues, E., Oliveira, G., Pereira, G. I., Bastos, J., Ferreira, J. P., Ribeiro, L. A., Figueiredo, N. C., Šahović, N., Miguel, P., & Garcia, R. (2018)	The Challenging Paradigm of Interrelated Energy Systems	The integration of energy systems should be supported by nature-based planning models to reduce ecological impacts.
		Multi-criteria scenario analyses should be used in planning, and environmental components should be prioritized.
		Interdisciplinary collaborations should be encouraged, and environmental assessments should be integrated into energy systems.
		Digitalization of distribution systems can facilitate the development of environmental feedback mechanisms.
		Ecosystem services (water cycle, carbon sinks, etc.) should be considered in energy systems planning.
Turconi, R., Simonsen, C. G., Byriel, I. P., & Astrup, T. (2013)	Life Cycle Assessment of the Danish Electricity Distribution Network	The environmental impacts of electricity distribution infrastructure should be assessed throughout its lifecycle (LCA).
		The environmental impacts of infrastructure choices, such as underground cables and the use of aluminum instead of copper, should be analyzed.
		Reducing energy losses during transmission and distribution is a priority for reducing environmental burden.
		With the increase in renewable energy sources, monitoring infrastructure impacts becomes even more important.
		LCA of electricity distribution networks contributes to the consideration of environmental components in planning decisions.
Leme, R. C., Paiva, A. P., Steele Santos, P. E., Balestrassi, P. P., & Galvão, L. de. (2014)	Design of Experiments Applied to Environmental Variables Analysis in Electricity Utilities	The effects of environmental variables (e.g., precipitation, temperature, humidity) should be modeled through experimental designs in electricity infrastructure planning.
		The impact of environmental variables on infrastructure performance (number of failures, maintenance costs, etc.) should be analyzed to support planning decisions.
		Energy distribution companies should develop more resilient and environmentally friendly infrastructures by taking into account the variability in natural conditions.
		Systems integrated with environmental data enable planning that prevents damage to biodiversity.

Author/s	Article Title	Strategies
Ajayi, V., Anaya, K., & Pollitt, M. (2022)	Incentive Regulation, Productivity Growth and Environmental Effects	Regulations aimed at increasing the efficiency of electricity grids should also include environmental performance criteria.
		Regulations should encourage companies to optimize both economic and environmental performance (e.g., eco-efficiency).
		Environmental incentives should be provided for infrastructure modernization aimed at reducing carbon emissions.
		Efficiency analyses (e.g., emissions-intensive locations) aligned with biodiversity conservation goals should be conducted.
Cunha, J. S., Fonsêca, N. C., Vieira de Lima, C. R., Santos, J. G., Pereira, H. de, Bezerra, B. M., & Lins-e-Silva, A. C. (2024)	*Minor loss or huge threat?*	It is recommended that new infrastructure projects be completely blocked in areas critical for biodiversity (e.g., the Atlantic Forest).
		Alternative site analyses should be conducted based on scientific data, and only the least harmful options should be considered.
		It is emphasized that project construction in protected areas should be thoroughly examined for environmental impacts.
		Preserving the integrity of ecological corridors and habitat connectivity is considered essential to prevent forest fragmentation.
		It is stated that assessments that consider long-term impacts should be conducted not only within the project area but also within the overall landscape.
		It is recommended that collaboration be fostered between the public, academia, and environmental organizations to support science-based decision-making processes.
		Indirect impacts, such as the carbon emissions and watershed impacts of forest loss, should also be included in project assessments.
Katovich, E. (2023)	Quantifying the Effects of Energy Infrastructure on Bird Populations and Biodiversity	The impacts of energy infrastructure should be estimated using models that consider behavioral responses specific to bird species.
		Integration of infrastructure with species distribution models is recommended, and risks, such as collision/electric shock, should be analyzed, particularly for sensitive species.
		Spatial data such as habitat use data and migration routes should be used in infrastructure planning; arrangements should be made according to dynamic ecological demands, not fixed routes.
		Complex ecological responses (e.g., indirect hunting pressure, habitat avoidance) should be considered, and these impacts should not be limited to direct mortality.
		Mitigation strategies should be developed specifically for infrastructure type and geography (e.g., visibility signs, cable insulation).
Hoffman, K. N. (2023)	Justifying nature-based solutions	Nature-based solutions (NbS) can enable the combined planning of biodiversity and carbon benefits in energy infrastructure.
		Blue-green infrastructures should be presented as an alternative to gray infrastructure, and the use of natural ecosystem services should be prioritized.
		Collaboration with local communities and traditional knowledge systems are considered critical to the success of nature-based approaches.
		NbS applications should consider not only ecological but also social and aesthetic values, thereby increasing public support.
		It is advocated that aesthetic and cultural values should also be integrated into decision-making mechanisms in policy-making.

Author/s	Article Title	Strategies
Raza, A., Syed, N. R., Fahmeed, R., Acharki, S., Aljohani, T. H., Hussain, S., Zubair, M., Zahra, S. M., Islam, A. R., Almohamad, H., & Abdo, H. G. (2024)	Investigation of changes in land use: LULC and PCA analysis	Remote sensing and spatial analysis techniques can be used to determine the impacts of infrastructure projects on land cover at an early stage.
		Decision support systems should be used to visualize the environmental impacts of infrastructure projects and develop preventative strategies.
		Agriculture, forest, and settlement transformations should be prioritized for projects such as energy infrastructure, and their impacts should be monitored using multiple criteria.
		The frequency of monitoring periods and data quality are critical for accurate modeling of land changes.
Syaban, A. S., & Appiah-Opoku, S. (2024)	*Unveiling the Complexities of Land Use Transition in Indonesia's New Capital City IKN Nusantara*	The multidimensional impacts of land use transitions (ecological, economic, social) should be considered in new infrastructure projects.
		Planning processes should be shaped not only by the current land cover but also by the potential risk of ecological degradation.
		Local people's knowledge and perceptions should be considered as active tools in protecting biodiversity, and participatory planning processes should be supported.
		Internal (population growth, urbanization pressure) and external (infrastructure investments) pressures should be considered together in terms of conservation priorities.
		Comprehensive planning for buffer zones located next to protected areas can prevent habitat fragmentation.
		Comprehensive environmental impact assessment and multi-criteria analysis systems are recommended for decision-making processes.
Burgin, S. (2016)	*What about biodiversity? Redefining Urban Sustainable Management to Incorporate Endemic Fauna with Particular Reference to Australia*	The concept of urban sustainability should be redefined with the perspective of protecting endemic species.
		Biodiversity criteria should be made mandatory in urban infrastructure planning, and priority should be given to local fauna species.
		Green space arrangements should be implemented to reduce the dominance of generalist and invasive species.
		Habitat islands with ecological functions should be planned in an integrated manner with infrastructure projects within the city.
		Urban planning processes should support landscape preferences with high biodiversity sensitivity.
		Long-term observation and assessment systems should be established for ecological monitoring and urban biodiversity management.
		Sustainable urbanization should not be solely human-focused but should be based on the sustainability of multi-species life.

Author/s	Article Title	Strategies
Sokół, M., & Łaska, G. (2024)	*Biodiversity and Ecosystem Services: Complementary Approach for Catchment Protection and Land Use in Northeastern Poland*	Biodiversity and ecosystem services should be considered as complementary planning themes.
		Basin-based conservation strategies should be developed, and water quality, agricultural production, and habitat continuity should be considered together.
		Multifunctional land use should be supported; both biodiversity and economic activities (e.g., agriculture) should be balanced.
		Infrastructure impacts should be reduced through nature-based solutions (e.g., buffer zones, natural barriers).
		The protection of native species should be integrated into all land use planning, not just within protected areas.
		The continuity of ecosystem services must be considered in land use changes.
He, X., & Wei, H. (2023)	*Biodiversity Conservation and Ecological Value of Protected Areas: A Review of Current Situation and Future Prospects*	The ecological value of protected areas should be systematically assessed, and management priorities should be determined based on these values.
		International priority areas, such as Key Biodiversity Areas (KBA), should be more effectively integrated into the protected area network.
		New areas should be declared strategically within the scope of the global 30% conservation target by 2030.
		Protected area systems should not only be expanded numerically but also their functionality should be enhanced qualitatively.
		Habitat continuity should be ensured by increasing the connectivity of terrestrial and marine protected areas.
		Conservation priorities should also be recognized in areas outside KBAs, with special attention given to these areas, for example, in energy infrastructure planning.
Aska, B., Franks, D. M., Stringer, M., & Sonter, L. J. (2023)	*Biodiversity Conservation Threatened by Global Mining Wastes*	The spread of mining waste (especially tailings storage facilities – TSF) is among the priority issues threatening biodiversity.
		During the planning of TSFs, decision support systems should be used to prevent spatial overlap with KBAs and protected areas.
		Because habitat degradation caused by mining activities leads to widespread environmental impacts that are not limited to the project site, cluster-based risk assessment systems are recommended.
		Waste spread, soil, and water contamination should be detected early through monitoring systems (e.g., remote sensing), and preventive strategies should be developed.
		Identifying biodiversity-sensitive raw material sources within supply chains should influence direct investment decisions.
		Mining projects should be evaluated not only in terms of environmental but also in terms of managerial and institutional capacity, as most damage is associated with weak governance.

Author/s	Article Title	Strategies
Dong, X., Gong, J., Zhang, W., Zhang, S., Hu, Y., Yang, G., Yan, C., & Li, F. Y. (2024)	Importance of including Key Biodiversity Areas in China's conservation area-based network	Quality, not quantity, should be the priority in protected area selection: Instead of focusing on area size, prioritization should be based on criteria such as species richness, carbon stock, and ecosystem services.
		Key Biodiversity Areas (KBAs) should be included in the conservation network: Nationally and globally defined KBAs should be used, particularly for the protection of high-impact endemic and threatened species.
		Strategic conservation planning should be conducted based on analysis of risks such as climate change and human pressures: Planning without considering these risks can jeopardize long-term conservation.
		Protected areas should encompass not only species but also ecological benefits such as carbon storage, aesthetic value, and nutrient cycling.
		Conservation objectives should be compatible with the socioeconomic structure of local communities; otherwise, land-use conflicts may arise.
		Priority areas should be identified through data-based spatial analyses: Distribution, threat level, and ecosystem services should be integrated into plans supported by decision support systems.
Yang, R., Dong, X., Xu, S., Wang, K., Li, X., Xiao, W., & Ye, Y. (2024)	*Fragmentation of Key Biodiversity Areas Highlights Attention to Human Disturbance Patterns*	The integrity of KBAs should be preserved because, despite their protected status, many KBAs are severely fragmented.
		Spatial patterns of fragmentation should be analyzed, and these analyses should guide conservation measures (for example, areas within KBAs where human activities are concentrated should be mapped).
		Because human-induced degradation, such as energy infrastructure, causes habitat fragmentation in KBAs, impacts should be assessed through scenario analyses before these projects are implemented.
		Energy investments within or near KBA boundaries should be replanned or reoriented to avoid disrupting habitat connectivity.
		Declaring a protected area alone is not sufficient; active monitoring and preventative policies against degradation trends are necessary.
		Using high-resolution spatial data, the impact of infrastructure projects on sensitive areas can be predicted, and conservation-focused spatial planning can be implemented.
Appelt, J. L., Saphangthong, T., Malek, Ž., Verburg, P. H., & van Vliet, J. (2023)	*Climate Change Impacts on Tree Crop Suitability in Southeast Asia*	Climate change impacts should be monitored spatially, and the impacts of these changes on habitat suitability should be considered in energy infrastructure planning.
		Energy investments should be directed away from areas where climate-induced habitat shifts are expected; areas that will gain conservation priorities in the future should be identified in advance.
		Competing land uses, such as agriculture and energy, should be addressed with holistic approaches from a biodiversity perspective, and harmonized land planning should be implemented across these sectors.
		Sustainable land use plans should be prepared on a scenario-based basis, taking into account the future distribution of species.
		Areas where endemic species live or overlap with production should be identified as sensitive areas, particularly in conservation planning.
		Energy infrastructure construction and operation should not be positioned in a way that reduces long-term climate resilience (e.g., large projects that disrupt microclimate).

Author/s	Article Title	Strategies
Miroshnyk, N. V., Likhanov, A. F., Grabovska, T. O., Teslenko, I. K., & Roubík, H. (2022)	*Green Infrastructure and Relationship with Urbanization: Importance and Necessity of Integrated Governance*	Green infrastructure should be integrated into urban development and energy infrastructure planning, and the impacts of gray infrastructure on nature should be mitigated.
		Habitat continuity should be ensured by prioritizing areas connected to ecological corridors in energy infrastructure projects.
		Increasing infrastructure demands due to urban growth should be balanced with nature-based solutions; for example, green belts should be protected in areas where power lines pass.
		The impacts of energy projects on biodiversity should be managed more effectively by ensuring integration between local and national management units.
		Planning processes should be structured to include community participation and multi-actor governance.
		The economic, social, and environmental functions of green infrastructure should be defined, and these functions should be linked to energy planning (e.g., carbon sinks, heat island effect, species refuge).
Kraus, D., Enns, A., Hebb, A., Murphy, S., Drake, D. A., & Bennett, B. (2022)	*Prioritizing Nationally Endemic Species for Conservation*	Prioritizing endemic species at the national level ensures more effective protection in areas where habitats are under pressure from transformation (e.g., in areas affected by energy projects).
		Energy infrastructure planning should consider not only existing protected areas but also areas with high concentrations of endemic species.
		Conservation investments and environmental impact assessments should be directed to areas where endemic species are found, allowing for more efficient use of limited resources.
		Detailed spatial analyses should be used to determine whether energy investments are disrupting habitat integrity, particularly for species at high risk.
		Policy recommendations should be developed in coordination with the geographic distribution of species; this requires the establishment of systems that integrate energy and protected area planning.
Peck, M. R., Desselas, M., Bonilla-Bedoya, S., Redín, G., & Durango-Cordero, J. (2024)	*The Conflict between Rights of Nature and Mining in Ecuador: Implications of the Los Cedros Cloud Forest Case*	Approaches based on the rights of nature principle provide a strong legal framework for limiting the impacts of large infrastructure projects, such as energy and mining activities, on biodiversity.
		Energy infrastructure decisions should be informed by ethical principles that are not solely human-centered but ecosystem-centered.
		In areas of high ecological value (such as cloud forests), energy projects should be clearly limited or prohibited by law.
		Court decisions can not only halt a specific project but also set precedents that recognize the rights of nature more broadly (preemptive and precedent rulings).
		Actors operating in the energy sector should review their investment decisions by considering environmental legal frameworks that include the rights of nature.
		Conservation-focused decision support systems should be integrated into the planning process, based on the intrinsic value of nature.

Author/s	Article Title	Strategies
Sreekar, R., Zeng, Y., Zheng, Q., Lamba, A., Teo, H. C., Sarira, T. V., & Koh, L. P. (2022)	*Nature-based Climate Solutions for Expanding the Global Protected Area Network*	Nature-based climate solutions (NbCS) offer an effective and cost-effective strategy for expanding the protected area network; this approach can also be used in energy infrastructure planning.
		By financing protected areas with carbon credits, both climate goals and biodiversity conservation can be served.
		Energy projects should be removed from areas with high carbon storage capacity and rich species.
		The protected area designation process should be shaped not only by political or legal criteria, but also by data based on ecosystem services and climate contribution.
		Integrating the energy sector with climate policies can ensure development aligned with conservation priorities.
		Priority areas should be multifunctional in terms of carbon stock and biodiversity; these areas should be exempt from energy projects.
Aticho, A., Beyene, A., Zelelew, S. A., Nigussie, A., Gutema, T. M., Bakkestuen, V., & Chala, D. (2023a)	*Observed and Projected Changes in Urbanization and Nature Conservation in Jimma, Ethiopia*	In rapidly urbanizing regions, energy demand is increasing, increasing the risk of direct conflict with protected areas; therefore, spatial analysis should be mandatory for energy investments.
		Nature conservation strategies should be revised to consider current urbanization pressures and future growth projections.
		Replanning protected areas in an integrated manner with the city can reduce conflict with energy infrastructure.
		Environmental impacts during urbanization should be monitored with early warning systems, and infrastructure projects should be directed to avoid triggering environmental degradation.
		Energy infrastructure planning should be supported by nature-based solutions to ensure spatial reconciliation between nature and human needs in rapidly growing cities.
Kiesecker, J. M., Baruch-Mordo, S., Baumgarten, L., Cameron, D. R., Cardenas Lopez, J. J., Crane, L., Evans, J. S., Fargione, J., & Naugle, D. E. (2017)	*Energy Sprawl Solutions: Balancing Global Development and Conservation*	A "Development by Design" approach is recommended, with which energy infrastructure is spatially planned to minimize impacts on biodiversity.
		Conservation priorities and energy needs are analyzed on the same map using GIS-based decision support systems, preventing conflicts.
		Offset and set-aside strategies are used to identify sensitive areas where energy investments cannot be made, and compensation mechanisms are defined.
		The identification of priority conservation areas at the global level is recommended as a guide for investment decisions.
		Land-use conflicts are anticipated and integrated into planning through scenario modeling.

Author/s	Article Title	Strategies
Moreira, F. (2019)	*Love Me, Love Me Not: Perceptions on the Links Between the Energy Sector and Biodiversity Conservation*	Strengthening the perceptions of energy sector stakeholders regarding nature conservation is recommended; training, guidance documents, and sectoral collaborations are important for this purpose.
		Sectoral guidance should be provided on biodiversity-friendly practices; for example, conservation experts should be included in project evaluation processes.
		Conservation directives should be aligned with energy legislation, thus eliminating ambiguities in the legal framework.
		Early-stage environmental impact assessment and public participation encourage biodiversity-friendly approaches in energy projects.
		Voluntary conservation commitments by energy companies have been recommended to mitigate biodiversity damage in direct investment regions.
Allard, S., & Aydınoğlu, A. U. (2012)	*Environmental Researchers' Data Practices: An Exploratory Study in Turkey*	Standard data formats and sharing protocols are recommended to facilitate sectoral collaborations.
Jetz, W., McGeoch, M. A., Guralnick, R., Ferrier, S., Beck, J., Costello, M. J., Fernandez, M., Geller, G. N., Keil, P., Merow, C., Meyer, C., Muller-Karger, F. E., Pereira, H. M., Regan, E. C., Schmeller, D. S., & Turak, E. (2019)	*Essential Biodiversity Variables for Mapping and Monitoring Species Populations*	The Essential Biodiversity Variables (EBV) concept enables the standardized collection of data, such as species distribution and abundance, at a global scale.
		Remote sensing and modeling-based data integration enables holistic biodiversity assessment for infrastructure planning.
		Predictive species distribution models can support energy infrastructure decisions in data-poor regions.
		Spatial and temporal consistency should be mandated for data integrity so that energy investments can be aligned with long-term conservation goals.
		Supporting local projects through international data integration (e.g., GBIF, OBIS) strengthens global-regional data harmonization.
Chamanara, J., Gaikwad, J., Gerlach, R., Algergawy, A., Ostrowski, A., & König-Ries, B. (2021)	*BEXIS2: A FAIR-aligned data management system for biodiversity, ecology and environmental data*	The FAIR data management principles (Findable, Accessible, Interoperable, Reusable) ensure the transparent and sustainable management of biodiversity data.
		It is recommended that biodiversity data used in energy infrastructure planning be stored on standardized platforms.
		Modular data management systems offer a customizable structure for different user profiles and energy-biodiversity relationships.
		Customizable interfaces allow institutions to perform data analyses tailored to their own needs.
		Time-series data storage and versioning should be integrated into the monitoring processes of energy projects.

Author/s	Article Title	Strategies
Chamanara, J., & König-Ries, B. (2014)	*A Conceptual Model for Data Management in the Field of Ecology*	A holistic model encompassing the data lifecycle is recommended; this model includes data planning, collection, analysis, sharing, and reuse.
		Proactive data management plans should be prepared for energy projects.
		Data flow processes designed through collaboration among stakeholders facilitate the assessment of the environmental impacts of energy infrastructures.
		Data standardization enables the consolidation of data from different sources and the integration of energy and biodiversity.
		Long-term data storage systems increase reliability in monitoring and decision-making processes.
Gadelha, L. M., de Siracusa, P. C., Dalcin, E. C., da Silva, L. A., Augusto, D. A., Krempser, E., ... & de Siqueira, M. F. (2020)	*A Survey of Biodiversity Informatics: Concepts, Practices, and Challenges*	The impacts of energy infrastructure on nature can be assessed holistically by developing interdisciplinary data sharing infrastructures.
		Systems compatible with national and global data standards enhance collaboration between the energy sector and nature conservation institutions.
		Open-access and publicly supported data platforms are recommended for the sustainability of data infrastructures.
		Technological capacity building enables energy companies to use biodiversity data meaningfully.
		International collaborations and networks increase the cross-border effectiveness of data-based conservation plans.
Costello, M. J., & Wieczorek, J. (2014)	*Best Practice for Biodiversity Data Management and Publication*	Open-access data sharing should be encouraged for data to be used in energy infrastructure planning.
		Adding detailed metadata to datasets enables decision-makers to interpret the data correctly.
		Mandating data sharing in publication policies increases the visibility of critical biodiversity information.
		Publishing standardized data in the correct format bridges the gap between infrastructure and environmental planning.
		Editorial and technical guidelines facilitate inter-institutional data integration to improve data quality.
Urbano, F., Viterbi, R., Pedrotti, L., Vettorazzo, E., Movalli, C., & Corlatti, L. (2023)	*Enhancing Biodiversity Conservation and Monitoring in Protected Areas*	Digitalization of monitoring systems has been recommended for the effective protection of biodiversity in protected areas.
		Faster and more reliable monitoring processes have been promoted through satellites, remote sensing, and data-sharing platforms.
		The development of early warning systems for managerial decisions has been advocated.
		The participation of local communities and the integration of local knowledge systems in data production have been prioritized.

Author/s	Article Title	Strategies
Gabi, A. U., & Abdullah, N. M. (2024)	*Optimizing Biodiversity Informatics to Improve Information Flow, Data Quality, and Utility for Science and Society*	Optimizing data management infrastructure (standardization, quality control, metadata use).
		Developing platforms aligned with FAIR data principles to increase the reusability and accessibility of biodiversity data.
		Encouraging public and private institutions to share data.
		Supporting open data policies and recognizing data sharing in academic reward systems.
Ball-Damerow, J. E., Brenskelle, L., Barve, N., Soltis, P. S., Sierwald, P., Bieler, R., LaFrance, R., Ariño, A. H., & Guralnick, R. (2019)	*Research Applications of Primary Biodiversity Databases in the Digital Age*	Creating integrative systems to increase the usability of primary databases in analyses.
		Integrating digital mapping and modeling tools to maximize the contribution of databases to scientific applications.
		Standardizing biodiversity datasets on a global scale to contribute to energy infrastructure planning.
		Interoperability facilitates the analysis of energy-biodiversity relationships by harmonizing data from different fields.
Enke, N., Thessen, A., Bach, K., Bendix, J., Seeger, B., & Gemeinholzer, B. (2012)	*The User's View on Biodiversity Data Sharing*	Designing user-friendly data sharing systems.
		Encouraging data management plans in all scientific research.
		Disseminating training on data sharing and increasing user motivation.
		Creating long-term data storage infrastructures.
van Strien, A. J., Meyling, A. W., Herder, J. E., Hollander, H., Kalkman, V. J., Poot, M. J. M., Turnhout, S., van der Hoorn, B., van Strien-van Liempt, W. T. F. H., van Swaay, C. A. M., van Turnhout, C. A. M., Verweij, R. J. T., & Oerlemans, N. J. (2016)	Modest recovery of biodiversity in a western European country: The Living Planet Index for the Netherlands	Encouraging standardized monitoring programs: Biodiversity trends can be regularly monitored using data collected through citizen science and volunteer monitoring programs.
		Using indirect methods to compensate for data gaps: In cases where species abundance data are unavailable, missing data can be supplemented by analyzing species occupancy trends.
		Habitat-Specific Monitoring Approach: Site-specific strategies can be developed by assessing the distribution of species across different habitats (e.g., agricultural lands, forests, wetlands, etc.).
		Developing indicators (such as LPI): Country-level decision support systems can be established using indices based on species abundance and distribution.
		Habitat-Based Strategies: Habitat restoration that combats intensive agricultural practices and nitrogen accumulation should be implemented to reverse the decline in biodiversity, especially in agricultural lands and semi-natural open habitats.

Author/s	Article Title	Strategies
Huvenne, V. A. I., Bett, B. J., Masson, D. G., Le Bas, T. P., & Wheeler, A. J. (2016)	Effectiveness of a deep-sea cold-water coral Marine Protected Area, following eight years of fisheries closure	Effective Implementation of Marine Protected Areas: In marine ecosystems, especially in sensitive areas such as cold-water coral reefs, limiting human activities (e.g., fishing bans) contributes to biodiversity recovery.
		The Importance of Long-Term Monitoring Programs: The success of protected areas has been measured through detailed monitoring studies conducted over eight years.
		Process-Based Management: Area management should be supported by monitoring structural and functional indicators of the ecosystem (e.g., species diversity, habitat complexity).
		Integration of research and conservation: Scientific research conducted in the field should be directly linked to conservation policies, enabling informed planning.
Hughes, K. A., & Pertierra, L. R. (2016)	Evaluation of non-native species policy development and implementation in the UK	Proactive strategies against invasive species: The spread of invasive species should be anticipated in energy infrastructure planning and integrated into conservation plans.
		Multi-actor collaboration: Effective policy implementation can be developed by ensuring coordination among public institutions, the private sector, and civil society organizations.
		Aligning legal regulations with strategy: Biodiversity policies should be structured to avoid conflicts with energy infrastructure plans.
		Data-driven decision-making: Centrally collecting and openly sharing data on the spread of invasive species is critical for risk management.
Bussotti, F., Papitto, G., Di Martino, D., Cocciufa, C., Cindolo, C., Cenni, E., Bettini, D., Iacopetti, G., Ghelardini, L., Moricca, S., Panzavolta, T., Bracalini, M., & Pollastrini, M. (2024)	Extreme climatic events, biotic interactions and species-specific responses drive tree crown defoliation and mortality in Italian forests	Forest health and species-based monitoring systems should be established, and the location of energy infrastructure should be based on this data.
		Species and habitats resilient to climate-related events should be identified, and infrastructure investments should be guided by these sensitivities.
		Integrated analysis methods that consider biotic and abiotic pressures together should be integrated into energy planning.
		Long-term monitoring data should be used to estimate the environmental impacts of energy projects.
Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	Mapping behavioral landscapes for animal movement: a finite mixture modeling approach	Behavioral landscape maps based on animal movements should be used to determine energy infrastructure migration routes.
		Essential habitats such as migration routes, feeding grounds, and sheltering areas should be protected during energy projects.
		Spatial patterns of animal behavior should be extracted using multi-model analysis techniques, and corridors should be designed based on this information.
		Energy projects should be removed from areas with high behavioral sensitivity.

Author/s	Article Title	Strategies
Lorang, M. S., Whited, D. C., Hauer, F. R., Kimball, J. S., & Stanford, J. A. (2005)	Using airborne multispectral imagery to evaluate geomorphic work across floodplains of gravel-bed rivers	Remote sensing-based monitoring systems should be used to protect sensitive habitats such as flood plains.
		Ecosystem services impacted by infrastructure projects (e.g., water retention capacity) should be assessed through spatial analyses.
		Imaging technologies capable of analyzing morphological changes at the micro-scale should be used in infrastructure planning.
		Hydrological and topographic dynamics should be considered in power line planning.
Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., … Zhu, Z. (2014)	Bringing an ecological view of change to Landsat-based remote sensing	Degradation and recovery processes in ecosystems should be monitored using satellite systems that provide long-term data, such as Landsat.
		Energy investments should be guided by analyzing the temporal patterns of environmental responses using annual satellite data.
		Classification methods designed to detect ecological dynamics facilitate the identification of priority areas for biodiversity.
		Sensor-supported decision support systems for monitoring ecosystem changes should be integrated into the energy sector.

Author/s	Article Title	Strategies
Huston, M. A. (2005)	THE THREE PHASES OF LAND-USE CHANGE: IMPLICATIONS FOR BIODIVERSITY	Analyzing land use change according to a three-stage development model: Transitions between agriculture, industry, and knowledge-based economies affect different biodiversity components at different times. The spatial distribution of land use pressures can be made predictable through this historical framework.
		Considering the priority use of high-productivity regions in the agricultural phase: Opening regions with high net primary productivity (NPP) to agriculture in the initial phase directly puts pressure on biodiversity in these regions. This trend can be considered in planning processes and regions with high biodiversity can be protected.
		Assessing the impacts of transportation infrastructure brought about by industrialization: The mobility of food and raw materials also enables the use of non-agricultural areas. In this context, regions where energy infrastructure will be built depend not only on productivity but also on transportation infrastructure. These relationships should be evaluated in terms of ecosystem integrity.
		Awareness of new pressures in mountainous and rural areas in the knowledge economy era: Improvements in transportation and communication lead to increased settlement and recreational use in previously inaccessible areas. This, in turn, creates new pressures on previously protected areas. Therefore, preventative protection strategies should be developed for such areas.
		Integrating NPP-based resource distribution analyses into decision support systems: Decision support systems that predict land use pressures can be developed using productivity-based modeling in biodiversity planning. This will help identify priority protection areas, especially for future energy investments.
		Focusing on preserving remaining biodiversity reserves in resource-poor areas: Low-productivity areas, previously not economically desirable, have recently become targets for recreation or energy infrastructure. These areas should now be prioritized for active conservation.
		Evaluating land use intensity through human-ecological parallels: The relationship between human population density and resource access exhibits similar dynamics to other species. This approach allows for population-pressure analyses to support biodiversity in infrastructure planning.
Theron, K. J., Pryke, J. S., & Samways, M. J. (2021)	Identifying managerial legacies within conservation corridors using remote sensing and grasshoppers as bioindicators	The effects of past management practices in conservation corridors should be analyzed: Habitat quality should be assessed using NDVI time series and biological indicators (e.g., locusts).
		Remote sensing habitat monitoring systems should be established: Corridors through which energy infrastructure is located should be spatially classified according to their degradation or recovery trends.
		Effective restoration strategies should be implemented in corridor management: Prioritization should be based on biological responses to address declining habitat quality.
		The spread of invasive species and the timing of intervention should be determined through remote sensing-supported analyses.
		The long-term effects of past management practices should be integrated into energy planning, taking sustainability into account.

Author/s	Article Title	Strategies
Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	Patterns of diversity along a habitat size gradient in a biodiversity hotspot	The relationship between habitat size and species diversity should be considered: Infrastructure projects can threaten species communities with higher uniqueness in small areas.
		Area size and connectivity should be considered together in conservation planning: The protection of small habitat islands depends not only on area size but also on connectivity at the landscape scale.
		When selecting the location for energy infrastructure, green corridors should be designed to ensure interhabitat mobility.
		Special protection status should be established for small habitats with high species specificity.
		All habitat dimensions should be included in planning, taking into account ecosystem representativeness.
VanderWilde, C. P., Newell, J. P., Gounaridis, D., & Goldstein, B. P. (2023)	Deforestation, certification, and transnational palm oil supply chains: Linking Guatemala to global consumer markets	Habitat loss due to land use should be prevented by establishing supply chain-based monitoring systems: Deforestation data can be used to monitor biological degradation within the impact area of energy infrastructure.
		Biodiversity protection performance should be monitored through certification systems: Transparency-based monitoring systems developed for high-impact sectors like palm oil can also be adapted to the energy sector.
		Sustainability documentation and environmental certifications should be integrated into the decision-making processes of energy projects.
		The pressure of transnational investment activities on local habitats should be made visible and limited.
		High-resolution remote sensing data and spatial analyses should be used to identify environmental degradation early before infrastructure investments.
		Supply chain maps should be used to mitigate biodiversity risks, and transparency should be ensured.
McCarthy, C., Banfill, J., & Hoshino, B. (2021)	National parks, protected areas and biodiversity conservation in North Korea: opportunities for international collaboration	The capacity of protected areas should be increased through international cooperation mechanisms: When energy investments overlap with transboundary or internationally important protected areas, nature protection can be ensured through these mechanisms.
		Strategies focused on capacity building should be developed: Energy-biodiversity harmony can be achieved by strengthening institutional capacity in areas such as technical personnel, data management, and monitoring systems.
		Ecosystem monitoring should be implemented through data sharing platforms and open access systems: Closed data systems can pose risks in energy infrastructure planning. International data sharing is of strategic importance.
		Planning processes aligned with global biodiversity policies (e.g., CBD, Ramsar) should be developed.
		Management deficiencies should be addressed, and protected areas should be made functional. This could prevent energy infrastructure from being diverted to sensitive areas.
		Establishing joint observation and monitoring systems has been proposed for isolated systems like North Korea; this approach could be extended to the energy sector.

Author/s	Article Title	Strategies
McCarthy, C., Banfill, J., & Hoshino, B. (2021)	Biodiversity conservation in North Korea using remote sensing: Evaluation of tree loss and fragmentation in Key Biodiversity Areas (KBA)	Forest loss and fragmentation trends in Key Biodiversity Areas (KBA) should be regularly monitored using remote sensing.
		If habitat fragmentation occurs within protected area boundaries, these areas should be reassessed and their protection status strengthened.
		Early warning systems for habitat degradation should be established in energy infrastructure planning using remote sensing data, such as NDVI time series.
		Monitoring and control systems should be established for the sustainable management of protected areas, and these systems should also include the environmental impacts of energy investments.
		Remote sensing-supported control systems should be proposed for inadequately managed protected areas; this can help identify unauthorized interventions by energy projects.
		Capacity gaps in the management of protected areas should be addressed through international support and data sharing, and conflicts with energy projects should be minimized.
Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	Mapping behavioral landscapes for animal movement: a finite mixture modeling approach	Modeling animal movements using behavioral maps should be used to reduce the impact of energy infrastructure on migration routes.
		Spatial models based on animal migration, feeding, and sheltering behavior should be considered in the planning phase of energy infrastructure projects.
		Migration routes and attraction centers should be defined using behavioral-based species-habitat interaction models, and energy lines should be removed from these areas.
		Monitoring systems that can detect species' behavioral adaptations should be established in areas affected by energy infrastructure.
		Direct impacts can be mitigated by analyzing behavioral responses using multi-source data (e.g., GPS, remote sensing, motion sensors).
		Corridor designs and buffer zones should be planned based on modeled behavioral landscapes.
Lawrence, A., O'Connor, K., Haroutounian, V., & Swei, A. (2018)	Patterns of diversity along a habitat size gradient in a biodiversity hotspot	Planning should be based on habitat size and isolation: Species diversity and abundance are positively correlated with habitat area; therefore, the protection of larger, connected habitats should be prioritized.
		Specialized conservation strategies should be developed for medium-sized habitats: Due to resource scarcity in small habitats and predation in large habitats, the highest species richness for small mammals is observed in medium-sized areas. This finding supports the development of strategies tailored to habitat size.
		Large and diverse habitats should be protected to control invasive species: The study found that invasive species richness is inversely proportional to habitat size. This suggests that large and diverse habitats are more resilient to biological invasions.
		To prevent community disassembly, habitat integrity must be preserved: Habitat loss leads to the non-random extinction of species and communities. Therefore, holistic protection of habitats, rather than fragmentation, is essential.
		Conservation plans should address biodiversity and disease ecology together: Tick (ectoparasite) density increases with habitat area, demonstrating that conservation strategies should consider not only species diversity but also disease risks.

Author/s	Article Title	Strategies
Dickie, M., Serrouya, R., DeMars, C., Cranston, J., & Boutin, S. (2017)	Evaluating functional recovery of habitat for threatened woodland caribou	In areas impacted by energy infrastructure, habitat restoration should be evaluated based on functional criteria, not just physical ones.
		The recovery of woody vegetation and the normalization of species behavior should be monitored together: The restoration of vegetation alone is not sufficient; the resumption of species use of these habitats should also be monitored.
		Wildlife movement data (e.g., GPS-based trapping and data logging) should be used in monitoring systems: Functional habitat recovery, especially for species that use large areas such as caribou, should be determined using such data.
		Post-energy project restoration should be prioritized based on species' habitat preferences.
		Restoration interventions should be designed for the long term, and the animals' level of return should be assessed over time.
		As in the caribou example, apparent habitat recovery may not necessarily mean that animals are using it: Therefore, ecological functions and species behavior should be the basis, not visible improvements.
Tracey, J. A., Zhu, J., Boydston, E., Lyren, L., Fisher, R. N., & Crooks, K. R. (2013)	Mapping behavioral landscapes for animal movement: a finite mixture modeling approach	Spatial behavior maps that distinguish different animal behaviors should be used in energy infrastructure planning.
		Critical zones should be defined for migratory or extensively mobile species based on specific behaviors (e.g., browsing, sheltering, orienting).
		Infrastructure should be removed from habitats where animals exhibit "slow-moving" or "intensive-use" behaviors.
		Behavioral landscape maps can help identify areas at high risk of overlapping energy projects in advance.
		Animal behavior should be analyzed in detail using long-term GPS tracking data and spatial modeling techniques.
		Landscape planning should consider not only species distribution but also the behaviors exhibited by species in that area.

Author/s	Article Title	Strategies
Shiklomanov, A. N., Bradley, B. A., Dahlin, K. M., M Fox, A., Gough, C. M., Hoffman, F. M., M Middleton, E., Serbin, S. P., Smallman, L., & Smith, W. K. (2019)	Enhancing global change experiments through integration of remote-sensing techniques	Integrating remote sensing techniques into experimental studies: New-generation remote sensing methods such as spectroscopy, thermal imaging, fluorescence monitoring, digital repeat photography, and unmanned aerial vehicles make it possible to collect field data more extensively and accurately.
		Supporting experimental site selection with satellite and aerial data: Remote sensing data can be used during the site selection phase to identify areas with high ecological representation.
		Monitoring plant characteristics with spectroscopy: Environmental stress responses can be observed by non-destructively measuring plant leaf biochemistry and morphology and monitoring them over time.
		Real-time monitoring of plant functionality with thermal and chlorophyll fluorescence imaging: Rapid plant responses to functions such as photosynthesis and transpiration can be precisely monitored using these techniques, allowing for a better understanding of ecosystem processes.
		3D structure monitoring with terrestrial laser scanners: Variables related to carbon sequestration, such as vegetation volume, height, and structural features, can be modeled in 3D.
		Expanding the temporal and spatial coverage of experimental observations: Data collection processes, limited by ground-based methods, can be repeated over larger geographic areas and at more frequent intervals thanks to remote sensing.
		Encouraging interdisciplinary collaboration: Remote sensing experts and ecologists are encouraged to collaborate from experimental design to data interpretation.
Middleton, A. D., Sawyer, H., Merkle, J. A., Kauffman, M. J., Cole, E. K., Dewey, S. R., Gude, J. A., Gustine, D. D., McWhirter, D. E., Proffitt, K. M., & White, P. (2019)	Conserving transboundary wildlife migrations: recent insights from the Greater Yellowstone Ecosystem	Spatial identification and mapping of migration routes is necessary: Wildlife migration routes should be defined in detail to avoid conflicts, especially in energy infrastructure planning.
		Transboundary collaborations should be established: Because species' movement areas often cross administrative boundaries, data sharing and coordination between local, regional, and national governments are crucial.
		Connecting corridors used by migratory species should be protected and restored: Energy projects should thoroughly assess the ecological impacts before intervening in these corridors.
		If existing energy infrastructures lie on migration routes, rerouting or adaptation studies should be undertaken.
		Migration dynamics should be monitored with long-term monitoring systems: Animal movements should be regularly monitored using technologies such as satellite tracking, GPS collar systems, and remote sensing.
		‘Mobility-based’ approaches should be adopted in energy infrastructure planning: This approach considers not only the presence of species but also their behavioral continuity.

Author/s	Article Title	Strategies
Kennedy, R. E., Andréfouët, S., Cohen, W. B., Gómez, C., Griffiths, P., Hais, M., Healey, S. P., Helmer, E. H., Hostert, P., Lyons, M. B., Meigs, G. W., Pflugmacher, D., Phinn, S. R., Powell, S. L., Scarth, P., Sen, S., Schroeder, T. A., Schneider, A., Sonnenschein, R., … Zhu, Z. (2014)	Bringing an ecological view of change to Landsat-based remote sensing	Long-term Landsat time series should be used for the ecological interpretation of habitat changes: Image analyses should be reinterpreted to monitor not only physical but also functional ecological changes.
		Ecological processes such as “degradation,” “recovery,” and “balance” in habitat change should be distinguished using remote sensing.
		The impact of energy infrastructures should be monitored not only as one-time effects but as cumulative effects over time.
		Change-focused time series analyses should be used instead of traditional classification: This method more accurately detects sudden declines or improvements in habitat quality.
		Determining degradation and recovery thresholds is essential for measuring the ecological sustainability of infrastructure projects.
		Local ecological knowledge and scientific data should be integrated into the interpretation of remote sensing outputs.
Benson, B. J., Bond, B. J., Hamilton, M. P., Monson, R. K., & Han, R. (2009)	Perspectives on next-generation technology for environmental sensor networks	Sensor-based systems for environmental monitoring should be expanded: Sensor networks that can continuously monitor soil, air, water, and biotic factors and provide real-time data should be established.
		Biological and physical variables should be monitored in energy infrastructure areas in real-time. This allows for interventions before impacts occur.
		Monitoring environmental parameters such as microclimate, soil moisture, temperature, and light in energy production and transmission areas helps detect habitat changes with early warning systems.
		Next-generation sensors should be designed to not only collect data but also integrate directly into decision support systems.
		Regular monitoring of environmental variables in renewable energy projects (especially wind and solar) is crucial for project optimization and minimizing impacts.
		The use of high-data-density sensor systems can be analyzed using techniques such as machine learning to create more precise forecasting models.
Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	The value of open power line habitat in conservation of ground beetles (Coleoptera: Carabidae) associated with mires	Protecting and evaluating open powerline habitats: Especially in sensitive ecosystems such as peatlands, managing the areas around these lines as well-maintained open habitats can contribute to biodiversity.
		Habitat management practices that increase species richness: Interventions such as grazing, regular mowing, or supporting native species around the lines can be beneficial for local fauna.
		Planning energy infrastructure with ecological value in mind: Power lines not only pose a risk; when managed properly, they can provide microhabitats for some species.
		Designing powerline systems to support species mobility in transition zones adjacent to protected areas: This allows powerlines to function as extensions of natural corridors.

Author/s	Article Title	Strategies
Farias, A. T., Hamilton, S. E., Pires, L. B., Canale, G. R., Santos, R. R., & Presotto, A. (2024)	The Impact of Land Conversion on Primate Habitats: Refining the Extent of Occurrence Data for Four Capuchin Species in North and Northeastern Brazil	Species distribution modeling based on habitat suitability should be conducted: Energy infrastructure plans should consider suitable habitat areas predicted by environmental variables, not just existing species data.
		EOO (Extent of Occurrence) data should be updated and used in decision support systems: Updating the EOO ensures accurate identification of areas where species are actually present and can survive.
		Habitat loss should be monitored using satellite imagery and integrated with distribution data: This integration allows for more precise prediction of habitat loss due to energy infrastructure.
		Energy projects should be removed from areas that could cause habitat loss or planned in conjunction with environmental mitigation strategies.
		Attention should be paid to the effects of habitat fragmentation and isolation, particularly in forest species: This effect is critical for long-term species survival in regions where energy infrastructure is planned.
IUCN (n.d)	EOO Calculator Tool Instructions	Potential habitats of species should be determined using EOO (Extent of Occurrence) calculations: Energy projects should be planned in areas that do not overlap with these potential areas.
		Standardized and scientifically based metrics, such as EOO, should be used in spatial decision-making processes.
		Prior to energy infrastructure investments, an analysis should be made of whether the project area falls within the EOO boundaries.
		Data on species distribution can be processed with software such as the Energy Erosion Calculation Tool to enable more precise conservation area delineation.
		Updating Energy Erosion calculations with habitat models and species observation data reduces the risk of energy infrastructure and biodiversity conflict.
Ponitka, J., & Boettner, S. (2020)	Challenges of future energy landscapes in Germany — a nature conservation perspective	Environmentally friendly scenario models should be developed for energy infrastructure: These models should be designed to optimize nature conservation objectives while meeting energy demand.
		Area requirements for infrastructure projects should be minimized to avoid overlapping with nature conservation areas.
		Renewable energy investments (especially wind and biomass) should consider species protection guidelines.
		Nature conservation priorities should be incorporated into the integration process at an early stage in land use plans.
		Potential conflicts between energy infrastructure and nature conservation should be identified in advance through strategic environmental assessment (SEA) processes.
		Buffer zones should be planned between protected areas and energy infrastructure, and biodiversity-friendly practices should be encouraged within these areas.
		Energy infrastructure decisions should be guided by data-based decision support systems to take biodiversity into account.

Author/s	Article Title	Strategies
Richardson, M. L., Wilson, B. A., Aiuto, D. A., Crosby, J. E., Alonso, A., Dallmeier, F., & Golinski, G. K. (2017)	A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation	Power line routes should be planned to minimize environmental impacts: Routes away from protected areas, rare habitats, and migration routes should be preferred, in particular.
		Green corridors should be created or restored to prevent habitat fragmentation caused by infrastructure.
		Infrastructure adaptation solutions, such as wildlife crossings, should be designed to protect species mobility.
		Habitat restoration should be carried out around the lines, and indigenous vegetation should be supported.
		Monitoring and evaluation systems should be established to monitor the long-term impacts of infrastructure on biodiversity.
		Biosecurity measures should be taken during infrastructure construction and operation to prevent the spread of invasive species.
		Technical measures (isolation systems, visual warnings, etc.) should be implemented for direct impacts such as bird strikes and electrocution.
		A holistic socio-environmental approach should be adopted in infrastructure planning, ensuring the participation of local people and expert ecologists.
Plewa, R., Jaworski, T., Gil, W., & Horak, J. (2020)	Establishment and maintenance of power lines are important for insect diversity in Central Europe	Protection and maintenance of open spaces within forests: Open habitats formed under power lines are particularly important habitats for insect diversity.
		Considering energy transmission corridors as alternative habitats for biodiversity: These areas have greater species richness (especially for butterflies and some insect orders) than closed forest areas.
		Continuing traditional forest management practices (e.g., creating clearings) along power lines: These types of clearings are gradually decreasing as natural disturbances (wind, grazing, etc.) decrease.
		Emphasizing target species such as saproxylic (deadwood-associated) insects in the environmental management of energy infrastructure: These species are critical for conservation and depend on habitat diversity.
		Integrating artificial habitats (power lines) with nature-based conservation strategies: This integration has the potential to create new habitats.
Kaługa, I., Sparks, T. H., & Tryjanowski, P. (2011)	Reducing death by electrocution of the white stork Ciconia ciconia	Making electricity poles technically bird-friendly: Stork mortality has been completely eliminated, particularly with the installation of electrocution devices.
		Raising awareness through iconic species (e.g., the white stork): Support from the public and energy companies has been more easily secured through these species.
		Increasing the responsibility of energy companies and social acceptance: Such practices have been encouraged for energy companies to reduce power outages.
		Integrating protection measures with energy transmission security: Transmission interruptions resulting from bird strikes have also been prevented, providing a two-way benefit.
		Disseminating applied engineering solutions: These solutions have been disseminated through international declarations such as the "Budapest Declaration."

Author/s	Article Title	Strategies
Ellwanger, J. H., Fearnside, P. M., Ziliotto, M., & Chies, J. A. (2024)	Pollution-Related Biodiversity Loss in Brazil: More Actions Required	Evaluations should be made to prevent pollution-related impacts in energy and infrastructure projects: Factors such as waste, air, and water pollution should be taken into account in planning.
		Primary pollutants affecting habitats should be monitored in infrastructure planning, and risk analyses should be conducted at the species and habitat level.
		Cumulative environmental impacts should be considered: Infrastructure projects should be evaluated not individually, but at a regional scale, to reveal the total pressure on biodiversity.
		Buffer zones and biological corridors should be established for sensitive species in industrial development zones (e.g., energy production areas).
		Environmental permitting processes for energy projects should utilize decision-making mechanisms based on spatial analyses related to biodiversity loss.
		Intersectoral integration is necessary to reduce pollutant impacts: The energy, environment, water, and agriculture sectors should plan together.
Hollmen, A., Välimäki, P., Itämies, J., & Oksanen, J. (2007)	The Value of Open Power Line Habitat in Conservation of Ground Beetles Associated with Mires	Open habitats crossed by power lines should be considered as a conservation tool: These habitats offer important microhabitats, particularly for species associated with marshes (mires).
		Instead of traditional agricultural and forested areas, energy corridors can provide alternative habitats for some species.
		Minimum tillage should be implemented in areas crossed by power lines: This is especially important for maintaining habitat continuity for belowground fauna.
		The continuity of microhabitats should be considered in energy infrastructure planning: Shaded openings or low vegetation constitute critical habitat for some species.
		It is emphasized that energy infrastructure should be defined as an area providing ecosystem services in conservation planning.
Farias, A. T., Hamilton, S. E., Pires, L. B., Canale, G. R., Santos, R. R., & Presotto, A. (2024)	The Impact of Land Conversion on Primate Habitats: Refining the Extent of Occurrence Data for Four Capuchin Species in North and Northeastern Brazil	Spatial Updating of Species' Actual Habitats is Necessary: Satellite data and habitat integrity analyses should be used to determine not only the potential but also the actual distribution areas of species.
		The concept of "Area of Habitat" (AOH) should be used in infrastructure planning: Planning based on Extent of Occurrence (EOO) data may obscure habitat loss.
		Regional-scale spatial analyses should be conducted for energy projects, and species' vulnerability should be assessed by considering local habitat conditions.
		Data-based habitat contraction analyses can be used as a decision-support tool in directing energy infrastructure.
		Special priority conservation areas should be designated for species with high habitat dependence, such as primate species.