



ENVIRONMENTAL GOVERNANCE AND LEGAL INTEGRATION IN THE EUROPEAN UNION UNDER DIGITAL TRANSFORMATION

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ABSTRACT

This paper examines how the European Union's environmental governance and legal harmonisation are being reshaped by digital transformation. Using legal analysis, it explores how core environmental principles – such as the precautionary principle, the polluter pays principle, and the integration principle – are being operationalised through data-driven regulation, real-time environmental monitoring and cross-border digital cooperation. It analyses how these digital mechanisms can make regulation more targeted and adaptive, enhance compliance and transparency, and require new legal instruments for cross-border coordination. The findings suggest that digital tools have the potential to strengthen both environmental protection and legal harmonisation, while also posing challenges of data standardisation, interoperability, and institutional capacity. The paper concludes that EU environmental law can remain effective only if its legal frameworks are adapted to integrate these emerging digital instruments in a coherent and principle-based manner.

KEYWORDS EU environmental law, sustainable development, governance, legal harmonisation, digital transformation

1. Introduction

Environmental law in the European Union (EU) has developed as a response to domestic challenges and international obligations. Initially, the Treaties establishing the European Community did not contain any provisions concerning environmental protection. However, the need for unified standards became increasingly pressing due to the differing environmental regulations across Member States, which created uneven competitive conditions and hindered the free movement of goods. Over time, the EU incorporated environmental goals into primary law, enabling the adoption of both horizontal

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and vertical legislation. The latter addresses specific environmental elements such as air, water, and soil, while the former takes an integrated approach to protect all components of the environment. One of the key goals of EU environmental policy is to ensure sustainable development by minimizing irreversible environmental damage and promoting responsible resource use.

In recent years, the rise of digital transformation has introduced new tools and challenges for environmental governance. These include real-time environmental monitoring, data-driven regulation, and cross-border enforcement mechanisms. While these innovations offer the potential for greater transparency and efficiency, they also raise questions about implementation, standardisation, and legal adaptation.

This paper explores in detail how digitalisation intersects with environmental law and governance in the European Union. In particular, it examines the impact of digital tools on the implementation of key environmental principles, the operation of both horizontal and sectoral legislation, and the prospects for legal harmonisation across Member States. By doing so, the paper not only identifies opportunities for more effective and transparent governance but also highlights the legal and institutional challenges that arise in adapting traditional frameworks to a digital era.

2. Basic Principles of European Union Environmental Law

Environmental legislation within the European Union is structured around two complementary approaches: vertical and horizontal legislation. This dual structure reflects the complexity of environmental protection, which requires both targeted and integrated legal responses. Vertical legislation focuses on specific environmental components, such as water, air, or waste, while horizontal legislation provides general mechanisms applicable across sectors.

In the context of digital transformation, the effectiveness of both legislative types increasingly depends on technological capacities such as real-time data collection, interoperable databases, and automated compliance systems. For example, horizontal instruments like environmental impact assessments (EIA) and public access to environmental information are now frequently implemented through online platforms, which raises questions about the standardisation of reporting formats and the digital divide in access to information. Similarly, vertical directives on pollution control or waste management rely increasingly on electronic monitoring and reporting systems, which enhance transparency but also require significant investment from national authorities to ensure compatibility with EU-wide databases.

This section therefore not only outlines the dual legislative structure but also analyses how digitalisation reshapes its operation, highlighting both the opportunities for greater harmonisation and the risks of fragmentation if technological infrastructures are not aligned across Member States.

2.1. Objectives and Principles

The environmental objectives of the EU include preserving, protecting, and improving the quality of the environment, protecting human health, the prudent and rational use of natural resources, and promoting measures at the international level to deal with regional or worldwide environmental problems (TEC, art. 174, para. 1). These aims are equally important and must be pursued in parallel.

Digitalisation is increasingly shaping how these objectives are pursued in practice. Real-time environmental monitoring networks, large-scale data platforms such as the European Environment Agency's Eionet system, and satellite-based observation tools like Copernicus make it possible to collect and analyse environmental data across the EU with unprecedented speed and precision. This enables policymakers to identify trends earlier, respond more rapidly to emerging threats, and better integrate environmental and human health considerations into decision-making. At the same time, the growing reliance on digital infrastructure highlights disparities in Member States' technical capacities and raises concerns over data quality, accessibility, and long-term interoperability. Thus, while digital transformation offers powerful tools to advance the EU's environmental objectives, it also creates new legal and institutional challenges that require coordinated governance.

2.2. High Level of Protection

According to Articles 174(2) and 95(3) of the EC Treaty, the EU's environmental policy must pursue a high level of protection while taking into account the differing conditions across the Union's regions. This objective also guides the legislative process: when preparing harmonisation proposals, the European Commission must ensure a high level of protection, and the same standard must be upheld by the Council and the European Parliament.

Digital transformation is playing an increasingly important role in achieving a high level of protection across the EU. Real-time data collection systems, remote sensing technologies (such as the Copernicus satellite programme), and centralised EU-wide databases enable a more accurate assessment of environmental risks and a more consistent application of protective measures. This helps ensure that high protection standards are maintained even in regions

with differing capacities or environmental pressures. At the same time, the uneven availability of digital infrastructure among Member States can threaten this uniformity, potentially leading to gaps in implementation or enforcement. Moreover, heavy reliance on automated data systems raises questions about data accuracy, validation procedures, and legal accountability. Therefore, while digital tools can support the realisation of a high level of protection, they also require coordinated legal and technical frameworks to prevent new disparities and ensure consistent environmental safeguards.

2.3. Precautionary and Preventive Principles

The precautionary principle and the principle of prevention are embedded in Article 174(2). The precautionary principle ensures that a lack of complete scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation. The preventive principle emphasizes acting before damage occurs. These principles underpin much of EU environmental legislation (Lee, 2014).

In the context of digitalisation, these principles gain new practical dimensions. Real-time environmental monitoring systems – such as the Copernicus satellite programme or national air and water quality sensor networks – allow regulators to detect emerging risks much earlier than traditional reporting systems. This enables authorities to take precautionary or preventive action before damage occurs, thereby strengthening the effectiveness of these principles. At the same time, the reliance on large and often automated datasets raises challenges relating to data accuracy, interoperability between national systems, and legal accountability: if decisions are based on incomplete or biased data, precautionary measures may be misapplied, or preventive actions may become disproportionate. Thus, digital tools can both reinforce and complicate the application of the precautionary and preventive principles within EU environmental law.

2.4. Source Principle

Also included in Article 174(2), the source principle asserts that environmental damage should be rectified at its source. This principle is closely related to prevention and precaution and supports the concept of proximity in time and space for ecological interventions (Jans & Vedder, 2012)

In a digital context, the source principle can be implemented more effectively through advanced monitoring and geolocation technologies. Remote sensing systems and sensor-based networks – for example those coordinated through the European Environment Agency's Eionet data infrastructure – make it possible to detect the exact geographic and temporal origin of pollution in near

real-time. This allows authorities to intervene directly at the source rather than addressing only downstream impacts. However, this approach depends on the availability of interoperable data and reliable attribution models: inaccurate or fragmented datasets can lead to misidentifying the actual source of harm, creating legal disputes over responsibility. Thus, digital tools can enhance the enforceability of the source principle but also create new challenges regarding data reliability and legal accountability.

2.5. *Polluter Pays Principle*

The polluter pays principle assigns financial responsibility for environmental harm to the party that caused it. According to Article 174(2), this principle ensures that the responsible economic actor internalizes the costs of pollution prevention and remediation ([Directive 2004/35/EC, preamble and art. 1](#)). It applies to lawful and unlawful activities and is a core component of the EU's environmental liability regime.

Digital technologies are increasingly transforming how the polluter pays principle is enforced. Data-driven monitoring systems and automated reporting platforms make it possible to trace emissions and discharges more accurately to specific operators, which strengthens the legal basis for assigning liability. For example, the Environmental Liability Directive may rely on geolocated sensor data, satellite imagery from the Copernicus programme, and digital emissions registries to establish causal links between polluting activities and environmental harm. This enhances transparency and can speed up the process of imposing financial responsibility. However, the use of complex datasets and algorithmic risk assessments also raises questions about data accuracy, the burden of proof, and the legal admissibility of digital evidence in cross-border cases. Thus, while digitalisation can significantly improve the practical enforcement of the polluter pays principle, it also introduces new legal and evidentiary challenges.

2.6. *Integration Principle*

The integration principle, laid down in Article 6 of the EC Treaty, requires that environmental protection requirements be integrated into the definition and implementation of other EU policies and activities. This principle acknowledges that ecological goals cannot be pursued in isolation but must be considered in fields such as agriculture, energy, transport, and industry ([Krämer, 2020](#)). The Amsterdam Treaty elevated this principle by making sustainable development a general objective of EU action.

Digital transformation is creating new opportunities and challenges for the practical implementation of the integration principle. Digital data platforms, such as the European Environment Agency's Eionet network and the Copernicus satellite programme, allow environmental indicators to be systematically embedded into other policy domains – for example, by integrating real-time emissions data into agricultural or transport planning systems. This supports evidence-based policymaking and helps ensure that environmental objectives are considered in all relevant sectors. However, integration through digital systems also requires interoperability between policy-specific data infrastructures, standardised data formats, and common legal safeguards on data use and access. Without these, the inclusion of environmental criteria risks becoming inconsistent or purely symbolic. Thus, digitalisation can significantly enhance the integration principle, but only if it is accompanied by strong legal frameworks ensuring coherent data governance across policy areas.

2.7. *Subsidiarity Principle*

According to Article 5 of the EC Treaty, the subsidiarity principle stipulates that action at the EU level is justified only when objectives cannot be sufficiently achieved by the Member States alone and can, therefore, be better accomplished by the Union. This ensures that decision-making remains as close as possible to citizens and that EU intervention is proportionate to the need.

Digitalisation is reshaping how the subsidiarity principle operates in practice. On the one hand, advanced digital tools – such as EU-wide data platforms, cross-border monitoring systems, and shared environmental information networks (e.g. Eionet) – enable Member States to address many environmental issues more effectively at the national level, thereby supporting decentralised action in line with subsidiarity. On the other hand, these same technologies reveal the cross-border nature of many environmental problems, such as air pollution or river basin management, which often require coordinated EU-level responses. This creates a tension: while digital systems empower local authorities, they also strengthen the case for more centralised EU intervention. Furthermore, the uneven digital capacities of Member States risk undermining this balance, as weaker systems may struggle to contribute to or benefit from shared platforms. Thus, digitalisation both reinforces and challenges the subsidiarity principle, highlighting the need for clearer legal guidance on the appropriate level of decision-making in a data-driven governance context.

3. Horizontal and Vertical Legislation

Environmental legislation within the EU is structured around two complementary approaches: vertical and horizontal legislation. This dual

structure reflects the complexity of environmental protection, which requires both targeted and integrated legal responses. Vertical legislation focuses on specific environmental components such as water, air, or waste, while horizontal legislation provides general mechanisms applicable across sectors. In the context of digital transformation, the effectiveness of both legislative types increasingly depends on technological capacities. Real-time data collection, interoperable databases, and automated compliance systems are now embedded in many legal instruments. For instance, horizontal mechanisms like environmental impact assessments (EIA) and public access to environmental information are often implemented through digital platforms, raising questions about standardisation and equal accessibility. Similarly, vertical directives on pollution control or waste management increasingly rely on electronic monitoring and reporting mechanisms, which enhance transparency but also require significant investment and common technical standards.

This section therefore not only outlines the dual legislative structure but also analyses how digitalisation is reshaping it, highlighting how digital tools can strengthen harmonisation across Member States, while also creating new risks of fragmentation if legal and technical infrastructures are not aligned.

3.1. Vertical Legislation

Vertical legislation refers to legal acts that address specific environmental components or issues – such as air, water, soil, or waste. These instruments often set emission limits, product standards, or sector-specific obligations (Hilson, 2023). For example, the Water Framework Directive (2000/60/EC) sets a comprehensive framework for water quality management across the EU. Similarly, directives on air quality, waste management, and noise pollution are all examples of vertical regulation (Directive 2000/60/EC; Directive 96/62/EC; Directive 2008/98/EC).

Vertical legislation helps achieve clear, measurable goals in distinct environmental sectors. However, the compartmentalised nature of these regulations may sometimes result in policy conflicts or inefficiencies when multiple ecological issues intersect.

Digital transformation is increasingly reshaping how vertical legislation is implemented and enforced. Many sectoral directives now rely on digital monitoring systems, automated reporting platforms, and interoperable databases to collect and verify compliance data. For example, air quality directives are supported by real-time sensor networks managed through the European Environment Agency's Eionet system, while water and waste directives require electronic registers and geospatial data reporting. These tools

enable faster detection of non-compliance, more transparent enforcement, and better comparability of data across Member States. At the same time, they also create challenges: they demand significant technical and financial capacity from national authorities, and disparities in digital infrastructure risk producing uneven enforcement across the EU. Furthermore, reliance on automated data flows raises legal concerns about data accuracy, validation, and the admissibility of digital evidence. Thus, while digitalisation strengthens the effectiveness of vertical legislation, it also requires robust legal and institutional safeguards to ensure consistent implementation.

3.2. *Horizontal Legislation*

Horizontal legislation, by contrast, aims to regulate multiple environmental components simultaneously. It provides tools and procedures applicable across various sectors and ecological elements (Lenaerts, 2011). These instruments often reflect broader policy objectives and integrate different aspects of environmental governance.

Digitalisation is profoundly changing how horizontal environmental legislation operates in practice. Many horizontal instruments – such as the Environmental Impact Assessment Directive (EIA) and the Access to Environmental Information Directive – are now implemented through digital platforms that allow for real-time data sharing, online public participation, and automated reporting across policy areas. These systems enhance transparency, improve the comparability of environmental data, and facilitate cross-sectoral coordination. For example, the European Environment Agency's Eionet network provides a unified data infrastructure that supports both national- and EU-level decision-making. At the same time, the integration of diverse data sources also raises challenges related to standardisation, data interoperability, and the digital divide between Member States with differing technical capacities. Therefore, while digital tools can significantly strengthen the integrative function of horizontal legislation, they also require common legal safeguards to ensure equal accessibility, data quality, and coherent application across the European Union.

3.2.1. *Key Areas of Horizontal Regulation*

- a. Environmental impact assessment (EIA) and strategic environmental assessment (SEA) are central instruments that ensure that environmental considerations are included in the early phases of project planning and policy development.

Digitalisation has significantly changed how these assessments are conducted. Most EIA and SEA procedures are now supported by online platforms that integrate real-time environmental data from sources such as the Copernicus satellite programme and national monitoring networks.

This allows faster data processing, more accurate impact modelling, and earlier detection of risks. At the same time, reliance on complex datasets creates challenges related to data quality, interoperability between Member States' systems, and the legal accountability of automated assessments.

- b. Public participation and access to environmental information are guaranteed by Directive 2003/4/EC and Directive 2003/35/EC, reflecting the principles of transparency and democratic engagement. Digital platforms have expanded public participation by enabling online consultations, e-submissions, and interactive access to environmental datasets. For example, the European Environment Agency's Eionet network provides open access to EU-wide environmental data, making it easier for stakeholders and citizens to engage in decision-making. However, this shift also raises concerns about the digital divide between regions, data privacy, and the long-term accessibility of digital archives.
- c. Eco-labelling systems, environmental management and audit schemes (EMAS), and environmental liability (under Directive 2004/35/EC) also fall under this category. These schemes increasingly rely on digital reporting systems and big-data-based risk assessments. Companies can submit EMAS audits electronically, while liability cases are often supported by geolocated monitoring data and digital evidence. This improves transparency and comparability across Member States but also creates legal challenges regarding the verification and admissibility of digital data in liability procedures.

3.2.2. *Integration and Coordination*

The need for horizontal legislation emerged from the realization that vertical approaches alone were insufficient for addressing complex, interrelated environmental issues. Integrated instruments help avoid conflicting policies and promote sustainable development across sectors. Horizontal regulation thus embodies the integration and precautionary principles ([Directive 2004/35/EC](#)).

Horizontal legislation plays a key role in legal harmonization across the EU, enhancing legal certainty and facilitating the internal market. It also fosters consistency in enforcement, particularly in transboundary environmental matters.

Digital transformation is profoundly reshaping how integration and coordination are achieved within EU environmental governance. EU-wide data platforms, such as the European Environment Agency's Eionet network and the

Copernicus Earth observation programme, allow environmental data from different sectors (such as energy, transport, agriculture, and industry) to be combined and compared in real time. This supports integrated policymaking and helps align environmental objectives with other policy domains, strengthening legal harmonisation across Member States. However, this also creates new challenges: ensuring interoperability between sectoral data systems, safeguarding data quality and security, and addressing disparities in digital capacity between Member States. Therefore, while digital tools can significantly enhance integration and coordination, they also require common technical standards and legal frameworks to prevent fragmentation and ensure coherent implementation throughout the EU.

4. Responsibility for the Environment and the Sectoral Legislation

Environmental responsibility is a cornerstone of environmental governance in the European Union. The EU's legal framework obliges both public and private actors to prevent environmental harm, remedy damage, and internalise environmental costs, and these obligations are implemented through horizontal and sector-specific legal instruments.

In recent years, however, the way these responsibilities are monitored and enforced has been profoundly shaped by digitalisation. While early legal acts such as the Environmental Liability Directive (2004/35/EC) did not contain explicit digital provisions, their enforcement increasingly relies on technological tools: geospatial monitoring data, satellite imagery from the Copernicus programme, and electronic reporting systems are now widely used to detect environmental damage, attribute responsibility, and document compliance. Similarly, sectoral legislation on water, air, and waste incorporates mandatory digital reporting platforms to enable cross-border coordination and timely oversight.

These developments enhance transparency and accelerate enforcement but also raise legal and institutional challenges related to data quality, standardisation, interoperability, and the uneven digital capacities of Member States. As a result, environmental responsibility in the EU is evolving into a hybrid system that combines traditional legal norms with digital enforcement infrastructures, requiring both legal harmonisation and investment in technological capacity.

4.1. *Environmental Liability*

The central instrument establishing environmental responsibility is Directive 2004/35/EC on environmental liability regarding preventing and remedying

environmental damage. This directive implements the polluter pays principle and places liability on operators whose activities cause or threaten to cause ecological harm (art. 1).

Under this directive:

If environmental damage has not yet occurred but there is an imminent threat, the operator must take all necessary preventive measures immediately (art. 5).

If environmental damage has already occurred, the operator must inform the competent authority and take all remedial actions while bearing the full cost of such interventions (art. 6).

The directive also provides legal standing to natural and legal persons, associations, and NGOs that meet specific criteria, allowing them to request action or initiate legal proceedings (art. 12; Kingston, 2017). However, the scope of the directive is limited and excludes some categories of environmental damage (e.g. nuclear accidents and marine pollution under international conventions).

Although the directive itself predates the digital transition and does not include explicit technological provisions, its enforcement has become increasingly data-driven. Authorities now use geospatial monitoring data, satellite imagery from the Copernicus programme, and digital emissions registers to identify the source and extent of environmental damage. Electronic reporting platforms also allow faster submission and cross-border exchange of evidence. These developments enhance transparency, accelerate liability procedures, and support more consistent enforcement across the European Union. At the same time, they raise legal questions about the reliability and admissibility of digital evidence and the uneven digital capacities of national authorities. Thus, digital tools both strengthen and complicate the practical implementation of the Environmental Liability Directive.

4.2. Sectoral (Vertical) Legislation

EU environmental law includes numerous sector-specific directives, which form the backbone of vertical environmental regulation. These include distinct legal frameworks for water, air, soil, waste, and nature protection.

In practice, the implementation and enforcement of these sectoral directives have become increasingly dependent on digital tools. Real-time monitoring systems, geospatial data platforms coordinated by the European Environment Agency's Eionet network, and satellite-based observations from the Copernicus programme now provide a data foundation for assessing compliance across the

European Union. These digital systems improve transparency, allow faster detection of non-compliance, and support cross-border coordination, but they also raise challenges related to data interoperability, accuracy, and unequal technical capacities among Member States.

4.2.1. *Water Protection*

The Water Framework Directive establishes a unified approach to water quality, integrating environmental objectives with sustainable use. It mandates river basin management plans and public participation to achieve “good status” for all EU waters ([Directive 2000/60/EC, art. 4–14](#)).

The implementation of this directive has increasingly relied on digital technologies. Real-time water quality monitoring networks, automated data loggers, and geospatial information systems now provide continuous data on pollutants, water levels, and ecological status. Platforms coordinated by the European Environment Agency and the Eionet network allow Member States to submit harmonised river basin data, which improves comparability and enables earlier detection of risks. These developments enhance transparency and support evidence-based policymaking, but they also raise challenges concerning data interoperability, the accuracy of automated measurements, and unequal technical capacities among Member States. Thus, while digitalisation strengthens the enforcement of the Water Framework Directive, it also requires robust data governance and technical support to ensure uniform application across the EU.

4.2.2. *Air Quality*

Air quality is regulated through [Directive 96/62/EC](#) and subsequent amendments. These define emission standards (acceptable concentrations in ambient air) and limit values (limits on pollutants from specific sources) ([Directive 96/62/EC](#); [Directive 2008/98/EC](#)). The directives target sulfur dioxide, nitrogen dioxide, and particulate matter.

The enforcement of EU air quality legislation has become increasingly data-driven. Dense monitoring networks now collect real-time air quality data across the European Union, while satellite observations from the Copernicus programme provide complementary large-scale data on pollutant dispersion. These data are compiled and validated through the European Environment Agency’s Eionet platform, which allows Member States and EU institutions to track compliance with limit values almost in real time. This digital infrastructure enables faster detection of exceedances, more targeted enforcement actions, and better public access to information. However, it also raises challenges, including the need for harmonised data standards, the calibration of diverse

sensor systems, and the legal admissibility of automated data in enforcement procedures. Thus, while digitalisation enhances the effectiveness of air quality regulation, it also demands stronger safeguards to ensure the reliability and comparability of data across Member States.

4.2.3. *Soil Protection*

Although the EU lacks a comprehensive directive on soil protection, various legal instruments address soil protection indirectly, such as the Nitrates Directive and hazardous waste legislation.

Despite the absence of a dedicated soil framework, the monitoring and enforcement of soil-related obligations have become increasingly digitalised. Remote sensing technologies, including satellite imagery from the Copernicus programme, and geospatial data platforms coordinated by the European Environment Agency's Eionet network, are used to identify land degradation, erosion risks, and nitrate pollution hotspots. Big-data-based risk assessment tools allow authorities to combine soil quality data with information on land use, fertiliser application, and industrial activity, enabling more targeted inspections and preventive measures. However, these tools also raise challenges related to data accuracy, the harmonisation of methodologies, and the limited digital capacities of some Member States. Thus, digital technologies can significantly strengthen soil protection efforts, but they also require common technical standards and adequate institutional support to ensure reliable and comparable results.

4.2.4. *Noise Regulation*

Several directives set limits on noise emissions from vehicles, equipment, and industrial activities. Directive 2002/49/EC, in particular, regulates noise mapping and action planning in urban and transport contexts ([Regulation \(EC\) No 1107/2009](#); [Directive 2001/18/EC](#); [Regulation \(EC\) No 1907/2006](#)).

The implementation of EU noise legislation has become increasingly digitalised. Member States now use advanced noise modelling software, digital sound level meters, and geographic information systems (GIS) to produce high-resolution noise maps required under the Environmental Noise Directive. These maps are published through online platforms, improving public access to information and enabling data-driven urban planning to reduce noise exposure. Digital tools also allow the integration of noise data with transport and land-use datasets, supporting more coherent policy decisions. However, these technologies raise challenges related to data standardisation, the calibration of measurement devices, and the long-term maintenance of digital platforms. Thus, while

digitalisation enhances the accuracy, transparency, and usability of noise mapping, it also requires harmonised methodologies and sustained technical capacity across the European Union to ensure consistent implementation.

4.2.5. Hazardous Activities and Substances

Specific regulations apply to hazardous substances, including chemicals, plant protection products, and genetically modified organisms. These instruments ensure that activities posing high environmental risk are subject to strict controls.

The regulation of hazardous activities and substances has become increasingly reliant on digital data systems and risk assessment tools. Under the REACH Regulation, for example, manufacturers and importers are required to submit detailed chemical safety data electronically to the European Chemicals Agency, which maintains a centralised digital database accessible to national authorities. Similar electronic reporting and approval systems apply to plant protection products and genetically modified organisms. These platforms enable large-scale data analysis and support early identification of high-risk substances, improving both transparency and enforcement. However, the complexity of these datasets raises challenges related to data accuracy, algorithmic transparency in risk modelling, and cybersecurity. Thus, while digitalisation enhances the efficiency and scope of hazardous substance regulation, it also requires robust data governance frameworks and harmonised IT capacities across the European Union to ensure reliability and legal certainty.

4.2.6. Nature Protection

The Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) form the legal basis of the Natura 2000 ecological network. These directives aim to conserve natural habitats and wild species across the EU. Member States are obliged to designate protected areas and maintain their conservation status.

The implementation and monitoring of these nature conservation directives increasingly rely on digital technologies. Satellite-based remote sensing through the Copernicus programme and geospatial mapping tools coordinated by the European Environment Agency are used to track land cover changes, habitat quality, and species distribution across Natura 2000 sites. Centralised digital reporting platforms allow Member States to submit standardised data on the status of protected areas, which improve comparability and supports early detection of ecological degradation. These developments enhance transparency and enable more proactive conservation planning, but they also raise challenges related to data harmonisation, the validation of automated ecological indicators, and disparities in digital capacity among Member States.

Thus, while digitalisation strengthens the effectiveness of the Habitats and Birds Directives, it also requires robust data standards and sufficient technical support to ensure consistent protection across the EU.

5. Conclusion

This paper has examined how the European Union's environmental legal framework is being reshaped by digital transformation. Using legal analysis, it reviewed the EU's core environmental principles, horizontal and sectoral legislation, and the allocation of environmental responsibility, focusing on how their implementation increasingly relies on digital tools. The study found that data-driven regulation, real-time monitoring systems, and cross-border information platforms have become essential for ensuring compliance, transparency, and harmonisation across Member States. At the same time, it identified persistent challenges, including data interoperability, disparities in digital capacities, and the legal admissibility of digital evidence. These findings highlight the need for coherent legal frameworks that integrate technological advances while upholding fundamental environmental principles.

The European Union's environmental legal framework is grounded in a robust set of principles and regulatory mechanisms that aim to ensure sustainable development and ecological integrity across Member States. However, as digital transformation accelerates, the nature of environmental governance is undergoing fundamental changes. Technologies such as real-time monitoring, electronic reporting, and cross-border data sharing are no longer peripheral tools – they are becoming integral components of legal implementation and compliance.

This paper has argued that traditional legal instruments – both horizontal and sector-specific – must increasingly adapt to a digital regulatory environment. The harmonisation of national laws within the EU now depends not only on aligning legal texts but also on standardising digital infrastructure and processes. While principles such as the “polluter pays” principle or the precautionary principle remain central, their effectiveness in practice is increasingly linked to the Union's capacity to integrate digital technologies into its environmental governance system.

Therefore, the future of EU environmental law depends on its ability to evolve in two directions simultaneously: preserving the foundational legal principles while actively developing digital capabilities that support enforcement, transparency, and accountability. A deeper integration between law and technology will be essential for addressing complex transboundary environmental challenges.

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