Camilla ACQUARONE[1] – Pranav SATYANATH[2] – Virginia MARAGLINO[3] – Marie-Claire DE BRUIJN[4] – Avisha PAWAR[5] – László MEZEY[6] – Rana ALSHAERI[7] – Laurène MUSELET[8]

From Pixels to Policy to the Court: The Current Legal and Jurisdictional Landscape of the Use of Remote Sensing Data for Environmental Protection in the EU

Abstract

The paper analyses the legal framework for the collection and distribution of remote sensing data, particularly in the field of sustainable development and environmental protection at the European level. The research firstly focuses on the historical evolution of space law at the international, European, and national levels, starting from the 1970s. In parallel, environmental law has rapidly developed since the Stockholm Conference of 1972, with thousands of sources regulating aspects related to nature, the environment,

1 | Doctor in Space Law at the University of Paris Cité, France; Contract Manager – Launch Services, AVIO S.p.A.; ORCID: https://orcid.org/0009-0000-0664-1050, e-mail: ca.spacelaw@outlook.com
2 | Policy associate at SkyServe; e-mail: pranav.rs115@gmail.com
3 | EUSPA – Security Authority Department – Administrative Support; e-mail: virginiamaraglino@gmail.com
4 | University of Cologne, Cologne, Germany; e-mail: mdebruij@smail.uni-koeln.de
5 | Sales Associate – AAC Clyde Space; e-mail: avishapawar1998@gmail.com
6 | PhD Candidate in Space Law at the University of Miskolc, Hungary; Intern at Central European Academy; ORCID: https://orcid.org/0009-0009-3830-1259; e-mail: mezey.laszlo@centraleuropean-academy.hu
7 | Regulatory and Legal Jr. Associate at Neo Space Group; e-mail: alshaerilaw@gmail.com
8 | Master's in Geographical Information Science at Lund University, Sweden; e-mail: laurene.mslt@gmail.com

Camilla ACQUARONE – Pranav SATYANATH – Virginia MARAGLINO, Marie-Claire DE BRUIJN – Avisha PAWAR – László MEZEY – Rana ALSHAERI – Laurène MUSELET: From Pixels to Policy to the Court: The Current Legal and Jurisdictional Landscape of the Use of Remote Sensing Data for Environmental Protection in the EU. *Journal of Agricultural and Environmental Law* ISSN 1788-6171, 2025 Vol. XX No. 39 pp. 263–298

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and sustainable development. However, the effectiveness of environmental law remains a challenge due to technical difficulties, high costs, and a lack of awareness at all levels. To overcome these obstacles, remote sensing offers valuable information for environmental policies, from conception to implementation. Therefore, satellite observation is considered to analyse whether the data obtained through remote sensing can have a real impact on environmental protection, supporting this sometimes-flawed legislation. A legal framework was established with UN Resolution 41/65 in 1986, defining principles of cooperation and access to satellite data, particularly for natural disasters. Europe, through its institutions and policies, plays a key role in the development of environmental law and the promotion of new technologies to facilitate the application of these rules and the deployment of ambitious policies. A preliminary question is whether European institutions are the most suitable legislative and judicial level to ensure environmental compliance or if controls and decision-making at the local level are more effective, although this effectiveness is difficult to assess. Regarding the use of remote sensing, despite the growing availability of satellite data and a move towards an 'Open Data' system promoting sharing, use, and archiving of these data through a favourable European framework, legal and technical constraints hinder free use in all areas. Limitations may exist due to risks to privacy or intellectual property. Additionally, certain applications of satellite data remain underutilised due to prohibitions related to national security or diplomatic reasons. One of the main obstacles at the member state level of the European Union is the reluctance of legal bodies and the courts to accept satellite data as evidence, often due to a lack of understanding of the technology and concerns about data accuracy and confidentiality. Furthermore, cost and technical complexity issues limit the widespread adoption of these technologies. From a legal and academic perspective, it is interesting to compare the approaches of member states, in light of the different rules of civil, criminal, and administrative procedure, and to identify anomalies or barriers to the admissibility of evidence from remote sensing. In conclusion, data derived from remote sensing offers powerful tools for environmental protection, but their effective use requires international cooperation, robust legal frameworks, and increased stakeholder awareness. To maximise the impact of these technologies, it is essential to overcome legal and technical obstacles and encourage broader and more informed adoption of these innovative tools, harmonising the practices of member states.

Keywords: Remote Sensing Data, Environmental Law, Sustainable Development, Space Policy, Earth Observation, Data Admissibility

1. Introduction and methodology

The use of satellites for Earth Observation (EO) traces its origins in the Cold War, when the Soviet Union and the United States developed advanced space capabilities for reconnaissance missions and to monitor each other's military capabilities. Since the launch of Landsat in 1972, satellites have become important tools for sustainable development and environmental protection. Improvements in sensor technology have enabled countries to closely monitor the Earth's ozone layer and track changes in ecological systems. Such capabilities help identify and proscribe harmful pollution practices, thus enhancing mitigation and adaptation efforts. However, given that EO capabilities continue to be essential for militaries worldwide, the use of remote sensing data is constrained in the name of national security.

While the UN Resolution 41/65 on the Principles Relating to Remote Sensing of the Earth from Outer Space—although a non-binding soft law instrument—encourages the free use of satellite data for environmental protection among states, in practice, the actual application of such unrestricted use of satellite data for environmental protection is frequently limited by legal and technical barriers.[9] At the international level, the International Court of Justice may not oppose the use of satellite data as evidence in cases of environmental law violations.[10] However, judges in European states have been hesitant to accept this type of evidence, and the admissibility of such data is often made on a case-by-case basis.

There are three reasons for such hesitancy. First, the *procedural rules* for using satellite data as evidence in court vary from country to country within the EU. Second, the *admissibility* of satellite data is often conditioned by compliance with legislation for protecting privacy or intellectual property. Third, countries continue to *doubt the reliability* of satellite data. The complexity of using satellite data as evidence for prosecuting violations of environmental law has been understudied in the existing literature.

This paper, therefore, will explore the regulatory frameworks governing the use and dissemination of remote sensing data under international law and within the European Union (EU). Then it delves into the legal concerns that limit how various actors can use remote sensing data to detect violations of international, European, national, and environmental laws. It specifically examines the legal frameworks of Germany, Austria, Italy, and the Netherlands to unpack the extent to which these laws either permit or prevent the use of satellite data for environmental protection.

The research adopts a multi-step and layered methodological approach. Initially, it undertakes a historical and descriptive review of the evolution of legal instruments in both environmental law and space law, aiming to contextualize the progressive intersection between these two fields. This first phase relies on a documentary and observational method, which allows for the identification and synthesis of key developments in international, regional and European legal frameworks.

In a second phase, the research applies a descriptive-analytical approach to selected European policies that explicitly associate remote sensing technologies with environmental protection. The goal is to highlight how space-based data is

9 | Gabrynowicz 2012, 181–185.
10 | ICJ Reports 1986, 582–583.

integrated into environmental monitoring and regulatory systems within the European Union.

Finally, the study employs an analogical reasoning method—not strictly a comparative legal analysis—to examine and confront specific legal cases or approaches adopted by different European countries. While this does not amount to a formal comparative methodology in the traditional sense, it allows for the identification of common patterns, divergences, and potential best practices in the use of remote sensing for environmental purposes across various national legal frameworks.

By studying these complexities closely, the paper addresses the possible need for comprehensive legislation and policy measures for environmental protection within the EU.

This research aims to explore the potential of remote sensing data in advancing environmental protection. It investigates whether such data can play a significant role, and if so, evaluates how it is currently applied, what challenges—both legal and technical—limit its effectiveness, and what improvements are needed. Ultimately, the study seeks to promote more strategic and informed use of remote sensing technologies, while encouraging greater consistency in how member states implement related practices.

2. Historical evolution of space technologies: from military to civil purposes

2.1. The evolution of Landsat

Remote sensing technology, which originated from early 20th-century aerial photography used primarily for military reconnaissance and mapping, has undergone a remarkable evolution over the past century. Initially, this technology was limited to capturing images from aircraft, serving as a critical tool for military operations and territorial mapping. The images obtained were monochromatic, and their interpretation required specialised skills to extract meaningful information about the terrain and objects on the ground.[11]

As technology advanced, the introduction of multispectral cameras and infrared sensors during World War II expanded the capabilities of aerial photography, allowing for the detection of features not visible to the naked eye. These advancements laid the groundwork for the transition from airborne to spaceborne remote sensing, marking a significant leap in the scope and scale of data collection. The launch of the first weather satellite, TIROS-1, in 1960 marked the beginning of the satellite remote sensing era. This milestone was quickly followed by deploying more sophisticated satellites designed to monitor Earth's weather patterns,

11 | NASA Landsat History n.d.

environmental conditions, and land use. The development of these satellites was initially driven by the Cold War, with a strong focus on military applications such as missile detection and intelligence gathering.[12]

Satellites equipped with sensors capable of capturing electromagnetic radiation across various spectral bands have since expanded their use beyond military applications to support a wide range of scientific and commercial purposes. These sensors collect data on reflected sunlight or emitted thermal energy from the Earth's surface and atmosphere, which is then transmitted to ground stations.[13] The data undergoes processing to create images that can be analysed to monitor environmental changes and manage natural resources. This ability to observe large-scale environmental phenomena with precision has made remote sensing indispensable in both scientific research and environmental stewardship.[14]

However, the potential of remote sensing for civilian applications soon became apparent. The launch of Landsat 1 in 1972 by NASA, as part of a joint effort with the U.S. Geological Survey (USGS), revolutionised the field by providing continuous, systematic coverage of the Earth's surface. This enabled scientists to monitor environmental changes, such as deforestation, urbanisation, and agricultural practices, on a global scale. The ability to capture data across multiple spectral bands allowed for more detailed analysis of Earth's surface, facilitating advancements in environmental science, agriculture, and natural resource management.[15]

As Cold War tensions began to subside, the focus of the Landsat program gradually shifted from its initial strategic objectives towards broader environmental monitoring and civilian applications. This transition was reflected in the technological advancements introduced with the launch of Landsat 4 and 5 in the 1980s. These satellites were equipped with the Thematic Mapper (TM) sensor, a significant upgrade that provided higher spatial resolution and the ability to capture data in seven spectral bands. The enhanced capabilities of the TM sensor allowed for more precise tracking of changes in land cover, vegetation healthiness, and water quality over time. One of the most notable applications of Landsat during this period was its role in the aftermath of the Chernobyl disaster in 1986. Landsat 5 played a crucial role in providing critical thermal imagery that helped confirm the severity of the incident. The satellite's ability to detect thermal anomalies in the surrounding area provided valuable information to scientists and authorities, demonstrating the practical and life-saving applications of remote sensing technology in disaster response and management.[16]

The post-Cold War era witnessed the continued evolution of the Landsat program, with the launch of Landsat 6, 7, 8, and 9. Each successive satellite

12 | Showstack 2022, 226–232.
13 | Goward et al. 2022, 357–358.
14 | Colwell 1984, 1305–1307.
15 | Williams, Goward & Arvidson 2006, 1171–1178.
16 | USGS n.d.

introduced new technological advancements, further expanding the scope and utility of the data collected. These missions enabled more comprehensive monitoring of Earth's changing climate, ecosystems, and land use patterns. The ability to observe and analyse such changes in near real-time became increasingly important for addressing global environmental challenges, from climate change to sustainable resource management.[17]

A key turning point in the Landsat program was the passage of the U.S. Land Remote Sensing Act of 1992. This legislation played a key role in ensuring the program's continuity by mandating that the U.S. government maintain a permanent global Landsat imaging archive. The act established a legal framework that guaranteed the ongoing collection, preservation, and distribution of high-quality Earth observation data. This stable foundation has been essential for long-term environmental monitoring, supporting a wide range of scientific research, policy-making, and commercial applications.[18] Prior to the passage of this legislation, the U.S. government attempted to privatise the program through the Land Remote-Sensing Commercialization Act of 1984, transferring operations to Earth Observation Satellite Company (EOSAT). However, this effort failed due to financial challenges, limited market demand, and national security concerns.

2.2. The Sentinel program

Parallel to the advancements made by the Landsat program, Europe developed its own remote sensing capabilities through the European Space Agency's (ESA) Copernicus initiative, which includes the Sentinel series of satellites. The program, including the Sentinel satellite missions, is governed by EU law, specifically Regulation (EU) No 377/2014. This regulation establishes the legal framework for the program and ensures free, full, and open access to Copernicus Sentinel data and service information for lawful uses.[19] The Sentinel satellite mission represented a significant leap forward in remote sensing, particularly in terms of technological sophistication and environmental monitoring capabilities.[20]

Sentinel-1, launched in 2014, marked the beginning of this new era. As a radar imaging satellite, Sentinel-1 offers all-weather, day-and-night observations, which are invaluable for monitoring natural disasters such as floods and earthquakes.[21] The program continued to expand with the launch of Sentinel-2 in 2015 and 2017, providing high-resolution optical imagery across 13 spectral bands. This capability is particularly useful for agricultural monitoring, forest cover analysis, and the management of water bodies and coastal areas. The frequent revisit

17 | NASA, Landsat History n.d.
18 | Williams, Goward, & Arvidson 2006, 1171–1178.
19 | Liang 2017, 181–185.
20 | ESA, The Sentinel Missions n.d.
21 | Nagler et al. 2015, 9371–9389.

time of Sentinel-2 satellites, every five days, allowed for the timely detection of environmental changes, making it an essential tool for effective environmental management.[22]

Sentinel-3, launched in 2016, focuses on ocean and land monitoring, while Sentinel-5P, launched in 2017, monitors atmospheric composition, providing data on air quality and ozone levels. These satellites contribute significantly to climate research, environmental protection, and public health by offering detailed and continuous observations of both land and atmospheric conditions. Sentinel-6, launched in 2020, further enhances the program's capabilities by measuring global sea-surface height, supporting climate studies and operational oceanography.[23]

2.3. Synergy between Landsat and Sentinel programs

The combined efforts of the Landsat and Sentinel programs have created a robust and complementary system for Earth Observation. The synergistic use of data from these programs enhances the accuracy and reliability of environmental monitoring. For instance, the high temporal resolution provided by Sentinel-2 complements the long-term historical data from Landsat, allowing for more effective tracking of environmental changes over time. This synergy is particularly valuable in applications such as tracking deforestation, monitoring urban sprawl, and managing natural resources, where precise and consistent data are critical.

The joint operation of the Landsat and Sentinel programs not only achieves technical synergy through their complementary Earth observation capabilities but also establishes a legal framework that promotes broad and open access to high-quality satellite data. Notably, the Sentinel program's data availability is backed by binding European Union legislation that mandates free, full, and open access within the EU. As a result, the shared open data policies of both programs have significantly democratized access to remote sensing information, making it widely available for public, scientific, and commercial use.[24]

This accessibility has not only spurred innovation and collaboration among scientists, policymakers, and environmental organisations but has also led to more informed decision-making and better environmental stewardship. The

22 | ESA, The Sentinel Missions n.d.

23 | Montenbruck, Steigenberger & Hugentobler 2021, 1235.

24 | The open data policy for Sentinel data is established under Regulation (EU) No 377/2014 of the European Parliament and of the Council, and further reinforced by the Copernicus Regulation (EU) 2019/696. Article 36 of the latter stipulates that the "data and information produced in the framework of Copernicus should be made available on a full, open and free-of-charge basis subject to appropriate conditions and limitations, in order to promote their use and sharing, and to strengthen European Earth observation markets"; Regarding Landsat data, the United States Geological Survey (USGS) formally adopted an open data policy in 2008, eliminating access fees. While not enacted through legislation, this policy is supported by the U.S. Open Data Policy (OMB Memorandum M-13-13) and relevant USGS directives.

detailed imagery and data collected by these American and European programs are increasingly being used to enforce environmental regulations, conduct impact assessments, and support legal actions against environmental violations.

Besides the technical perspective and comparisons with American examples, we should now focus on the European legal framework that enables the use of remote sensing data for environmental protection and enforcement against environmental crimes.

3. Legal framework and implications of remote sensing technology in environmental crimes

The rapid advancement of remote sensing technology and the increasing availability of Earth observation data have driven the need for a comprehensive legal framework to regulate their use and sharing. This framework began forming during the Cold War, focusing on both military and civilian applications. The United Nations (UN) has been instrumental in shaping international laws and guiding non-binding instruments governing remote sensing, starting with the 1967 Outer Space Treaty, which established that space activities should benefit all humankind. Building on this, the UN's Resolution 41/65 in 1986 emphasised the importance of sharing environmental data, especially during natural disasters, while respecting state sovereignty.

The Landsat program has been central to these legal discussions, particularly regarding issues of national sovereignty and data sharing. Early Landsat missions raised concerns about privacy and the use of satellite imagery without the consent of the observed countries. However, as the environmental benefits of remote sensing became clearer, there was a growing consensus on the need for international cooperation.[25]

Building on these early legal challenges, the framework governing remote sensing continues to evolve, especially in response to the increasing involvement of private companies and the commercialization of satellite data. This expansion necessitates regulations addressing intellectual property rights, data security, and the responsibilities of private entities in sharing data for public benefit. Moreover, the integration of emerging technologies, such as AI and machine learning, into remote sensing processes presents new legal and ethical challenges that must be addressed to ensure responsible and equitable use. As remote sensing capabilities grow, a robust and adaptive legal framework will be essential to balance national interests with global good.

25 | Williamson 2000, 233–244.

3.1. Legal foundations of environmental protection and introduction to environmental trials

Regardless of how fast our society develops and advances technologically, human dependence on the environment and natural resources has been constant since the dawn of history. In 2022, the United Nations General Assembly (UNGA) adopted a resolution (building upon a similar text adopted by the Human Rights Council in October 2021)[26] affirming the right of every individual to a healthy environment.[27] This decision underscores the intrinsic connection between human rights and environmental health, forcing states, international organisations, and business enterprises to secure and ensure a healthy environment for all.[28] Environmental crimes, however, are indiscriminately affecting all countries, posing significant threats to biodiversity, national security, and socio-economic development.[29] These crimes are defined as "illegal activities that harm the environment and are intended to benefit individuals, groups, or companies through the exploitation, damage, trade, or theft of natural resources. This includes, but is not limited to, serious crimes and transnational organised crimes."[30]

Recognizing that environmental crimes have such significant repercussions, a multi-level approach to protection is necessary, along with the successful prevention of harm requiring strict regulations. The necessity of protecting the environment was first recognized at the international level by the 1972 Stockholm Declaration[31] and later reinforced by the 1992 Rio Declaration on Environment and Development;[32] even though the above-mentioned declarations have marked a major step in the international recognition of the importance of preventing harmful interference with the environment, it is important to emphasize that they are non-binding international declarations. This means that, while they express political will and establish guiding principles, they are not legally enforceable in the same way as treaties or conventions.[33]

Environmental protection has also been integrated at European and regional levels, for example through the 1999 Treaty of Amsterdam, which mandates the integration of environmental protection into all EU sectoral policies to promote sustainable development,[34] and national legislation. Important to highlight in this context is the old Roman law principle *nulla poena sine lege* ('no penalty without a

26 | UN News 2021.
27 | UN News 2022.
28 | Ibid.
29 | Geneva Environment Network 2024.
30 | UNEP 2024.
31 | United Nations 1972.
32 | Ibid.
33 | Viñuales (ed.) 2015, 85–97.
34 | Treaty of Amsterdam 1997.

law'), which is fulfilled in a sense that environmental crimes are legally prohibited, consequently providing a legal basis for punishment.

Turning back to the European level, various initiatives are responsible for identifying, investigating, and prosecuting environmental offenders, including individuals and organisations.[35] These efforts address a range of environmental crimes, such as air and water pollution, hazardous waste violations, pesticide-related offences, and wildlife crimes. However, the role of law enforcement in environmental matters encompasses two primary functions: monitoring and sanctioning.[36]

- Monitoring involves overseeing compliance with environmental laws and ensuring adherence to regulations.[37]
- Sanctioning refers to the actions taken when violations are detected through monitoring, leading to appropriate enforcement measures.[38]

By combining these two aspects, law enforcement agencies aim to uphold environmental laws and mitigate the impact of environmental offences.

4. EU's remote sensing capabilities

In the early 80s, European countries gave the ESA the task of creating and running the first European remote sensing satellite, ERS-1, and then ERS-2[39]. Since then, and thanks to the combination of changing military and strategic environments and the increasing interest in satellite images and data, there is a growing international market for geo-spatial information and high-resolution commercial remote sensing[40]. Today, satellites operating at higher spatial resolutions can provide significantly more detailed information, and the most modern recent satellites are able to produce pictures with greater visibility, allowing us to observe objects like buildings, ships, and cars in a far more accurate way.[41] In order to promote long-term prosperity, improve security, and assist in the implementation of sustainable policies, remote sensing is essential. The competence of the EU in remote sensing and its application throughout Europe and its member states are examined in the section that follows.

35 | Dighe et al. 2012, 65–70.
36 | Billiet 2012, 322–328.
37 | Ibid.
38 | Ibid.
39 | European Space Agency Remote Sensing Data n.d.
40 | Institut Français d'Histoire de l'Espace, 2018.
41 | Purdy et al. 2010.

4.1. Use of remote sensing for enforcing environmental protection

The European Union has established significant competence in remote sensing which opens the door for environmental enforcement through a combination of policy frameworks, technological advancements, and institutional collaborations. A notable legal framework is the INSPIRE Directive (2007/2/EC), which aims to establish a comprehensive spatial data infrastructure across the European Union. This directive mandates the sharing of geospatial data across EU countries, facilitating better decision-making and fostering innovation. It answers the identified problems related to lack of availability, quality, organisation, accessibility, and sharing of spatial information common to many policies and activities across various levels of public authority in Europe.[42] INSPIRE has become a model in the world and a milestone for the implementation of transnational services.[43]

Furthermore, one must put an emphasis on EU's flagship, the Copernicus Programme which provides data and information to all users on a full open and free-of-charge basis allowing for the development of many downstream services.[44] In order to improve access to big data from space and maximise benefits to the different user communities, the EU has invested in developing advanced data processing and distribution systems. The Copernicus Data and Information Access Services (DIAS)[45] platform allows users to access and process Copernicus data easily. This accessibility ensures that a wide range of stakeholders, from policymakers to scientists and private sector actors, can leverage remote sensing data for various applications such as environmental enforcement. The success of DIAS strongly relies on the relationships between Copernicus actors such as Member states and other participating countries, which thus makes it possible to connect EO to many domains.[46]

Another essential component of the EU's remote sensing and space capabilities is the Galileo system, the EU's Global Navigation Satellite System (GNSS), designed to provide highly accurate global positioning services. The system is operated by the European GNSS Agency and ESA, with programme oversight by the European Commission (EC) and political oversight by the European Council and the European Parliament. Unlike the US GPS or Russia's GLONASS, Galileo is under civilian control, ensuring independence and strategic autonomy in Europe. Galileo significantly enhances the EU's remote sensing competence by providing precise positioning data that complements the observational data from Copernicus.[47]

42 | United Nations Statistics Division n.d.
43 | Guo, Goodchild & Annoni 2020, 676.
44 | Ibid., 654–655.
45 | Copernicus, Accès aux données – DIAS. n.d.
46 | Guo, Goodchild & Annoni 2020, 660.
47 | Ibid., 676.

The application of remote sensing for environmental enforcement in the EU takes different approaches. The use of remote sensing can act as an environmental compliance tool and environmental monitoring. The Copernicus Programme provides critical data for tracking changes in land use, deforestation,[48] desertification, and biodiversity. Furthermore, it has a key role in monitoring climate change as satellites measure key indicators such as sea surface temperatures, atmospheric composition, and ice sheet dynamics. This data helps scientists understand climate trends and supports the EU's commitments under international agreements like the Paris Agreement.

In 2023, the European Union Agency for the Space Programme (EUSPA) issued its report on the EU Space Programme for Green Transformation with an emphasis given to the business benefit from a myriad of possible applications for EU space data, which translates into not only greener practices, but also cost reduction and increased efficiency.[49] The EUSPA highlights the benefits and usefulness of using space data especially in a path to decarbonisation of energy resources. Such businesses can be significantly supported by Copernicus and Galileo data. The EUSPA's report puts an emphasis on how remote sensing technology can further facilitate collaboration between companies, governments, and other stakeholders to address pressing environmental challenges.

EO and GNSS are becoming more efficient and more applied as tools to provide a better understanding of the effects of climate change, extreme weather conditions and human activities' impacts. For instance, remote sensing data can be an extremely useful instrument in terms of intense socio-political phenomena on Cultural Heritage monuments, which represent a long tradition in Europe. In 2019, a four-year EU-funded initiative HYPERION supported sustainable maintenance and mitigation strategies for damaged sites.[50] In Venice, the vulnerability maps produced by HYPERION proved to be essential in helping local authorities in assessing meteorological threats and gathering useful information for more effective methods of restoration and safeguarding historic and cultural sites against environmental and human hazards.[51]

Remote sensing data can also serve in policy enforcement and regulatory monitoring. It is the case for the European agricultural sector where satellites are used to monitor farm subsidies payments.[52] Most EU countries use the technology

48 | Purdy et al. 2010.
49 | EU Agency for Space Programme 2023.
50 | European Union Agency for the Space Programme 2024.
51 | Hyperion Project EU 2019.
52 | According to Carleer et al. 2005 "Launched in 1962, the European Union's Common Agricultural Policy (CAP) is a partnership between agriculture and society, as well as between Europe and its farmers. Its objectives are to:
- Support farmers and improve agricultural productivity by ensuring a stable supply of affordable food,
- Guarantee reasonable support for EU farmers to combat climate change and promote sustainable resource management,

to identify crops, to determine correct areas of agricultural parcels and check if claimants are compliant regarding environmental conditions for subsidies eligibility. EU Member States use satellite-based monitoring systems for inspection and enforcement of fisheries under community legislation.[53]

In the framework of the Common Agricultural Policy, farmers became eligible for subsidies as long as they maintained their land in good condition and complied with standards on public, plant, and animal health and welfare.[54] Payment eligibility is the responsibility of the EU member states, for which each country needs an Integrated Administration and Control System, including a Land Parcel Identification System (LPIS). The development, update, and revision of the LPIS, which can be based on existing maps and documents from national land registers, is increasingly based on high-resolution aerial photography and satellite imagery.[55]

In the Netherlands, remote sensing technology plays a crucial role in facilitating a direct financial intervention for beach nourishment. This process is designed to strengthen coastal protection by replenishing dunes and beaches that have been eroded. Airborne laser altimetry measures the elevation of the beach's dry areas to determine the necessary sand volume, while sonar surveys the underwater sections. The data collected guides the contractors responsible for the beach nourishment. The central government, specifically the Ministry of Public Works, oversees the maintenance of coastal defence lines, utilising a financial instrument to support its objective of enhancing coastal defence through beach nourishment. EO significantly enhances the effectiveness and efficiency of this policy by accurately assessing the required sand volume.[56]

Similarly, remote sensing can also be used for monitoring offenders, since it can monitor individual sites or areas where environmental offences have been known to occur historically, hence finding its strength as being used for historical evidence. Indeed, the systematic archiving of satellite images can – in theory – provide regulators with a relatively impartial snapshot of any location at any given time. In 2006, a prosecution for an offence linked to an illegal landfill site occurred in the UK, and the Environment Agency managed to time the offence between May 2005 and January 2006 thanks to the available images, which is longer than

• Preserve rural areas and landscapes across the EU,
• Maintain rural economies by promoting jobs in agriculture, agri-food industries, and related sectors.
The CAP is financed by two funds: the European Agricultural Guarantee Fund (EAGF), which provides direct economic support to market players, and the European Agricultural Fund for Rural Development (EAFRD), which finances rural development. The EU budget for 2021 allocated a total of €168.5 billion in commitment appropriations. In 2021, the CAP accounted for 33.1% of the EU-27 budget (€55.71 billion)" and European Parliament The financing of the CAP n.d.

53 | Purdy et al. 2010.

54 | The European Union's Common Agricultural Policy is based on a series of regulatory instruments, the most important of which is Regulation (EU) 1305/2013 on rural development support through the European Agricultural Fund for Rural Development (EAFRD).

55 | De Leeuw, van der Meer & de Wit 2010.

56 | Ibid.

what was stated during the prosecution.[57] This highlights the practical function of imagery archives for prosecuting authorities. If they had access to such imagery, then they might have used this in court to press for a harsher and more equitable sentence.[58]

4.2. Implementation challenges and future directions

Europe has established significant competence in remote sensing through a combination of policy frameworks, technological advancements, and institutional collaborations. Despite extensive use of remote sensing, the actual application of EO in terms of environmental compliance is currently more theoretical than applied. Its use in this field has been limited to date, partly because its development has been technology-led, with a noticeable lack of legal co-operation and input on technology design and applications. Because those working in the environmental law sector have little to no awareness of the capabilities of these new EO technologies, their application has been inadequate in comparison to their potential. Before they can be utilised in an environmental compliance context, better understanding and communication is needed regarding whether they can achieve desired enforcement and monitoring outcomes.[59]

5. Constraints of using remote sensing data for enforcing environmental crimes

A number of technical and legislative obstacles still stand in the way of Europe's efforts to deploy and make use of remote sensing as a strategic tool for environmental tutelage. These obstacles prevent remote sensing technologies from reaching their full potential and have a direct effect on data accessibility, integration, and development of a coherent regulatory framework. In order to fully recognise the advantages of remote sensing for environmentally sustainable management, it is imperative that these challenges be addressed.

5.1. Technical constraints

The use of remote sensing data in legal applications, such as enforcing environmental crimes, carries with it not only legal constraints but technical challenges as well. To accurately understand the information present in the data, one must also understand how the data was processed, including calibration steps, what the

57 | Purdy et al. 2017.
58 | Purdy et al. 2010.
59 | Ibid.

chain of custody of the data is, and whether there is any room for manipulation in this process, as well as how it is presented and interpreted in legal proceedings. Additionally, one must also take into account the differences in the systems used to take data, such as different levels of resolution, as well as the differences in the conditions under which the data was taken (e.g. different levels of cloud cover). In order to facilitate the use of remote sensing data in enforcing environmental crimes, we therefore recommend establishing a baseline set of requirements and guidelines for the system resolution as well as the data quality, calibration and security.

5.2. Calibration

The calibration of the data is an important preprocessing step that is needed to ensure that the data reflects the physical reality. Inaccuracies in the data can stem from both sensor effects, such as residual charges left behind in pixels causing amplification of the signal in those pixels, or varying throughput of different filters. Physical effects such as atmospheric scattering and absorption, the presence of haze, or even the moisture content of soil can also affect the measurements taken by an EO satellite. These effects must be calibrated out. There are two types of calibration that are needed for imagery from Earth observation satellites:

- Geometric calibration: This involves matching pixels in the imagery to coordinate locations on Earth.[60]
- Radiometric calibration: This involved converting sensor units, e.g. digital numbers or DN, to physical units to enable reliable quantitative measurements from imagery. This calibration could be done absolutely using reflectance measurements taken from objects on the ground as the truth.[61] However, this is costly and not possible to do when using archival data. Instead, the common approach is to adopt relative corrections based on a reference image.[62] It is unlikely that the relative radiometric calibration will be consistent across different EO data providers.

5.3. Other data processing steps

In addition to calibration, a number of other steps are needed to process the raw data into an image. Generally, the raw data has to be transferred to a receiving and processing station. Some applications, such as providing imagery to Arctic ships and thermal infrared imagery to forest fire fighters, employ real-time processing of the data, however the resulting images are generally low resolution.

60 | Jacobsen 1998; Mohr & Madsen 2001; Wang et al. 2014.
61 | Slater et al. 1987; Thome et al. 1997.
62 | Yang & Lo 2000.

In general, image processing can include image enhancement, such as contrast stretching and spatial filtering,[63] as well as image transformations which manipulate multiple bands of data to generate new images which highlight particular features better than the original images.[64] Additionally, image classification and analysis can involve the classification and analysis of the image to identify homogeneous groups of pixels which represent various features of interest.[65] In order to use remote sensing data in a legal setting, it is essential that these data processing techniques and their effect on the interpretation of the data are well understood.

5.4. Chain of custody

Data from remote sensing systems moves through a chain of custody, where a number of different people and systems handle the data between its collection by a satellite and its presentation in a courtroom. Given increasing capabilities to alter images and generate deepfakes, it is essential that a traceable and secure chain of custody is in place to ensure the reliability of the data. Aspects of creating such a secure system could include secure electronic records of the data processing steps, and the systems and individuals involved, as well as cryptographic and encryption technologies to strengthen e-signature, timestamp and file authentication.[66]

5.5. Presentation and interpretation in legal proceedings

In addition to the data processing steps described above, when remote sensing images are presented in legal proceedings, the manner in which they are presented might change the information content and interpretation, e.g. if the images are printed out, their resolution could be reduced. Moreover, the complex nature of remote sensing information often requires the testimony of an expert witness to establish its reliability, accuracy, and to interpret it as intelligible evidence. This involves both providing input on the data collection and processing, as well as the interpretation of the processed data. Such reliance on an expert witness might bias the proceedings due to differences in each party's resources and ability to hire prominent experts, and the experts themselves may experience confirmation bias when interpreting the images, based on their side's desired outcome of the proceedings.[67]

63 | Deekshatulu 1983.
64 | Natural Resources Canada 2008.
65 | Ibid.
66 | Kwok 2024.
67 | Lins 1979.

5.6. Inconsistency of data

Not only do the data processing, presentation and interpretation steps described above result in potential inconsistencies, but the data collection process itself might lead to inconsistent data quality across remote sensing systems, and even temporal variations for a single system. The resolution achieved by remote sensing systems, including spatial, radiometric, spectral and temporal resolution, can vary significantly across systems.[68] Spatial resolution is the area on Earth's surface represented by each digital pixel in the image, while radiometric resolution refers to the amount of information in each pixel, i.e. how many digital values are available to store information. Spectral resolution is defined by the capacity of the system to distinguish wavelengths, i.e. have narrow bands, while temporal resolution refers to the frequency with which a satellite returns to the same observation area, and is determined by the satellite's orbit.

These properties vary greatly from satellite to satellite, resulting in large differences in the data quality (e.g. some systems may provide high spatial resolution, but only a few wavelength bands, while others might have hundreds of bands, but low spatial resolution). In fact, countries may also impose limits on the resolution of remote sensing systems. For example, until 2023, the United States did not allow the commercial sales of imagery with a resolution better than 25 cm.[69] Additionally, even for a single remote sensing satellite, varying conditions can impact the data quality, even at constant resolution. For example, increased cloud cover might lead to worse data quality.

These variations in data quality can complicate the process of using remote sensing data in legal proceedings, as there is no guidance for the minimal acceptable data quality, yet poor-quality data can be difficult to understand and interpret correctly.

6. Legal constraints on using remote sensing satellites for environmental purposes

Owing to the inimitable advancements in technology, the collection, organisation, storage, and distribution of earth observation information, decision making concerning environmental protection has been revolutionised. Satellite remote sensing data, supplemented by geographic information systems (GIS), work as formidable tools to resolve environmental and legal problems. Images processed from satellite-based data not only serve as pieces of evidence, but also simplify

68 | Earth Science Data Systems 2019.
69 | Hitchens 2023.

complex datasets of information. With this, it becomes imperative to discern the shortcomings it presents in a legal aspect.

6.1. Data accuracy and authenticity

Anything produced as evidence in a court of law is deemed to be true and accurate. However, the technical nature of satellite data exposes it to intentional and unintentional inaccuracies. Digital imagery basically relies on the pictorial representation of binary codes.[70] Therefore, images derived from satellite data involve a certain degree of subjectivity, as the data that is transmitted to the ground stations on Earth is in a digital format and requires manual operations to create recognisable imagery. In this process, assumptions made by data processors and interpreters are inexorable, resulting in the imagery being manipulated in intentional and unintentional ways. Thus, when there are no definitive legal guidelines for ensuring authentic data processing stages, the assessment of the overall data becomes complex and inconsistent. For instance, in a case regarding the land boundary between Cameroon and Nigeria, satellite imagery that was used led to confusion owing to the conflicting interpretations of the imagery and did not ultimately prove either party's point.[71] This underscores the significance of agreeing on a unanimous standard for accessing the accurate interpretation of imagery.

6.2. Issues with liability

Although issues surrounding accuracy and authenticity can get better with technological advancements and framing objective guidelines, the issues surrounding liability remain relatively unexplored. The UN Remote Sensing Principles – the sole non-legally binding instrument dealing with remote sensing – only addresses matters concerning data gathering and dissemination, and does not address matters relating to the supply, use and consequences of the data application. The principles do not outline any liability for the end-users or third parties that use the data in an abusive manner. Damages that could arise from the misinterpretation/manipulation of the data are not considered. For instance, in times of natural disasters if aid workers rely on the satellite imagery providing information regarding damage assessments in an area that is wrongly interpreted, there is no clear provision on how a claim for liability could be imposed on the data suppliers and analysts. In these cases, users are also less reliant on such data in critical times, and suppliers are also unequipped for liability risks and unanticipated litigation charges.

70 | Purdy 2006.
71 | Ito 2011.

Presently, if disputes regarding the use and application of data do occur, they could be looked through the lens of contractual and tort law, albeit varying in different jurisdictions. Since the supply of data is categorically administered by contracts, the issue of contractual liabilities plays a significant role. In most of the contracts regarding the distribution and use of data, the data generators include provisions that set aside liability for damages, under the terms and conditions of supplying data. Ergo, the remedies that are available to data users are severely limited. For instance, data generators such as Spot Image mandate that they will not be responsible for the supply of 'faulty products' or for the 'damages arising out of or inability to use the product.'[72] Although different entities provide different liability disclaimers, the cardinal principle is the fact that data suppliers always waive off liability associated with the data that is provided.[73] Similarly, when working on GNSS as well, contractual and third-party liability are the only methods for recourse. For a long time owing to the military nature of most of the GNSS like the GPS and GLONASS, responsibility for any errors was not a major cause of concern. Taking into account the civil usage of GPS, as open signals are offered free-of-charge, the US government denies any liability for the performance of its signals or products. Interpreting the term 'contract' in the widest sense possible, the very infeasibility for the data supplier to supervise who receives and uses the product negates the existence of a contract.[74]

Contrary to this, when asserting non-contractual liability, things are very different. Non-contractual or third-party liability, similar to tort liability, could be asserted when the damage occurs outside of the contractual relationship. Simply put, liability is based on the fact that one party is the cause of the damage, which is sustained by another party.[75] When claiming this sort of a liability, circumventing the rule of sovereign immunity, which renders any claims against the US government inadmissible, would be key. While there are exceptions to this rule, owing to the global usage of the GPS, the jurisdictional issue of non-US citizens claiming damages in a US court would persist.[76] However, the situation surrounding the European Galileo system has become distinct since it was launched. Galileo intended to offer Commercial Services (CS) that rely on fees and are based on a purely contractual relationship between the GNSS operator, the data providers and the end users.[77] The owner of the Galileo system, European Union, and the provider, the GNSS Agency (GSA) hold responsibility on contractual and non-contractual basis under the Treaty on the Functioning of the European Union (TFEU).[78] Thus,

72 | Spot Image 2007.
73 | Atsuyo 2011.
74 | Von Der Dunk 2004, 129.
75 | Ibid.
76 | Epstein 1995, 262–268.
77 | Baumann 2015.
78 | Ibid.

end users have the right to seek compensation from several stakeholders that are involved in the GNSS system. However, even under this, contractual liability does not extend beyond European states. Thus, if an entity in India suffers damage owing to the wrong signals from Galileo, they lack the contractual right to recourse as that of their European counterparts. This analysis of the GNSS services makes it clear that the intention of data providers is to deny liability in cases of unlimited beneficiaries, and even in cases of cost-based services there is no specific regime that exists to protect the rights of third parties outside contractual relations, categorically for foreign claimants. Ultimately, in cases of liability concerning satellite-based data, including but not limited to navigation services, potential claims for damages are complicated owing to the number of actors involved and overlapping supply chain, the primary contractual and non-contractual obligations, multiple jurisdictional complications and the competencies of the judiciary.

6.3. Intellectual property right issues

The UN Principles on Remote Sensing, while ensuring accessibility to data on a non-discriminatory basis, do not address IPR issues surrounding the data. Opposed to this, states have afforded IP protection to their data, keeping in mind their national interests and furthering commercialisation. In this regard, under the application of IP rights to satellite data, requires an understanding of the differentiation between primary (raw) data, processed data and analysed data. Raw data is essentially all the signals that are picked up by the sensors on the satellite and are delivered to Earth by telemetry.[79] Processed data, on the other hand, is data that is a product of data handling operations and involves a degree of creativity. Copyrights for remote sensing data are governed under the Berne Convention on Copyrights.[80] Since raw data is merely a representation produced by a machine, it is not granted protection under the Convention. Conversely, since processed and analysed data is a value-added product, it falls under the Convention and is afforded IP protection. In this case, since this type of data is subject to IP regulation, ensuring its non-discriminatory access as mentioned under the UN Principles, becomes incompatible.

Simply put, depending on the characteristics of the data, it could be protected under the law, which varies in different jurisdictions. For instance, under the domestic law in the US, raw data could be available on a non-discriminatory basis, but processed data is subject to copyright, in line with the Berne Convention. Similarly, in the European Union under the Directive 96/9/EC, protection would be granted to sui generis rights.[81] As per the European Model, IPR protection can be

79 | Gummadi et al. 2022, 13–28.

80 | Berne Convention for the Protection of Literary and Artistic Works 1971.

81 | Directive 96/9/EC on the legal protection of databases 1996, 20–28.

granted to both raw, and processed data, unlike in the US. The European derivative can thus only be enforced in Europe, and to its nationals.[82] This copyright protection permitted to processed data fuels the debate regarding commercialisation of data, as opposed to non-discriminatory and equal access to data that the Principles promote. Moreover, these inconsistencies in practice in different jurisdictions is problematic to the international nature of data production and distribution and thus furthers the need for a common regime that deals with IPR protection of remote sensing data.

6.4. National restrictions on satellite data

While the Landsat satellite paved the way for commercial remote sensing satellites, the weak resolution of the imagery in the early decades meant that national security apprehensions were very low. Following this, although the 1986 UN Resolution attempted to balance the rights of the sensed and sensing states, individual nations put forth their own domestic policies, notwithstanding the discordance with the UN Resolution[83]. Specifically, the use of commercial imagery during the 1991 Gulf War, highlighted the susceptibility of such data for furthering military and national security objectives. Owing to these security concerns, nations restricted the sale of such data, if national interests were affected.[84] For instance, the US has devised this policy of 'shutter control', wherein in periods when national security or foreign policies could be compromised, data collection and distribution may be restricted.

Although shutter control has never been implemented as a legitimate policy directive, the US government has put it into effect when required. Following 9/11, the government bought all exclusive rights to the high-resolution images of Afghanistan available in the US market. Through this they ensured that it would be impossible for any other actor to get hold of the commercial US imagery used to surveil the country.[85] Similarly, the Kyl-Bingaman Amendment too prohibits US-based companies from releasing high-resolution images of Israel and the Occupied Territories.[86] In effect, for more than two decades, the resolution limit was 2 metres, hence no US company could sell data with resolution less than the prescribed 2 mts. However, as accessibility to technology improved, and US companies straggled behind their competitors, the policy was ultimately amended. In 2020, the resolution limits were dropped from 2 metres to 40 metres. Thus, while many countries may still impose restrictions based on national security, the

82 | Ibid.
83 | Gabrynowicz 2015, 88–188.
84 | Bhalla 2014, 98–115.
85 | Kang 2024.
86 | U.S. Department of Commerce n.d.

commercialisation of remote sensing data has compelled governments to loosen export control measures or lag behind in the race.

In addition to these restrictions owing to national security concerns, nations may also impose restrictions in tandem with their domestic law protecting privacy rights of their citizens. Typically, while nations regulate privacy rights, it leads to inconsistent and varied policies to regulate satellite data. For instance, in the European context, the General Data Protection Regulation (GDPR) becomes relevant when considering geolocation data by navigation satellite services. Under Article 4(1) of the GDPR, location data is stated as a factor through which a person could be identified directly or indirectly, thus considered an 'identifier' of personal data.[87] Notwithstanding this, several provisions of the GDPR deal with processing of personal data in the context of satellite data, including obligations of the data processors and controllers, the rights of data subjects, and the transfer and protection of data.[88] Although the GDPR provisions deal with personal data protection matters, the legislation is regional in scope and does not address issues specific to satellite data.

7. Analysis of legal cases

In most cases, environmental offences are frequently addressed through informal measures, such as warnings, while the more severe violations may necessitate more serious, formal sanctions. The concept of *ius puniendi* (right to punish) introduces a dual-track approach that operates through criminal and administrative penalties to enforce environmental laws more effectively,[89] while also highlighting the complementary nature of these enforcement mechanisms. Sanctions can be further categorised into punitive sanctions, which aim to penalise offenders, and remedial sanctions, which focus on rectifying environmental damage and preventing future harm.[90]

Administrative sanctioning – similar to the compensation mechanism under civil law – is primarily a monetary expression of social disapproval[91] which operates through various administrative fines designed to be broadly applicable, ensuring proportionate punishment for breaches of environmental law and conservation of nature.[92] Factors such as nature, severity, scope, and consequences of non-compliance are taken into account to determine appropriate penalties.[93]

87 | Bu-Pasha et al. 2016, 312.
88 | Ibid., 52–58.
89 | Billiet, 2012.
90 | Ibid.
91 | Ibid.
92 | Ibid.
93 | Ibid.

Criminal penalties, on the other hand, are responsible for ensuring the prosecution of the most serious offences in environmental health and nature conservation, dealing with more severe violations of environmental law for which the consequences are stricter, including imprisonment. It is worth noting that while European environmental protection is mainly rooted in national legislation, "which predominantly uses the administrative enforcement track for environmental crimes", the EU realised that Member States, in some cases, cannot provide effective protection of the environment through administrative sanctions alone. Consequently, at the European level, the Eco-Crime Directive of 2008 aims at supplementing the existing administrative sanction system with criminal law penalties to strengthen compliance with environmental protection laws.[94]

The Directive underlines that Member States must criminalise the most serious infringements of rules within their criminal law system, requiring liability for both natural and legal persons. However, the phrase *nulla poena sine iudicio* addresses the idea of no penalty without a trial or no punishment without judgement. Indeed, the fundamental right to a proper administration of justice outlines a set of guarantees applied specifically to criminal proceedings.[95] The use of satellite images as evidence in environmental procedures is becoming more important in criminal and civil proceedings, as certain demands must align with the requirements mandated in judicial courts.[96]

7.1. Germany

There is no specific codification of EO as evidence in Germany. Therefore, the general laws regarding the use of evidence apply. The German Code of Civil Procedure (ZPO) and the German Code of Criminal Procedure (StPO) foresee several ways of presenting evidence: judicial inspection/visual inspection, witness evidence, expert opinion, documents, and interrogation of parties. Under German law, EO evidence can be considered analogous to a photograph.[97] As such, it falls under the evidence option of 'visual inspection' or 'judicial inspection'. The use of satellite imagery as evidence, however, is limited due to reasons such as privacy concerns[98] and the fact that EO data are only snapshots and therefore may not be up to date, and hence invalid.[99] For the latter case, the trial court may also order that one or more experts should be consulted during the inspection (§ 372 para. 1 ZPO).

94 | Directive 2008/99/EC of the European Parliament and of the Council 2008.
95 | EU Charter of Fundamental Rights, Title VI on Justice Article 47.
96 | Billiet 2012.
97 | Sa'id Mosteshar 2013, 155.
98 | See the elaborations of the court on a case involving pictures taken from the air in BVerfG, Beschl. v. 02. Mai 2006, 1 BvR 507/01, NJW 2006, 2836, 2837.
99 | VG Sigmaringen (5. Kammer), Decision of 27.03.2020 – 5 K 3036/19.

German jurisprudence makes use of satellite imagery or EO evidence in several instances. In most cases in Germany, the judgements refer in a general manner to 'satellite images'. However, when looking at several judgments that consider satellite images, the source of most of the satellite images used as evidence in proceedings is provided by Google Maps and Google Earth.

As such, the classification of EO data as evidence was examined by the Administration Court of Regensburg in 1996.[100] The court relied on a written expert opinion evaluating a satellite image from the Landsat Thematic Mapper (TM). It ruled that satellite images are not documents (private records), but visual evidence. In 2021, the Higher Regional Court (OLG) Düsseldorf classified Google Maps and Google Earth images as *general knowledge evidence*. Specifically, it stated that aerial photographs such as Google Maps or Google Earth are generally accessible on the internet and hence can be regarded as commonly known facts. As such, they would be open to the appellate court's cognisance without the need for them to be set out in the judgement.[101]

EO has been used as evidence in cases involving a wide range of issues. They are used to determine the location of buildings, landmarks, crime scenes, and much more. As courts in Germany regularly rely on EO, it can be seen that courts recognise such information as part of the overall evidence. In its decision of 05.01.2021, the Higher Regional Court Düsseldorf used images provided by Google Maps and Google Earth to assess the details of the scene in order to determine the plaintiff's infringement of traffic regulations.[102] Subject of the judgement of 03.07.2010 of the Regional Court of Neuruppin was the conviction of a Berlin police officer for manslaughter by close range shooting of a criminal wanted for arrest. In its judgement, the Court used satellite images to identify the crime scene and determine whether the location was a public place where many people were passing.[103] Apart from identifying crime scenes, EO data as evidence plays a role in the determination of road layouts, building permits, asylum procedures or planning and land use.[104] A case in which satellite images were dismissed as evidence regarding the Judgement of 16.11.2005 of Administrative Court Minden.[105] Here, satellite images which could have provided information on the size of certain land areas were deemed inaccurate and dismissed as evidence.

100 | VG Regensburg (Administrative Court of the City of Regensburg, Germany) Final Decision of 25/4/1996 (RO 7 K 94.1846 at 7) (unpublished).

101 | OLG Düsseldorf, Decision of 5.1.2021 – IV-2 RBs 191/20.

102 | OLG Düsseldorf, Beschluss vom 5.2.2021 – 2 RBs 191/20.

103 | Neuruppin Regional Court, judgement of 03.07.2010 – 11 Ks 321 Js 2/09.

104 | See e.g. VG Schleswig (2. Kammer), Decision of 10.12.2020 – 2 B 50/20; KG Berlin, 12. Zivilsenat, Decision of 28/05/2009, 12 U 43/09; VG Hannover (12. Kammer), Beschluss vom 09.02.2023 – 12 B 4795/22; OLG Koblenz (1. Strafsenat), Urteil vom 24.02.2021 – 1 StE 3/21; Bundesverwaltungsgericht (Federal Administrative Court), Decision of 2 December 2008, BVerwG 4BN14.08; Verwaltungsgericht Ansbach, 9. Kammer, Judgment of 11/06/2008, AN 9 K 07.02197.

105 | VG Minden, 3. Kammer, Judgment of 16/11/2005, 3K 2986/03; reported in AUR 2006, 433–437.

Satellite images have, however, also been used regarding cases surrounding environmental changes and insights in Germany. In 2023, the Administrative Court Munich dealt with a case on the possibilities of remedying errors in the event of disregard of the concentration effect under the immission control law for private access routes to wind turbines requiring planning permission. Here, the court regarded satellite images brought forward by the plaintiff who intended to prove that an area was deforested, which was not permitted in full either by the authorisation or by a supplementary clearance permit and therefore unlawful.[106] In 2018, a case before the Administrative Court Gelsenkirchen involved an air quality plan. The court used publicly available satellite images on Google Maps to verify the possibility of widespread pollution with nitrogen dioxide.[107] For that, it used Google Maps to identify heavily used roads with high traffic volumes and regard the classification of the same on the platform in the color red as further indication that the roads are heavily used. In a different case involving the construction and operation of a dairy cattle barn for up to 1.000 cows and 80 calves by an environmental association, the court rejected satellite image analyses by LANDSAT from the years 2009 and 2010 as evidence.[108] According to the court, the quality of the satellite images was not sufficient, and that the analysis did not cover enough and was considered as too old. It was considered that the analyses were only snapshots, and that recorded data could be subject to major changes and could hence be not up to date and invalid.

7.2. Austria

Similar to Germany, the possible methods to bring forward evidence in court proceedings is governed by the Austrian Code of Civil Procedure (ZPO) and Austrian Code of Criminal Procedure (StPO). The possible modes to present evidence are judicial inspection/visual inspection, witness evidence, expert opinion, documents, and interrogation of parties. In Austria, the use of EO data as evidence is also not codified in its laws but can, just like elaborated in Germany above, be classified as falling under the evidence of visual inspection.

In Austria, the court decisions using satellite imagery in their decisions refer in a general manner to 'satellite images' or Google Maps and Google Earth, without providing the source or kind of EO information used. Nevertheless, by referring to EO information, the courts also present a general acceptance of EO information being used as evidence in court proceedings. In court proceedings, EO images, among other things, prove crime scenes, locations of streets, buildings, towns, airports, animal habitats, and the exact courses of rivers. EO data from satellites,

106 | VGH Munich (22. Senat), Decision of 07.02.2023 – 22 CS 22.1908.
107 | VG Gelsenkirchen (8. Kammer), Decision of 15.11.2018 – 8 K 5068/15.
108 | VG Sigmaringen (5. Kammer), Decision of 27.03.2020 – 5 K 3036/19.

however, has also been used in court proceedings to prove certain environmental changes with regards to weather. In its case of 2002, the UVS Lower Austria considered satellite images when examining visibility on the road during fog.[109] It decided, however, that smaller fields of fog could not be evaluated with satellite images and also determined that visibility was subjective. In a different judgement, the Austrian Administrative Court dealt with the determination of hunting grounds.[110] It relied quite extensively on the use of satellite images as evidence, specifically considering certain landmarks, vegetation, water level and animal use of an area where the plaintiff wanted to conduct hunting.

7.3. Netherlands

In the Netherlands, environmental regulation is primarily administrative with no specialised environmental tribunal. Exceptions exist where administrative decisions intersect with other areas, affecting district administrative procedures.[111] Administrators have the authority to sanction environmental violations. Decision-making impacts are typically confined to involved parties and do not extend broadly.[112]

Regarding the admissibility of evidence derived from satellite data, no rule explicitly prohibits their use in Dutch administrative or civil courts. On the contrary, the Court has noted that remote sensing is a common and accepted practice within the European Union,[113] and therefore acceptable in the Netherlands.

In courts, remote sensing data are comparable to radiographs or DNA graphics, requiring expert interpretation. The court cannot independently judge the technical aspects without expert input. This practice ensures that technical determinations are accurate and reliable.[114]

109 | UVS, Senat-MI-01-2048, 05.11.2002.
110 | VWGH, 2012/03/0082, 27.11.2014, L65003 Hunting Wild Lower Austria.
111 | The OECD Environment Programme The Environmental performances review of the Netherlands n.d.
112 | For the legal system, visit: http://www.rechtspraak.nl/English/Judicial-System/Pages/default.aspx.
113 | This recognition is indirectly based on Article 7 of Regulation (EC) No. 3508/92 (Council Regulation establishing an integrated administration and control system for certain Community aid schemes) in connection with Regulation (EC) No. 1036/1999 (Corrigendum to Council Regulation (EC) No. 1036/1999 of 17 May 1999 amending Regulation (EEC) No. 3508/92 establishing an integrated administration and control system for certain Community aid schemes, concerning the deadlines for submitting aid applications under the compensatory payment scheme for rice producers (OJ L 127, 21.5.1999)) and has taken place from the cases: Partnership A and B to C against the Minister of Agriculture, Nature Management and Fisheries in The Hague, LJN AD9994, College van Beroep voor het bedrijfsleven, AWB 01/550 (1 March 2002), available online: http://jure.nl/ad9994; Farmer A. v. Dutch Minister of Agriculture, Nature Management and Fisheries, LJN: BI4304, College van Beroep voor het bedrijfsleven, AWB 07/442 (28 April 2009), available online: http://jure.nl/bi4304.
114 | Keijser 2018.

As regards the use of satellite data for the resolution of environmental disputes, there is much more case law than in other European states,[115] particularly concerning the detection of fraud in obtaining Community funding under the Common Agricultural Policy (CAP).

To give a measure of the importance of environmental issues in the Netherlands, in the case of Urgenda v. The State of the Netherlands for the first time, a national government was directly ordered to step up its efforts to combat climate change.[116] Moreover, what makes this decision emblematic is the fact that the Court based the sentence on the violation of the European Convention on Human Rights (ECHR). In this sense, the protection of the human rights of Dutch citizens goes hand in hand with the pursuit of ambitious climate targets, in particular the reduction of carbon emissions by at least 25%, originally planned for the end of 2020.[117]

To provide some examples of the use of satellite data as legal evidence, we can mention several cases, such as Partnership A and B v. Ministry of Agriculture, and Farmer A v. Dutch Minister of Agriculture. Concerning the first case, the Ministry of Agriculture used satellite data to evaluate subsidy requests, facing challenges regarding the admissibility and accuracy of this data[118]. Despite a 5% error margin, the court accepted the satellite data, emphasising the necessity of expert validation to ensure reliability.

In another subsidy-related case, the Ministry used satellite data to deny a request based on land use regulations.[119] The court upheld this decision, reinforcing that expert analysis is crucial for interpreting satellite images and ensuring compliance with agricultural policies.

Upon reading a number of judgments, we have noticed that the parties involved are trying to challenge the validity of satellite data by other counter-expertise. The potential margin of error of satellite data therefore seems to have become a delaying device to challenge the accusation. Challenges to satellite data's validity must be substantiated by proving errors. Courts rely on expert testimony to determine the accuracy of satellite-derived information. In subsidy disputes, the burden of proof lies with the party contesting the satellite data, ensuring rigorous scrutiny of the evidence presented.

115 | By searching on the website rechtspraak.nl, we were able to identify approximately 250 results using the word 'satellite' and 'satellite image', in their Dutch translation. It should be noted that the text of the judgments was consulted using a fairly summary translation provided by Google Translate, which does not allow us to appreciate the finesse of the drafting. The generalities of the parties involved are often anonymized in the Netherlands.

116 | Rechtbank Den Haag [District Court of The Hague, Commercial Division], 24.6.2015, Urgenda Foundation v The State of the Netherlands, Case No. C/09/456689/HA_ZA 13-1396 (Netherlands), online: [Urgenda].

117 | See on this subject: Meguro 2020, 729–735.

118 | Partnership A and B to C against the Minister of Agriculture, Nature Management and Fisheries in The Hague, LJN AD9994, College van Beroep voor het bedrijfsleven, AWB 01/550 (1 March 2002).

119 | Farmer A. v Dutch Minister of Agriculture, Nature Management and Fisheries, LJN: BI4304, College van Beroep voor het bedrijfsleven, AWB 07/442 (28 April 2009), http://jure.nl/bi4304.

In conclusion, the Netherlands exemplifies the integration of satellite technology in environmental and administrative processes. The maturity of this approach is supported by specialised academic training and the presence of expert societies like GeoRas. Dutch courts clearly affirm the value of satellite data, solidifying the country's status as a leader in environmental jurisprudence.

7.4. Italy

The Italian Penal Code permits "the acquisition of writings or other documents representing facts, persons, or things by photography, cinematography, phonography, or any other means," according to the Court of Cassation.[120] Therefore, even Google Earth images have the potential to be a reputable source of completely admissible documentary evidence in courts. Nevertheless, the court will still need to evaluate the images' content and confirm that they accurately depict the situation at hand.

In the *Caliandro Case*, Google Earth Pro offered photograms that attested to the Tribunal of Brindisi's charge that some unlawful renovation was carried out in order to enlarge the in issue building property.[121] "The photographs portrayed by Google have the value of evidence and are fully usable under the Criminal Procedure Code, as they represent facts, persons, or things," the Court of Cassation declared in its ruling about the images' evidential value. [122]

Google Earth maps have become one of the most widely used tools for exploring satellite maps on the internet, partly because EO data acquisition is free of charge and easy to access.[123] However, Google has its limitations compared to other EO data suppliers due to the fact that its maps may not be updated frequently and have a lower resolution. Indeed, the Italian courts can determine whether to utilise Google Earth as proof evidence based on the specifics of each case. Moreover, the Court's entire evaluation consists of more than just Google Earth assessments.

The Rovigo Case of June 2002 is one of the most interesting examples of using EO data to determine the cause of ground subsidence affecting a historic building in the town of Rovigo (RO) and the resulting damage to historic structures.

An Italian team at Politecnico di Milano developed the Permanent Scatter Interferometric Synthetic Aperture Radar (PSInSAR), which is especially beneficial for tracking minor movements in the ground surface over time.[124] In a nutshell, the case reports basement fissures caused by subsidence that emerged in a

120 | Articolo 234, comma 1, cod. proc. pen.: "È consentita l'acquisizione di scritti o di altri documenti che rappresentano fatti, persone o cose mediante la fotografia, la cinematografia, la fonografia o qualsiasi altro mezzo."
121 | Caliandro Case, Tribunal of Brindisi. Date of hearing: 15/02/2022.
122 | Court of Cassation. Penal Section, Sentence n° 39087/2021. Caliandro Case. Useful link: https://www.donnegeometra.it/wp-content/uploads/2023/07/sentenza-cassazione-17102022-39087.pdf
123 | Purdy 2013.
124 | London Institute of Space Policy and Law 2012.

historic building. According to the owner, the adjacent landowner's excavation of the neighbouring land is what caused the sinking. When sufficient historic data is available, it is possible to compare the past and present modifications to identify changes in the environment and determine whether or not a shift of land-level reference points occurred in the location of interest.[125] Such historic data allowed for the *Rovigo Case* to demonstrate that the adjacent land's subsidence occurred after excavation, not before, proving that the excavation was the reason for the subsidence. Two distinct study teams acquired three data sets from ESA and processed them through two unique chains of analysis, and five separate measures were conducted to guarantee dependability, and the results' identity contributed to the evidence's credibility.[126] It has been demonstrated that EO data is a beneficial complement for additional sources of information, including professional assessments, geological models, and technical data.

Recent Court of Cassation case law in civil and tax disputes has also brought to light the extent of satellite data.[127] In this instance, the appellant filed an appeal after the Regional Tax Commission (CTR) demonstrating that an automobile with advertisements on it had been parked in a particular location from 2009 to 2014. A 2014 municipality file, a 2010 Google Street View report, and 2009 Google Street View images served as the starting point for this evidence. Stating among other reasons, the taxpayer disputed that the proof and the collected data acquired from the Internet were not legitimate. However, the Court ruled that this claim was unjustified, admitting the probative value of the Google Earth evidence. The documentation was indeed supplemented by additional aspects, such as the fine report of the municipal civil servant, provided that other findings existed. This court's case law has repeatedly upheld the notion that the photography evidence represented 'pre-constituted' evidence, meaning that it indicates, absent proof to the contrary, that the images accurately depict the objects and locations *antes* the appeal.

In a nutshell, in a scenario where there is no disagreement, the satellite pictures represent 'legal' documentation, and as a result, the court will be obligated to accept the information contained in the Google Earth imagery as proven. Nevertheless, in the event of a disagreement, these photographs will be a mere presumption, allowing the court to freely appraise them. In conclusion, a case-by-case assessment that balances the need for justice to take its course and the protection of the rights of the accused, appears to be the way forward.

In Italy, ad hoc doctrine pertaining to satellite images for legal processes is being developed judgement-by-judgement. To enable communication between technical, legal, and administrative entities, a common language spanning

125 | Sergieieva 2022.
126 | London Institute of Space Policy and Law 2012.
127 | Judgment of the Civil Court of Cassation No. 308 of 10/01/2020.

regulatory and scientific challenges is essential. The Italian situation highlights the need to investigate ways to involve experts in the use of EO information as evidence, utilising resources other than Google and emphasising the importance of encouraging cooperation amongst the different specialists and methods of EO and remote sensing data and being able to incorporate such data as evidence in the most transparent way possible.

8. Conclusion

From its beginnings in aerial photography in the early 20th century, remote sensing has developed into a vital tool for tracking criminal activity and environmental changes. Landsat's relevance in environmental protection is demonstrated by landmark applications, such as its part in assessing the 1986 Chernobyl disaster. However, despite tremendous advancements in remote sensing technology, the intricacy of environmental laws and major technical challenges keep hindering the use of satellite-derived data into legal proceedings.

The integrity and dependability of remote sensing data are essential for their effectiveness in legal cases. Significant technical hurdles include precise data calibration for consistency and cross-system imagery comparisons, and data processing transparency, which calls for the implementation of more sophisticated cryptographic techniques and improved visibility on whether data has been altered or transformed in any way. To guarantee data admissibility, a set of stronger, standardised procedures for data quality should be developed, defining essential baseline standards for spatial, spectral, temporal, and radiometric resolutions. Moreover, establishing more secure, traceable protocols for handling data is necessary to prevent tampering or loss of integrity.

From privacy concerns to intellectual property rights and national security considerations, the legal framework surrounding satellite data is fraught with complexities. Due to their open-source nature and free data use, Google Maps or Google Earth are the more often publicly cited sources in the majority of court cases which employ satellite imagery. Preferences for these platforms reflect a larger reluctance to deal with high-resolution or proprietary data, which often requires expert interpretation and additional scrutiny for admissibility. Increasing awareness among professionals about the capabilities and constraints of remote sensing could help foster greater confidence in its use.

The use of remote sensing into environmental regulation can provide a potent means of enforcing rules and safeguarding ecosystems as Europe looks to further its commitment to sustainable development. By taking modest actions, the European legal system might fully use satellite data as a tool for environmental stewardship and liability, guaranteeing a safer environment for coming generations.

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