Article

Digitalization and AI in European Agriculture: A Strategy for Achieving Climate and Biodiversity Targets?

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Abstract: This article analyzes the environmental opportunities and limitations of digitalization in the agricultural sector by applying qualitative governance analysis. Agriculture is recognized as a key application area for digital technologies, including artificial intelligence. This is not least because it faces major sustainability challenges, especially with regard to meeting the climate and biodiversity targets set out in the Paris Agreement and the Convention on Biological Diversity, as well as the water-related objectives of EU environmental legislation. Based on an overview of the possible applications of digital technologies in agriculture, the article offers a status quo analysis of legal acts with relevance to digitalization in the EU agricultural sector. It is found that a reliable legal framework with regard to product liability and product safety, as well as data privacy, data access, and data security is important in this context. In addition, the European Common Agricultural Policy, as the most important funding instrument for digital innovations in the agricultural sector, should be designed in such a way that it links digitalization-related objectives more closely with sustainability targets. So far, the existing EU governance does not fully exploit the potentials of digitalization for environmental protection, and sight is lost of possible negative side effects such as rebound and shifting effects. Therefore, the article also offers proposals for the optimization of EU governance.

Keywords: digitalization; artificial intelligence; agriculture; precision farming; environmental law; agricultural law; sustainability; governance; climate; biodiversity

1. Introduction

Many hopes are pinned on digital innovations. They are, among others, expected to contribute to tackling societal challenges such as environmental protection and sustainability, e.g., by making resource use and energy consumption more efficient, by optimizing logistics along the entire value chain, or through better monitoring processes and environmental use [1–5]. All of this should contribute to achieving the Sustainable Development Goals, and to implementing the European Green Deal [1,4,6,7]. For years, digitalization and artificial intelligence (AI) have been strongly discussed and advanced with regard to the agricultural sector [5,8–25]. In its communications 'Artificial Intelligence for Europe' from 2018 and '2030 Digital Compass: the European way for the digital Decade' from 2021, the EU Commission recognized the agricultural sector as a key application area for AI, in which sufficient investment is needed to achieve environmental and sustainability targets, including social and health objectives [2,4,9,26,27].

Agriculture is particularly important with regard to the two major global sustainability challenges of climate change and biodiversity loss, and their associated problems of pollution, disrupted nutrient cycles, the scarcity of fresh water, hunger, poverty, and wars for resources, etc. (see, e.g., [8,10,28–30]). Intensive, conventional agriculture, especially

livestock farming, is responsible for around a quarter of global greenhouse gas emissions, e.g., due to CH_4 (methane) emissions from the digestive processes of ruminants, from the storage and distribution of manure, and due to N_2O (nitrous oxide) emissions from agricultural soils, especially as a result of N (nitrogen) fertilization. In addition, CO_2 (carbon dioxide) emissions are released by land-use changes such as deforestation, and by the use of fossil fuels, for instance for tractors and other fuel-intensive machinery, as well as for the energy-intensive production of synthetic N fertilizers using the Haber-Bosch process [30–34]. Taking into account not only agriculture but the entire food sector, the emissions are even higher [35]. Agriculture is also responsible for almost three quarters of all biodiversity loss. The main contributors are habitat losses due to land-use changes, the removal of landscape elements on agricultural land, monocultures, and the application of pesticides and other agrochemicals [30,36–40]. At the same time, livestock farming accounts for around three quarters of the world's agricultural land, including areas for pasture and fodder production, and is responsible for a correspondingly high level of resource use [8,41–43].

Thus, conventional agriculture including intensive livestock farming without a livestock-to-land ratio contradicts the target of Art. 2(1) of the Paris Agreement (PA) [44] to keep the global average temperature increase to well below 2 °C, and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels. At the same time, conventional agriculture frequently conflicts with Aichi Targets B and C of the Convention on Biological Diversity (CBD) [45], which call for the halting of the loss of species and habitats. Both international, legally binding agreements require comprehensive changes in all sectors, including the agricultural sector. In particular, they require zero emissions within a maximum of two decades and a significant reduction in animal husbandry [28,30,35,37,46–52]. In addition, environmental quality objectives are set at the EU level. Agriculture is often responsible for missing these targets. For example, N and P (phosphorus) surpluses cause water eutrophication, especially in regions with high livestock density [53–55]. However, the deterioration of the status of European aquatic ecosystems is counteracting the objectives of the EU Nitrates Directive [56] and the Water Framework Directive [57] (on the infringements proceedings of the European Commission due to Germany's violation of the Nitrates Directive see [58]; on the non-compliance of Germany and further EU Member States with the Water Framework Directive see [59,60]). At the same time, the nutrient-related problems of water bodies are closely related to soil degradation [61–63].

Technical, and in particular digital, innovations offer a number of promising starting points in this regard—either individually or in combination. For instance, precision farming allows for increased levels of automation and optimization of arable farming and animal husbandry. Fertilizers can be applied more efficiently and adapted to the site on the basis of an accurate (real-time) assessment of the nutrient demand using sensor technology. This prevents nutrient surpluses which are harmful to water bodies. In principle, not only the use of fertilizers, but also the use of pesticides, water and other resources can be optimized by adapting the application to the location. GPS-guided machines, drones and robots can replace heavy, energy-intensive agricultural machinery and prevent, for example, soil compaction. Sensors and remote sensing using satellites can provide a comprehensive database i.a. on land use, for example for the determination of the type of crops grown, their yields, and their condition (see Section 3.1 and, among others, [6,8,10,14,15,17,64,65]). Based on this, efficient management practices can be identified. At the same time, increased computing power enables the evaluation of enormous amounts of data (Big Data). Algorithms and AI offer new opportunities for data processing and knowledge gain. Data transfer is optimized by grid development; open, standardized file formats; and improved interface management. This is also beneficial for monitoring and control. The administrative burden can be reduced by capturing data once and by sharing it among public authorities [1,15,66,67]. Furthermore, online approval procedures are conceivable. All of this supports policy implementation and monitoring, which is usually very complex and time-consuming, especially in the areas of environment, climate and agriculture, as many

individual processes are involved. Besides this, technological progress supports fact-based political decision-making [20,27,68].

However, the question arises of whether digitalization can achieve not only selective improvements, but also a more sustainable agriculture as a whole, which is in accordance with globally binding climate and biodiversity targets, reduces further environmental threats, and can feed the growing world population simultaneously. As indicated, this implies (i.a., in the interest of zero emissions, which may include offsetting residual emissions to a limited extent [69]) the phasing out of fossil fuels, a strong reduction of animal husbandry, an efficient use of resources, and the promotion of a circular economy including closed nutrient cycles and the prevention of local nutrient surpluses, as well as the abandonment of environmentally harmful pesticides [28,30,35,37,46–52]. It is also questionable to what extent the existing control instruments at the EU level can sufficiently guide digitalization in the direction of supporting more sustainable agriculture in line with the requirements mentioned above, and what challenges and obstacles exist.

To answer these questions, after describing the methodology of this article, a brief insight into the technical possibilities of digitalization and AI in the agricultural sector is given. Then, the legal challenges and the relevant legal areas at the EU level are analyzed, and recent developments are described. This includes questions of product liability, data privacy and financing digitalization in agriculture, for which the EU's Common Agricultural Policy (CAP) is of particular importance. In addition, general challenges to governance instruments—such as rebound and shifting effects—will be examined before discussing the findings and drawing a conclusion.

2. Materials and Methods

This analysis contributes to the discussion of the potentials of digital innovations to promote sustainability in the agricultural sector. In particular, the article answers the questions of whether digitalization and AI in European agriculture are promising strategies for achieving climate and biodiversity targets, and which governance effects existing EU law shows in this respect. In particular, recent developments and challenges in relevant legal areas are discussed.

As a first step, the article reviews the relevant literature on ecological challenges related to agriculture, and on the possibilities of digital technology and AI in the agricultural sector. With regard to the reports on the state of the environment, priority is given to the publications of scientifically recognized international institutions, such as the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the Secretariat of the CBD, the Food and Agricultural Organization of the United Nations (FAO), and the United Nations Environmental Programme (UNEP). Besides this, the article examines relevant publications from European official authorities such as the European Commission and the European Court of Auditors regarding their statements on digitalization in agriculture. Furthermore, international scientific literature on the challenges and opportunities of digitalization in the agricultural sector are analyzed, with a focus on current papers that have been published mainly since 2018. In this respect, the research covered both overarching articles on digitalization and agriculture or digitalization and sustainability, as well as more specific topics such as remote sensing or AI-controlled fertilization. In addition to the international scientific literature and publications from official authorities, online references from manufacturers of digital innovations are used to give an insight into the state of the art.

In a second step, based on the review of literature, relevant legal acts for governing digitalization in the EU agricultural sector are identified by using the EUR-Lex database [70], which collects and publishes all of the official documents of European institutions. Then, the article examines the existing legal instruments of the EU in order to determine whether they pave the way for the use of digitalization to achieve the given environmental targets. In this article, the internationally binding environmental goals from Art. 2(1) PA, with its 1.5 °C limit, and the Aichi goals B and C of the CBD, which call for a halt of biodiversity

loss, serve as a benchmark. As mentioned above, both agreements require comprehensive changes in the agricultural sector. Furthermore, two environmental quality objectives of the EU with strong relevance for the agricultural sector, and in particular for fertilization, are taken into account. The objective of the Nitrates Directive is to limit the nitrate pollution of waters to below 50 mg/L. Simultaneously, the Water Framework Directive prohibits the deterioration, and even decrees the improvement of the ecological and chemical status of surface waters and the quantitative and chemical status of groundwater, respectively. The assessment of digitalization against specific, binding environmental targets particularly distinguishes the article from other articles that examine the impact of digitalization on the sustainability of agriculture (see e.g., [8,10,14]).

In terms of methodology, the article applies a qualitative governance analysis (sometimes also called legal impact analysis) [29,71–73]. It examines the effectiveness of potential or existing control instruments on the basis of a given objective, taking into account human motivational factors and the typical control problems that arise as a consequence. Behavioral research in various disciplines (sociology, economics, psychology, ethnology, etc.) applying different methods (experiments, surveys, participant observation, etc.) identified the following set of driving factors of human behavior: self-interest; values; conceptions of normality; emotional constraints such as convenience, denial and habits; peer pressure; the tendency to make excuses; difficulties in perceiving distant challenges; and structural problems such as path dependencies and problems of collective goods [28,74,75]. Based on this knowledge of the motivational factors of consumers, producers, entrepreneurs, and politicians, etc., and on empirical findings—for example, on resource consumption—typical governance problems with respect to sustainability can be identified. They include rebound effects, spatial and sectoral shifting effects, problems of depictability, a lack of rigor in setting targets, and enforcement deficits. They limit the effectiveness of policy instruments [29,71–73]. Effective instruments should therefore avoid these governance problems. At the same time, the instruments have to be designed in such a way that they achieve the given objectives. Based on these findings, the article analyzes the existing EU instruments in terms of their steering effects on digitalization in the agricultural sector, and it proposes improved governance options that avoid the aforementioned governance problems in addition to achieving the environmental targets from the PA, the CBD, the Nitrates Directive, and the Water Framework Directive.

3. Results

The following subsections give an insight into the potentials of digitalization and AI in agriculture. Then, the existing EU governance framework of digitalization is analyzed. Subsequently, it is shown that the current legal framework has shortcomings in terms of conformity with ecological targets and requires optimization.

3.1. Potentials of Digitalization and AI in Agriculture

Digital technologies such as AI, information and communications technologies (ICT), sensors, remote sensing, the Global Positioning System (GPS), the Internet of Things (IoT), robots and 5G, etc., have the potential to increase technical efficiency, business and economic performance, and sustainability in the agricultural sector in line with the environmental objectives described above [8,10,14,18,26,76].

An AI—a very special and prominent part of digitalization—can analyze its environment and, with a certain degree of autonomy, derive intelligent courses of action to achieve certain goals. It is able to evaluate enormous amounts of data in order to offer efficient solutions based on the detected correlations. Examples of software-supported AI systems are search engines, translation software, image recognition software, and speech and facial recognition systems. AI systems can also be embedded in hardware, such as robots, autonomous vehicles, drones, or applications of the IoT like small, interconnected sensor devices [2,77]. So-called 'weak AI' works within the limits of its programming to solve or optimize specific application problems, while 'strong AI' should evolve inde-

pendently after a first phase of specific programming, and should no longer act only in a reactive way, but rather independently, flexibly and 'consciously' (so far, there is no strong AI in this sense—see [78] for more information on this). Many AI applications require not only a high level of computing power, but also large amounts of high-quality data to perform optimally [2]. AI can be classified into several categories, including machine learning, in which algorithms detect patterns in existing data and apply these findings to new data [2,77]. Machine learning, in turn, is further divided into different types, including supervised and unsupervised learning, reinforcement learning, and learning by means of various decision tree models [6,79,80]. Based on the working principle of nervous systems, machine learning is also feasible using artificial neural networks. If several of these neural networks are linked together in such a way that they represent different layers of abstraction of a learning system, this is called deep learning. With the help of all these procedures, algorithms first use exemplary training data to learn, e.g., how to categorize objects in order to be able to accurately classify previously unknown objects into specific categories [77,81].

With regard to agriculture, autonomous agricultural vehicles and small field robots can use such image recognition methods, for instance, to identify and mechanically remove weeds and pests, or to destroy them with pesticide microdoses. This can significantly reduce the use of pesticides and thus preserve biodiversity [2,10,12,82,83]. Another possibility is the drone-assisted release of Trichogramma ichneumon flies to fight caterpillar infestations on arable land [84]. Precision farming further allows a more sustainable use of fertilizers in agriculture to prevent water pollution. Sensor technology can be utilized to determine the nutrient demand on a small scale. Low-weight field robots or GPS-controlled, autonomous steering systems enable the targeted application of fertilizers, and can prevent soil compaction caused by heavy agricultural machinery or frequent driving across the field [17,77] (see [85] for information on the agricultural robot Contadino, which has different modules for sowing, weed and pest control, fertilization, etc.). Even accurate fertilization with manure, which is a heterogeneous material, is made possible by precision farming technologies. Near-infrared spectroscopy allows the nutrient analysis of the manure right on the field. By adjusting the speed of the tractor, more or less manure per area is applied [86].

Small, autonomous field robots can also access previously unused areas. In addition, the robots can relieve farmers and harvest workers, etc., from risk-exposed or strenuous work [10,12], e.g., applying pesticides or harvesting under difficult climatic conditions such as those in greenhouses (see [87] on a sweet pepper harvesting robot). Today, robots are regularly used during the grape, apple, strawberry and nut harvests. The use of image recognition to ensure that only ripe fruit are harvested helps to avoid harvest losses and thus food waste [12,88]. Multispectral images from satellites and drones can provide information on the ripeness and condition of the cultivated crops, and can thus help to derive the optimal harvesting time and further management recommendations [6,10,64,65,89,90].

It is also possible to monitor the movement, temperature and dietary intake of livestock, and to automatically adjust heating and feeding devices with the help of AI [2]. This potentially gives farmers more time for other tasks, such as checking animal welfare [2]. In addition, the collection of data from animal husbandry can reduce resource and medication use and improve animal health (see [12,91] for data-driven decision support in dairy farming). Besides this, the monitoring and automated adjustment of livestock feeding allow for a decrease in digestion-related CH_4 emissions from ruminants [92,93]. Modified feeding can also influence the nutrient excretion of the animals (see e.g., [94] on increasing P feeding efficiency). In terms of wildlife protection, flying drones with thermal cameras can be used to detect wildlife damage, and to rescue fawns from a field before the combine harvester drives off [95,96].

AI can also help to protect groundwater from pollution caused by fertilization. Because the nitrate concentration can vary considerably over time and space, the reliability of individual measurements is limited. AI-based models allow a more accurate prediction

of the nitrate concentration in groundwater than the currently common methods. Based on the data and predictions, appropriate protection measures can be derived with spatial differentiation [97].

The combination of different technologies with respect to the data they generate, such as those from machines, sensors, earth observation systems, plant growth models, or environmental and yield data analysis, can lead to new insights into cultivation methods and environmental impacts, and can thus support more sustainable management decisions [98]. This requires appropriate connectivity and data transfer between various applications (see, for example, the cloud-to-cloud solution 'DataConnect' from Claas and John Deere, and the software provider 365Farmnet that enables the manufacturer-independent transfer of all important machine data [99]). In principle, digital technologies can measure the ecological footprint along the entire food chain, e.g., in terms of emissions of CH_4, CO_2, N_2O and other N compounds, energy use, the use of water and fertilizers, or agricultural land use. This data can be better collected, aggregated, correlated and visualized using digital technologies. Such information is not least relevant for considering environmental costs when pricing food. Moreover, they serve as a basis for consumer decisions [5,8,15–17] (for a critique on knowledge as a motivational factor for sustainable consumer decisions, see [28]).

3.2. Governance of Opportunities and Limitations of Digitalization and AI in Agriculture

There are almost no limits to the diversity and innovation of digital technologies in the agricultural sector. However, digitalization in EU agriculture as a whole faces a number of challenges. First of all, the current use of digital innovations in agriculture is still relatively rare on average [10,26]. In many cases, insufficient information about existing technical possibilities, a lack of the necessary skills, and high investment costs make access to technology difficult. Simultaneously, further research and development is needed in many areas. Another prerequisite for the use of digital technologies is the literacy of the users, which regularly represents an obstacle to a digitalized agricultural sector, especially in developing countries (The different levels of access to relevant infrastructure are discussed under the keyword 'digital divide' [100].). In other cases, the basic infrastructure is deficient, particularly an (adequate) internet connection [17,26]. By the end of 2017, only 47% of rural areas in the EU were connected to fast broadband [26]. Thus, first of all, an appropriate infrastructure is required in order to allow the advantages of digital innovations to be exploited at all. In addition, a legal framework which clarifies questions of product liability and guarantees data protection and security, among other things, is needed [10,15,17,19,20]. This is a prerequisite for incentivizing investment in digital innovations that guarantee benefits for the public, and for creating acceptance, especially for AI applications and the data collection required for them. Shared European standards and fast communication infrastructure are important factors to avoid market fragmentation and to enable a digital single market, e.g., cross-border cooperation and exchange in developing (legally compliant) data pools and digital applications [77]. In addition, new technology should be affordable for small and medium-sized farms, instead of being accessible only for large farms with large financial resources [8,82]. All of this requires not only private but public investment as well (see e.g., [10]).

3.2.1. Product Liability

At present, the issues of product liability and product safety in connection with the use of digital technologies and AI in agriculture are not fully clarified. There are open questions, for example, when an AI-based robot makes a decision that has not been preconsidered [2]. In the agricultural sector, for example, economic damage and safety risks could result from AI-supported harvesting, in which unripe fruit is picked; if animals are injured during automated feeding; if thresholds for fertilizer and pesticide application are exceeded by robots; or if autonomous agricultural machinery is steered incorrectly [12]. The 'Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and

robotics' [101] published by the EU Commission, and the report 'Liability for Artificial Intelligence and Other Emerging Digital Technologies' of the Expert Group on Liability and New Technologies [102] highlight the special characteristics of AI and the IoT. These are, in particular, the complexity of actors, software, hardware and services; the opacity, i.e., the lack of transparency of AI systems, as they are black boxes; the connectivity and openness with regard to update requirements and interaction with other systems; the autonomy of AI systems, i.e., the limited human control; and the data dependency; as well as the vulnerability with regard to digital security [12,101]. The legal framework—especially the Product Liability Directive [103], the General Product Safety Directive [104], the Machinery Directive [105], and agriculture specific legislation such as Regulation (EU) 167/2013 on the approval and market surveillance of agricultural and forestry vehicles [106], etc.—needs to be adapted to these special features, as well as to technological progress continuously, particularly with regard to AI, which is not yet specifically regulated by the above-mentioned legal acts [2,77]. At present, this frequently implies legal uncertainty [12]. Again, comprehensive and high-quality data sets, ideally in non-proprietary (open) file formats (see next section), can increase the quality of AI decision-making and thus avoid errors. This is especially true with regard to non-discriminatory data sets, as otherwise the discrimination may be adopted by the AI [107]. Nevertheless, it is probably not possible to legally exclude all uncertainties with regard to liability issues when using AI due to its heterogeneous design and manifold possible applications.

3.2.2. Data Privacy, Data Access, Data Security

Currently, a small number of large technology companies own a large share of the world's existing data [1]. In order to counteract market concentration, market imbalances in access to data, and dependencies on and potential surveillance by private or public authorities, precautions regarding data protection and data security are necessary [1,17,19,66,90]. The fundamental right to the protection of personal data is guaranteed in Art. 8(1) of the Charter of Fundamental Rights of the European Union (CFR) [108] and Art. 16 of the Treaty on the Functioning of the European Union (TFEU) [109]. The right to the protection of personal data entails that personal data has to be processed fairly for specified purposes and on the basis of the consent of the person concerned or another legitimate, legal basis. Concerned persons have the right of access to their personal data, as well as the right to have it rectified (Art. 8(2) CFR). Moreover, the EU is committed to the liberal democratic values enshrined in Art. 2 Treaty on European Union (TEU) [110]. AI applications, in particular, could in principle affect several of these rights, such as the right to human dignity, the right to non-discrimination, the right to privacy, and the right to (entrepreneurial) freedom [2].

The General Data Protection Regulation (GDPR) [111], the Regulation on the free flow of non-personal data (FFD) [112], the Cybersecurity Act (CSA) [113], the Open Data Directive [114], the Digital Content Directive [115], and a number of sector-specific legal acts are the first steps towards establishing a legal framework for improved data access, the interoperability and quality assurance of data, and a more responsible use of data at the EU level, although there is room for amendment, specification and improvement in many aspects [1,116]. A secure management of data in compliance with fundamental rights is also a basis for the successful handling of strategically important AI, which, as mentioned before, requires high data quantity and quality [2]. Hence, the EU needs a governance for data that provides clear, fair and practicable rules for data access, transfer and use, while respecting the right to the protection of personal data, consumer protection and competition law. On this basis, European data pools are to be established in order to enable Big Data analytics and machine learning [1]. As each sector has its own characteristics, not only a common cross-sectoral European data space but also sector-specific data spaces in strategic domains are to be established, including a common European agriculture data space and a common European Green Deal data space [1,12]. They aim to enhance the sustainability, performance and competitiveness of the agricultural sector through processing and analyzing production, environmental and other data for the development

of precise and tailored production approaches at the farm level. Likewise, they should support the Green Deal targets on climate change, biodiversity, circular economy, zero-pollution, and deforestation, e.g., by realizing digital projects such as 'GreenData4All' and 'Destination Earth' [1]. In addition, further planned data spaces, such as the one for public administration, are related to agriculture, for example, in terms of IT-supported law enforcement and the reduction of administrative costs [1]. In November 2020, the European Commission published a proposal for a legal framework for the governance of European data spaces. The proposal for the so-called 'Data Governance Act' [117] aims to facilitate the cross-sectoral sharing of data by companies and public authorities, and to improve access to personal and non-personal data, i.a., by means of neutral data intermediaries. Furthermore, the use of data for purposes of general interest is to be promoted. Now, the proposed regulation has to be negotiated between the European Parliament and the Council. It remains to be seen whether shortcomings of the proposal, in particular vague terms such as 'data altruism' or 'data re-use', as well as insufficient requirements for the anonymization of personal data, e.g., with regard to (reversible) pseudonymization, can be addressed during the legislative process.

In relation to individuals, including those involved in agriculture, the 'personal data space' is particularly important: the EU wants to empower individuals to exercise control over their data, for example, by imposing strict requirements for access to machine-generated data and for interfaces for real-time data access. Here, a 'Data Act' should create the necessary legal framework, for which a proposal is to be prepared in 2021, possibly referring to an extended portability right for individuals under Art. 20 GDPR (the right to data portability) [1]. In order to prevent power monopolies, dependencies and vulnerabilities, it would in general be important that the data sovereignty and rights of use over the farm's own agricultural data belong to the farmers, and not to manufacturers of agricultural machinery [66].

In principle, the GDPR guarantees the protection of personal data, including data privacy-friendly presettings for certain technologies. The free flow of non-personal data within the Union is regulated by the FFD. The GDPR, in turn, applies to inseparably mixed data sets, as this is the only way to ensure effective data protection in compliance with fundamental rights [12]. However, the scope of application of the GDPR only covers natural persons such as farmers, but not legal entities such as agricultural holdings. In this respect, it is once again crucial for data protection whether the data can be assigned to a specific person. Although this is likely to be the case for most agricultural data, uncertainties in this respect mean protection gaps in the GDPR with regard to its application in the agricultural sector [3]. These gaps are, so far, usually closed by private contracts, especially because private law, such as the Directive (EU) 2016/943 on the protection of undisclosed know-how and business information [118], is only applicable to a limited extent in the agricultural sector [12].

In 2018, EU agricultural stakeholders, including the farming and the machinery sector, developed a code of conduct for the sharing of agricultural data by contractual agreement, which refers to business-to-business (B2B) data use, and covers in particular non-personal data [1,119]. Experience with this voluntary code can be taken into account when designing a legally binding framework [12]. In 2019, 25 EU Member States signed a declaration on 'A smart and sustainable digital future for European agriculture and rural areas'. It aims to promote research and innovation, and the development of the European agriculture data space [76]. For example, at least five large experimental and test areas for AI applications in the agricultural sector are to be established in the EU, research and development shall be networked more closely, and farmers shall be better qualified for the use of AI and digital infrastructure, and shall supported in their application. Access to innovative, digital solutions shall also be ensured for small farms. The expansion of broadband shall be promoted. In addition, geographical, meteorological, environmental and climate-related data are to be used more intensively, in accordance with the Open Data Directive for the development of joint databases to promote precision farming solutions. Last but not

least, the traceability of agricultural products shall be enhanced, for instance by means of Blockchain technology, which could also support regional value chains [5,16,26,66].

Despite the amount of potentially relevant legal acts, questions of data collection, ownership, access and use, security, and protection in the agricultural sector have not yet been fully clarified in legal terms. However, at the same time, providing (legally set) uniform solutions for heterogeneous operator models (e.g., public, private or mixed), for data management, for software programming, or for the openness of program code is difficult. If software is developed within the framework of research projects funded by public grants, this is a good reason to offer the code or software as open source ('public code for public money') [90]. Moreover, at least the (non-personal) data generated using public funds should be increasingly accessible and usable for third parties, in accordance with the Open Data Directive. According to Art. 2 No. 14 and recital 16 Open Data Directive, an open format is a file format that is platform-independent and can be freely used, re-used and shared by anyone and for any purpose with minimal or no legal, technical or financial constraints. This is the case with data from the EU space program Copernicus, which collects earth observation data using, among others, the Sentinel satellites, e.g., on land use, vegetation, water and ice cover [2,6,7,25,27,65,68,120]. Closely related to this is the possible revision of the Directive establishing an Infrastructure for Spatial Information in the EU (INSPIRE) [121] and the Directive on public access to environmental information [122]. Their review is planned for the fourth quarter of 2021 or the first quarter of 2022 [1]. Here, it seems appropriate to follow the FAIR data principles developed for scientific data: the data should be findable, accessible, interoperable and reusable for humans and machines [1,12,15,123,124]. However, questions of data protection remain unresolved here as well. Open data and open source rather counteract power concentrations and their corresponding dependencies. Nevertheless, the interests of individuals, in particular the right to privacy and security, and also the protection of business secrets, have to be taken into account as well [27,67]. After all, especially in agriculture, there is hardly any non-personal data or data suitable for anonymization. For example, geodata relevant to agriculture may be subject to data protection requirements, while agricultural machinery data may allow conclusions to be drawn about farmers, for example, with regard to working hours or the productivity of the farm [3,12]. Consequently, the GDPR will often be the applicable legal act for the agricultural sector, notwithstanding the aforementioned protection gaps and the fact that AI-related legal uncertainties are not fully clarified yet (see [12] for possible solutions within and outside of the GDPR).

The better these legal uncertainties are eliminated and a balance is found between openness to innovation and data protection in line with fundamental rights, the greater the chance that (at best manufacturer-independent) data platforms and clouds can be used securely for smart applications in the agricultural and food sector. The more data and algorithms are openly available, the better solutions can be developed by and for small and medium-sized enterprises [15,66,90]. At the same time, open, standardized data formats and an optimized interface management, for example with regard to standardization in order to enable communication between different devices, counteract asymmetrical power relations (regarding interface management, see e.g., the standard for ISOBUS ISO11783, which enables communication between tractors and different devices) [66]. In addition, antitrust regulations could be considered to prevent data monopolies and surveillance. Antitrust concerns increasingly arise with regard to algorithm-based pricing, which takes into account competitor prices, and supply and demand situations, but can also be customer-specific on the basis of collected data on farmers and consumers. Here, dominant market positions bear the risk of exploitation and discrimination, which are generally inadmissible pursuant to Art. 102 TFEU, even though there is also a need for supplementation and specification in some cases for AI applications [125,126].

3.2.3. Financing—The Common Agricultural Policy as a Key Financing and Steering Instrument in European Agriculture

The CAP—along with the European structural and investment Funds and the EU framework program for research and innovation, 'Horizon Europe'—is an essential source of funding for the promotion of digital solutions in the agricultural sector and in rural areas [26]. With a 37.8% share of the total EU budget in the period 2014–2020, the CAP represents the key steering instrument for the agricultural sector. In total, 75.6 % of the budget is provided by the European Agricultural Guarantee Fund (EAGF) for the first pillar, with its direct payments to farmers. Furthermore, 24.4% of the budget is allocated to the second pillar for the European Agricultural Fund for Rural Development (EAFRD), which finances multi-annual programs and measures, including agri-environmental and climate measures, together with the Member States [127]. Little will change in the budget distribution in the new CAP funding period 2021–2027 (postponed to 2023) (for the regulation proposals from June 2018 see [128–130]), and the two-pillar structure will remain in place [128,131] (critically on this [132]). According to the proposed CAP Strategic Plan Regulation for the future CAP (hereinafter called Draft Regulation), the key novelties of the reformed CAP are the system of conditionality, which incorporates the statutory management requirements (SMRs) and the standards for good agricultural and environmental condition of land (GAECs) from cross-compliance and greening requirements in a streamlined form (Art. 11 and 12 Draft Regulation); eco-schemes, i.e., voluntary environmental programs to be financed from the first pillar (Art. 28 Draft Regulation); and greater renationalization of responsibilities. From 2021, Member States will have to submit so-called 'Strategic Plans' in which they lay down how the financial support of the EAGF and EAFRD contributes to achieving the objectives set out in Art. 6 Draft Regulation (see below) [128]. Among other things, the Strategic Plans are intended to support technological innovation and digitalization for more environmentally- and climate-friendly agriculture [26]. However, Member States are left with considerable scope for design. This is associated with a high degree of uncertainty in estimating the potential environmental impacts and the digitalization-friendliness of the new CAP, especially because no final decision on the future CAP has yet been made.

In 2017, the EU Commission had already pointed out in its communication on 'Food and Agriculture of the Future' that the CAP has to enable the EU agricultural sector to connect farmers and rural areas to the digital economy [133]. The CAP should promote technological innovation and digitalization, among other things, to enable resource efficiency and thus more environmentally- and climate-friendly agriculture. Inequality in the use of technological and digital innovation in different regions of the EU and between different farm sizes is to be reduced [133]. In line with this, the EU's 'Coordinated Plan on Artificial Intelligence' envisages investment in platforms and large-scale pilot projects to integrate AI and robotics into EU agriculture [26,68,77]. The Coordinated Plan builds on the EU Strategy on AI, which recognizes agriculture as one of the key sectors for the use of AI, as described at the beginning of this paper [2]. Furthermore, the Draft Regulations for the new CAP link agricultural policy with digitalization, in particular with the EU's Digital Agenda [128].

In accordance with Art. 5 Draft Regulation, support from the EAGF and EAFRD shall foster a smart, resilient and diversified agricultural sector, ensuring food security. It is also intended that the financial support contributes to the EU's environmental and climate-related targets. At the same time, the socioeconomic fabric of rural areas shall be strengthened. The cross-cutting objective is to modernize the sector, in particular by promoting and sharing knowledge, innovation and digitalization in agriculture and rural areas. The objectives of the CAP are specified in Art. 6(1) (a) to (i) Draft Regulation. Objective (b) in Art. 6(1) directly addresses digitalization, which is, i.a., supposed to enhance competitiveness. Objectives (d), (e) and (f) state that the CAP should contribute to climate change mitigation, sustainable resource management and the protection of biodiversity. However, there is no linkage of the environmental and climate-related objectives with the keyword 'digitalization' in Art.

6(1) Draft Regulation [128]. Rather, the focus of objective (b) on competitiveness could even counteract the achievement of climate and biodiversity objectives, for example by promoting 'competitive' livestock farming that takes advantage of economies of scale and thus tends towards more animals, rather than a reduction in animal numbers. Besides this, both the general and the specific objectives of the CAP in Art. 5 and 6 Draft Regulation are terminologically imprecise. Making a 'contribution' is vague in content, difficult to measure, and legally not enforceable. Furthermore, a concrete reference to the global climate and biodiversity targets of the PA and the CBD is lacking. An increased use of digital innovation in line with global environmental goals is thus not supported per se by the objectives of the new CAP.

A key element in pursuing the objectives set out in Art. 5 and 6 Draft Regulation, including environmental and climate protection requirements, is the linking of direct payments under the first pillar to environmental requirements, which will be specified in the new framework of conditionality from 2021/2023. However, as in the past, conditionality—with its GAB and GAEC standards—lacks a clear commitment to the objectives of the PA and the CBD. In contrast, a direct link between digitalization and sustainability was established with the proposed Farm Sustainability Tool for Nutrients (FAST) in accordance with the new GAEC 5 (Art. 11 and 12 in conjunction with Annex III Draft Regulation). GAEC 5 required Member States to provide to farmers an electronic farm sustainability tool that includes nutrient management plans, a complete nutrient balance sheet, and information on soil condition, management practices, cropping and yield data, as well as legal thresholds and other regulatory requirements. In addition to basic functionalities regarding nutrient management, it was intended to enable the system to be supplemented by further modules (recital 22 and Annex III Draft Regulation) [128]. It remained open whether the system was only supposed to be a kind of material flow balancing, or whether further technical options should contribute to the optimization of nutrient or resource use, such as the integration of additional data sources, e.g., from machines or remote sensing, and whether the system was supposed to be used directly for control by the authorities. However, as a result of the negotiations of the EU Agriculture and Fisheries Council at the end of October 2020, GAEC 5 was removed from the framework of conditionality [134]. In any case, such digital or 'electronic' instruments in these kinds of frameworks mainly serve to achieve the established standards and targets, for instance from other GAB and GAEC regulations, or from the general and specific CAP objectives. If those are too weak and not in line with global climate and biodiversity targets, a digital instrument cannot cure the CAP's lack of ambition. This is even more the case as the new framework of conditionality partially weakens the environmental requirements of the CAP [132,135], which have been criticized for a long time anyway (see among others [136]). Consequently, the CAP's new environmental requirements also contrast the EU Green Deal [135].

Meanwhile, hopes are pinned on the so-called schemes for the climate and the environment ('eco-schemes'), which, according to Art. 28 Draft Regulation, shall reward environmentally- and climate-friendly agricultural practices going beyond the GAB and GAEC standards and other mandatory requirements under national and EU law. At the end of October 2020, the ministers of agriculture agreed to reserve 20% of the first pillar funds for eco-schemes [137]. Apart from the fact that this accounts for only a relatively small share of the budget for direct payments, it remains to be seen to what extent the eco-schemes will also cover digitalization-related issues with clear links to environmental and climate concerns. So far, there are no specified minimum requirements at the EU level in this respect.

With regard to digitalization, a similar conclusion can be drawn for the environmental, climate and other management commitments under the second pillar of the CAP according to Art. 65 et seq. Draft Regulation. Firstly, it is up to the Member States to design the types of intervention for the second pillar. Secondly, there are no specific requirements at the EU level regarding the targeted promotion of digitalization. It is merely envisaged that the

voluntary management commitments shall support the achievement of the specific CAP objectives in accordance with Art. 6(1) Draft Regulation.

Digitalization is mentioned in Art. 13 Draft Regulation, which provides that Member States shall include a system of farm advisory services in the CAP Strategic Plans. These advisory services shall, among other things, cover the development of digital technologies in agriculture and rural areas as referred to in Art. 102 (b) Draft Regulation (Art. 13(4) (f) Draft Regulation). The advisory services shall provide up-to-date technological and scientific information obtained on the basis of research and innovation (Art. 13(2) Draft Regulation). This offers the opportunity to incorporate suitable innovations from research projects directly into agricultural practice. However, again, a link to climate and biodiversity targets is missing. Thus, Art. 13 Draft Regulation does not contribute purposefully to fostering digital innovations linked to sustainability. Once again, there is a risk that technical progress will be used solely to increase efficiency and productivity.

In turn, Art. 102 Draft Regulation contains a more detailed description of the necessary elements of the CAP Strategic Plans to be developed by Member States, as listed in Art. 95 Draft Regulation. Art. 102 Draft Regulation refers, in particular, to the elements that ensure the modernization of the CAP, with Art. 102 (a) stipulating that the CAP Strategic Plan should provide information regarding the way in which the plan shall contribute to the general objective of the promotion, transfer and dissemination of knowledge, innovation and digitalization. Art. 102 (b) demands a description of the strategy for the development of digital technologies in agriculture and rural areas, and for the use of these technologies to increase the effectiveness and efficiency of CAP Strategic Plan interventions. In addition, the SWOT analysis pursuant to Art. 95(2) (b) in conjunction with Art. 103(2) Draft Regulation requires an evaluation of the CAP Strategic Plans with regard to their contribution to the general digitalization goal. According to this, Member States have to deal with the topic of digitalization as a central element of the future CAP when drawing up their Strategic Plans, even though any link to the environmental and climate objectives is lacking and much scope for design remains within the Member States. Meanwhile, keywords such as 'AI', 'precision agriculture' and the like are not mentioned in the proposed regulation.

Apart from the funding function of the CAP in terms of using and disseminating digital technologies, the submission of the applications, reporting and control of the CAP itself are increasingly organized digitally. Digital data management is highly relevant given the amount of data within the CAP. Thus, digital solutions should also support the way to a results-oriented CAP, for example through simple and effective digital tools for the implementation of the CAP, especially related to area, agri-environmental and climate monitoring, satellite-based control and the exchange of data between authorities (see in particular Art. 22–24 and 64 et seq. Draft Horizontal Regulation on the financing, management and monitoring of the CAP [129]) [3,9,10,20,25,26]. While this supports the proper implementation of the CAP, it does not change the fact that governance potential is likely to remain unused under the future CAP in order to target the digitalization of agriculture in line with the EU's climate and biodiversity commitments and water-related environmental objectives.

3.3. Questionable Conformity with Ecological Targets: Rebound and Shifting Effects, as Well as the Resource and Energy Consumption of Digitalization

Up to this point, the potential of digitalization to protect the environment has been shown to be considerable, but the existing governance instruments have not yet fully exploited this potential. In the following, it is demonstrated that—measured against the environmental objectives described above—the potential of digitalization is limited even with optimal incentives, and that digitalization may even have counterproductive effects, which need to be addressed by other governance instruments.

As a matter of principle, it is important to avoid the nullification of productivity and efficiency gains in agriculture through rebound and shifting effects [13,27]. For example, if fewer pesticides and fertilizers are applied per hectare as a result of digital innovations such as precision farming technologies, this saving could be compensated by an overall

increase in cultivation, e.g., of fodder and energy crops. The use of new technologies could also contribute to a further intensification of the sector. Previously unused areas could, for instance, be made accessible by small field robots. It would also be conceivable for farmers, who saved money by reducing inputs, to invest in other areas. In a worst case scenario, financial savings could be used, e.g., to expand livestock stables in order to increase livestock numbers, especially because the drafts for the future CAP do not mention a reduction in the number of animals kept, which would be necessary to combat climate change and global biodiversity loss.

Investments in new, emission-intensive agricultural machinery would also be imaginable. In principle, a farm that is to become increasingly digital will need new technological equipment anyway. In a favorable case, machines can be shared by several farmers, although there are restrictions to this approach given limited, favorable sowing, fertilizing and harvesting periods and the like. Even if new equipment is low in emissions and very efficient, its manufacture, operation, maintenance and disposal will always require a certain amount of resources and energy. Moreover, data processing and storage also consume considerable amounts of energy. The current energy demand of the ICT sector, especially for data centers, cloud services and connectivity, is estimated at 5–9% of global electricity consumption, and more than 2% of all greenhouse gas emissions [1,27].

Overall, while the opportunities for increased environmental and climate protection resulting from the use of digital innovations in the agricultural sector are frequently emphasized, the focus to date has often been on improving operational efficiency, yield optimization and competitiveness [13,22,82]. However, the empirical evidence on the environmental gains achieved by digitalization in agriculture is highly heterogeneous and depends on manifold factors, such as the country, area, cropping system and management practices, technology, and time, etc. [10]. At the same time, rebound and shifting effects can only be excluded to a large extent by an absolute, cross-sectoral and geographically broad-based limitation of resource consumption. Similarly, the achievement of environmental goals in terms of zero fossil fuels and strongly reduced animal husbandry cannot be achieved through individual optimizations in technology, nor through digitalization and AI [49,71]. This requires overarching governance approaches, which are discussed below.

4. Discussion

Digital innovations and AI have a wide range of promising applications in the agricultural sector, and with regard to meeting the targets of the PA, the CBD, and the water-related environmental objectives enshrined in EU law with particular relevance to agriculture. For instance, precision farming technologies allow site-adapted, efficient fertilization, both with synthetic/ mineral fertilizers and with manure. Needs-based fertilization is an essential starting point for the avoidance of nutrient surpluses which get discharged into water bodies and lead to eutrophication. This thus directly serves the fulfillment of the objectives of the Nitrates Directive and the Water Framework Directive. At the same time, as mentioned at the beginning, nutrient surpluses are particularly high in areas with high livestock density. Selective changes, such as efficiency improvements in manure application or feeding, are no substitute for a regional and absolute reduction in livestock numbers, both from a nutrient and from a climate perspective. This is especially true because high animal numbers without a livestock-to-land ratio result in a high demand for feed, and correspondingly high, biodiversity-relevant land use and resource inputs, except in the case of pasture farming. Without a reduction in livestock farming, neither the 1.5 °C limit according to Art.2(1) PA nor the Aichi Targets of the CBD can be achieved [8,28,30,35,37,46–52,66]. With regard to precision farming, it should further be noted that even a few pesticides placed purposefully can endanger biodiversity [66]. Digitalization-supported improvements of efficiency, for example a decrease in CH_4 emissions from the digestive processes of animals or a reduction of water use and climate-relevant (N) fertilization and pesticide use, are of course not superfluous. They complement other reduction measures. Besides this, digital technologies and sensor technology enable a more accurate measurement of

emissions and environmental impacts, which is an important starting point for deriving and implementing environmental and climate protection measures. With regard to the 1.5 °C limit, digitalization can contribute significantly to the phasing out of fossil fuels, because a decentralized, renewable and smart energy system, i.e., the energy revolution, depends on digital solutions. A good example is the time-differentiated feed-in and use of electricity, not least in the agricultural sector. However, at the same time, increased power consumption by digital infrastructures further intensifies the pressure on renewable energy sources, and on compensation measures for the remaining, unavoidable emissions. One thing to bear in mind is that even though the share of ICT and digitalization in the economy has increased in recent decades, the reports on climate change, biodiversity loss and ecosystem degradation do not provide the all-clear [30–40,67].

In this article, the exact potential for savings that can be achieved through digitalization in the agricultural sector, for example with regard to the use of fertilizers, was not elaborated. This would first require a baseline of the previous fertilization and the nutrient supply of the soils, for which hardly any supraregional studies are available. The same applies to pesticides and other input factors. There are limits to such studies anyway, because the nutrient demand depends on the specific characteristics of different soils, e.g., in terms of nutrient availability, and also of different plants and cultivation systems or weather conditions (see [138–140] using the example of P). Nevertheless, a trend has been identified in terms of potential efficiency gains and thus resource savings, but also in terms of limitations of digitalization.

Digitalization can support sustainable agriculture, but it is no panacea [10]. The potential of using digital technologies, including AI, in the sustainability sector lies primarily in being one of several strategic elements for the achievement of environmental goals. Even this will only succeed if the potential of digitalization is fully exploited and negative effects are avoided. With regard to regulatory and subsidy law, this article analyzed the status quo of legislation and identified the corresponding gaps. In addition, some suggestions for optimization were made, even though not all of the legal issues of the developing subject could be finally clarified. In particular, it should be emphasized that in addition to strengthening the details of regulatory and subsidy law, a sustainable digitalization of agriculture requires the existence of comprehensive and effective instruments for meeting the objectives of the PA and the CBD. In terms of instruments, it is suitable to address the major drivers of various environmental problems through primary energy emissions trading that removes fossil fuels from the market within two decades [28], and through another emissions trading system for animal products that reduces livestock farming in line with the climate target (in addition to a livestock-to-land ratio to avoid regional nutrient hotspots [71]).

However, the needs for phasing out fossil fuels and strongly reducing the consumption of animal products, i.e., frugality, have so far had little prominence in the discussion on the topic of digitalization in the agricultural and sustainability sectors. Yet more measurements, more evaluation with the help of new technologies, and the application of products in a more targeted manner do not automatically result in a better or sufficient protection of the environment [66,67]. This is especially true when ambitious targets are lacking, such as reducing pesticide use, lowering nutrient surpluses, or minimizing livestock density. In principle, digitalization is not an end in itself. Rather, digitalization is dependent on the targets. In the agricultural sector, digitalization serves, in particular, to implement the right to food, which is anchored, i.a., in Art. 11 of the International Covenant on Economic, Social and Cultural Rights (ICESCR) [12,67,141,142], and to meet the requirements of the PA, the CBD and other environmental regulations (which also have a basis in environmental human rights [28,49]). Digitalization can help to achieve such sustainability goals [3,67]. In this respect, a digitalization strategy for agriculture has to be guided by these objectives, as well as by other values enshrined in EU law, such as the precautionary principle from Art. 191(2) TFEU, the fundamental right to data protection pursuant to Art. 8 GrCh and Art. 16(1) TFEU, and the values from Art. 2 TEU, including non-discrimination [67]. In terms of AI, this also means that the aforementioned objectives need to be integrated

into the algorithms, rather than focusing exclusively on the improvement of technical efficiency [27,66,67].

Prerequisites for using digital technologies including AI are rapid grid development and the advancement of data infrastructures, as well as the exploitation of the advantages of open data, open source and (open) standards for interfaces. ICT and data infrastructures could also be operated under public law instead of being provided by the private sector (with the legislative competencies for the general provision of digital infrastructure lying primarily with the Member States [67]). In addition to public investment, it is also important to provide training, advice and information on new technologies, as well as appropriate research funding, whereby digitalization in the agricultural sector and beyond should always be tied to sustainability objectives [3,10,17,27,66,67].

5. Conclusions

If digital innovations and AI are to foster a more sustainable agriculture in terms of a substantial contribution to achieving climate and biodiversity targets, as well as other environmental quality targets, this will not happen as a matter of course; rather, the use of technology has to be clearly aligned with these targets. At the same time, it is important to create an appropriate legal framework for fair access to and the safe use of technologies.

This means, among other things, that product liability and product safety law has to be adapted more closely to AI-specific characteristics in order to create more legal certainty. In addition, the design of data privacy, data access and data security in line with fundamental rights (and simultaneously, in a way that promotes innovation) provides an important basis for AI in the agricultural sector [10,12,15]. Besides this, the common European agriculture data space can be an important starting point if it is configured appropriately. Furthermore, the future CAP should not only promote digitalization and AI, but above all ensure that these technologies are linked to environmental and climate protection. At the same time, rebound and shifting effects have to be avoided, because the efficiency gains achieved through digitalization should not be partially or fully negated by additional consumption or by consumption elsewhere [27,67].

In principle, digitalization has the potential to promote sustainability in the agricultural sector if it is perceived as a strategy for achieving binding environmental goals, and if it is designed accordingly. At the same time, comprehensive, effective instruments in line with the PA and the CBD are needed to complement and embed the digitalization-related strategy.

Abbreviations

AI	Artificial intelligence
Art.	Article
B2B	Business-to-business
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CFR	Charter of Fundamental Rights of the European Union
CH_4	Methane
CO_2	Carbon dioxide
CSA	Cybersecurity Act
EAFRD	European Agricultural Fund for Rural Development
EAGF	European Agricultural Guarantee Fund
FAIR	Findable, accessible, interoperable, reusable
FAO	Food and Agricultural Organization of the United Nations
FAST	Farm Sustainability Tool for Nutrients
FFD	Regulation on the free flow of non-personal data
GAEC	Standards for good agricultural and environmental condition of land
GDPR	General Data Protection Regulation
GPS	Global Positioning System
ICESCR	International Covenant on Economic, Social and Cultural Rights
ICT	Information and communications technologies
INSPIRE	Infrastructure for Spatial Information in the EU
IoT	Internet of Things
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology
N	Nitrogen
N_2O	Nitrous oxide
P	Phosphorus
PA	Paris Agreement
SMR	Statutory management requirements
SWOT	Strength, weaknesses, opportunities, threats
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the European Union
UNEP	United Nations Environmental Programme

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