Precision agriculture in Europe

Legal, social and ethical considerations

STUDY

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Precision agriculture in Europe: Legal, social and ethical considerations

Study

Abstract

Precision agriculture or precision farming, is a farming management concept using digital techniques for monitoring and optimising agricultural production processes. Although it does not constitute an autonomous technological field of large-scale application, precision agriculture, based on a number of technologies coming from outside the agricultural sector, raises significant legal and socio-ethical questions.

With rapid technological developments in big data analytics and cloud computing propelling the ‘precision agriculture’ phenomenon, an assessment is needed of the suitability of the EU legal framework to cope with the ethical and regulatory challenges that the digitisation and automation of farming activities may pose in the years to come. Among other things, the collection and processing of data within this management framework is expected to cause major shifts in roles and power relations.

The key question is to what extent, for what goals and for whose benefit precision agriculture will be used. Technology in itself is neither good nor bad, it is the way in which it is used that determines the effect. Thus, the main challenge is to develop a framework that can cope with the potential threats to the privacy and autonomy of individual farmers in a pragmatic, inclusive and dynamic manner.

The study illustrates the different ways in which the current EU legislative framework may be affected by the respective technological trends. It analyses the issues that might have to be dealt with, lists the European Parliament committees concerned and identifies the legislative acts that might need to be revisited, especially in view of the upcoming communication on the future of the Common Agricultural Policy (CAP).

To do so, a scanning of the EU legal and policy landscape has been performed, covering a wide range of dimensions of agricultural policy and related fields, such as environment, health and climate change. This points towards areas of EU law that may need to be adjusted or revised due to the potential multiple effects associated with precision agriculture. The study also provides a series of overarching recommendations that EU actors may wish to take into account when dealing with precision agriculture.
This study, which examines the legal, social and ethical considerations surrounding precision agriculture, is based and draws upon the Scientific Foresight project 'Precision Agriculture and the future of farming in Europe' (PE 581.892) requested by the European Parliament's Science and Technology Options Assessment (STOA) Panel. The technical horizon scan of that project was conducted by a team of scientists from Wageningen University and VetEffecT, upon the request of the STOA Panel, and managed by the Scientific Foresight Unit within the European Parliamentary Research Service. The scenario development and foresight phase were conducted by Cornelia Daheim, Future Impacts, with Erica Bol and Silke den Hartog – de Wilde.

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1. Introduction

Precision agriculture (PA) (also referred to as precision farming, smart farming, site-specific crop management or satellite farming) is a data-based management approach that is characterised by the collection and use of field-specific data. This can then be used to adjust the application of inputs to specific characteristics of small units of cropland and grassland to optimise fuel and input use (and to reduce losses that would otherwise cause pollution). It is based on technological spill-overs from other sectors and relies on numerous technologies and infrastructures, such as data gathering and management systems, geographic information systems (GIS), global positioning systems (GPS), microelectronics, wireless sensor networks (WSNs), and radio frequency identification (RFID) technologies. Precision agriculture is about supporting farming decisions with a view to using the right amount of inputs in the right place at the right time.

It is one part of a wider digitisation in the field of agri-food production, which provides agriculture with more tools for fine-tuning decision-making. The main concept of precision agriculture is enabling optimisation, meaning helping precise application of inputs, such as fertilisers, pesticides and irrigation water, which can result in a positive environmental impact (e.g. by reducing losses that would otherwise be lost to the water or air). In general, appropriate agricultural data management makes it possible to capture and combine data on, among other things, soils, climate, crop varieties and farm management. Moreover, by using common data standards that enable interoperability between precision agriculture technologies, there is potential for reducing administrative burden and using agricultural data for multiple purposes.

Precision agriculture may also become a way to help measure part of the environmental footprint of farming, which may facilitate farmers’ compliance with good agricultural management standards and may enhance farmers’ role as public goods providers and support guaranteeing a fair remuneration for specific efforts. Agricultural data management and precision agriculture may also make farming more transparent by improving the process of tracking, tracing and documenting. The use of digital technology is not exclusive to industrial agriculture; organic farming or any other agro-ecological approach could also make use of digital information tools in order to improve farm management. Appropriate agricultural data management and precision agriculture has also been proposed as a way to facilitate the better implementation of EU rules, especially in the fields of the Common Agricultural Policy and in a set of connected policies such as, among others, environment and food traceability.

For the purposes of this study, farming is approached as a way of life that has multiple socio-economic and environmental functions that need to be managed in a sustainable way. Moreover, digital technology and precision agriculture tools are viewed as applicable horizontally to different types of farm management. Industrial agriculture might be the most advanced in applying digital technology, but precision agriculture is not considered as a synonym for the use of digital technology in agriculture. Such an assertion would imply that, in order to use digital technology in agriculture and collect comprehensive data (including on the environment), the EU would need to support a type of farm management (industrial agriculture) that relies on practices that may have a negative environmental impact (monoculture, use of pesticides and fertilizers, high energy input etc.).

Although it does not constitute an autonomous technological field, the digitisation of agriculture, based on a number of technologies coming concurrently from outside the agricultural sector, such as global positioning systems, cloud computing, drones and the Internet of Things (IoT), raises significant legal and socio-ethical questions. These concern notably the terms of safeguarding sustainable agri-food production, the conditions under which farmer-related data are collected and processed and the role of the individual farmer. These questions need to be addressed as agricultural data management and precision agriculture gradually acquire a large-scale application. In fact, the rapid technological developments in this traditional area of human activity trigger the need for an assessment of the suitability of EU law to cope with the significant ethical and legal challenges that the digitisation and
automation of farming activities may pose in the years to come. The study does not approach precision agriculture and digitisation as a panacea that could handle all the growing pressures on ecosystems and the multiple challenges that the farming sector is currently facing. The gradual application of precision agriculture should not replace the need to continue designing and applying measures to protect and foster biodiversity. From an environmental point of view, for instance, it is clear that precision agriculture may indirectly affect the shaping of parcels of land and landscapes. In fact, designing and applying measures to protect and foster biodiversity in particular through mainstreaming agro-ecological principles across diverse farming systems will need to be continued or even enhanced because of precision agriculture's side-effects.

The analysis, by presenting socio-legal reflections that are of relevance to the work of the European Parliament (EP), illustrates the different ways in which the current EU legislative framework may be affected by the various technological trends. It lists the issues that might have to be dealt with, the parliamentary committees concerned, and the legislative acts that might need to be revisited, especially in view of the forthcoming Communication on the future of the Common Agricultural Policy (CAP). To do so, a scanning has been made of the current legislation – pertaining to a wide range of dimensions of farming and dependent fields, such as environment, health, climate change and food safety – mostly pointing towards areas of EU law that may need to be adjusted or revised due to the potential deployment of precision agriculture and its increased capacity to collect and process a massive amount of farm-related data.

The focus of the study is on evolving approaches for agricultural data management in general and on the increasing potential of precision agriculture for data provision from certain farms in particular. Both developments may require re-shaping rules and norms in several policy areas, including those of the CAP, environmental protection, food safety, animal welfare and climate change. Although the regulatory implications of agricultural data management and precision agriculture can be approached from a variety of legal perspectives, there are also issues that can only be dealt with through ethical analysis that could feed into the EU policy-making process both through codes of conduct and ethical impact assessments. It is hoped that the analysis will give Members of the European Parliament a better overview of the various questions they are likely be confronted with in the coming years, and a forward-looking instrument to help the EP to plan actions pro-actively.

**European Parliament Committees concerned**

AGRI – Agriculture and Rural Development  
EMPL – Employment and Social Affairs  
ENVI – Environment, Public Health and Food Safety  
IMCO – Internal Market and Consumer Protection  
ITRE – Industry, Research and Energy  
JURI – Legal Affairs  
LIBE – Civil Liberties, Justice and Home Affairs  
REGI – Regional Development  
TRAN – Transport and Tourism.
2. Challenges

The adoption of technologies for sustainable farming systems is a challenging and dynamic issue for farmers, extension services, agri-business and policy-makers. The development of precision agriculture presents some critical challenges, which require a clear strategy to support a smooth transition. Although precision agriculture is not a separate technological field as such, the question arises as to whether it should be viewed in a holistic manner, namely as an entirely new legal category, or instead should be analysed solely in relation to the technological means used within its framework. In fact, the challenges surrounding precision agriculture can be divided into two broad categories: those that are inherent to the technological means used in precision agriculture (drones, robots, GPS, etc.), such as issues of technological control, human safety, civil liability and privacy, and those that emerge alongside the development of precision agriculture as an autonomous technological field. These challenges include the cost of precision agriculture technological equipment, farmers' financial constraints and access to credit as well as farmers' familiarity with certain digitisation tools.

The lack of broadband infrastructure in rural areas and connectivity to devices (e.g., on a tractor, a computer that records what is going on, or a device for satellite photography privacy issues), ensuring effective data ownership in the context of big data and the lack of standards, and the limitations on the exchange of data between systems, all constitute further barriers and challenges that need to be addressed. Precision agriculture also raises questions in relation to the terms of interaction between humans and machines – particularly regarding the lack of independent advisory/consultancy services, technology push, food security and whether precision agriculture would further aggravate the employment situation in the field of agriculture.

Precision agriculture technology, being dominated by data exchange, can create monster-sized data, which can include field-specific information on planting, pre-season and in-season crop-input choices and investment, management strategies and harvesting practices. A major legal challenge associated with the systematic introduction of precision agriculture in Europe largely stems from the way of processing large amounts of information (mostly agronomic data) accumulated through a variety of technical means that is of high importance to farmers and farm organisations, and the use of decision algorithms.

While it is clear that the farmer owns the data generated on his fields, with increasing amounts of data being created about farming and by farmers, the identification of the different forms of field level data on yield and input performance being generated by the technology has become an overriding issue that remains relatively unexplored. Data quality, which has always been a key issue in farm management information systems, is more challenging with big, real-time data. Intelligent processing and analytics for big data is also more challenging because of the large amount of often unstructured, heterogeneous data which requires a smart interplay between skilled data scientists and sector.production experts.

Moreover, farming in Europe is very heterogeneous. There is, in general, a big difference between approaches implemented on large-sized and small-sized farms. There is also a lack of a critical mass of independent advisers, whereas the vast majority of farms belong to sole holders, who are family farmers and also the main agricultural employers (and millions of rural inhabitants rely on family farming for their livelihood). The size of farms and the farming techniques they use is often related to environmental, biodiversity, health and other issues, and affects the shape of landscapes in general. Combined with the high diversity of traditional agricultural landscapes that form part of the cultural and natural heritage, this in itself constitutes a source of a number of policy challenges. Among the main challenges associated with precision agriculture, one can refer to its technical accessibility and affordability. This is particularly
relevant, given the lack of interoperability standards\(^1\) and of technical protocols that would allow communication between machinery and tools/instruments, the serious limitations on the exchange of data between systems, including communication between equipment with other components of the PA hardware, and the special infrastructure, connectivity and compatibility requirements.

Precision agriculture is also associated with the use of expensive heavy machinery which represents significant up-front investment costs for farmers. This comes with the risk of locking them into a single overproduction model of farming or technology provider or vendor as they need to sell more to pay off the debts they incurred when purchasing high-cost equipment. The high start-up costs associated, in some cases, with a risk of insufficient return on the investment, can become a serious challenge in terms of the affordability of the technological component of precision agriculture. The case would be further challenged if external costs of precision agriculture, albeit potentially reduced, were to be internalised through this form of farming (e.g. pollution, water over-abstraction). Another societal challenge is that, while companies delivering precision agriculture technologies are getting bigger, they are becoming smaller in number. Already in the short term, monopolies may emerge as a result of data becoming concentrated in the hands of one big player. This would leave farmers and authorities little room for price negotiation for the acquisition of technologies and related services whilst dependency, control and unfair practices could present a substantial threat to farmers’ viability.

Additionally, given the technical complexity of precision agriculture, its use and operation require the provision of advisory/consultancy services specialised in data management. Such specific services would probably not be independent, and may generate competition and fragmentation with regard to current farm advisory services providing comprehensive and impartial advice for farmers. Moreover, the very diverse types of agricultural stakeholders, ranging from big business, financial, engineering and chemical companies and food retailers to industry associations and groupings of small suppliers of expertise in specialist areas, may become a challenge in itself, given the current lack of common standards enabling real interoperability and clear and transparent communication. In the somewhat longer term, this may even influence food security in Europe; the companies providing precision agriculture technologies may eventually merge with big companies which are already integrating the livestock chain, or combine seed supply with production of plant protection products, etc., directly impacting primary production and food prices.

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3. Policy areas

3.1. Farming

EP Committees: AGRI, ENVI, ITRE, REGI, EMPL

In the field of agriculture, any information related to location plays a fundamental role; regular monitoring through sensor networks is necessary in order to collect the evidence and data that is required by various pieces of EU agricultural legislation for managing aid to farmers and for promoting agricultural practices beneficial for the climate and environment (greening of the CAP). Given the considerable need for geographic data for the management of the EU agricultural policy, geo-spatial information has become a defining factor in the implementation of this policy, which includes the establishment and maintenance of the Integrated Administration and Control System (IACS).

More specifically, according to the CAP legal requirements, each Member State has established an Integrated Administration and Control System (IACS), including an identification system for agricultural parcels, known as the Land Parcel Identification System (LPIS), as the spatial component. Using computerised geographical information system techniques for the identification system for agricultural parcels is in fact a legal obligation prescribed under Council Regulation 73/2009. By localising, identifying and quantifying agricultural land eligible for EU support via very detailed geo-spatial data, IACS has become the most important system for the management and (administrative and on-the-spot) control of payments to farmers made by the Member States in application of the Common Agricultural Policy. It enables a set of comprehensive administrative and on-the-spot checks on subsidy applications, which is managed by the Member States and provides for a uniform basis for controls and on-the-spot checks performed by national authorities.

LPIS is an IT system established on the basis of maps or land registry documents or other cartographic references that make use of computerised GIS techniques. It records all agricultural parcels in the Member States that are considered eligible for annual payments of the CAP area-based subsidies to farmers. It is used for cross-checking during the administrative control procedures and as a basis for on-the-spot checks by the paying agency. These include checks as to whether farmers have respected a set of rules under cross-compliance, introduced as from 2005, which also apply horizontally to area-related rural development schemes, such as agri-environment and less favoured area support schemes. For the purpose of the CAP controls on cross-compliance and greening, several further types of data related to a set of regulations are collected alongside geo-spatial information. These include, for instance, requirements related to environment, health, soil, animal welfare, food safety, climate change, water protection policies, etc., and standards for good agricultural and environmental conditions. During the 2014-2020 CAP, LPIS has also been used to monitor compliance with certain greening obligations (agricultural practices beneficial for the climate and the environment) that are part of direct aid to farmers.

Precision agriculture may offer a holistic view of the CAP requirements from a legal and information points of view. It may enhance the efficient implementation of the Common Agricultural Policy via the collection of geo-referenced data on soil characteristics, weather-related indices, and crop status at land parcel level. Given that the 2003, 2007 and 2013 reforms of the Common Agricultural Policy have resulted in significant changes in the data required from farmers to accompany applications, precision agriculture and its standardisation potential may have an indirect positive effect upon the way the application for direct CAP payments is handled and lead to a simplification of the control and verification procedures. The volume and accuracy of the data generated by precision agriculture may in this case help the aforementioned control system and alleviate the burden of inspections carried by farmers, national administrations and the EU inspection and funding services.
Information recorded and produced in the framework of data management and precision agriculture activities may be used to facilitate those various LPIS and IACS administrative and control procedures that are focused on the verification of eligibility conditions but that also support performance-based controls as a new methodology. Beyond the challenge of collecting comprehensive and precise farm-focused data and establishing high quality datasets, standardisation, knowledge integration and interoperability of data exchange in agriculture constitute additional barriers to the shaping of a harmonised approach in terms of designing common implementation norms and practices. The interconnectivity of information systems suggests the possibility of linking information systems, so that data from one system could be automatically consulted by another system at a central level.

This solution requires technical compatibility between the systems, as well as strict privacy safeguards and access control rules. There are different levels of interoperability affecting data, such as technical (the use of data management systems that allows connection with other systems), semantic (the use of metadata and knowledge organisation systems for the description and organisation of data, based on existing standards) and legal (the use of appropriate licences that allow the exchange of data between different systems and providers). Interoperability, being viewed as something more than interconnecting ICT-systems, comes with certain risks that refer to the possible infringement of data protection principles, and in particular of the purpose limitation principle.

The majority of the spatial data in question is now subject to the process of pan-European standardisation and harmonisation, triggered by the INSPIRE Directive. Unification of data models for 34 themes, covering a wide range of areas, including agriculture and aquaculture facilities, coordinate reference systems, cadastral parcels, transport networks, hydrography, land cover, ortho-imagery, soil, human health and safety, natural risk zones, habitats and biotopes, energy resources, and others, is in fact one of the key aims of the INSPIRE Directive. However, it should be said that difficulties are still experienced in the agricultural domain in obtaining access to LPIS data in general (owned by Member States and only some of them make it available), in spite of the implementation of the INSPIRE framework. Creating common standards and a shared 'language' between communities, could bring valuable input for the CAP and other policy areas. This would enhance interoperability and harmonisation through explicit definitions of data standards and feature types, their aggregation into classes, attributes of feature types, domains of these attributes, etc. The INSPIRE implementing rules on interoperability of spatial data sets and services (IRs) and technical guidelines (data specifications) can serve as a basis for such a harmonisation effort as they specify common data models, code lists, map layers and additional metadata on the interoperability to be used when exchanging spatial datasets.

Adequate data approaches and precision agriculture can further detail the properties of reference parcels together with their relationships with other component of IACS, in particular, with declarations and payments, farmer registers, and a more targeted cross-compliance. Beyond its inherent ability to collect data and substantiate specific parameters, precision agriculture could support the harmonisation of standards, the aggregation of databases and the simplification of the current system and as such give an impulse towards a system able to modernise the CAP. Precision agriculture may become an important factor in data standardisation and harmonisation that in effect may facilitate data sharing and lead to a less bureaucratic CAP. It can also be supportive in facilitating the shaping of uniform requirements in relation to parameters such as reference parcel, land cover type, farming limitation, farmer aid application, agricultural parcel, farmer sketch and crop code. Closely linked to the need for standardisation and harmonisation of data exchange and format, precision agriculture could also support the farmers’ declaration document because the geographical accuracy of agricultural parcel maps produced in PA should be sufficient for farmers to be able to use them for the submission of their digital payment applications. The introduction of precision agriculture may pave the way for Member States to implement digitisation programmes as regards the relationship between government and agricultural holdings, with a view to obtaining a 'single farm file' involving the integrated and synchronous management of crop data. Common EU standards and appropriate agricultural data
management, as well as precision farming, could make farming more transparent, improve tracking and tracing of agricultural products and also become a source of improved predictions on the quality of agricultural products.

At the same time, the introduction of precision agriculture may also in itself become a carrier of various challenges of legal or regulatory interest. First of all, from a technological perspective, some of the main challenges include compatibility issues limiting the development of technology, low deployment of digital technology, limited data infrastructures on farms not designed for data sharing, extensive brand protection by large companies (vendor lock-in), poor compliance with standards for software development and data formats, sharing of data, (business models for) data management and interconnectivity strategies. Common standards, connectivity and interoperability are the key issues in this field. Rural wireless and broadband coverage is patchy, while standards for sensor networks are still under development and specialist agricultural software is still maturing. Beyond the diversity of rural environments and stakeholders, rural areas, especially in southern and Eastern Europe, tend to lag behind urban areas in broadband deployment which is crucial for the efficient use of big data for farming purposes. Interoperability at the EU level is currently facing major challenges, including sub-optimal functionalities and technical limitations, gaps in the EU’s informational architecture, a complex legal and policy landscape, overall fragmentation of EU data management architecture and limited interoperability between information systems. Additionally, given that rural areas often suffer from rather poor broadband availability, high speed connectivity is important, not just for farmers, but for the entire rural economy.

Precision agriculture is knowledge-intensive and adds complexity to the decision-making processes because of the large amount of information to be processed. Data rapidly accumulates in sets too bulky and complex to be studied without software and alone does not create insights. The large amount of information available to farmers collected via different precision agriculture techniques may require additional specialist advice and guidance on how this information is incorporated into actual management plans. The data still need to be standardised, to generate useful input for farm decisions. Under the rural development pillar of the CAP, a measure on advisory services is already available for possible uptake by Member States, according to Article 15 of Regulation 1305/2013 (for various types of advice) and to Article 28 (for advice in relation to agri-environment-climate commitments).

Farm advisory services and the European Innovation Partnership enable support for the uptake of new technologies, new management approaches specific to local conditions and tailor-made solutions. If Member States programme the advisory measure, farmers can be funded for the use of expert advice and the necessary knowledge and information required for implementing farm operations. For instance, the funding for advisory services under Article 15 has helped farmers at the time of the introduction of the cross-compliance mechanism under the CAP payments. Cross-compliance links CAP payments to compliance by farmers with standards stemming from EU rules related to environment, food safety, public, animal and plant health, animal welfare, and for maintaining land in good agricultural and environmental conditions (GAEC). If farmers are found not to comply, they are sanctioned and their payments are reduced.

At the time of introduction of cross-compliance (2005-2007), support for advice helped farmers in their understanding of the requirements in order to meet the new EU rules. Provided that it is programmed under rural development by Member State authorities, support for farm advice is available in the Member States and any farmer can have access on a voluntary basis. Farm advisers play a central role in recommending, delivering and giving support to farmers on new data management technologies, including precision agriculture. The increasing use of precision agriculture creates an additional challenge for established farm advisory services. Farmers should be enabled to receive personalised, targeted advice based on the information/data they own and provide to their adviser. To this aim, common data standards are needed and farm advisory services will need dedicated tools and training on agricultural data management.
Also, open-source environmental, geographic and satellite imagery data should become accessible to advisory schemes allowing the latter to develop balanced information dissemination without bias or special interests. The farm advisory services in Member States can in principle play a special role in supporting precision agriculture, providing support and advice to farmers regarding technology and precision agriculture methods as an independent body not linked with commercial companies. Given that precision agriculture is currently almost entirely based on the private sector offering devices, products and services to the bigger farmers who can afford it, public service advice is generally very limited. In the majority of Member States, access to independent advisory services linked to public bodies, co-operatives and farmer associations, where the farmers can get additional information in order to make decisions, is limited and rather unstructured. The role of independent advisers, who can combine agricultural and environmental understanding, is critical as they can be consulted by farmers as impartial sources of knowledge and experience, rather than private company consultants whose role may for instance include product sales as a condition for their support.

If common data standards are agreed and data is made easy interoperable, and if the right policy approach is applied for advisory services support, data from precision agriculture can support advisory services to improve the management and efficient use of resources, by facilitating more accurately targeted and improved management of crops and livestock on individual farms. This will also enable more tailor-made advice for the farmer, since the combination with other data (e.g. environmental data, financial data, research data on best practices, advisory data, etc.) can lead to improved and more specific advice. The integration of data management and information systems is needed to advise farmers on implications resulting from different scenarios at the point of decision-making during the crop cycle.

Precision agriculture is capital intensive, rather than labour-intensive, due to the purchase cost of technology and the time investment for technology education required. The purchase cost of the precision agriculture infrastructure and services is high due to the investments needed in order to make use of this technology on an individual/farm-based level and the fee associated with the respective specific service. In fact, processing and use of big data products, without common EU standards, is an expensive operation that mainly only big companies can afford. Real-time data is highly valuable to investors and financial traders in a market where the slightest informational edge may lead to high profitability and even market distortion. Currently, large organisations seem to be more engaged in technology adoption, due to their structure and budget, and can more easily invest in dedicated innovations, training and knowledge provision, since they can reduce the risks associated with the investment. Investments in expensive or highly specialised machineries or technologies can be afforded mainly by big farms, or are usually delegated to service providers. Small farmers in the current situation without common standards often prove unable to fix or adjust equipment, forcing them to risk delays and expenses when going back to manufacturers for appropriate technical support.

In the context of precision agriculture, there are also some serious issues with compatibility between farm instruments and tractors. Another general concern among farmers is hardware and software compatibility and choosing the right technical systems for conducting PA. It is important that different technologies, especially hardware devices, are compatible with other electronic components and systems. The vast majority of these instruments are often only compatible with other tractors of the same brand due to the proprietary file formats. Tractors and other agricultural machinery, which are currently equipped with several monitoring capabilities, rely on standards such CAN/ISOBUS or rely on wireless technologies using battery powered devices in environments where using wired technologies would be

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2 P.G. Carter and S.L. Young ‘Applications of remote sensing in precision agriculture for sustainable production’ in M. Oliver, T. Bishop, & B. Marchant (Eds.), Precision Agriculture for Sustainability and Environmental Protection, USA, p. 97.
too costly. Current precision agriculture systems are based and should comply with ISO 11787.\(^3\) However, there are still equipment incompatibilities, as well as incompatibilities between owned and contracted farm equipment. The use of existing long-range communication protocols that are presumed to be already available may represent an advantage for some application cases, since it removes the need to deploy a new data collection infrastructure, thus accelerating system deployment.

The increase of precision agriculture technology components in agricultural machinery used in Europe triggers the need for adjusting EU legislation governing EU farm equipment to the new technological realities. The established administrative requirements for the approval and market surveillance of agricultural vehicles need to be differentiated from legislation on automobiles and take into account the need to implement the translation of gathered data into Farm Management Systems (FMS) and to improve the standardisation of data exchange/communication. Regulation 167/2013 applies to all types of tractors independently of their maximum speed (which is not specified) and their traction system; this means it is no longer limited to top speed of 40 km/h and wheeled tractors, but extends also to tracked units.

All types come under application and, if certified for conformity, can all be given type-approval recognised in all the twenty-eight European Union Member States. That may fit well with tractors designed for precision agriculture purposes, bearing in mind that each country maintains the right to regulate circulation in national territory as far as speed limits, weight, size, etc. are concerned. Additionally, in case more farmers start choosing drones or smart tractors instead of conventional tractors, questions may arise with regard to whether drones should also be considered as falling under the scope of EU rules on agricultural machinery, such as Regulation EU 167/2013 that deals with type-approval for farm trailers and other towed agricultural machinery such as sprayers, balers, etc. Achieving this will require stronger participation of the private sector and adoption of new production arrangements, such as contract farming that integrates information delivery mechanisms as part of the farmer service strategy.

Legal instruments and other key texts:


- European Parliament resolution of 7 June 2016 on technological solutions for sustainable agriculture in the EU (2015/2225(INI))


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\(^3\) ISO 11787:1995 Machinery for agriculture and forestry -- Data interchange between management computer and process computers -- Data interchange syntax provides the means to enable communication between on-farm process computers of stationary and mobile agricultural equipment or machinery, and management computers. Specifies an Agricultural Data Interchange Syntax (ADIS) to exchange data electronically. It implies that the syntax is not intended for real-time data exchange.


• Regulation 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles Text with EEA relevance, OJ L 60, 2.3.2013, pp. 1–51

• Commission Communication of 29 February 2012 on the European Innovation Partnership 'Agricultural Productivity and Sustainability' (COM(2012)0079)


• Commission Regulation 1122/2009 of 30 November 2009 laying down detailed rules for the implementation of Council Regulation (EC) No 73/2009 as regards cross-compliance, modulation and the integrated administration and control system, under the direct support schemes for farmers provided for that Regulation, as well as for the implementation of Council Regulation (EC) No 1234/2007 as regards cross-compliance under the support scheme provided for the wine sector OJ L 316, 2.12.2009, pp. 65–112


### 3.2. Data management

**EP Committees: JURI, LIBE, IMCO**

Data management generally covers the organisation, administration, and governance of data and aims at ensuring a high level of data quality, accessibility processing and security. The agricultural sector is creating increasing amounts of data, from many different sources processed by a wide range of actors. This is providing input for agri-food decisions with regard to planting, fertilising and harvesting crops.

Precision agriculture is information-intense, generating an immense influx of valuable (and sometimes valueless and even risky) data and concerns a variety of actors involved in collecting, retaining, processing, exchanging and sharing data. These include producers, data collectors and managers, independent agricultural data banks and data cooperatives. It relies heavily on the provision of site-specific information including data, maps and images.

The use of robotic drones/UAVs (unmanned aerial vehicles) equipped with high-tech cameras and sensors in the context of precision agriculture represents an increase in the scale of aerial data collection. This constitutes an unprecedented challenge for the legal protection of privacy rights as well as of personal and business data and images. It should be stressed that not all agricultural data is managed by precision agriculture, as the latter is mostly applicable to a limited number of (larger) farms. Many other actors are also involved in managing agricultural data, such as banks and advisory services. In particular, the Member State authorities managing the agricultural data needed for CAP payments, are dealing with a large set of data. This includes not only geographical data (measurement and location of parcels and landscape features) but also data related to regulations on the environment, health, soil, animal welfare, food safety, climate change, water, etc.

As smart machines and sensors appear on farms and farm data grows in quantity and scope, farming processes will become increasingly data-driven and data-enabled. Coupled with the adoption of the technology is the rapid accumulation of large amounts of agricultural data on individual operations and fields with more data points than can be comprehended in any standard analysis, leading to challenges for precision agriculture industry providers. An enormous amount of data is required to generate treatment maps, which are collected through connected sensors/valves/tractors, thus creating new data-supply chains. These large amounts of different types of data are collected by drones, robots and sensors in general and include climate information, satellite imagery, digital pictures and videos, transition records or GPS signals. The complexities arise due to the fact that these technologies support very detailed data capturing, which in principle can be shared (cloud technology) and interpreted with big-data techniques. By linking and combining data from different sources—such as real-time nitrogen sensing or GPS-connected prescription maps—a farm produces many types of data that can be classified into different categories: agronomic data, financial data, compliance data, metrological data, environmental data, machine data, staff data, personal data, financial data and operational data (employee data, usage data related to inputs such as fertiliser, and other mapping, sensor and related data created or needed to operate including raw data, field data and experimental data).

It should be mentioned that not all categories of data involved in precision agriculture such as agronomic data, compliance data and meteorological data, actually qualify as personal data (‘information relating to an identified or identifiable natural person’ in accordance with Article 4(1) of Regulation 2016/679). Confidential farm-related data concerning particular farming techniques, soil
fertility and crop yields, but also certain financial and other personally identifying information that may be subject to legal restrictions, is also collected. Consequently, the issues raised by the processing of each category of data may differ. Some categories of data will certainly qualify as personal data in practice due to their relationship to a 'natural person'. These include financial/economic data and staff data or other data derived from people's behaviour, and sometimes environmental data (as far as it is derived from human activity). For instance, by measuring fields one can easily acquire a view on the income of the farmer, which usually qualifies as personal data. The qualification of personal data, and therefore application of EU data protection rules, must be made on a case-by-case basis (according to the context/purpose of the processing).

The collection of visual data via precision agriculture can lead indirectly to the identification of individuals, even though it is focused on the collection of data for crop management and any collection of personal data, such as images of people, is likely to be both minimal and incidental. Although the specificity of the used technology and the arena in which it is deployed means that generally drones in this context are less invasive, they still provide any user with the potential to directly identify individuals and their behavior. The accuracy and detail of the data collected by these means, combined with images or location, or both of these data points, can potentially enable identification, which may ultimately infringe privacy. The potential introduction of prescriptive farming practices, given insights gained from big data and the use of farming data to determine creditworthiness, could result in drones being used to monitor the farming activities of clients to ensure they are complying with best practices. The fact that drone data combined with GIS data could easily provide information about a specific individual's behaviour and actions is a clear example of a potential privacy infringement. Repeated flying over other people's farms and homes could be deemed violation of privacy if imagery is taken of other farms, their geographical details, landscape, natural vegetation and cropping patterns, as well as private and public buildings in that area.

Moreover, when considering certain vulnerable communities and contexts, some types of agricultural data may be delicate in and of themselves. Precautions should be taken in determining whether to collect and share data on community-held land, resources and agriculture, especially when it comes to sensitive data on water resources and forest rights. Given the potential collection and processing of personal data, the application of precision agriculture, approached as a carrier of real-time information, poses legal questions about the need for respecting privacy, protecting farmers' data, the relationships of trust/power and the terms of storage via a third party or in a cloud computing environment. The collection and processing of huge quantities of untapped farming data entails risks associated with storage and access to confidential information concerning specific agricultural operations, access by farmers to data in a non-proprietary form and making confidential information sufficiently anonymous to avoid misuse when brought together by third parties.

Given the special quality of real-time information obtained at farm level and the technology used to collect, store, use, manage, share, process and communicate it, farming data is of significant value. Its processing could be of particular economic importance for both farmers and the entire food supply chain as it can reveal when and where the crops are, the amount and cost of yield and the farm's profits. Data gathered from sensors and hi-tech farm equipment, alongside satellite imagery, census data and geospatial data on crop health, crop productivity and irrigation patterns, can currently provide a lot of information about a farm and its activities, all without the active consent of the farmer. Data in a vacuum on its own has no value; but once information is gleaned from the data, it then becomes valuable. Technology providers can use the information to give growers 'field prescriptions,' which are valuable to a grower who can focus inputs for optimal yields on a per-field basis. But that information can be even more valuable to second or even third parties. It is the information produced through the processing, aggregation and elaboration of seemingly unconnected data sets that leads to data monetisation. The data is a commodity, especially when that data can be combined and analysed with data from other farmers in the region, state, country or globally, for that matter. Data combined with
other farm data can be crunched, tweezed or bludgeoned into showing trends, predict market futures or the adoption of new crop technology. Thus, its potential misuse could lead to anti-competitive practices including price discrimination and speculations in commodity markets that may affect food security especially in Europe. Technological control or expert-driven control of farming practices and data may in effect lead to market arbitrage as commodities market traders can have precious farm-related data on their terminals and base trading and pricing decisions upon it.

Several privacy and data protection risks may arise also in relation to the terms of processing of data (such as images, sound and geo-location relating to an identified or identifiable natural person) carried out by the equipment on-board a drone. Such risks can range from a lack of transparency of the types of processing, due to the difficulty of being able to view drones from the ground, to possible function creep. The latter is due to the continuous development of databases and the interlinking of two databases designed for two distinct purposes – which results in a third purpose for which they were not designed – and due to severe limitations in knowing which data processing equipment is on-board, for what purposes personal data is being collected and by whom. Furthermore, profiling is happening in the agricultural sector too, with farm profiling.

The processing of farm data, as far as it constitutes personal data, may constitute an interference with the right to the respect for private life guaranteed by Article 8 of the Council of Europe Convention on Human Rights and Article 7 of the Charter of Fundamental Rights of the European Union. This is because it challenges the right to intimacy and privacy guaranteed to all individuals in the EU and can therefore be allowed only under specific conditions and safeguards. However, not all processing of personal data in the course of precision agriculture processing will constitute a limitation under Article 7. There can also be risks in relation to Article 8 of the Charter regarding the right to protection of personal data. It must be underlined that, where the processing of farm data also involves personal data, the rules of the EU data protection legislation must be complied with.

As far as non-personal data is concerned, the identification and specification of ‘data ownership’, ‘trade secrets’ or ‘intellectual property issues’, competition law aspects, public data and usability, access to machine generated and machine-to-machine data, constitute some additional data-related challenges. For example, details on soil fertility and crop yield have historically been considered akin to a trade secret for farmers, and suddenly this information is being gathered under the guise of technology and miracle yield improvements. A management system like precision agriculture, which heavily depends on data, maps and images, is likely to create new concerns about data management, access to data, the ownership of aggregated data, control of the data generated, assimilated, and manipulated through precision agriculture activities, raising a series of tricky questions: Who owns the data? Do you own the data (as an individual or a business) or does another organisation own it? Does using a particular software service mean that ownership is transferred to the service provider? Who ought to have access to the data generated by precision agricultural equipment? Who owns the secondary and tertiary uses of the data; can this ownership be limited or expanded, and in what way? Who is the owner if the data is collected under a separate contract (e.g., custom harvesting or custom applicator)?

How are ownership and licensing of data regulated when contract farmers are not the owners of the land, thus potentially disrupting the agricultural value chain? Is the data secure? Are there privacy implications with the data gathered by precision agricultural equipment? Who owns analysed data? Which are the data versions and which part are you sharing? How are the different data parts, versions and derivatives separated? Is it clear which part of the data is primary versus derived versions? Is it clear which part is personal or private versus machine-generated? Who owns each part and how do you separate what is being shared? There are also data ownership issues in relation to data collected by GPS and whether these would be owned by the company rather than free to use for the farmer.

Although there is at present no EU legislation that specifically regulates the question of ownership in data, and although ownership-like rights currently available are limited to intellectual property rights
and trade secrets, the determination of data ownership, especially of datasets or derived data that may affect the content of the agreements/contracts signed by private providers of agricultural technological know-how in the form of data licences, is of particular importance. These licences may define the rights to use, transform, and monetise the data. While relying on contracts may seem to provide greater flexibility to the contracting parties, it nevertheless comes with various difficulties. In particular, the lack of harmonisation of contract law in the EU, but also the limits of contractual arrangements towards third parties, and the issues related to the validity of data-related agreements, create a high legal uncertainty that affects the entire data value chain and all data flows. It is therefore concluded that such a situation is not sustainable in a data-driven economy, given also the fast-increasing development and adoption of data mining and analysis tools.

Data ownership is a widely discussed concern within the agricultural community. Because of how the data moves through the different stages of collection, management, and use, the ownership of (private big) data needs to be defined in relation to who controls the value of the data. Raw, large agricultural data sets that may hold little value to the end consumer might develop special value to a third party who is able to aggregate it and analyse it for a different purpose (e.g., a company might be interested in seed, yield, and input rates for determining future pricing of their product). All the data available – from sensors and connected machines, external weather information, satellite images, information from drones, and past growing information – are transformed into valuable business data via precision agriculture. It should be noted that information in this field has spurred significant investment and development of information-based (i.e., data and decision support-based) agricultural services that are based on service agreements that may waive farmers’ data ownership rights. This may signal an unprecedented power shift in the industrial farming process.

The potentially multiple uses of data collected in the framework of PA (as a decision tool for farm-related decisions or by third parties who could aggregate it for determining future pricing of an agricultural product) raise the question of the effects of secondary and tertiary uses of this same data with regard to ownership, and in particular on how benefits will return to the farmer owning the basic data. The clear main policy concern is centred on the potential of those who use the farmers’ data to direct and control the data sets, and in effect profit on the basis of their further elaboration and processing. Most companies state that farmers own the data they produce. However, once data is aggregated with other farmers’ data, it appears to become the property of the company and is mostly no longer retrievable or exchangeable. Information related to yields and performance contained in this data can hold incredible value and could provide a market advantage to seed and fertiliser companies as it is a mix of real, personal and intellectual property data inextricably linked to the land. This private information about crop yields and soil fertility, which some consider trade secrets, which could be used for pricing purposes and decrease a natural competitive edge, can either be created by people or generated by machines, such as sensors gathering climate information, satellite imagery, digital pictures and videos, purchase transaction records or GPS signals from a variety of sources via the use of algorithms.

While many companies say that farmers are the owners of their data, in real practice that is not always the case. It has yet to be clarified who legally owns the data and how the farmer can effectively share the benefits created by the use of his data. ‘Primary data’ is seen as owned by the farmer while, strangely, ‘computed data’ is currently seen as being owned by the one who did the computing. The ownership of data becomes even more ‘murky’ once it is aggregated with other farmers’ data. In many cases, this then seems to be considered in the ownership of the aggregating company. It should be said that there is also a major differentiation between standards and types of data, given that there is lack of a common European or international standard for creating and sharing data. Significant risks also arise when data is collected across a high number of farms and then processed in real time, as there is no automatic protection granted to factual or raw data, which may also be confidential information. What will happen when big multinational companies that develop seeds and/or agricultural machinery (tractors, equipment, milk robots etc.) acquire data analytics companies for the development of behavioural
patterns and business models for each aspect of farming? The use of surveillance systems and monitoring procedures in the field of precision agriculture also raises issues of the security of data processing operations, including vulnerability to cyber-attacks and hacking of the food system.

Given that smart sensors and devices through their integration with additional technologies and systems can collect and produce big amounts of data related to the whole supply chain, precision agriculture gradually becomes associated with the management of big data. Big data refers to gigantic digital datasets held by corporations, governments and other large organisations, which are then extensively analysed using computer algorithms. In the field of agriculture, the majority of big data is predominantly public-level big data collected, maintained, and analysed through publicly funded sources. However, collecting and managing big data in the field of precision agriculture that originate with the farmer may heavily affect decision-making and the balance of powers in this field due to the fact that the technical expertise and capacities available for performing such actions is rather concentrated in a limited array of private companies.

An additional legal challenge in processing big data stems from the wide range of actors involved in the farm data chain and the fragmented and uneven character of the relevant data ecosystem: those who create data (farmers), those who have the means to collect it (data brokers), and those who have amassed the expertise to analyse it (data analytics) and currently shape the rules about how the data will be used, who gets to have access, and who gets to participate. Different actors within the sector have vastly different levels of access to information – ranging from agricultural companies, to ministries, distributors and even researchers, thus raising issues of information asymmetry. Challenges for the successful adoption of shared data schemes exist, as farmers are generally reluctant to provide free access to their farm management data, including spatial data such as within-field soil variability, crop status and livestock data sets.

A new 'big data digital divide' as a form of economic and social inequality may emerge as farmers most often lack the tools or the context to analyse their own data and are mostly unaware of the extent to which their data get stored, traded and analysed for future use. Such a divide may lead to the formation of an asymmetric relationship between those that collect and mine large quantities of farm-related data and farmers that may potentially exacerbate power imbalances in this area. Accurate and actionable data requires considerable technical skills to handle data mining and analysis method and system. As precision agriculture is intrinsically information-intensive and high-technology driven, farmers face many difficulties in efficiently managing the enormous amount of data that they collect. They may also lack the skills, support, independent advice and time needed to analyse the data and critically interpret the information. Given also that there is a mismatch in the scale, precision and accuracy of data coming from different sources, no mechanism exists that could control data before it is used in algorithms and the interpretation of products created by algorithms processing large data sets is rather subjective.

Many farmers are also wary that the collection and processing of this data may lead to high levels of insight into the economics and operational workings of their farms. Many of the smaller actors often have the least access to sources of information, such as market data, which larger institutional players receive weekly. This relates directly not just to issues of availability mentioned often when it comes to open data, but also of accessibility and distributions channels. Overall, it seems clear that the people suffering most from these information gaps are those with the least resources to spare: rural farmers, smallholder farmers, or those unable to pay for access to databases or technology that would make accessing the information easier for them.

From the perspective of smallholder farmers, it seems difficult to know exactly how this data is being used and where it is going. This is because of a lack of transparency around what is really happening with farmers’ data and more essentially, lack of systems to cope with this issue. Farmers’ organisations fear that, if big companies control the data, monopolies risk being created and production will be focused on economic gain at the expense of other objectives. An enormous threat is that in view of this
informational overload, companies may bypass the farmer entirely and amass a significant amount of previously proprietary, private, or untapped farming data. They could do this directly through a wifi-data connection, sensors and new data analytics applications and in effect gain a privileged position with unique insights into what farmers are doing around the clock, on a field-by-field, crop-by-crop basis.

The issue of data management and data compatibility forms one of the main current limitations to the wider spread of common tools and methods to handle data gathered by several sensors, approaches and temporal and spatial scales. In particular, one of the main restrictions for data sharing among institutions, farmers, advisers and researchers is due to non-standard software and data formatting solutions. The challenge is to properly manage the large data sets that are acquired by different sensors, and to enable data sets to be shared easily, irrespective of the sensor model and brand used. As modern farms are increasingly equipped with all kind of sensors, data management, data storage, data sharing and interconnectivity strategies are urgently needed.

Given the emergence of the internet of living things and the rapid development of sensor technology, tracking and tracing, the management of the legal and technical challenges associated with the use of soil sensors and seed planting algorithms create additional complexities for the farmers. Other challenges include institutional constraints as well as the reliability, manageability and limited knowledge surrounding the applicability of this technology and its adaptability to all farm types and sizes. Precision agriculture systems may be placed into farm environments where the connectivity is usually rather poor, and may not be able to share data even with other systems on the same farm. Hardware/software providers are not necessarily incentivised to share data with other systems as they strive to offer complete systems of their own. Furthermore, compatibility issues in precision agriculture are limiting the development of technology, as it prevents data exchange between instruments, and interconnection of equipment. There is a lack of, or poor compliance with, standards for software development and data formats, limited data infrastructures on farms that are not designed for data sharing, and extensive brand protection by large companies.

In addition to the difficulties in data management and data compatibility, it is often difficult to store the large amounts of data generated. Farmers, consultants, advisers, and related companies need a data infrastructure that can collect, store, visualise, exchange, analyse and use large amounts of data, and they require a legal framework to deal with the ownership and the use of data outside of the farm premises. The lack of cohesion in data exchange and the vendor lock-in scenario, which occurs even where a standard such as ISOBUS exists, limit the uptake of precision agriculture. Several standards are available, but these have been created by unrelated organisations and they are not centrally indexed.

**Legal instruments and other key texts**

- Commission Communication on Building a European Data Economy, COM/2017/09 final
- EDPS Opinion 8/2016, Coherent Enforcement of Fundamental Rights in the Age of Big Data
- EDPS Opinion 4/2015, Towards a New Digital Ethics: Data, Dignity and Technology, September 2015
- EDPS Opinion 7/2015, Meeting the Challenges of Big Data: A Call for transparency, user control, data protection by design and accountability, November 2015
3.3. Protection of natural/agricultural environment and food safety

**EP Committees: ENVI, ITRE**

### 3.3.1. Nature protection

Farming activities may have an effect on land cover, landscape structure and local biodiversity in complex and unpredictable ways. Precision agriculture may potentially contribute to the assessment and monitoring of the pressures that arise from agriculture and to the mitigation of the pressures of agricultural activities upon the environment, for example, through a more efficient use of water or optimisation of pesticide/fertiliser treatments. Precision agriculture may also help the transition to sustainable agricultural approaches and the integration of environmental protection requirements in the CAP, in line with Article 11 of the Treaty (TFEU). It could define certain environmental practices in a more precise manner and also make cross-compliance rules and greening measures of the CAP less vague, manageable and potentially more comprehensive.

Acknowledging that the soil, weather and microclimate vary both spatially and temporally, precision agriculture, via its data collection instruments, has the potential to facilitate a more accurate assessment of the implementation of EU environmental legislation in the fields of water and air protection and a nuanced quantification of environmental pressures and risks. However, it should be said that a number of environmental criteria cannot be measured by precision agriculture, such as counting birds or flora (biodiversity), pollution of groundwater, emission of greenhouse gases.

Moreover, with more standardised data and a set of accompanying measures, the structures of the Common Agricultural Policy may be in a position to incentivise and compensate for additional efforts to support environment or mitigate climate change with dedicated management practices. The full, free
and open data and services’ information provided by Copernicus, combined with information produced by other remote sensing technologies (e.g. drones) and/or in situ data, may enable companies of all sizes (from established players to innovative SMEs) to bring to the market new and efficient environmental services addressing the local and individual needs of farmers.

At the same time, it should be mentioned that large-scale industrial farming has often had unintended but damaging consequences for the environment and biodiversity, primarily through promotion of uniformity and high usage of chemical fertilisers and pesticides. This uniformity may be indirectly triggered by precision agriculture, as it can lead to bigger parcels and smaller landscape elements, which provide for natural enemies of pest and insects and help biodiversity conservation. Additionally, precision agriculture can be seen mostly as an enabling instrument with no guarantee for environmental results and benefits as there is no certainty that the farmer will indeed follow the options and advice proposed by digital technology tools.

Although the mechanism for gathering materials from individual plots/farms via precision agriculture has still to be designed, and the benefits provided to the environment have not been widely assessed, with no quantified figures available, geo-referenced data collected via precision agriculture tools may be used for policy monitoring (regulatory mechanisms and control), for environmental impact assessment of farm practices or for traceability requirements of agricultural products. An equitable use of agricultural data may allow for targeting mitigation measures where they are most needed, thereby contributing to more efficient agriculture and lowering its environmental footprint. Improved use of agricultural data could also help the environmental pressures of agriculture to be more measurable and verifiable (by precision measurement), internal costs to be externalised and the effects of more environmentally friendly practices at the level of the watershed or the small region to be assessed. The collection of across-the-board data, combined with an EU approach for common data standards may lead to the shaping of an informational basis that could facilitate the design of more coherent environmental and regional policies, the convergence and development of common cross-border standards for measuring and monitoring sustainability and the promotion of value-chain certification.

Earth observation data, provided by the GMES/Copernicus land monitoring service and processed in the context of precision agriculture, may facilitate the measurement of environmental performance, the creation of buffer zones, the use of different crop varieties, the strengthening of the knowledge base regarding the pressures of agriculture upon climate, energy, water, waste and pollution, the development of models and algorithms using large quantities of data collected from the small, low-cost and robust field sensors now available, and the establishment of new benchmarking practices for environmental performance. Small farms are generally less active in benchmarking, unless organised by cooperatives that could enrich farm-specific data with benchmarks, and return them to the farmer. This influx of valuable data, as prescribed in the framework of the INSPIRE Directive, could contribute to the continuous and systematic monitoring of agricultural activities from an environmental perspective. Earth observation data produced via precision agriculture can lead to cost reduction in terms of savings on seeds, water, pesticides and fertiliser thanks to input optimisation during the planting and growing phases, which will have to be weighed against the financial investment to be made for the precision agriculture machinery. By combining precision agriculture data with Copernicus layers, several environmental and regional policies, such as the EU Soil Thematic Strategy, may start relying on sound land-use information as a fundamental reference layer.

Given the variety of definitions of sustainability and the lack of a common EU or international standard for measuring and monitoring sustainability (Sustainable Development Goals), using agricultural data, including that generated by precision agriculture techniques, may shape a better documented evidence-based approach and may facilitate the shaping of a more effective model of sustainable agriculture. It should be mentioned that from an environmental point of view, precision agriculture will not replace the need to continue designing and applying measures to protect and foster biodiversity. Collecting better data on industrial agriculture will not make farming as such sustainable, but may only reveal the
extent of its pressures upon the environment. Since there is no evidence concerning the potential of precision agriculture-driven reductions in environmental impacts, the contribution of precision agriculture has to be limited to the fact that it will only improve the picture on the pressures of industrial agriculture upon the environment. Furthermore, big data produced via precision agriculture techniques will not solve the inherent, intrinsic problems of the environmental externalities of industrial agriculture.

Geo-location of activities could, for instance, be used by farmers as evidence of compliance with the Nitrates Directive. This concerns the protection of waters against pollution caused by nitrates from agricultural sources. It aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. EU legislation in this field requires the establishment of action programmes to be implemented by farmers within Nitrate Vulnerable Zones (NVZs), as well as of measures such as limitation of fertiliser application and taking into account crop needs, nitrogen inputs and soil nitrogen supply. These parameters could be measured and assessed in detail by the application of precision agriculture techniques. The technological means used by precision agriculture may contribute to the improvement of the efficiency of nitrogen, phosphorous and potassium use, in order to reduce their impact on the environment and the use of plant protection products, fertiliser and water, and also to combat soil erosion. With greater knowledge about the soil and understanding of crop requirements and condition, fertilisers and pesticides can be applied in more precise amounts, and when and where they are needed. Furthermore, if data generated via precision agriculture is integrated in a unique LPIS-IACS with common EU standards, impacts on biodiversity may be better monitored. While precision agriculture may help the reduction of the use of nutrients in certain types of agriculture, it may have less to offer to other types of farming (e.g., less input intensive and agro-ecological farming).

The use of plant protection products forms part of EU cross-compliance rules linked to CAP payments, which are based on the agricultural data controlled in the IACS system. Also precision agriculture, as an enabling tool, aims to strengthen the efficiency of key agricultural management practices. Using system-based approaches to collect and analyse data and optimise interactions between the weather, soil, water and crops, it is designed with a view to lower pesticide, fertiliser and water use while improving soil fertility and optimising yields. Its application could streamline a cost-effective, safe to use and more efficient implementation of the regulatory framework for the use of plant protection products.

Precision agriculture may respond to the challenges of implementation of EU legislation on herbicides and pesticides and support compliance with the respective legal instruments. These challenges stem from the fact that land in Europe cannot be managed in a uniform way because soil, drainage, and topography are rarely uniform over farms or within fields. More specifically, this management strategy aims to make use of fertilisers and herbicides only where and when they are needed. It needs to be mentioned that Regulation 1107/2009 made it mandatory for EU farmers to apply integrated pesticide management on their farms, while EU Directive 2009/128/EC on the Sustainable Use of Pesticides establishes a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management (IPM) and alternative approaches or techniques, such as non-chemical alternatives to pesticides. The directive specifies that Member States shall take all necessary measures to promote low pesticide-input pest management, giving wherever possible priority to non-chemical methods, so that professional users of pesticides switch to practices and products with the lowest risk to human health and the environment.

It has been argued that the sustainable use of pesticides is based on the empowerment of farmers to apply agronomic practices (such as crop rotation to introduce more nature and predators into the field), use resistant crop varieties, biological control, and buffer zones. To ensure the mandatory change towards sustainability of agricultural production, it is essential that Member States integrate the requirements of the UN Sustainable Development Goals fully into EU policies such as the Common Agricultural Policy. Precision agriculture could facilitate the application of Good Agricultural Practices
Precision agriculture (GAP). This is enshrined in all relevant EU and international legal instruments that have been adopted in order to address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products.\(^4\) It may also help address the control points or compliance criteria of certification schemes for GAP and help in the identification and the measurements of the quality parameters needed to meet the requirements of sustainable development if cross-checked with monitoring data on the ground.

A legal framework on precision agriculture could address this regulatory need in order to help meet the legal requirements regarding integrated pest management and the sustainable use of pesticides. The distance requirements and other soil-specific parameters related to the application of plant protection products could benefit from, and eventually adjust to, the capabilities of farm drones. At the same time, it is important to mention that evaluations made by the European Commission and the European Food Safety Authority (EFSA) of how Member States are encouraging sustainable use of pesticides, indicate that in the majority of Member States, forecast and warning systems on pest outbreaks are freely available online and in place. So, while certain aspects of precision agriculture (like weather forecasts and pest simulation programmes) are useful, it may never become able to replace a good crop rotation for arable farmers, and as a result may not be able to ensure sustainability in the farming sector.

Precision agriculture may also have the potential to improve animal welfare, and so can contribute to EU policies on this topic. Animal welfare forms part of EU cross-compliance rules linked to CAP payments, which are based on the agricultural data controlled in the IACS system. Traceability can also play a role in providing evidence concerning compliance with animal welfare rules. Thus, precision agriculture can facilitate compliance with EU rules on animal welfare as the recording of the movement of vehicles is a basic requirement in the realm of animal transport legislation. Traceability can also play a role in providing evidence regarding compliance with animal welfare rules. The geo-traceability ‘added value’ that PA can provide may trigger clear interest for some private certification processes. By using PA technology, farmers can better monitor conditions and behaviour of livestock, whilst diseases undetectable by traditional means will be prevented by automated optical sensing and intelligent planning options. This means that they could have faster alerts in case animals need special attention, not only on the farm but also during transport. Regulation 1/2005 introduced a requirement for vehicles approved for long journeys to be equipped with a navigation system so as to improve the quality of the controls on travelling times and resting periods, while at the same time reducing administrative burden. The legislation requires that the system records the following information: the transporter’s name and authorisation number, the opening/closing of the loading flap and the time and place of departure and destination. Precision agriculture methods and techniques could be of added value both for the implementation, monitoring and further specification of this legal instrument.

Moreover, the monitoring organisations and EU operators that act in the framework of the implementation of the EU Timber Regulation - which prohibits placing illegally harvested timber and products derived from such timber on the EU market - could make use of UAV-gathered imagery of illegal logging and land occupancy and data provided by precision agriculture tools and databases so as to formulate the necessary due diligence systems. These systems could provide access to information regarding the sources and suppliers of the timber and timber products being placed on the internal market for the first time. It is on the basis of such information that operators should carry out a risk assessment and develop mitigation measures. Information tools utilised in precision agriculture could potentially facilitate field inspections and checks of compliance with the requirements set out in Articles 4 and 6 of the Timber regulation. While more efficient algorithms and hardware could be developed, and even if precision agriculture has been associated with promises about increased fuel use efficiency

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resulting in lowering carbon footprints, the energy intensity of precision agriculture (and, indeed, that of all digital processes) may become a challenge in itself in the future. At the same time, the introduction of robots to the farm may require certain modifications to the natural or agricultural environment which is an environmental challenge in itself.

Last but not least, the diversity and quality of plant genetic resources play a crucial role in agricultural resilience and productivity, thus being a determining factor for long-term farming and food security as established by the International Treaty for Plant Genetics and Resources. The Treaty states the need to promote the sustainable use of plant genetic resources for food and agriculture, including the development and maintenance of diverse farming systems that enhance the sustainable use of agricultural biological diversity, broadening the genetic base of crops and increasing the range of genetic diversity available to farmers, supporting the wider use of diversity of varieties and species in on-farm management and the conservation and sustainable use of crops.

Precision agriculture is intrinsically linked with large farms which run on uniformity (large-scale monoculture with the focus on a single variety over a wide area that is highly dependent on external inputs and specialised crops). However, this is the very driver of genetic erosion on farmland if small farmers themselves decide to replace numerous local varieties with fewer new ones. Any decline of the agricultural biodiversity used in food and agriculture has an impact on the sustainability of agriculture. Small farms that mostly practice high-diversity agriculture, farmers’ own guess work on crop diversity, best practices and cultural approaches, do not yet find a place in precision agricultural systems that operate on the basis of advanced computer decision support systems working with big data.

Legal instruments and other key texts:

- Regulation 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing


- Commission Regulation (EC) No 33/2008 of 17 January 2008 laying down detailed rules for the application of Council Directive 91/414/EEC as regards a regular and an accelerated procedure for the assessment of active substances which were part of the programme of work referred to in Article 8(2) of that Directive but have not been included into its Annex I (Text with EEA relevance), OJ L 15, 18.1.2008, p. 5–12


- Council decision of 24 February 2004 concerning the conclusion, on behalf of the European Community, of the International Treaty on Plant Genetic Resources for Food and Agriculture; OJ L378 of 23/12/2004, p.1


3.3.2. Food safety, security and food traceability

Precision agriculture can actively contribute to food security and safety and provide a digitalised roadmap of the plant and animal products life cycle, from farm to fork. By improving tracking, tracing and documenting tools and services and geo-referencing, and almost all (if not all) data and activities in a digital form, precision agriculture makes farming more transparent and allows vendors in the food supply chain to become informed of the best production practices as well as about crop health. Within cross-compliance, traceability forms part of basic rules related to all CAP payments. Plant farming, livestock farming, food processing and food distribution are all parts of the value chain to deliver products to the final consumer. Precision agriculture, via its real time detection potential, may help to provide the facts sought by consumers on how their food is grown. Nearly all precision agriculture software can track production practices, including the time, types and amounts of materials applied to a field and record the choice of hybrid seed and treatments.

Precision agriculture software may also provide a basis for the development of smart monitoring systems that can enhance the traceability of products and processes, boost the economy of data from the traceability point of view and improve transparency in the value chain, fighting food fraud and unfair competition. The incorporation of intelligent tools into the agro-industry, which make use of big data, is an opportunity to produce in a healthier, safer and more traceable way. Data handling may be extended, from providing information to growers for their production decisions to providing data to consumers for their food decisions, thus contributing valuable data to help consumers make informed choices about food. Precision agriculture may potentially play a role in driving food prices down, although the magnitude of the effect is difficult to quantify.

Gathering data and empirical information is a growing requirement for food safety agencies, certification bodies, but also European consumers. In other words, precision agriculture has the potential to support the geo-traceability of farm products ensuring quick and accurate trace-back and recall when necessary, or providing information on agricultural products provenance to the public. These geo-referenced data are more and more often required for policy monitoring (regulatory mechanisms and control), for environmental impact assessment of farm practices or for traceability requirements of agricultural products. New standards and the related technologies could lead to giving people more insight into nature and food production because it enables them to track and trace the products that they consume. IT not only impacts individual stages in the value chain, but also helps integrate them by tracking the progress of crops and foodstuffs from production to consumption, providing the information needed for traceability.

The potential of precision agriculture to collect and deliver accurate information about a wide range of farm-related parameters, via assisted steering tractors installed with GPS and variable metering
machines and the use of drones, can contribute to a better understanding of the impacts of soil properties, and of fertilisers/pesticides efficiency, enrich the environmental impact assessment of farm practices and the design of traceability requirements of agricultural products. In view of the potential of precision agriculture to facilitate compliance with the different traceability requirements set out in Union law, it should be mentioned that for the purposes of this study, the term 'traceability' is used in the broader sense. Under EU law, ‘traceability’ means the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution.

The concept of traceability in agriculture simply refers to all stages of collection, classification, conservation, and application of data related to all necessary processes in the food supply chain in order to provide assurance concerning the origin, location, and product history for consumers and other stakeholders, as well as use in crisis management in case of problems in food quality and safety. Thus, traceability is the ability to detect the farm where the product was grown and inputs have been consumed. It also provides the ability to review records to determine the accurate location and product history in the food supply chain. Regarding the definition of traceability in the field of food security and safety, it can be stated that traceability is the ability to document all relevant elements needed to determine a product's life history, such as movements, processes, and controls. Thus, traceability is a tool for better and more effective management for food manufacturers, farmers, and end-users in terms of quality of the food product.

For example, in the framework of the EU General Food Law Regulation, the traceability requirement is only for food safety purposes. As such, it is limited to the 'one-step back – one step forward' approach. However, in the framework of other pieces of EU legislation, there are other direct/indirect traceability requirements for purposes other than safety (e.g. food labelling – allergens, origin of unprocessed meat of pigs, poultry sheep and meat for food information purposes, beef labelling, honey, etc.). Additionally, precision agriculture has a strong potential to promote sustainable farming in terms of the rational use of agricultural resources and the optimisation of harvesting periods. By means of available technology such as aerial or satellite photographs of the agricultural parcels, provided by precision agriculture, it may become possible to carry out a measurement of the size of a given parcel and to check land use, land cover and land management without actually going to the field. In addition to its effects on the promotion of food safety, detecting the source of possible contamination, facilitating the product recall procedure, and controlling risks related to public health arising from product consumption are among other goals of traceability to obtain food security. Besides the ability of the traceability potential of precision agriculture to provide opportunities to track the products through a system, or to recall products quickly and easily during a crisis, traceability can also improve production efficiency, decrease labour requirements and costs, improve inventory control, verify product claims and improve food safety.

Via the setting of EU standards and the expansion of precision agriculture, the food chain will be easier to monitor for producers, retailers and customers. This is a basic growing requirement for agricultural payments in the CAP, food safety agencies, certification bodies, but also at the EU level (EU General Food Law). The system in place to ensure traceability of food products and to ensure the cross-border follow-up of information to swiftly react when risks to public health are detected in the food chain is the RASFF (Rapid Alert System for Food and Feed). The collation and analysis of large integrated data sets is particularly useful in addressing and developing an efficient, responsive, efficient and sustainable food-chain that will benefit farmers, the economy, consumers and the environment. At the same time, the application of very strict and continuous monitoring would probably result in the detection of a very large number of warning situations. By leveraging data-driven transparency and cooperation across the agri-food value chain, the quality of food products in agri-food chains can better be monitored, potential losses will be reduced through tracking and tracing, and the farmer providing such data can be rewarded for the investment done in this field. In fact, a seamless exchange of (big) data may have a significant
impact on food chains. Important changes include the end-to-end tracking and tracing and virtualisation of food chains, and the broadening of direct farmer-consumer markets supported by information technologies.

EU common data standards and data about products, how they are produced, processed and preserved through the entire food supply chain, via automatic identification technology, produces an important data source for tracking and tracing and early warning systems. Via smartphones, wearables and sensors, an enormous amount of data about livestock is collected. Analysis of this data can lead to better insights for tailor-made advice to farmers. That ensures further optimisation and sustainability of business in the agri-food sector and prevents resources waste. Crop and livestock monitoring will give better predictions on yield and quality of agricultural products. This particular track-and-tracing capacity could be of particular relevance to the tracing and certification requirements for genetically modified crops and organic products, as well as for compulsory control databases such as the TRAde Control and Expert System (TRACES). TRACES manages the official controls and route planning, quickly and efficiently online when consignments of animals, semen and embryo, food, feed and plants, to be accompanied by health certificates or trade documents, are exported to the EU or traded within the EU single market. The application of rules regarding the financial support to farmers for production losses related to climatic and environmental events could benefit from readily-available and easily repeatable drone imagery and detailed assessment of crop losses after natural disasters, allowing all stakeholders to more accurately and quickly calculate pay-outs.

The geo-traceability requirements for genetically modified (GM) crops are another example of its potential applicability in a densely regulated field of EU action. Traceability enables tracking GMOs and GM food/feed products at all stages of the supply chain and also makes labelling of all GMOs and GM food/feed products possible. It allows for close monitoring of potential effects on the environment and on health. Where necessary, it can allow the withdrawal of products if an unexpected risk to human health or to the environment is detected. All operators involved, i.e. farmers or food and feed producers who introduce a product in the supply chain or purchases such a product, must be able to identify their supplier and the companies to which the products have been delivered. The customers should be provided with information such an indication that the product - or certain ingredients - contains, consists of, or is obtained from GMOs and information on the unique identifier(s) for these GMOs. Clear traceability offers additional insurance against false information or fraud, such as to the organic food sector or to consumers opting for products from short supply food chains (locally produced food labelling in shops). Full traceability can also play a role in providing evidence concerning compliance with animal welfare rules and others. The geo-traceability ‘added value’ that precision agriculture may trigger is of clear interest for some private certification processes. Therefore, they have the potential to make farming more transparent and will improve tracking and tracing of agricultural products.

Common EU data management standards and precision agriculture could also play a significant role in terms of plant health. Tracking of field operations such as chemicals sprayed and use of fertiliser will allow growers to grade products and to monitor food safety. Technological solutions can be harnessed to increase production, improve the means of distribution and tackle food waste, and improve traceability in the supply chain. Introducing a carbon footprint labelling scheme would help consumers to choose the products with the lowest impact on the environment and provide them with insight as to where there food comes from, as it enables them to track and trace the products they consume. The spread of the Internet of Things\(^5\) may further contribute to a more efficient, near-real-time monitoring of the environment.

\(^5\)In the Internet of Things, smart devices - connected to the internet - are controlling the farm system and extending conventional tools (e.g. rain gauge, tractor, notebook) by adding context-awareness through all kinds of sensors, built-in intelligence, and the capability to execute autonomous actions or doing this remotely.
and analysis enabling better decision making and actuation, not only at the production stages, but (and this is where a lot of the value lies) throughout the whole value chain.

The use of satellite imagery to quantify spatial variation within fields has been extensive; quantifying field variation is necessary to determine how to improve field management to achieve the goal of food security. Food security can be enhanced through integration of the spatial information at the field scale combined with information about the most effective management practices to be implemented within the field. The capacity of precision agriculture to identify areas with insect or disease pressures, or nutrient deficiencies, and to provide precious information for an improved nutrient or pest management, could enhance food security. At the same time though, it needs to be mentioned that European agriculture is very diverse. While precision agriculture may help the reduction of the use of nutrients in certain types of agriculture, it may have less to offer to other types of farming, e.g. less input intensive and agro-ecological farming.

**Legal instruments and other key texts:**


### 3.3.3. Climate change mitigation

The Intergovernmental Panel on Climate Change (IPCC) has reported that agriculture is responsible for over a quarter of total global greenhouse gas emissions. Agriculture is highly GHG intensive and both contributes to and is affected by climate change. The sector, like all sectors, is facing growing pressure to reduce its emissions so as to mitigate climate change and become a potential mitigating force. The
Food and Agriculture Organization of the United Nations (FAO) introduced the concept of 'climate-smart agriculture' (CSA) to respond to these combined challenges, with the aim of enhancing agricultural productivity while reducing GHG emissions. According to the FAO, it has three main objectives: the sustainable increase of agricultural productivity, the adaptation and building of resilience to climate change, and reduction of GHG emissions. The implementation of CSA technologies has substantial potential to reduce climate change impacts on agriculture.

Within the UNFCCC process, countries have confirmed the importance of enhancing climate technology development and transfer to developing countries and there is a range of different bodies under the Convention working on adaptation. To facilitate this, in 2010 the Conference of the Parties established a dedicated mechanism for technology, the Technology Mechanism and processes that could be enhanced, scaled-up and better integrated to promote the development and implementation of technologies for adaptation. The Technology Mechanism consists of two bodies: the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). In addition to these structures, two permanent subsidiary bodies have been established by the Convention are the Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI). These parties traditionally meet in parallel twice a year (SBSTA). The SBSTA’s role is to provide the COP with advice on scientific, technological and methodological matters, a key part of which is promoting the development and transfer of Environmentally Sound Technologies.

Agriculture can contribute to global climate change mitigation efforts and carbon sequestration, while data driven precision agriculture can help to tackle these issues and contribute to a more sustainable production. Climate-smart farming practices can increase sustainable production, ensure climate-resilient farming that could cope with changing and adverse weather patterns, and reduce emissions from the agricultural sector by encouraging productive, resource-efficient and circular systems. Agriculture accounted for 10.1% of the total GHGE in the EU-28, which corresponds to 464.3 million tCO2e. Enhancing the resilience of farmers to threats posed by climate change and GHG emissions is set as an explicit objective of the EU Common Agricultural Policy. Promoting farming practices that combat climate change is a powerful tool to decrease livestock greenhouse gas emissions, improve climate conditions and also to preserve nature and increase the agriculture sector’s viability. The recent Paris Agreement underscored the need for agriculture to become more efficient and climate friendly. Though agriculture is not mentioned by name, food security, food production, human rights, gender, ecosystems and biodiversity are explicit in the Agreement. The preamble of the Paris Agreement makes specific reference to 'safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change' and also refers to human rights, gender, ecosystems and biodiversity, all issues that are central to agriculture.

Precision agriculture technologies can contribute to the building of an evidence base drawn from data on agriculture sectors, food security, potential climate impacts and mitigation potential, help identify activities with synergies between food security, adaptation and mitigation, as well as possible trade-offs. Given a lack of data and information in many respects, precision agriculture can help identifying key areas where mitigation actions can be complementary to food security and adaptation. The role of automated farming technologies in responding to challenges such as food security and climate change is recognised at the international level. The remote sensing capacity of precision agriculture to detect land cover change may contribute to climate change mitigation. Despite efforts to halt deforestation and other changes in land use, the conversion of ecosystems is still taking place on a large scale. Land use change causes emissions as stored carbon from soil and vegetation is released to the atmosphere. Agriculture is an important driver of changes in land use (especially deforestation) due to the expansion

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6 Climate Smart Agriculture: Policies, Practices and Financing For Food Security, Adaptation and Mitigation, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy (2010)
of agricultural activities (livestock and crops) into forested lands or wetlands and aquaculture into mangrove forests. Approaches that look across different land uses and the trade-offs involved are needed in order to find solutions to the competition for land and water resources for food, energy, income and carbon-storage.

Agriculture, forestry and other land uses — known as AFOLU — is a significant source of greenhouse gas emissions, but it can also be part of the solution. The AFOLU category combines the two sectors: LULUCF (Land Use, Land Use Change and Forestry) and Agriculture. Converting forests into agricultural land emits huge amounts of greenhouse gases. Using sustainable forest and land management practices can instead help those ecosystems retain and store a significant amount of carbon. AFOLU accounted for 24% of the total anthropic emissions in 2010, including 11% from forestry and other land uses. Keeping carbon in the land (sequestration) can also mitigate climate change through 'avoided' emissions. Techniques include converting non-forest land to forests; planting trees or allowing forests to regenerate naturally; restoring peatlands; and converting crop land to permanent pasture. Mixing trees with crops (agroforestry) or with forage and livestock can also be effective ways to sequester carbon. Remote-sensing technologies for precision agriculture may provide useful information on land use change in agriculture.

Setting up common standards for EU agricultural data management and precision agriculture constitutes an opportunity to approach this farming concept as an adaptation technology. The United Nations Framework Convention on Climate Change (UNFCCC) defines technologies for adaptation as 'the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change'. The appropriate application of technologies demands consideration of the particular political, economic, social and ecological context. Agricultural practices and technologies that enhance productivity, food security and resilience in specific agro-ecological zones and farming systems can achieve improvement of nitrogen use efficiency by adjusting application rates based on precise estimation of crop needs, thereby achieving the mitigation of both direct and indirect GHG emissions. Site-specific fertilisation coupled possibly through precision agriculture techniques present an opportunity to account for soil heterogeneity within a field and therefore to reduce fertiliser amounts and adjacent nutrient loss. Nutrient management optimises the balance between production and GHG mitigation in agriculture.

Precision agriculture and its nutrient management dimension may be potentially considered as a specific management change that can influence GHG emissions from agriculture. Nitrogen applied in fertilisers and manures is not always used efficiently by crops. Improving this efficiency can reduce emissions of N2O, generated by soil microbes largely from surplus N, and it can indirectly reduce emissions of CO2 from N fertiliser manufacture. Moreover, handling data from the LPIs and IACS systems and precision agriculture can facilitate the detection of land cover changes by remote sensing (RS). Although this is more complicated for detecting and quantifying changes in carbon stocks, remote sensing is essential for estimating forest cover from remotely sensed data and measuring changes in land cover. This is because of the high temporal resolution imagery offered by many satellites, the relatively low cost of imagery (compared to conducting expensive field inventories) and the large ground area that can be represented within a single image. Remote sensing will be essential to establish baselines and monitor progress in reducing emissions from deforestation. Precision farming may also provide detailed agronomical and environmental information that could be used as a justificatory basis for mitigation measures.

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Legal instruments

- Decision No 529/2013/EU of the European Parliament and of the Council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities, OJ L 165, 18.6.2013, p. 80–97


3.4. Safety

EP Committees: JURI, TRAN, EMPL

The use of drones for farming purposes raises questions that pertain to safety issues, third-party civil liability and insurance, including the sharing of accident and risk situation data as well as to trans-boundary identification of types of small UAVs. During operation of agricultural drones, damages may occur to a vehicle, if it strays and drops on crops, others’ properties or into waterways etc. This raises concerns about who can effectively deploy and operate drones using remote controllers or computer programmes. It also elicits questions about licensing, privacy of drone usage and intrusions, taking into account parameters such as geography, topography, cropping systems, type of drones in use and economic aspects of drones. Liability for the actions of robots may need to be determined, particularly if robots acting autonomously cause damage to people, property, crops or the environment.

Large civilian drones exceeding 150 kg are regulated by EU law and monitored by the European Aviation Service Agency. For civil remotely piloted aircraft systems (RPAS) with an operating mass of 150kg or less, as well as model aircrafts, it is the Member States and the national civil aviation authorities that are responsible for the regulatory control of their operation. As a result of the fact that the current regulatory framework is ill suited for drones and drone operations, smaller drones - that is mostly the types of drones used in the frame of PA - are regulated by national rules based on the principles agreed in the frame of the 2015 Riga Declaration on Remotely Piloted Aircraft.

This quantitative threshold may be removed if the recent Commission’ proposal on drones is endorsed by the European Parliament and the Council of Ministers.10 In the framework of this recent legislative proposal, the European Commission proposes several essential requirements for unmanned aircraft (drones). The proposal states that the drone must be safely controllable and manoeuvrable and be designed to fit its function and take into account privacy and protection of personal data by design and by default. Identification of the drone and of the nature and purpose of the operation should also be possible. The Commission suggests that the drone operator be responsible for its operation and should have knowledge and skills proportionate to operating the drone safely. It also calls upon organisations involved in drone design, production, maintenance, operations, related services and training, to establish a safety occurrence reporting system. The proposed safety standards would be based on the principle that RPAS must provide an equivalent level of safety to ‘manned’ aviation operations, where appropriate.

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9 T. Ehmke, (2013), Unmanned Aerial Systems for Field Scouting and Spraying. CSA News, pp.4-9

It needs to be mentioned that the US Federal Aviation Agency (FAA) recently adopted a rule for drones or 'small unmanned aircraft systems' (sUAS) weighing less than 55 pounds (25kg). According to this rule, a process for obtaining certification as a remote pilot in command (Remote PIC) is introduced and will apply to those who operate a small UAS for commercial uses or incidental to a business, such as for farming purposes. Therefore, farmers who want to use a drone in the farm operation need to understand and comply with these provisions. Safety and security are paramount for any RPAS operations and rules and that they must be commensurate with the risks, thus in accordance with the principles of proportionality and necessity.

As with drone use in other areas, safety is still a large concern and an important issue, largely because these aircrafts are unable to detect and avoid manned aircraft. There is still the possibility of a drone malfunctioning or an operator error occurring and causing harm to bystanders, especially in case the person operating the drone will not be able to see and avoid manned aircraft, and/or there is a failure in communication between the operator of the small UAS and the small UAS itself. When using drones for PA, flight reporting must be mandatory and a case-by-case risk assessment procedure should be followed. Currently, a discussion has started at the EU level about whether the use of drones should be considered as aerial application for the purposes of Directive 2009/128/EC on the sustainable use of pesticides. Aerial spraying is banned in accordance with Article 9 but Member States can grant derogations. Where drones are used in plant protection, Member States are currently following the aforementioned derogation.

Given that in Europe a large number of licence-free frequency bands are used for small drones on the basis of specific European recommendations and decisions, there is a likelihood of interference between drones and other usage in populated areas which may lead to loss of control over the drone. Because of the popularity of Wi-Fi, especially in the 2.4000–2.4835 MHz, there is a reasonable chance of interference between drones and other usage in populated areas, which may lead to the loss of control over the drone. The receiver of the drone may pick up a high level of interference because of the height of its flight. Therefore, together with the low transmission power requirements, only drone flights within line of sight of the pilot and with low safety requirements can use these frequencies. In order to perform a flight, drones have a need for (a certain amount of) wireless communication with a pilot on the ground. In addition, in most cases there is a need for communication with a payload, like a camera or a sensor. To allow this communication to take place, frequency spectrum is required. The

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12 By way of derogation from paragraph 1, aerial spraying may only be allowed in special cases provided the following conditions are met:

(a) there must be no viable alternatives, or there must be clear advantages in terms of reduced impacts on human health and the environment as compared with land-based application of pesticides;

(b) the pesticides used must be explicitly approved for aerial spraying by the Member State following a specific assessment addressing risks from aerial spraying;

(c) the operator carrying out the aerial spraying must hold a certificate as referred to in Article 5(2). During the transitional period where certification systems are not yet in place, Member States may accept other evidence of sufficient knowledge;

(d) the enterprise responsible for providing aerial spray applications shall be certified by a competent authority for authorising equipment and aircraft for aerial application of pesticides;

(e) if the area to be sprayed is in close proximity to areas open to the public, specific risk management measures to ensure that there are no adverse effects on the health of bystanders shall be included in the approval. The area to be sprayed shall not be in close proximity to residential areas;

(f) as from 2013, the aircraft shall be equipped with accessories that constitute the best available technology to reduce spray drift.
requirements for frequency spectrum depend on the type of drone, the flight characteristics and the payload. Since frequency spectrum does not end at national borders, therefore international coordination on the use of frequency spectrum is required. Spectrum is needed to ensure commercial, safety and policy objectives, such as wireless control links, tracking, diagnostics, payload communications, and collaborative collision avoidance, including vehicle-to-vehicle communications, are achieved. Legal issues on frequency spectrum usage and electronic equipment (national and international legal matters on frequency spectrum and equipment requirements) as well as frequency spectrum and vulnerability (an insight in available frequency spectrum and associated risks in using the frequency spectrum) and surveillance and compliance (enforcement of frequency spectrum use, equipment requirements, and the need for international and European cooperation) need to be addressed.

The allocation and management of radio spectrum in the European Union is administered by national administrations, as radio spectrum remains principally the responsibility of Member States. While the European Commission does not manage radio spectrum directly, its task is to ensure that the use and management of radio spectrum in the EU takes into account all relevant EU policies. A framework for Radio Spectrum Policy in the EU was launched by the 2002 regulatory framework for electronic communications, and particularly by the Radio Spectrum Decision (676/2002/EC). The Radio Spectrum Decision defines the policy and regulatory tools to ensure the coordination of policy approaches and harmonised conditions for the availability and efficient use of radio spectrum for the internal market. To assist the Commission, two complementary bodies were set up following the Radio Spectrum Decision in 2002, to facilitate consultation and to develop and support an EU Radio Spectrum Policy: the Radio Spectrum Policy Group (RSPG), which is a group of high-level national governmental experts to help the Commission developing general Radio Spectrum Policy at Community level, and the Radio Spectrum Committee (RSC) is a committee under Regulation 182/2011/EU, which assists the Commission in developing technical implementation measures to ensure harmonised conditions across Europe for the availability and efficient use of radio spectrum.

For small drones no specific frequency allocations have been made on an international level for command and control or payload. Given the major developments in this area in the past few years, the demand for frequency spectrum is ever increasing. The lack of reserved frequency spectrum means that drones can, in most countries, only make use of generally available (licence-free) frequency spectrum. Within Europe a large number of licence-free frequency bands have been allocated. Several European recommendations and decisions, such as Recommendation 70-03 of the European Radio-communications Committee, provide a list of all these bands together with technical limitations and requirements. Since these bands are licence-free, the frequency band is shared with other unlicensed users on a secondary or tertiary basis. Two popular licence-free bands used for drones for command and control and payload communications, the 2.4000–2.4835 MHz and 5.470–5.725 MHz bands, have to comply with the regulations that apply to broadband data transmission systems like Wi-Fi. In Europe, the band 5.725–5.875 MHz is available for non-specific short-range communication with a maximum transmission power of 25 mW effective isotropic radiated power. In case drones destined for PA purposes are used for long distances, special regulatory arrangements need to be made with the competent national authority as a licence may be required. The radio equipment on board drones up to 150kg therefore needs to comply with the essential requirements of the Radio Equipment Directive (2014/53/EU)\textsuperscript{13} and Electromagnetic Compatibility (EMC) Directive 2004/108/EC for command and control communications.

Drones require radio systems to allow communication between the drone and the pilot. Regulation 216/2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, is only applicable for drones with a weight above 150 kg and only for control and non-payload communications. Manufacturers and importers have the responsibility for compliance of their drones before placing them on the market. If the drone complies with the essential requirements, a CE marking has to be affixed to the drone or possibly to the packaging or the accompanying documents and a declaration of conformity has to be published.

The use of drones in this context may violate the right of farmers, livestock producers, and landowners to property and privacy. The use of drones in open fields in rural, sparsely populated areas calls for the creation of special buffer zones that will prevent trespassing over land, livestock feedlots, and farm sites and the possible privacy and security implications. Drones can be noisy, frighten livestock and annoy landowners, thereby creating a nuisance and reducing property value. This in effect raises the question about the need for new rules to provide protection to farmers that is equivalent to the level of protection that landowners enjoy in surface land. Trespassing is a legal term that mainly refers to the entry onto land without consent of the landowner and touches upon a wide variety of offences against a person or against property. Flying a drone safely above another’s property at a height that does not interfere with the owner’s ordinary use of the land does not in principle constitute a trespass. Matters do become more complex and less certain, however, where a drone flies over another’s property on multiple occasions, or even hovers in one place and takes multiple pictures. Such situations raise the following questions: does the use of drones constitute trespass or nuisance? Is it enough to premise liability irrespectively of whether he thereby causes harm to any legally protected interest of the other? Law in this area is not abundantly clear on where a landowner’s exclusive control of airspace ends and the public airspace begins. Modern interpretations of property law hold that property owners’ airspace rights extend to as much of the space above the ground that is occupied or used in connection with the land. Nuisance claims can also be filed against drone operators if their activity leads to a ‘substantial and unreasonable interference’ with the use of your property.

As RPAS could be used unlawfully, the European Aviation Safety Agency (EASA) would need to develop the necessary security requirements, particularly to protect information streams. Moreover, the current third-party insurance regime has been established mostly in terms of manned aircraft, where weight (starting from 500 kilograms) determines the minimum amount of insurance, thus there might be a need for the Commission to assess the necessity to amend the current rules taking RPAS into account. Last but not least, there is also a need to consider the introduction of additional legal safeguards in the form of access restrictions, use of less dangerous substances, training, safe disposal and integrated ethics management.

Legal instruments and other key texts:


- Communication from the Commission to the European Parliament and the Council, 'A new era for aviation: Opening the aviation market to the civil use of remotely piloted aircraft systems in a safe and sustainable manner' COM(2014) 0207 final
- Roadmap for the integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System, Final report from the European RPAS Steering Group, June 2013
- European Parliament Report of 25 September 2015 on safe use of remotely piloted aircraft systems (RPAS), commonly known as unmanned aerial vehicles (UAVs), in the field of civil aviation (2014/2243(INI))
- Opinion of the European Data Protection Supervisor on the Communication from the Commission to the European Parliament and the Council on 'A new era for aviation - Opening the aviation market to the civil use of remotely piloted aircraft systems in a safe and sustainable manner'
4. Socio-ethical considerations regarding precision agriculture

Agriculture can be considered as a never-ending experiment, the consequences of which are frequently unpredictable, especially when it becomes intertwined with technological advances. Ethical issues in the field of agriculture have gained prominence largely due to the fact that agriculture is characterised by practices that involve both social and ecological systems. According to experts, agriculture has become an issue of moral concern because of the mismatch between global food supplies and human nutritional needs, the impact of agribusiness on rural employment, the consequences of modern agricultural biotechnologies for human and animal welfare, and the effects of intensive production systems on the sustainability of the global environment. Technological success in the field of agriculture has mostly come at a high environmental cost and has not managed to solve the social and economic problems of small farmers, which have generally benefited the least from this boost in production.

Some of the challenges brought forward by precision agriculture could be addressed by traditional forms of law or novel approaches to regulatory governance of technological risks. However, not all concerns associated with agricultural data management and precision agriculture can be translated into or dealt with by legislative initiatives and tools. This is primarily due to the specific uncertainties, unknowns and assumptions attached to its promises and effects in general. Assessing technologies for farming systems from a sustainability perspective is in its infancy. The use of criteria such as production, productivity, farm incomes, employment and trade may not be sufficient; there is a need for assessing sustainability by taking into account environmental, social and ethical considerations.

The increasing use of data in agriculture and the gradual introduction of precision agriculture in European farming in combination with the lack of human resources raise a variety of socio-ethical challenges that resemble those that emerge on multiple occasions when technology is introduced in economic activities where the human element is more than vital. The gradual application of precision agriculture may lead to the following socio-ethical risks: dependency, monoculture, augmentation of the digital divide, possible data concentration and manipulation, including farmers' dependence on external inputs delivered from high-tech providers and the subsequent lock-in effects, threats against the sustainability of small, local farms, genetic erosion, control and unfair practices. Threats to autonomy and dignity may take the form of objectification, where a farmer is treated as an information tool or source serving purposes that are not necessarily in the interest of small farmers.

Among the main ethical risks associated with precision agriculture, one can also distinguish an increasing dispossession of farmers' autonomy and control over their production process, uneven access to technology, threats against farmers' privacy and data ownership and challenges to intergenerational and distributive justice in the agro-food domain. The latter mainly concerns food safety and ecological considerations, the principle of sustainable development and the need to take into account the needs of future generations. The most profound effect of precision agriculture lies in its potential effects upon social values and local farming structures, including the potential societal changes this technological trajectory may trigger along with its uptake rate. The key question is to what extent, at which cost, for what goals and for whose benefit precision agriculture will be used. If new technologies or new practices are involved, are they likely to widen the gap between the rich and the poor, both within countries (particularly in developing countries) and between developed and developing countries, given the system cost? How can a balance be struck between increased productivity/efficiency, traditional farming and environmental sustainability?

First of all, the mechanisation of small fragmented farm holding is expensive and beyond the reach of resource-poor farmers, particularly in view of the lack of evidence that variable rate technology provides adequate financial return. The degree of mechanisation in agriculture is mostly linked to the size of the farm, thus in countries where the average agricultural area per farm is small, farmers may feel less inclined or simply do not have the financial resources necessary to purchase farming machinery or make use of specialised agricultural services. The combination of high purchase cost and, in particular,
uncertainties regarding the potential benefits, raise issues of legal proximity/accessibility of precision agriculture technological products by individual farmers. In fact, many of these so-called solutions provided by precision agriculture are financially impossible for most farmers caught up in high input costs and low farm gate prices. The accessibility of precision agriculture may be further compromised due to the possible difficulties in gaining access to credit, changes in interest rates and price of commodities, and adverse effects of climate on yield, such as lack of rainfall.

Given the need for considerable technical skills to handle data mining and analysis method and system throughout the agri-food production and value chain, farmers need to be ‘in the loop’ of data analysis in order to continue maintaining/building expert knowledge and the high entry price of digitisation of farming. However, farmers are traditionally not equipped to manage and analyse the data they generate, given the long-standing digital divide across regions, countries and age groups in Europe. It follows that those with resources to acquire the tools, the technology, the data and the expertise have an automatic advantage over other players. This is particularly significant when costs associated with drone use for precision agriculture increase in proportion to the capabilities of payloads and 'add-ons' and the breadth of their application. Smaller and more vulnerable operators can be left behind if they rely on less efficient farming methods on account of not having the means to access tools for precision agriculture. In addition, small farmers could become unduly influenced by large seed conglomerates that might striate pricing structures that can potentially disadvantage smaller players in the market and increase consumer prices for citizens and potentially affect EU food security.

Typically, market-driven technological progress, such as the one that characterises precision agriculture, may lead to the intensification of farming systems, and the pursuit of productivity and efficiency at the expense of the natural resource base, the sustainability of modern farming systems, traditional farming methods and family farms. The Food and Agriculture Organization of the United Nations (FAO) defines a family farm as 'an agricultural holding which is managed and operated by a household and where farm labour is largely supplied by that household'. Family farms are by far the most common type of farm in the European Union, encompassing a wide range of agricultural holdings: from small, semi-subsistence farms with only family workers, and farms which have to rely on other gainful activities for a diversified source of income, through to much larger, more productive farms which nevertheless maintain family management. Family farms dominate the structure of EU agriculture in terms of their numbers, their contribution to agricultural employment and, to a lesser degree, the area of land that they cultivate. There were 10.8 million farms in the EU-28 in 2013, with the vast majority of these (96.2 %) classified as family farms.

Combining drone data with social media data, as well as with meteorological, topographical and consumer data, in precision agriculture raises significant issues around identifiability, discrimination and equality and the digital divide. In relation to the latter, it needs to be mentioned that the average age of European farmers - almost one third of farm managers in the EU-28 are aged 65 years or over - constitutes an additional socio-ethical challenge that can further enhance the intra-European digital divide. The digital era is relatively new, thus an ageing agricultural workforce may not be able or willing to make use of precision agriculture technologies. in Portugal half (50.1%) of all farm managers were aged 65 or over, while in Romania, Cyprus, Italy, Bulgaria, Lithuania and Spain at least one third of all farm managers were aged 65 or over. These figures suggest that older farm managers (working beyond 65) were principally located in the southern EU Member States and in several of the Member States that joined the EU in 2004 or more recently. Related to the latter, the average age of tractors has increased steadily over the last 30 years, which is due to both the longevity of the machines as well as their high cost of purchase. Because of this, a large number of tractors used are currently not state of the art and are not network-enabled, making digitisation more difficult.

Given that decisions on the adoption of technologies at the farm level often cannot be separated from decisions taken elsewhere in the food chain, the effects of technology adoption at farm level extend beyond the farm and may influence, either through formal ownership structures or contractual relations,
the whole food chain and create significant information and data asymmetries. Data asymmetry arises when smallholder farmers with rather limited resources reveal their most personal farm details to gain access to the benefits of technology, while those who can transform the collected data into useful information reveal little to nothing about the back-end processes or how or where the information will be kept or used. As a result, farmers become dependent on large food retailers and input suppliers for seeds, fertilisers, machinery and pesticides, who demand the application of particular agronomic practices and the quick delivery of farm products that should have certain quality features. Uncertainty as to how to treat and safeguard data, the lack of standards for sensor networks and the patchy coverage of rural wireless and broadband may facilitate the augmentation of the existing information asymmetries and the empowerment of well-resourced actors, such as the major technology providers, as well as of the agricultural equipment manufacturers whose primary focus is on data management, collection or analysis, and who can afford to pay for these services. Hence, the management and use of agricultural data and the introduction of precision agriculture raise issues of economic and technological control of farms/local agricultural production. Small farmers and local farming communities will not be able to keep up with this evolution without dedicated support and cooperation actions. Instead, there is a risk that those who own the data may control the data outputs and can transform farming activities into a 'control room'. The farming sector is already characterised by high inequalities if one compares the profits made by the largest agricultural companies and smallholder family farmers. Unequal access to and use of information could widen social inequity, exacerbate yield gaps in agriculture and render farmers critically dependent on global agriculture technology providers leading to the development of bottlenecks.

As a result of these asymmetries, farmers' own particular needs and rights may be ignored, and inequalities are at risk of growing due to data-driven insights, rather than being reduced. This raises the following questions: What happens if companies that deliver hardware solutions such as farm control systems, smart tractors, feed systems etc. start also delivering software solutions that collect, store and process the data? They may use the data to create decision support for the individual practitioner, but also to analyse the data aggregated from multiple farms. The latter allows benchmarking, but also creates new insights. This may signal an unprecedented power shift in the industrial farming process. Though big data can be a powerful tool for farming, can they be used equitably? What are the ethics, power dynamics, and possible consequences surrounding the use and analysis of big data in agriculture and food production? Moreover, a potential impact of the intersection between big data and drone data is the augmentation of the digital divide, including the undermining of local practice through the inability of individuals and organisations to either compete with large organisations or operate outside of technological systems that become the new norm. This issue is particularly prevalent in precision agriculture, which can result in significant impact upon the life chances of local and small farmers as well as rural areas.

Therefore, uptake of precision agriculture, in combination with the shortage of skills required for working with this management concept, might lead to a rapidly growing digital divide between small and big farmers. Smaller and medium size farmers will lack the farm income, investment capital or specialised technical knowledge to acquire technological equipment for precision agriculture and to sustain the cost of precision agriculture services. Adopting technologies involves uncertainty and trade-offs and information on the costs and benefits of adopting technologies in agriculture is often imperfect. Thus, technology adoption is made in a climate of uncertainty with a large element of 'trial and error' in its application, and the speed and extent of adoption vary considerably among farmers. At the same time, there are concerns about relying on non-independent external experts, including fears regarding possible dependency on technology providers (i.e. providers of wireless connectivity, sensors/actuators, edge devices, IoT solutions, decision support systems at the back office, data analytical systems, geo-mapping applications, etc.), providers of agricultural equipment and machinery (tractors, autonomous equipment, farm buildings, etc.), providers of specialist products and inputs (e.g. seeds, feeds, and
expertise in crop management and animal husbandry), and other market actors that set prices and shape the market into which farmers and growers sell their products).

Moreover, wider uptake of big data is likely to change both farm structures and the wider food chain in unexplored ways, as happened with the wider adoption of the tractor and the introduction of pesticides in the 1950s. Big data applications in smart farming will potentially raise many power-related issues. There might be companies emerging that gain much power because they get all the data. In the agrifood chain these could be input suppliers or commodity traders, leading to a further power shift in market positions. This power shift can also lead to potential abuses of data. Thus, big data cannot be treated as a technical matter separable from their particular social and agronomic context, and in particular from questions of justice and ethics given that in several cases ‘citizen-sourced’ information is primarily benefiting commercial actors and other elite interests, rather than the citizens. The use of big data in combination with extensive use of automated decisions and predictive analysis may also lead to broader undesirable changes in the development of our societies. As indicated in a 2014 report of the US White House, ‘some of the most profound challenges revealed during this review concern how big data analytics may... create such an opaque decision-making environment that individual autonomy is lost in an impenetrable set of algorithms’. Unless individuals are provided with appropriate information and control, they ‘will be subject to decisions that they do not understand and have no control over’. Individuals cannot efficiently exercise control over their data and provide meaningful consent in cases where such consent is required. This is all the more so as the precise future purposes of any secondary use of the data may not be known when data is obtained. If data ownership, transparency and information balance between technology providers-data processors and farmers are not ensured, processing of big data in the frame of precision agriculture that represent or correspond to records generated at the production level and owned by the farmer or rancher (e.g., yield, soil analysis, irrigation levels, livestock movement, and grazing rates) may undermine the autonomy of farmers, public and private sector agricultural business, and society at large and possibly lead to major shifts in roles and power relations among traditional and non-traditional players. In fact, precision agriculture may lead to a change of the meaning of ownership given that its devices and information generated by them may compromise the autonomy of farmers in multiple ways.

Consequently, precision agriculture may lead to ‘technological imperative’ in farming and to the concentration of economic power in the process industry, with retailers as linchpins in matching supply and demand within the supply chain. Monopolisation, through a gradual merging of precision agriculture provider companies with data analytics/mining ones, may even threaten EU food security in the longer term. It will also clearly increase dependencies, as already visible in other heavily IT driven sectors where the big players seem to become more powerful than any government. For instance, Monsanto’s acquisition of Climate Corporation and its data analysis and recommendation tool has enabled Monsanto to offer a one stop-shop service on a global scale. The other ‘big six’ of the seeds industry – Syngenta, DuPont Pioneer, Bayer, BASF and Dow – are also developing their own IT-platforms. If the future CAP is to promote a data-driven model of farming as the predominant one there is a risk that other alternatives are underfunded and undermined. Farmers, especially small farmers, are entangled in a world-wide web of technological and economic development that is centred upon the formulation of an integrated offering of equipment and services for farmers (one-stop solution) that they are unable to influence. There are concerns that the technology providers’ requirement that farmers only use authorised software can be commercially devastating, and may even lead them to acquire hacked software. This entanglement may be further strengthened due to the fact that computer algorithms are widely used in the field of precision agriculture. The use of deep learning algorithms to create farm-related insights and implement the right crop protection strategy, the collection by drones of information to be remotely processed by an artificial intelligence algorithm, and the development of ‘prescriptions’

for farmers through statistical models and algorithms in the frame of precision agriculture, raise
important socio-ethical questions about whether farmers’ knowledge and decision-making capacity can
be replaced by algorithms and change the way farms are operated and managed.

How can farmers exercise the right to information when confronted with big data, artificial intelligence
and algorithms? How to evaluate the bias in automated decisions when artificial intelligence and
machine learning is used? How can farmers effectively supervise a technology provider using
intensively big data, artificial intelligence and machine learning? At the same time, there is growing
evidence that, due to a variety of technical, economic and social factors, some algorithms and analytics
can be opaque, making it impossible to determine when their outputs may be biased or erroneous,
including the logic used in algorithms to determine assumptions and predictions. There is a risk that
even well-engineered computer systems can produce unexplained outcomes or errors and that ever
more powerful algorithms would be controlled by a few decision-makers and reduce farmers’ self-
determination.

The new General Data Protection Regulation, which is due to come into force across the EU in 2018, is
the first piece of legislation to explicitly address algorithmic discrimination. It is expected to affect the
routine use of machine learning algorithms and possibly restrict automated individual decision-making,
allowing users to ask for an explanation of an algorithmic decision made about them. The European
Parliament, in its resolution of 14 March 2017 on fundamental rights implications of big data: privacy,
data protection, non-discrimination, security and law-enforcement (2016/2225(INI)), emphasised the
need for much greater algorithmic accountability and transparency with regard to data processing and
analytics. It also called on the Commission and the Member States to identify and take all possible
measures to minimise algorithmic discrimination and bias and to develop a strong and common ethical
framework for the transparent processing of personal data and automated decision-making that may
guide data usage and the ongoing enforcement of Union law. In an earlier legislative initiative resolution
of 16 February 2017 on civil law rules on robotics (2015/2103(INL)), the European Parliament called for
safeguards and for the possibility of human control and verification to be built into the process of
automated and algorithmic decision-making.

Sometimes, the discussion on the potential of farm robotics and satellites is distracting and so far
removed from the realities of small farmers, especially in outermost regions facing serious
unemployment and cohesion problems, or those whose farms are situated on steep slopes or in
mountainous areas. Among the social impacts that may be caused by agricultural mechanisation and
precision agriculture, one should mention the potentially negative effects of digitisation upon the
(/agricultural) labour market and rural employment with human labour potentially being increasingly
replaced by robots and computers. This is especially true in regions with high rural unskilled
populations and the possible alienation of animals, farmers and citizens due to the robotisation and
digitisation of farm management systems. The technological change we are experiencing in the field of
agriculture may not only risk further displacing certain groups of farmers, but could lead to a decline in
overall employment in the farming sector.

Even if the risk of technological unemployment could be discounted, job displacement and changes in
the role of the farmer may take place in addition to many jobs being retooled. The magnitude of these
changes will vary from country to country, potentially having an adverse impact on those farmers who
are not able to make the transition to new jobs. Fast-moving innovations in ‘precision agriculture’ –
particularly data-driven developments based on geospatial positioning and satellite imagery
technologies – may further decrease the labour force as highly-specialised farms seek to upgrade.
Therefore, precision agriculture is seen as a labour-saving technology which may further contribute to
the gradual decrease of on-farm employment and to what is known as digital unemployment.

Precision agriculture technologies, which in effect enables long-distance farming, may also change
popular images of farmers/farming. It could also undermine farmers’ emotional attachment to the land,
as farms can be run from behind computer screens. Further digitisation and automation in agriculture
might also lead to a weaker relationship between humans and nature. It could even be counterproductive from the point of view of protecting landscapes and landscape features which provide for biodiversity and green corridors. In the long run, farms may become more like factories in terms of tightly controlled operations for turning out reliable products, detached as far as possible from nature.

A potential digitisation of agricultural activities questions the need for a return to agricultural practices on a human and natural scale. This reluctance to accept the 'digital capture' of farming practices can be understood as a resistance to utilitarian accounts of agriculture and nature. These are based on economic efficiency and increased productivity models, and on the conceptualisation of the natural environment as a commodity for human needs. In this context, nature's own strategies and principles of operation are neglected, cost and profit considerations determine the use of natural resources and, instead, nature is challenged efficiently to supply agri-food products as commodities in an instrumental economic exchange among chain actors.

Moreover, precision agriculture challenges normative conceptions of 'nature with more reductionist, molecular conceptions. It does' not seem to aim at maximising use of natural resources while protecting them from exhaustion and thereby allowing natural regeneration. Nor does it seem to promote a different model of agriculture that is sustainable and multi-functional, where stewardship of the land, preservation of the resource base, preservation of the small biota that are rich in biodiversity, the value of rural communities and the value of the agricultural landscape acquire important status. European agriculture is very diverse and, while precision agriculture may help the reduction of the use of nutrients in certain types of agriculture, it may have less to offer to other types of farming (e.g., less input intensive and agro-ecological farming). Thus, there is a need to address the question of the balance between the cost of introducing the technology versus the expected benefits for the farmers and biodiversity.

The question therefore arises as to how to conceptualise precision agriculture technologies that are not strictly associated with the instrumentalisation and commodification of nature, but instead are embedded in, and in accordance with, the natural environment. Moreover, the concept of intellectual property (IP) on the farm has rapidly been expanded with the introduction of agricultural hardware and software tools. Sensor technology, equipment-based data and farm management software are creating a whole new class of agricultural IP: data and knowledge about the farm itself. Such an approach may signify lack of access to innovations for small farmers, may induce innovation that is ethically unacceptable and trigger the need for enforcing the concept of 'farmers' rights', as introduced by the International Treaty on Plant Genetic Resources for Food and Agriculture. There is also a high risk that farming in Europe becomes dependent on non-European production for technology and machinery for data management and precision agriculture. As a result, the potential technological capture of agricultural activities may affect food security as well as local social cohesion and current agricultural models. It may also increase the vulnerability of farmers and of whole regions, thus accelerating the speed of decline of small farms, the environment and the landscape.
5. Recommendations

In view of the legal and socio-ethical questions raised by the possible wide-scale application of precision agriculture in Europe, the case for public intervention with regard to the elements listed above is clear. This intervention should take place swiftly and primarily in the form of standards and safeguards so as to encounter the fast evolution in digitisation and prevent the possible establishment of private monopolies. The purpose of the following overarching recommendations is to provide a series of suggestions that EU actors can take into account when dealing with precision agriculture, including the consideration of critical elements such as the socio-economic status of European farmers, the terms of processing of farm-related data and the sustainable use of agri-environmental resources.

A regulatory intervention in the field of precision agriculture must primarily take into account farm size, land tenure and access to information/location. In addition, it should take account of the particular features of the European agricultural sector (sizes and diversity of farm structures) and the ever-growing capacities of super-computing technologies to enhance the competitiveness and the environmental character of farming in Europe. Therefore, any public policy initiative in this field should seek adequate solutions that can be suited to the various types of farms in Europe, and support the necessary forms of cooperation and collaboration which enable also smaller and medium sized farms to profit from the new technology and to cope with the powers of digital service providers. It should also take into account productive and structural specificities, as well as the different socio-economic contexts in which agricultural systems operate. Any EU-led initiative to shape EU common data standards and cooperation approaches should take into account the needs of family farming (small or complex spaces, specific cultures and/or livestock, preservation of high quality or special varieties).

An EU-wide systematic application of precision agriculture should be accompanied by measures that will acknowledge the role played by farm seed systems, empower farmers, and broaden the genetic base of modern plant and animal breeding programmes, in accordance with the Nagoya Protocol, Regulation 511/2014, and Implementing Regulation 2015/1866. At the same time, the application of precision agriculture needs to take place without prejudice to the EU intellectual property legislation on the protection of speciality crops, long-standing farming practices and of traditional farming knowledge in general. Rural development measures may play a role in independent information provision and advice to farmers on how to combine existing farming systems with or without precision agriculture, including exploiting cost-benefits.

Mitigation measures at farm level need to be included in European, national and regional regulations to fulfil the EU-28 commitments and recommendations concerning climate change mitigation. The current Common Agricultural Policy includes several instruments that can significantly help mitigate climate change, but a more precise approach to the mitigation measures at farm level is required. Setting up common EU data standards harmonising LPIS and precision agriculture could provide the carriers of such an approach. Such standards can facilitate the implementation of mitigation measures at farm level, especially as precision agriculture departs from industrial models of agriculture. There is also a need for encouraging the implementation of low-emission techniques for storage, transportation and land spreading of manure. This would lead to a significant improvement of the plant uptake of nutrients from the manure, thus reducing the need for mineral fertilisers and reducing the risk of water and air contamination. Better monitoring of the land application techniques is one of the key factors in reducing total ammonia emissions. Consequently, each country should ensure that low-emission slurry application techniques are used with band spreading (using trailing shoe or trailing hose systems),
injection or acidification. Such practices are already applied without precision agriculture but could be further broadened thanks to common data management standards. There also needs to be an assessment of the nutrient status of the soil before adding fertilisers. High resolution nutrient mapping needs to be undertaken to inform this.

**Need to introduce a privacy by design and a privacy by default approach**

The value of European agriculture strongly depends already now – and in the future much more - on data (from food safety, tracing and tracking of brands, organic food, etc.). Data collected by precision agriculture tools needs to comply with the applicable data protection rules, and data protection authorities are obliged to monitor the subsequent collection and processing of personal data. In the context of data use and sharing with other stakeholders with an economic interest (such as the owner of the precision agriculture system hardware, the tenant, landowner, or cooperative), there is a clear need to protect the farmer from possible discrimination and social or economic exclusion and stigmatisation by increasing transparency and decreasing informational imbalance.

When the data collected in the context of the application of precision agriculture techniques contains personal data from individuals, the solutions should carefully deal with the issues related to the affected individuals' privacy. They should enforce a respectful collection of data (agreed consent about use and benefits generated) with an emphasis on the ease of interpretation of outputs and data and the provision of straightforward information which can be easily fed into the farmers' decision-making process. For personal data derived from precision agriculture tools, a privacy by design and a privacy by default approach is needed. This should include a data protection impact assessment as a suitable tool to assess the impact of the application of drone technology on the right to privacy and data protection. These instruments should be designed on the basis of principles such as accountability, consent, limiting collection and use, disclosure and accuracy.

A regulatory intervention in this field can clarify the terms and conditions including with regard to withdrawing from the process of collection and transmission of data. Personal data must be collected for a specific purpose and may not be further processed in a way that is incompatible with that purpose. A limit should be introduced for the use of sensitive data, e.g. medical or financial data, and the data of vulnerable individuals, for business intelligence analyses. At the same time, the technical particularities of precision agriculture call for an approach that will shape definitions of sensitive data, anonymised information, standards of care, oversight procedures, administrative controls and special data management and informed consent plans. Informed consent procedures must ensure that farmers are informed in a clear and unambiguous way when their data is being collected.

Moreover, there is a need to subject drone operations to impact assessments such as privacy or social impact assessments. It is important to move beyond a consideration of technologies and operations as privacy invasive or not privacy invasive. Rather, the focus should be on the potential issues raised by each multidimensional technology deployment, given not only what the technology itself will be doing but also the potential additional uses to which the data generated by the system could be put. Furthermore, in order to raise awareness among users, manufacturers of drones could provide sufficient information within the packaging (for example, in the operating instructions) relating to the potential intrusiveness of these technologies and, where possible, maps clearly identifying where their use is allowed.
Data collected from farmers should remain the property of the farmers; any system using it should ensure that only the data for which farmers have given permission is used and shared, and that the farmer continues to own all data created by his or her operations. A farmer automatically owns all information generated on his farm and is free to allow other groups, possibly wanting the data for economic reasons, to use such data. Data ownership for the farmer should be a condition sine qua non. Collection, access and use of farm data therefore should be permitted only through the affirmative and explicit consent of the farmer. Farmers should be granted appropriate and easy access and be able to retrieve their own data further down the line, unless the aggregated data is not linked to farmer ownership. Furthermore, farmers should in no way be restricted should they wish to use their data in other systems. Therefore, strengthening effective data ownership by farmers regarding non-personal data is an issue that requires special attention. There is a need to ensure that farmers get a return from sharing their data, provide their consent and are informed in a clear and unambiguous way when their data is being collected, used or shared. They should also not be liable for the misuse of farm data and should retain access and control of data produced on the farm or during farming operations, including spatial data such as livestock data sets and crop status. Making farmers the owners of their data and providing opportunities to control the flow of their data to stakeholders should help build trust with farmers for exchanging data and harvesting the fruits of the analysis of big data. Protecting farmers’ rights on ownership and sharing of data could be supported also by providing guidance on fair and transparent contracts at the EU level.

When third parties are involved in data collection on farm operations, the third party should reach an agreement with the farmer so as to ensure continued ownership and data availability for the farmer. Such a contract should allow the farmer to control who gets the data produced by his or her technology devices or machines and what exactly can be done with it. But it should also recognise the right of the farmer to benefit from and be compensated for the use of data produced on the farm or during farming operations, and the need to grant the farmer a leading role in controlling the access to and use of data from his/her farm. The contract should also provide farmers with the possibility to opt out and terminate or suspend the collection and usage of their data, provided that the contractual obligations have been met. This must be clearly stated in the contract and farmers should be informed of the consequences of these decisions. Data ownership and access should be organised in such a way that farmers’ competitiveness is improved and their autonomy is protected. Common standards and connected devices should enable multiple use and exchange of data, so as to avoid entering the same data for various purposes and to reduce administrative burden.

It needs to be emphasised, however, that beyond the formalities of a contract, farmers should at all instances be aware and reminded when and with whom their data is shared. Where different stakeholders are involved in the use of farmers’ data, the benefits of sharing the data should be returned to the farmer. Any data sharing initiative should be based on trust generated by effective and operational ownership for farmers with regard to the data and the farmers’ right to receive insight into the results and safeguard anonymity. Data-ownership business models that are attractive enough for service providers should also enable a fair share between the different stakeholders and reward data owners for the use of their data. There is also a need for safeguards to properly ensure effective ownership, to see that the data generated is available at all times for use by its owners and that the data can be made available to the different stakeholders and can be shared across different domains to support more sustainable and productive farming. Within this context, more research is needed to develop a user-centric cloud-based farm management system in Europe.
The role of law in this context is both to develop fair-use 'precision agriculture/technology use agreements', signed between companies and farmers, and to prevent commercial actors from gaining unique insights into what farmers are doing around the clock, on a field-by-field, crop-by-crop basis. There is also a need for a uniform type of contract (that may include a non-disclosure agreement) between farmers and technology providers, especially in relation to the explicit agreement the farmer must give at any instance upon data use and sharing with other stakeholders, such as the owner of the precision agriculture system hardware, the tenant, landowner, or cooperative. Such a contract should also cover issues such as archiving of data and the specification of licensing terms; it should ensure that a farmer is notified, in an easily located and readily accessible format, of when his data is being collected and how the farm data will be disclosed and used or accessed.

Technology providers should explain to farmers the purposes for which they collect and use farm data. They should also clarify the possibility and effects of a farmer's decision to opt in, opt out or disable the availability of services and features offered by the technology provider. The technology provider should also develop a system which enables the return of benefits to the farmer when sharing his data and provide for the removal and secure destruction of farm data. A set of criteria needs to be introduced for legitimate processing, complying with the purpose limitation, data minimisation and proportionality and transparency principles. A contract of this kind should address issues such as the confidentiality of the raw data, generated maps and management recommendations; the ownership of the raw data used in GIS mapping; control of, or access to, that raw data; what happens with the data if the farmer changes service providers; whether GIS maps are the property of the service provider or the farmer and whether any of the farmer's data (in either raw or processed form) may be assimilated, deposited, or transferred to a third party database, and whether or not permission from the farmer will be sought or need be granted.

In the context of precision agriculture, all contracts should use simple and understandable language and clearly define the purposes for which the data can be used, ensuring that any transfer or change to the data is traceable. When assisting farmers in entering contractual relationships with service providers, in addition to basic contractual provisions, legal experts should be prepared to address issues such as the ownership and confidentiality of the raw data, generated maps, and management recommendations, the terms of potential transfer of raw or of processed data to a third party database, and questions of privacy, trespass and negligence. Member States should be incentivised and supported in organising training and information for all involved stakeholders in their country, and exchange of experience between Member States in these matters should be encouraged.

If third parties benefit from working with farmers' data, they should be contractually obliged to obtain the prior explicit, express and informed consent of the farmers and the benefits should be shared and the approach agreed beforehand. Systems need to be developed and contractual clauses need to be designed that would allow farmers to benefit from the revenues generated by the processing of data related to their farming activities in case a third party should use 'it to generate extra income. The farmer needs to retain the right to be compensated for the use of data produced on the farm or during farming operations, and at all instances to be informed in a clear and unambiguous way when his/her data is being collected.

An attempt to regulate the operation of precision agriculture in contractual terms needs also to take into account cultural perceptions, including farmers' concerns regarding the perceived 'outsourcing' of the monitoring/management of their farms to electronic systems managed by third parties. Related to the latter, the risk of 'being locked in' with a single manufacturer/data controller must also be taken into account when shaping the terms and conditions of licensing this technology. Instead of depending on a multinational company, farmers could be able to bring their data from one service to another and benefit
more, no matter the size of their farm. Therefore, legal safeguards need to be introduced urgently in order to ensure that 'control over data' (and indirectly food security) from the European agricultural sector does not lie outside of Europe nor in the hands of a few big private companies.

Last but not least, special initiatives need to be taken in establishing and safeguarding the 'right to repair'. This obliges manufacturers to make goods easier to repair, and to inform users how long a device is likely to last, above all, stressing that that independent repair entities have the same access to product information, spare parts and repair tools as manufacturer-owned ones.

In the context of precision agriculture, there are risks linked with secure processing and ownership of large volumes of site-specific data that may be of a sensitive character. There is therefore a clear need to introduce legal safeguards and allocate the relevant data management tasks in a balanced and transparent manner. Thus, it is necessary to adopt all the appropriate security measures, ensure any benefit generated by processing farmers' data flows back to the farmer and delete or effectively anonymise any personal data which is not strictly necessary. Especially with regard to the use of drones for precision agriculture, a limited number of authorised persons, to be specified, should be allowed to view or access the recorded images. Limited access should be granted to the above-mentioned persons, on a need-to-know basis, and encrypted storage and transmission of information should be safeguarded. Manufacturers of agricultural machines (tractors, equipment, milk robots etc.) should use technological measures, such as passwords or encryption, to protect competitors and third parties from copying, tampering or pirating the valuable, reliable software code that controls the vehicle. The adoption of governance schemes for the protection of personal data that could guarantee effective anonymisation and storage and security should be considered, along with the introduction of safeguards on privacy. However, it needs to be emphasised that anonymisation is often ineffective in small sized regions and for small crop volumes.

Further, logs of all instances of access to and use of recorded material should be protected along with the introduction of stringent data storage periods and automatic deletion or anonymisation procedures. In relation to the latter, given that on certain occasions it is impossible to render data fully anonymous, there is a need to make use of separate analytical databases and the removal of unnecessary data fields to prevent the data being re-identified. It is also important to develop security measures, security protocols for handling asymmetric risks from dual-use, mission creep and misuse of security-related research, as well as new vulnerabilities that may be exploited by hackers either to corrupt the operation of systems, or to extract commercial or other sensitive data. Data in databases must be kept under a pseudonym and encrypted so that individual farmers cannot be identified. Access to data, in read-only or fully editable modes, should be strictly audited and any transfer or change to the data (e.g. input, modification, removal) should be fully traceable, e.g. accompanied by metadata about the author. The data sets should only be used for as long as is strictly necessary for the relevant analyses to be carried out. In addition, data should only be accessed by those with the necessary qualifications and under no circumstances may be accessed by unauthorised persons. EU initiatives are also needed for enhancing cyber-security, encryption and network security, when the data is stored (e.g. in cloud services) or in transit and to avoid the use or damage of RPAS by third parties.

Moreover, the use of farm robots raises the need for introducing standards and protocols that would safeguard control, monitoring and the reversibility of their functions or decisions. Strict liability and insurance instruments for products and users are needed given that the main question will be who is responsible for these technologies. For example, if autonomous machines end up causing harm to plants, animals or humans, where will the responsibility lie? This also ties in with the issue of safety. Thus, special attention should be paid to the possibility of making ex-ante risk assessment compulsory for all
kinds of farmer-tractor/drone interface and of introducing special safety safeguards and testing protocols for the research into and development of the new generation of tractors and of special risk assessment procedures that could take non-technical, psycho-social factors parameters (i.e. indirect impacts of machine-machine communication) into account.

Further, any public intervention needs to take into account data-management and storage concerns and ensure a high level of legal control of critical system operations including security of supply and safety. There is also a need to introduce multiple certification standards and safeguards to ensure that the robot itself is safe for users and does not infringe on their right to physical integrity. Effective verification and certification could be embedded at the design stage of farm robots. An overall assessment of the safety and effectiveness of these robots should be performed along with feasibility studies and the development of solutions for the safe implementation of planned mobile robot applications. Within this context, individual risk assessment during the development of a new robot solution and assistance with ‘Conformité Européenne’(CE) label certification could be introduced. At the same time, the overall application may also need to be considered (process, fixtures, gripper technology, robot), i.e. not only the robot itself, and keys for acceptance of partial automation or a mixed human-robot environment should be identified. Special procedures need to be introduced that would ensure and manage system’ predictability, and increase human understanding of the increasing complexity of automated safety.

Moreover, assessment procedures are needed to ascertain the functionality and safety of automated systems, including standardised test procedures for pilot tests, recording of data, infrastructure requirements, cross-border testing, etc. Special risk assessment protocols need to be created so as to accommodate safety concerns stemming from possible data security threats, but also to tackle the risks associated with increased connectivity and integration of vehicles and complex logistics networks. The co-existence of these factors may lead to exposure to potential criminal or malicious attacks or misuse, which could result in significant financial loss, and, in the worst case scenario, injury and fatalities. As the technology unfolds, many other legal concepts need to be re-shaped so as to accommodate drone use, including invasion of privacy, nuisance, and trespass.

Legislation needs to ensure that security protection measures are in place against physical, electronic or cyber-attacks, as well as transparent and harmonised contingency procedures, decision capabilities to ensure standardised and predictable behaviour in all phases of flight, and third party liability and insurance/security clauses inserted into the flight authorisation and contractual agreements between farmers and agricultural technology providers. Rules in this area should also focus on issues such as airworthiness, certification specifications, the identity of the drone and the owner/operator, ‘geofencing’ and no-fly (exclusion) zones. Rules for drones in this area should be formed in accordance with the Riga Declaration. Among other things, this states that remotely piloted aircraft systems (RPAS) need to be treated as new types of aircraft with proportionate rules based on the risk of each operation; that public acceptance is key to the growth of RPAS services, and that the operator of an RPAS shall be responsible for its use. In the case of precision agriculture, legislators could follow a property rights approach to aerial surveillance. This approach provides landowners with the right to exclude aircraft, persons, and other objects from a column of airspace extending from the surface of their land up to a certain height above ground level. Such legislation can address the potential harm of persistent surveillance, a harm that can be committed by unmanned aircraft. Legislators could also adopt data retention procedures that require heightened levels of suspicion and increased procedural protections for accessing stored data gathered by aerial surveillance. After a legally determined period of time, all stored data should be deleted. Legislators could enact transparency and accountability measures, requiring the publication on a regular basis of information about the use of aerial surveillance devices.
Legislators could also recognise that technology such as geo-fencing and auto-redaction may mean that aerial surveillance by drones becomes more protective of privacy than human surveillance. Geo-fencing (i.e. the capability of automatically maintaining the drone in a position compliant with some geometric or geographical limitations), emergency recovery, command and control data link and detect and avoid, are all domains requiring legal attention when using drones in the context of precision agriculture. The implementation of safety functions using suitable components in accordance with predetermined requirements, the constant updating of security measures, the safeguarding of system’ predictability, and the strengthening of human understanding of the increasing complexity of automated safety, can be operationalised via specific contractual clauses or regulatory interventions. There is also a need for greater follow-up in tracking the adoption of technologies for sustainable farming systems, accountability of research efforts and policies for technology dissemination and adoption and ex-post assessments of results.

Alert sensors, which could prevent possible collision with houses, birds and electrical masts, but could also facilitate the identification of these drones by the competent authorities and other aircrafts, thus ensuring full traceability, could be introduced. It is vital to ensure the timely availability, including in real time, of safety-relevant information in order to allow it to be analysed and disseminated without unnecessary delay. Unmanned aircraft operating rules should be clear, enforceable, and harmonised across Member States, in order to ensure a safe operation of unmanned aircraft and a culture of compliance amongst operators. The responsibility for accidents, liability claims and taking out insurance for an RPAS needs to remain with the operator of the system. Regulation (EC) No. 785/2004 on insurance requirements for air carriers and aircraft operators needs to be adapted to better take into account RPAS specificities, given that the insurance framework is very much based on the framework for manned aircraft which in effect might cause obstacles for the insurance of light RPAS. An insurance scheme for light RPAS should therefore be developed.

Within this frame, the current division of competences between the EU and Member States regarding regulation of unmanned aircraft, based on quantitative thresholds, needs to be re-examined and possibly abolished. Instead, an operational, risk-based set of criteria should be promoted that would ensure respect for privacy, data protection and security requirements relating to this potentially highly intrusive new technology. Further, the drone needs to be visible and identifiable (using emitted wireless signal, flashing lights or buzzers, bright colours) and should avoid as far as possible flying over or near private areas and buildings. Certification and approval requirements for individualised (or custom) drones, including component upgrades, need to be introduced. Similarly, there is a need for effective verification and certification at the design stage of precision agriculture tractors and drones and for a clear distribution of tasks, roles and responsibilities among operators, farmers, data controllers and data managers.

From a legal perspective, beyond the design of a fair contract and thorough privacy, safety and data-ownership clauses, two further initiatives could safeguard the balance between farmers and tech providers in this field: the establishment of an EU-wide independent, farmer-centric data repository and the adoption of a ‘code of best agricultural data management’. The latter would focus on the promotion of the following principles: ownership, collection, access and control, transparency, terms and definitions, disclosure, use and sale limitation, data retention and availability, contract termination, unlawful or anti-competitive activities and liability safeguards. The so-called ‘licence to operate’ for farmers requires more and more proof of compliance with regulations or (quality) claims. Law in this area is also expected to introduce clauses that could safeguard an equitable use of big data analytics and
provide common standards for data management. Within this context, it is recommended to focus on the development of standards and easy to use protocols and software that could facilitate the uptake and daily use of precision agriculture benefiting farmers and their consultants.

The EU-wide independent, farmer-centric data repository should be under governance of EU public authorities to guarantee security, interconnection and interoperability and to avoid misuse of data. The geospatial data already collected in the framework of the CAP payments, and existing EU standards linked to this system, may provide a good base for developing this data repository. The currently collected data already links to a variety of data stemming from compliance with EU legislative requirements in the fields of environment, health, soil, animal welfare, water, food safety, climate change, etc. Moreover, such an EU-wide repository has a huge potential for administrative simplification, both for farmers and for Member State administrations. It could also enable a set of synergies with applications related to, for example, traceability of food, certification schemes (organic production, geographical indications), research and innovation projects, etc. The not too distant future will provide even more opportunities for capturing and sharing data at an EU scale.

Within this frame, a new farm information management system may need to be developed, that could facilitate instructions to operators, the certification of crop production process and cross compliance of standards. Farm advisers will be needed to analyse the data of a farm and help farmers, both large and small ones, to know more and understand the added value of managing their data in an effective way (e.g. about the nutrient balance of their soil). All farmers should benefit from that, not only those that can afford to pay for the services of private advisers. Law in this area should ensure that farmers will be included in the design, testing and dissemination of data management schemes in order to help improve their effectiveness (e.g. soil nutrient mapping technologies). Further, rules on agricultural data management and precision agriculture may possibly even lead to the development of a European legal framework for data management linked to integrated production, or EU guidelines for this voluntary model of production.

As is the case with other production models, in order for products obtained under the integrated production system to have a guarantee label, accredited certification bodies must check and certify these products. Moreover, there is a clear need to build capacity among smallholder farmers and less well-resourced actors in the sector on how to deal with the growing amounts of data becoming available. Simply making data available is not enough to address these differences, and more needs to be done, potentially through providing low-cost advisory services on data use, or more accessible capacity-building options which clearly outline the reasons behind such offerings. Practising responsible data approaches should be a key concern and policy of the larger actors, from ministries of agriculture to companies gathering and dealing with large amounts of data on the sector. Developing policies to proactively identify and address these issues will be an important step to making sure data-driven insights can benefit everyone in the sector.

**Strengthening the transparency of data processing**

Ensuring transparency of the process by which sensors collect, process, and make use of personal data, including the terms of use of algorithms and exploring the need for compulsory insurance in case of damage caused by the illicit treatment of personal data, are of outmost importance. A mechanism should control data before it is used in algorithms and the subjective character of the interpretation of products created by algorithms processing large data sets should be tackled. Special rules need to be adopted in order to introduce a transparent data approach throughout the agri-food and other value chains, based on the common EU standards that facilitate data exchange and knowledge-sharing while preventing misuse of natural monopolies or lock-in effects in terms, for example, of allowing changing
service/hardware/software providers. The latter may emerge as farmers may be locked into doing business with a single provider because their data is being held by that provider.

While large-scale agricultural enterprises may have the financial means to buy the data they would need, smallholder farmers cannot afford to pay for access to data. Publicly available open data is a key tool in levelling the playing field, particularly for the least-resourced actors in the entire data ecosystem of European farming. Such a data model for precision agriculture should be customisable and scalable, to comply with the respective international standardisation approaches and European legislation, and address the needs of farmers. The availability of open data such as actual cultivation data, statistical data, sensor data, web-connected sensor data, local weather data and satellite image sensing data, development in situ of soil, mineral or organic material, soil pollution, landscape interaction and effective agro-biodiversity, may increase the possibilities for farmers and their service providers to deliver meaningful knowledge in order to take decisions that will improve their farm operations and make strategic decisions on investments. This type of data can empower farmers and may allow them to easily switch between suppliers, share data with government and participate in short supply chains, rather than integrated long supply chains.

Combining public data with the farmers' own data, possibly supported for the analysis by independent advisers, can help small and medium farms to make better use of data and improve their insight in the farming and market processes with a view to supporting competitiveness and improving sustainability. The combination of public data and farmers' data can support a level playing field for an agricultural data 'ecosystem' for all farms. The development of data exchange for the precision agriculture information systems based on EU common standards may address the problem of digital division and facilitate the focus on real farming problems and need; its absence may limit the uptake of precision agriculture. The development of common interoperability standards requires the involvement of finance and advisory services and managing authorities (agriculture, environment, food authorities) that work with various types of agricultural data.

Making data work for agriculture and nutrition requires a shared agenda to increase the supply, quality, and interoperability of data, alongside action to build capacity for the use of data by all stakeholders and access to wide bandwidth in the internet (4G / 5G). The data model should be designed in accordance with the requirements of the INSPIRE Directive and the ISO standard 19156:2011 – geographic information – observations and measurements, and the principles used within the Land Parcel Identification Systems (LPIS). At the same time, there is a need for shaping common formats for sending data derived from precision agriculture techniques to a centralised public body (e.g. a managing authority for CAP measures), or using metadata analysis for standardising, processing and integrating large volumes of data as an input to farmer-centric decision-support systems. The EU-wide independent, farmer-centric data repository under governance of EU public authorities will be an essential cornerstone in this regard.

Moreover, shedding light on the use of algorithms during the design and deployment process should be an important aspect of the process of regulating the application of precision agriculture at the European level. There is a need to ensure accountability and/or the transparency of the algorithms that underpin many business models and platforms in the digital single market. Similarly, it is important to prevent bias, also in relation to the distribution of tasks, roles and responsibilities among robots and operators, by taking into account the varying degree of automation and development of the various application areas and the high variety of types of user interface, handover, conveying, etc.
The Common Agricultural Policy, through the Member States’ rural development programmes, provides for a number of instruments which are available to the Member States to encourage the uptake of precision agriculture and incentivise the better use and management of data (e.g. information actions, advisory services, investments in physical assets, innovation projects and cooperation measures). There is a need to develop precision agriculture tools designed for small and medium-sized farms, which are easy to use, affordable and with low maintenance cost, as well as customised advisory services. Small farmers may be unable to keep up with new technologies because of lack of knowledge or investment capital. This could lead to a large digital divide between big and small farmers. Therefore, having independent advisory services in place with sufficient knowledge and access to the data is very important. As agricultural data management and precision agriculture requires technical competence, a system of support and training for advisers across the EU would be very much desirable.

Support for cooperative approaches may tackle the problem of too limited farm size or lack of finances. Article 25 of Regulation 1305/2013 on cooperation states that support can be granted to promote forms of cooperation involving at least two entities, including activities such as the development of new practices, pilot projects, joint action undertaken with a view to mitigating or adapting to climate change, joint approaches to environmental practices, logistics, etc. To incentivise common approaches, collective investments may be granted a higher aid rate than usual (Article 17(3) of Regulation 1305/2013).

Innovative projects of European Innovation Partnerships (EIPs) operational groups profit from this support and can also spread the innovative knowledge through an EU wide EIP network linked with EU research and innovation projects under Horizon 2020. Another possibility to organise better data management and precision agriculture for smaller farms could be to incentivise efforts coordinated by producers’ organisations which may be supported by Common Market Organisation funds. A Common Market organisation is a set of measures that enables the European Union to monitor and manage, either directly or indirectly (via producer organisations supported by operational programmes), the markets of agricultural products.

From a legal perspective, special financial incentives need to be provided especially to medium and small-scale farmers before farmers are able and willing to adopt precision agriculture. Also farmers in outermost regions, remote rural areas, less favoured areas and mountainous areas will need to be provided with all available technological solutions to ensure that farmland is used in a more sustainable manner. Farm measures that require new infrastructure or testing collaborative approaches could be supported through the second pillar of the Common Agricultural Policy. A set of aspects have to be tackled before farmers are able and willing to adopt precision agriculture. These include yield-limiting factors that can be addressed with precision agriculture, access to agronomic data, perceived economic benefits and access to extension services and/or consultants which require local experimentation, observation and learning, a matching of extension methods to local circumstances and management of social and economic factors within the precision agriculture framework at a range of scales.

Precision agriculture hardware should be affordable and with low maintenance cost. Widening the application of precision agriculture through financial incentives might induce scale effects and reduce the cost of the technologies. The sensors should be user-friendly, easy to mount and maintain, and enable farmers to make the right management decisions and realise them reliably in the field, and include ‘as-applied’ data for sustainability reports. In the case of precision agriculture, the technologies and sensors deployed should provide good performance in real farming conditions and robustness to cope with the farm environment, whilst software and application management interfaces should be adequately adapted to ensure acceptability and ease of adoption by end-users. Technical solutions related to data management and compatibility for mainstreaming precision agriculture are critical for its successful
application, as the 'solutions' are normally a combination of hardware and software with appropriate implementation and data acquisition, storage and sharing.

Assessment procedures to ascertain the functionality and safety of automated systems – including standardised test procedures for pilot tests, recording of data, infrastructure requirement for cross-border testing along rules governing the testing, licensing and operation of this technology – are needed. EU farmers who invest in certified sustainable technologies could be made automatically eligible for the greening direct CAP payments, while farmers who do not reach a specific demonstrable sustainability level could still use the traditional CAP greening scheme. This vision will require e-skills, cost feasible technological equipment, a proper broadband infrastructure in rural areas and data management. The point is to seek solutions (including training and access to the internet) that apply to all farmers, no matter the size of the farm, the region or the sector; this will induce scale effects and reduce the cost of the technology. Within this frame, policies are needed to ensure high-speed data transmission and harmonised interoperability European standards that will promote more reliable rural internet access and wireless capabilities, accompanied by the appropriate infrastructure and services for data processing and regular software updates.

Need to develop an ethics code of conduct for designers and users/farmers

Technology in itself is neither good nor bad, it is the way in which it is used that determines the effect. The key is to develop, introduce and accompany technology in an approach based on ethical principles and foreseeing its likely impacts. Given that the challenges for the adoption of robots include issues such as the robustness of the technology for agricultural applications and the aging target user group, the social acceptability of robots in the landscape may need to be considered by taking into account environmental requirements, rural development needs and the uneven level of European farmers’ technological exposure and agility. In this context, the introduction of precision agriculture could be accompanied by means of a socio-ethical impact assessment that takes account of both environmental (risks and benefits to human health and the environment) and social implications (how agricultural technologies will affect access to social, economic and institutional structures and fair allocation of benefits), including sustainability, food and feed security and safety.

The digitisation of farming as a human activity via precision agriculture, and the potential dependency on tech providers, reinforced by the increasing financialisation of agricultural commodities trade and the financial speculation on agricultural commodities, highlight the need to protect the ethical autonomy and integrity of farmers, and to protect certain traditional specialisms so as to retain food sovereignty and reduce inequalities. This will not happen without significant policy initiatives supporting the redistribution of information and communication capacities, the precise role of loss and damage in the context of agriculture, natural environment and adaptation, the adoption of common data standards enabling data exchange for multiple purposes, support for collaborative approaches, training, on-farm demonstrations, advice, etc. Within this frame, the importance of the preservation of small family farms should be mentioned. Such structures promote and embody important moral values or virtues such as integrity, self-reliance, responsibility to community and wholesomeness, all of which is of the utmost importance for the social acceptance of precision agriculture.

Moreover, in order to assess the economic benefits/risks for farmers, a series of parameters including farm size and the investment cost associated with the implementation of precision agriculture (information costs, costs involving data processing, specific licence fees, software and hardware products for data analysis, and learning costs) need to be taken into account. Such an analysis would require the attachment of monetary value to environmental goods such as the receiving agricultural environment including the tillage, seeding, fertilisation, herbicide and pesticide application, harvesting and animal husbandry, as well as the relevant ecosystem services; it would also need to take into
consideration the significant variation of field sizes and farming practices across Europe. These initiatives should aim at empowering farmers in the frame of all food production supply chains - compared with retailers and technology providers - rendering them a constitutive part of the process that affects the switch to a digital agricultural sector. Gaining the technology and skills to make use of precision agriculture requires an injection of resources and the organisation of a critical mass of independent advisers.

In view of the future human-centred challenges generated by technologies, a governing framework for the integration of data management that includes PA as a distinct legal category is needed to guide and compliment the various legal recommendations or the existing national or EU acquis. Thus, the attempt to regulate emerging technology of this kind should be accompanied not only by technology data standards but also by ethical standards, and with procedures that could address the needs and ethical dilemmas of researchers, practitioners, users and designers alike. Thus, beyond the need for an EU-wide independent, farmer-centric data repository under governance of EU public authorities, setting common standards for data and providing management guidance, including a standard set of contractual clauses, an ethics code of conduct for all actors involved in the processing of farm data needs to be considered to focus on stigmatisation and benefit-sharing when data is shared.

Socio-ethical considerations, especially in relation to the changing role of farmers and to whether traditional farming can be combined with technologies, should be a key concern in all ongoing and future efforts to enhance acceptability of precision agriculture. There needs to be a bottom-up dialogue between the farmers and the technologists. Precision agriculture must be viewed and used as a means, and not the end, for ensuring the future of agricultural development and evolution. There is a need for a careful examination of the possible ethical implications that appear to be arising from particular configurations and uses of big data in the realm of food and agriculture.
6. Conclusions

Embracing new technologies can at times be difficult for farmers who wish to take advantage of digitisation. Expensive machinery, the absence of infrastructure and lack of knowledge – those are some of the challenges the agricultural sector has to overcome today. Precision agriculture and agricultural data management are expected to raise a variety of additional socio-ethical and legal challenges, given also that the agri-food value chain has characteristics that make it different from value chains in other industries. As the debate on the Common Agricultural Policy 2020 kicks off, how are these challenges going to be addressed? The preceding legal analysis points primarily to those challenges that may arise in case precision agriculture becomes mainstreamed especially across medium- and small-size farms.

The most profound effect of precision agriculture lies in its potential effects upon social values, the autonomy of the farmer and the sustainability of local farming structures. These impacts are associated with the affordability of precision agriculture technologies, the enhancement of the likely digital divide among those using precision agriculture, the transparency of the algorithms used and the good governance of data sharing and ownership, informational asymmetries and dependence on high-tech providers potentially leading to monopolies which in turn may have an impact on food security, regional cohesion, local genetic resources and traditional knowledge. Due to the scale, technical complexity, and infrastructural requirements of precision farming, uptake of precision agriculture might lead to a reliance of the vast majority of farmers on off-farm service support, to a rapidly growing digital division between small and big farmers, and significant power shifts. These can in turn lead to potential abuses of data by agricultural commodity markets or manipulation by major multinationals because small farmers might lack the investment capital or knowledge to acquire precision agriculture technologies, which in effect may signal an unprecedented power shift in the industrial farming process.

Such a tendency may be rebalanced, among other things, through the introduction of common standards and an EU-wide independent, farmer-centric data repository under the governance of EU public authorities in order to guarantee security and interoperability and to avoid misuse of data. A coherent data management approach should respect the data ownership principle, while organising how data will be shared between stakeholders in the agri-food chain. Such an approach should place the farmer at the epicentre of the data ecosystem providing him with the possibility to choose who can access, use and process data related to his or her farm, but also offering the farmer a fair part of the data-driven revenue. The public authorities should take a proactive role in organising and guaranteeing standardisation, farmers staying owners of their data and enabling interoperability.

Moreover, beyond privacy and data ownership concerns, accessibility and affordability of this technology, and incentives for cooperation between farmers in the field of agricultural data management, should be another key consideration in all ongoing and future efforts related to precision agriculture. Empowerment of farmers and the provision of better and increased support for impartial advisers are needed to overcome the perceived complexity of precision agriculture solutions. Equitable data management, affordable entry points and technical compatibility for mainstreaming precision agriculture are critical for its successful application, as the ‘solutions’ are normally a combination of hardware and software with appropriate implementation and data acquisition, storage, standardisation and sharing.

An inclusive coordination of the various policy initiatives in this field is of essential importance for shaping a further developed conceptual framework for European agricultural data management. Farmers will have to be informed about the potential, the cost and benefits of investments in digital technology and the economic viability of precision agriculture. They will also have to be supported to understand their position in a digital environment (data ownership, interoperability, etc). Farmers will need support from intermediaries such as farm advisers to take up the newest technologies and help with tailor-made decisions on data use which are adapted to the specific farm context. The future advisory services need dedicated preparation and training to be ready for such tasks, which could be
supported with CAP funding under the second pillar. Within this frame, there is a need to identify fair and acceptable ways to support data sharing among the various stakeholders so as to ensure that the benefits of the digital revolution in agriculture reach everyone involved, especially farmers.

Besides the need for an EU-wide data repository, the aforementioned challenges also trigger the need for safeguarding compliance with the EU general data protection framework, not as a means to reduce company liability, but to prevent and mitigate the risk to the rights of farmers as data subjects. At the same time, the *sui generis* features of precision agriculture raise the question about the need for shaping a special set of rules and the need for elaborating common EU data standards and guidelines on how technology use agreements should be shaped, and the terms and conditions under which ownership of data collected via precision agriculture techniques could be defined. An EU-wide initiative in integrating precision agriculture into the ecosystem of agricultural management technologies needs to take into account not only the diversity of farming practices, topography and farm sizes, but also the localised character of the land tenure system, the degree of national/local digitisation of farming practices and the uneven landscape of digital and data processing skills among farmers.

Moreover, there is a need for implementation assistance to EU Member States that could help enhancing digital infrastructure in rural areas, transition to applying common data standards as well as potential support measures for farmers and advisers. Collaborative projects are required to test out, monitor and evaluate specific measures and counteract negative perceptions about precision agriculture. The benefits of agricultural data management and precision agriculture for more efficient water productivity management is an area of high importance for further analysis as well as the assessment of the relevant environmental footprints. The roles of the farm advisers supported under Rural Development and the European Innovation Partnership (EIP) on Agricultural Production and Sustainability already established within the CAP could be fostered as these instruments allow Member States to develop and share appropriate knowledge and expertise.

The CAP currently already collects geospatial data which link to a number of data on compliance with EU legislative requirements in the fields of environment, health, soil, animal welfare, water, food safety, climate change, etc. A future CAP could reduce administrative burden if data capturing is done according to common standards and if agricultural data management and exchange are well organised and supported. The increased complexity of agricultural and food systems inhibits easy solutions and makes calculations as to the financial benefits uncertain. However, these issues can be resolved though better information management systems, enhancing the use of data interchange standards and clear management methods. Rendering databases interoperable thanks to common standards could have a substantial impact in many areas and respond to the variety of challenges described above.

Many existing and new data flows could fulfil multiple uses and be brought to a higher level through improved data exchange applications, in particular if simultaneously supported by independent advisory services making use of the harmonised standards, e.g. for benchmarking farms and supporting on-farm decisions, whereas compulsory recorded animal data can help improve breeding and husbandry on farms. At the same time, it should be mentioned that precision agriculture is not relevant to the CAP only from an administrative perspective—in terms of simplification, transparency and tracking purposes—but also in terms of having the potential to facilitate the transition to sustainable agricultural approaches and the integration of environmental protection requirements in this policy area in line with Article 11 of the Treaty on the Functioning of the European Union.

Moreover, recording the application of plant protection products under integrated pest management schemes and data collected in the framework of agri-environmental measures, can help to optimise cost-efficient production. Nutrient application data and soil analysis linked to area-based payment mapping systems could provide valuable input for regional farm nutrient recycling, waste management and environmental impact monitoring. Better use of data may support cooperative and logistics initiatives connecting producers and consumers, and strengthen the position of farmers’ in the supply chain.
There is also a need for a simpler and more flexible governance framework, more geared towards national and local conditions, and better suited to delivering synergies with other sectors by enhancing and promoting data exchange, knowledge crossovers and integration of resource use. Such a framework should be better aligned with the circular economy and the 'from farm to fork' approach, (i.e. by reducing harvest losses and waste and implementing waste recycling systems). This would improve the visibility of existing systems for specific promotional labelling and encourage further innovation in the promotion of the diversity of European agricultural products. Concerns over inequality and the role EU law could play in this context may justify claims for a 'fairer' distribution of the total surplus value resulting from innovation in precision agriculture, and for an increasing focus of on the way the total value is allocated between the various segments of the agri-food chain. Within this frame, a rethinking and rehabilitation of some of the core concepts, such as sustainability, data ownership and autonomy, is needed.

Finally, the existing EU framework that is applicable to data-driven farming needs to become more reflexive in terms of integrating this systems approach in ways that are socially acceptable, beneficial to and useable by farmers, sustainable and desirable, so as to prevent potential technology push and, in the case of precision agriculture, reduce the current technology uptake gap. Such acceptability may be achieved by safeguarding the integration of impartial advisers, as well as by ensuring that farmers get value from data and that their interests underpin the operation and functionalities of the system. In view of the ongoing structured dialogue regarding the current difficulties and needs for modernisation and simplification of the CAP, which will feed into the upcoming communication on the future of the CAP, there should be a better focus on farmers' rights, their real needs, concerns and local conditions, while not compromising policy goals, so as strengthen farmers' sense of 'ownership' throughout the agri-food chain in the choice of technology. Holding a balance between economic, social and environmental realities and expectations, involving all the stakeholders across the value chain and safeguarding the active participation and positive attitude of farmers and local cooperatives, may prevent precision agriculture being seen as a demand-creating innovation and farmers being locked in by a single supplier of software and/or machinery.
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The aim of this study is to illustrate the different ways in which the current EU legislative framework may be affected by the digitisation and automation of farming activities and the respective technological trends.

The study analyses the issues that might have to be dealt with, identifying the European Parliament committees concerned and the legislative acts that might need to be revisited, especially in view of the forthcoming Commission communication on the future of the Common Agricultural Policy (CAP). It also provides a series of overarching recommendations that EU actors may wish to take into account when dealing with precision agriculture.

To do so, an analysis of the multiple ethical and legal challenges associated with precision farming technologies has been performed, along with a scanning of current legislation in a wide range of areas of EU policy-making, including agricultural policy and related fields, such as environment, health, food safety and climate change.