Report on the State of the Art of Precision Agriculture Technologies

Report developed in the frame of the project "Precision Agriculture System to limit the impact on the environment, on health and on air quality of grape production WINEGROVER"- LIFE19 ENV/IT/000339

Smart City Cluster

WineGrover

Contents

1 Introduction

This study was developed in the framework of the LIFE19 ENV/IT/000339 Winegrover project "Precision Agriculture System to limit the impact on the environment, on health and on air quality of grape production", in relation to action D.1 "Public awareness and dissemination of results" and focuses on "Dissemination Planning and Execution". The purpose of the document is to provide an overview of the state of the art of European agriculture also providing legal, social and ethical considerations and the state of the art of technology. The report also provides an analysis of the wine sector in Spain and China.

2 Precision Agriculture in Europe and Asia

2.1. The state of European agriculture

Global agriculture is facing a number of major challenges in the years to come: rapid world-wide population growth, climate change, an increasing demand for energy, resource shortages, accelerated urbanisation, dietary changes, ageing populations in rural areas in developed countries, increased competition on world markets, and lack of access to credit and land grabbing in many developing countries.

At the same time, agriculture in Europe and other parts of the world is at an important crossroad. The increasing digitalisation of agricultural practices make it possible to produce plant and animal products with ever higher efficiency and ever lower environmental impact.

This chapter presents the main results of a stocktaking exercise focussing on the framework conditions under which agriculture takes place in Europe today (subsection 1-2) as well as key aspects of precision agriculture, concerns and future trends are discussed (subsection 3-6).

1. Agricultural production in the EU;
2. Business models of farming in Europe;
3. Trends in precision agriculture in the EU;
4. The economics & governance of digitalisation and precision agriculture;
5. Environmental impact of precision farming and
6. Skilled workforces & precision agriculture.

The underlying, more detailed analysis papers can be found in Annex 1 of this report, “Precision Agriculture and the Future of farming in Europe – Technical Horizon Scan”.

The wide diversity of agriculture throughout the EU, particularly regarding farm size, types of farming, farming practices, output and employment, presents a challenge for European policy makers. European policy measures therefore should differentiate between the Member States, taking into account that opportunities and concerns vary greatly per country.

2.1.1. Overview of agricultural production in the EU

Overall, in the EU, the area of land available for agriculture is gradually declining with increased forestry and urbanisation, so productivity must increase if we want to maintain or increase output.

Of the EU agricultural land, 60% is arable, 34% permanent pastures and grazing, and 6% permanent crops, such as fruits, berries, nuts, citrus, olives and vineyards.
The total utilised agricultural area is 174 million hectares (ha), which comprises 40% of the EU land area.

In the EU there is a long-term decline in the number of holdings with a corresponding increase in the area per holding. Between 2005 and 2013, the average rate of decline was 3.7% per year, resulting in the number of holdings reducing by 1.2 million and average holding area rising from 14.4 to 16.1 hectares. The area of agricultural land fell by 0.7% over the same period.

The state of agriculture in Europe varies considerably from one agricultural sector to another, as illustrated with the following key sectors:

Cereals
The EU is self-sufficient in cereals and is a net-exporter. Over 50% of cereal production is fed to livestock and the demand for animal feed has a major influence on the market, both within the EU and internationally. World demand is expected to remain strong over the medium-term with prices being maintained.

Grapes
Spain, France, Italy, Portugal, Romania, Greece and Germany each produce over 0.8 million tonnes of grapes and account for 94% of EU grape production. The average yield at EU level is 7.9 tonnes per hectare, varying from 3.4 to 11.5 tonnes per hectare in individual Member States.

Of the total EU grape production, 92% went to produce wine.

Olives

In 2013, the EU harvested area of olives was 4.9 million hectares, producing 13.6 million tonnes of olives. Spain, Italy, Greece and Portugal account for 99% of EU production. Ninety-five per cent of production is used to make olive oil, with the remaining 5% being olives for table use. The average EU yield is 2.7 tonnes per hectare with averages in Member States ranging from 0.8 to 3.7 tonnes per hectare.

Meat

Most meat produced in the EU comes from pigs (55%), chickens (25%), cattle (18%), and sheep and goats (2%).

The EU is self-sufficient in total meat production. However, it produces only 80-90% of its consumption of sheep and goat meat. Beef and veal production is about the same as consumption, pig meat production is 11% in excess of consumption and poultry meat is 4% in excess of consumption.

World demand for sheep and goat meat is expected to increase, but EU exports will be limited to an increase of 0.1% per year by competition from Australia and New Zealand. Poultry meat production is expected to grow by 4% between 2015 and 2025 and exports are expected to increase by 1.4% per year over the same period.

Milk and dairy products

The EU is self-sufficient in milk and dairy production and exports the excess mainly as cheese and milk powder. The EU is the world's largest producer of cows' milk. The USA has by far the highest milk yields per cow at over 10 000 kg/annum. Argentina is second with 6 419 kg/cow, followed by the EU with 6 327 kg/cow.

The medium-term outlook, due to population growth and increasing preference for dairy products, will result in an increasing world demand and rising prices for milk and dairy products. Prices are currently low due to increased supply coupled with reduced exports. World imports are expected to increase by 2.4% (over 1.4 million tonnes) per year with China remaining the main importer.

EU milk production is expected to grow by 0.8% per year until 2025. Deliveries to dairies are expected to grow slightly faster at 0.9% per year as on-farm consumption and direct sales decline.

2.1.2. Business models of farming in Europe

In 2013, there were 10.8 million farm holdings (farms) in the EU, occupying 174 million hectares. The regular agricultural labour force (excluding seasonal workers) comprised of some 22.2 million people.

Employment

In the EU, farms with a sole legal holder employ 86% of the active workforce (as measured in annual work units (AWU)). Farms that are legal entities employ 12% and group holdings employ 2% of AWU.

Between 2010 and 2013 the number of farms fell 11.5% from 12 million to 10.8 million. The annual rate of decline between 2005 and 2013 was 3.7%.

The number of regular agricultural workers fell by 12.8% from 25 million in 2010 to 22 million in 2013. However, the number of full-time equivalent jobs (also called "Annual Work Units" or AWU) fell by just 4.4% over the same period, highlighting an increasing level of employment.

These figures highlight the long-term decline in the number of farms in the EU and gradual consolidation to form larger farms. As part of the consolidation process, the number of regular agricultural workers is declining.

Thirty-one per cent of farmers are older than 65 years, whilst 6% are younger than 35.

Most farmers in the EU have not been formally trained in agriculture: 70% only have practical experience, 20% have received basic training and 8% have attended a full agricultural training course. However, these averages do not reveal wide differences between Member States. In addition, a higher proportion of farmers over 65 years (80%) have no training.

Farm economics

Farm output, as measured by standard output (SO, in Euros per hectare), varies widely between Member States. On an area basis, average standard output in different Member States varies from 527 to 11 095 euros per hectare.

Some of this difference can be attributed to the particular range of farming activities. On an area basis, indoor horticulture generates 46 377 euros of output per hectare across the EU, whereas cereals, oilseed and potato crops generate only 824 euros per hectare on average. However, there are also large variations between Member States in standard output per hectare for each type of activity.

For legal entities, group holdings generate 2 218 euros standard output per hectare, compared to sole holders at 1 939 euros per hectare and legal entities at 1 729 euros per hectare. However more dramatic differences are evident between legal types in terms of output per labour unit

(AWU). Group holdings generate 97 059 euros per AWU, compared to 72 044 euros per AWU for legal entities and 27 930 euros per AWU for sole holders.

The four types of farming producing the most standard output at EU level are dairying; cereals, oilseeds and protein crops; pigs and poultry. These four types are among the most important sectors across most Member States.

However, vineyards are the type of farming producing the most standard output in France and Italy. Sheep, goats and grazing livestock is the most important type of farming in Greece, and outdoor horticulture is the most important type of farming in Malta.

2.1.3. Trends in precision agriculture in the EU

A wide range of enabling technologies for PA are available. These technologies are used for object identification, geo-referencing, measurement of specific parameters, Global Navigation Satellite Systems (GNSS), connectivity, data storage and analysis, advisory systems, robotics and autonomous navigation. First implementations of PA practices already exist in arable, vegetable and dairy farming, but PA technologies can also be applied to other sectors. At the moment, a lot of progress has been made in PA development, and the PA market is fully embraced by the sector and investors, but the full potential of PA has not yet been harnessed.

How does precision agriculture influence policies?		
Policy issue	Description	Effect on policy objective*
Competitiveness of EU farming	Farm holdings will apply PA technologies to produce 'more with less', increasing the competitiveness of farm holdings and agri-food chains. Large farms will benefit the most.	+
Farm holding size and number	Farm size will increase because of the required investments in PA technologies and know how. The number of farms will go down, which is the current trend already.	=
Jobs on farms in primary production	The number of jobs on farm holdings will decrease due to the implementation of PA technologies, especially on farms where still a lot of work is done by low skilled workforces.	-
Skilled workforces	PA requires more farmers skilled in (ICT) and a mature services industry.	+
Business development in agri-food chains	PA offers many opportunities for service industry (sensor industry, ICT, IoT, machine companies) and food companies (processors, logistics, retail) when the PA market grows.	++

Multi-functional agriculture	Farm holdings will focus more on farming when they invest in PA technologies and know how.	=/-
Demographic and rural development	PA may slow down or stop the trend of people leaving rural areas in the EU for better life in cities because it creates new business opportunities and work for highly skilled persons.	+
Food security	Sensor based monitoring systems and Decision Support Systems (DSS) will provide farmers and stakeholders with better information and early warning on the status of crops and animals and improve yield forecasts	++
Food safety	Sensor based monitoring systems and DSS plus track and trace systems will provide farmers, processors and other stakeholders with better information and early warning on quality of food products.	++
Transparency of agri-food chains	See food safety	++
Sustainable production	PA technologies allow the production of 'more with less'. The use of natural resources, agrochemicals, anti-biotics and energy will be reduced to the benefit of both farmers and the environment, thus in turn society.	++
Climate change and action	See sustainable production and Food security. Farmers and stakeholders can detect effects of climate change on agricultural production in an earlier stage and take action.	+
**++ and + are positive, = is neutral or unknown, - and -- are negative effects*		

Table 1. How does precision agriculture influence policies?

2.1.4. Economics and governance of digitalisation and precision agriculture

For the development of precision agriculture practices, question of data management, data ownership and access to open data is of key importance. Special attention is needed for establishing an open data approach throughout the food chain, with adequate standards that facilitate data exchange while preventing misuse of natural monopolies or lock-in effects. 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 harvest the fruits of the analysis of big data.

Rural development policy and regional policy should guarantee access to wide bandwidth in the internet (4G / 5G) and help to find new forms of employment in case agriculture becomes less labour intensive.

Common Agricultural Policy

Four main regulations currently govern the CAP:

(i) Regulation (EU) No 1305/2013 - Rural development regulation;
(ii) Regulation (EU) No 1307/2013 - Direct payments regulation;
(iii) Regulation (EU) No 1308/2013 - Common Market Organisation (CMO) regulation;
(iv) Regulation (EU) No 1306/2013 - Horizontal regulation.

Regional policy

- One step further than the rural development policy there is Europe's regional policy. It is important that not only farmers but also others in the countryside should become fully computer literate and have good access to the internet (by broadband glass fibre or 4G/5G). Our analysis in previous chapters identified the risk that some countries or regions in Europe could face a rural exodus when unmanned tractors are introduced and when some decisions are made at a distant location. Regional policies should accommodate such developments and see how employment can be created in other sectors.

- Article 174 of the Treaty on the Functioning of the European Union aims at reducing disparities between the levels of development of different regions and provides particular attention to rural areas affected by industrial transition. Regulation (EU) No 1303/2013 lays down common provisions on the European Structural and Investment Funds, such as the Regional Development Fund, and the Cohesion Fund which can help regions.

Environmental policy

- ICT will support environmental policy: the environmental impact of agriculture becomes measurable and verifiable by the digitalisation of agriculture (precision measurement). This allows external costs to be internalised even leading to true cost accounting. Environmental policies could force farmers to use ICT to collect more environmental data and have that made available. Using economic incentives in environmental policy (like taxing mineral surpluses at farm level) becomes then an option.

Relevant legislation:

- Council Directive 91/676/EEC (The Nitrates Directive)
- Directive 2000/60/EC (The Water Framework Directive)
- Directive 2001/81/EC (the National Emission Ceilings Directive)
- The Clean Air Policy Package
- Directive 96/61 on Integrated Pollution Prevention and Control (IPPC). This IPPC Directive has been replaced by Directive 2008/1/EC without changing its substantive provisions.

In 2006, the EC came up with an European strategy to combat soil pollution. It concerned a Thematic Strategy on soil protection within a framework directive. However, because several countries believe that soil protection does not belong in an EU law, the EC decided in May 2014 to cancel the Directive.

Food safety policy

- The General Food Law Regulation (EC) 178/2002 provides the general principles of food safety which include the requirement for food businesses to place safe food on the market, for traceability of food, for presentation of food, for the withdrawal or recall of unsafe food placed on the market and that food and feed imported into, and exported from, the EU shall comply with food law.

Competition policy

- The EU competition policy concerns the internal market of the EU. It involves rules for fair competition between companies and therefore aims at anticompetitive behaviour, reviewing mergers and state aid, and encouraging liberalisation. The EU legislation concerning liberalisation is based on Article 3 of the Treaty on the Functioning of the European Union (TFEU).

Innovation policy – research and science

- The seven-year EU Horizon 2020 research programme should further support the development of ICT-innovation for agriculture and the food sector.

- Besides supporting innovation developments in priority areas and in SMEs, mainly through Horizon 2020, the EC also fosters the broad commercialisation of innovation in the EU by means of public procurement for innovation, design for innovation, demand-side policies for innovation, public sector innovation and social innovation. Furthermore, European Innovation Partnerships (EIPs), which have also launched in agriculture, are a new approach to EU research and innovation.

Industrial policy

- The legal basis of the industrial policy is Article 173 of the TFEU. In its communication 'Preparing for our future: Developing a common strategy for key enabling technologies in the EU' (COM (2009) 0512), the Commission stated that the EU would foster the deployment of Key Enabling Technologies (KETs).

- In January 2014 the Commission launched the communication 'For a European Industrial Renaissance' (COM (2014) 0014) focusing on more coherent polices in the field of the internal market, including European infrastructure such as information networks, as well as for goods and services. To support achieving its policy goals the EC manages the following support programmes: COSME (programme for the competiveness of enterprises and SMEs), Horizon

2020, Galileo and Copernicus. The EU industrial policy also supports the protection of Intellectual Property Rights (IPR).

Poperty rights

- For promoting innovation, employment and improving competitiveness, the protection of intellectual property is important for the EU. In 2011 the EC adopted a comprehensive IPR strategy, which also includes patents. The purpose is to make innovation cheaper and easier for business and inventors in Europe.

Data policies

- Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data is relevant for policy of the EU on data. The Regulation aims to strengthen citizens' fundamental rights in the digital age and facilitate business by simplifying rules for companies in the Digital Single Market.

Open data

- The Directive on the re-use of public sector information (Directive 2003/98/EC, known as the 'PSI Directive') entered into force on 31 December 2003 and was revised by Directive 2013/37/EU. The Directive is focused on the economic aspects of the re-use of information rather than on the access of citizens to information. Member States were obliged to transpose Directive 2013/37/EU by 18 July 2015.

2.1.5. Environmental impact of precision agriculture

Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD). This regulation lays down general rules governing Union support for rural development, financed by the EAFRD and established by Regulation (EU) No 1306/2013.

The relevant rules are:

Article 14 (Knowledge transfer and information actions): Member States could facilitate, for instance, the sharing of relevant PA experiences on decision making and impact measurements.

Article 15 (Advisory services, farm management and farm relief services): This measure includes advice for the delivery of best agronomic practices and integrated pest management, linked to the economic and environmental performance of the agricultural holding. These elements can be embraced by PA.

Article 17 (Investments in physical assets): This measure applies to farm modernisation and intensification.

Article 28 (Agri-environment-climate): This measure supports farmers willing to carry out operations related to one or more agri-environment-climate commitments, shifting towards more environmentally sustainable farming systems. It is also possible to propose measures that engage the whole farming system in holistic approaches where farmers are paid for applying a number of agronomic practices in combination. It relates to commitments for both livestock and cropping systems. PA may provide agronomical and environmental justifications for that measure.

Article 35 (Cooperation): Cooperation can relate to pilot projects, joint action undertaken with a view to mitigating or adapting to climate change and joint approaches to environmental practices including efficient water management. PA may contribute to these requirements.

In addition, precision irrigation strives to make efficient use of water in terms of timing and location. This can be considered under:

Article 46 (Investments in irrigation): Investments that ensure effective reduction of water use, the improvement of existing irrigation installations including water metering and measurement of water use can be considered as the basis for precision irrigation.

More general activities in terms of technology transfer and exchange or transfer of information from research, field experience or other industrial sectors, can be stimulated under the following articles:

Articles 55, 56 and 57 (European Innovation Partnership Network EIP)

EU Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (the Nitrates Directive 1991) 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. It requires the establishment of action programmes to be implemented by farmers within Nitrate Vulnerable Zones (NVZs) on a compulsory basis. These programmes must include:

- measures already included in Codes of Good Agricultural Practice, which become mandatory in NVZs; and
- other measures, such as limitation of fertiliser application (mineral and organic). These must take into account crop needs, nitrogen inputs and soil nitrogen supply, and the maximum amount of livestock manure to be applied (corresponding to 170 kg nitrogen/hectare/year).

Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (Annex 1) establishes specific measures as provided for in Article 17(1) and (2) of Directive 2000/60/EC in order to prevent and control groundwater pollution. The Directive also complements the provisions preventing or limiting inputs of pollutants into groundwater already contained in Directive 2000/60/EC and aims to prevent the deterioration of the status of all bodies of groundwater. **EU Directive 2000/60/EC** sets out general provisions for the protection and conservation of groundwater.

EU Directive 128/2009/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. IPM is based on dynamic processes and requires decision-making at strategic, tactical, and operational levels.

EU research and Innovation programmes (EU-Agriculture R&D, 2016)
Research and innovation will be financed mainly by two funding streams: **Horizon 2020** (research & innovation) and the **Rural development policy** (innovation):

- The EU nearly doubled its efforts with an unprecedented budget of nearly 4 billion euros allocated to Horizon 2020's Societal Challenge 2 'Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy'. Aside from Societal challenge 2, several parts of Horizon 2020 are of interest to agriculture, forestry and the agri-food chain.

- In synergy, the EU has set 'Fostering knowledge transfer and innovation in agriculture, forestry and rural areas' as the first priority for the Rural development policy 2014-2020. Rural development programmes will finance agricultural and forestry innovation through several measures which can support the creation of operational groups, innovation services, investments or other approaches.

In those two funding streams there are nine programmes of greater interest to innovation in agriculture, food and forestry. In these programmes there is ample scope to deal with issues of components that relate to Precision Agriculture and improved good agricultural practices.

Process	Technique	Expected environmental gains
Timeliness of working under favourable weather conditions	Automatic machine guidance with GPS	Reduction in soil compaction Reduce carbon foot print (10% reduced fuel consumption in field

		operations)
Leave permanent vegetation on key location and at field borders	Automatic guidance and contour cultivation on hilly terrain	Reduction of erosion (from 17T/ha. Y and perhaps lower) Reduction of runoff of surface water and fertilisers Reduced flood risk
Reduce or slow down water flow between potato/vegetable ridges to slow water	Micro dams or micro reservoirs made between ridges ("tied ridges") Ridges along field contours	Reduced sediment runoff Reduced fertiliser runoff
Keep fertilisers and pesticides at recommended distances from water ways	Automatic guidance based on geographic information Section control of prayers and fertiliser distribution	Avoidance/elimination of direct contamination of river water
Avoid overlap of pesticide and fertiliser application	Section control of sprayers and fertiliser distribution	Reduce/avoid excessive chemical input in soil and risk of water pollution
Variable rate manure application	On-the-go manure composition sensing Depth of injection adjustment	Reduced ground water pollution Reduced ammonia emissions into the air
Precision irrigation	Soil txture map	Avoidance of excessive water use or water logging Reduction of freshwater use
Patch herbicide spraying in field crops	Weed detection (on lie/weed maps)	Reduction of herbicide use with map-based approach (in winter cereals by 6-81% for herbicides against broad leaved weeds and 20-79% for grass weed herbicides) Reduction of 15.2-17.5% in the area applied to each field was achieved with map-based automatic boom section control versus no boom section control
Early and localised pest or disease treatment	Disease detection: - Multisensor optical	Reduction of pesticide use with correct detection and good

	detection - Airbonce spores detection - Volatile sensors	decision model (84.5% savings in pesticides possible)
Orchard and vineyard precision spraying	Trees size and architecture detection Precision IPM	Reduction in pesticide use of up to 20-30% Reduction of sprayed area of 50-80%
Variable rate nitrogen fertiliser application according to crop requirements and weather conditions	Crop vegetation index based on optical sensors Soil nutrient maps	Improvement of nitrogen use efficiency Reduction of residual Nitrogen in soils by 30 to 50 %
Variable rate phosphorus fertiliser application according to crop requirements and weather conditions	Crop vegetation index based on optical sensors Soil nutrient maps	Improvement of phosphorus recovery of 25%
Crop biomass estimation	Crop vegetation index	Adjust the fungicide dose according to crop biomass
Mycotoxin reduction	Crop vegetation index and fungal disease risk	Optimisation of fertilisier dose and fungicide use on the basis of higher disease risk in areas with crop density

Table 2. Expected environmental gains from main PA processes and techniques

2.1.6. Skilled workforces and precision agriculture

Workforce and skills aspects are critical for the further development of the farming sector in the EU. Farming in the EU faces many challenges: financial crises, global competition, climate change and rising costs have all put pressure on the farming community. Historically, in response to these challenges the EU created the Common Agricultural Policy (CAP) in 1962, presented as a 'partnership between agriculture and society and between Europe and its farmers' (European Commission, The European Union Explained, 2014).

The original aim of the CAP was to improve agricultural productivity, creating a stable supply of affordable food for consumers and to ensure that EU farmers could make a reasonable living. However, in 2013 the CAP was reformed in response to the more recent challenges of food security, climate change and sustainable management of natural resources and the countryside across the EU in order to keep the rural economy alive. Furthermore, recent

Eurostat figures suggest that the farming population is aging, and many young people no longer see farming as an 'attractive profession' (European Commission, The European Union Explained, 2014). In 2012, the EU's Directorate-General for Internal Policies stated that 'barely 6 % of EU-27 holdings are owned by farmers under 35 (around 5 % in the EU-15 and 7 % in the EU-12). Despite the limitations of the statistical information, the number of young farmers seems to have declined steadily in all countries. Moreover, the prospects for the future may be even bleaker' (DGIP[1], 20122). Young people have become distanced form the way that our food is produced and, with more and more of our population living in urban centres, finding new ways to attract young people into the agricultural sector is becoming increasingly difficult.

Recognising the serious nature of this problem, the reformed CAP 2014-2020 introduced new and strengthened measures to encourage young people to set up in farming, including various forms of financial support. Some measures are obligatory for Member States, such as the 'Young Farmer Scheme', where young farmers receive a 25% supplement to the direct aid allocated to their farm for a period of five years.

In a report published in 2010, Mark Shucksmith[2] identified one of the most pressing issues for the future sustainability of rural communities as 'the exodus of young people.'

There is a cross-relationship between rural youth and those who are Not in Education, Employment or Training (NEET). The differences in defining NEET amongst EU member states make it difficult to draw cross country comparisons. Forming a central role in European Policy debate NEET has recently been mentioned in both the Europe 2020 agenda and the 2012 Employment Package.

2.2. Scenarios helping to identify future opportunities & concerns, and related legislative issues

In order to explore possible future impacts and developments, and to identify related possible areas for opportunities and concerns which may appear in the coming decades, a foresight exercise has been organised with technical experts, foresight specialists, a diverse group of selected stakeholders (including farmers' and agricultural machinery representatives, NGOs, and EP staff working in the area), and assistants of MEPs involved in the work related to CAP. This exercise led to the development of a set of alternative scenarios, describing possible (extreme) futures of agriculture in Europe. These fictional and exploratory scenarios have been entitled:

1. 'Economic optimism', being centred on purely economically driven development under

the paradigm of free markets;

2. **'Global sustainable development'**, being characterised by a supra-national push towards sustainability;
3. **'Regional competition'**, based on the paradigm of a fall-back to a state of competing regions; and
4. **'Regional sustainable development',** characterised by the principle of sustainability realised in tightly knit local communities.

The role of these scenarios is to capture the main opportunities, concerns, hopes and fears of the participating stakeholders. They are summarised in this chapter, with further detail presented in Annex 2 of this report.

The scenarios were then used for exploring possible future hopes and opportunities, as well as concerns or fears, that society might hold about those futures, especially in the area of skills for farmers and on sustainability of farming practices.

In addition, the participants identified a first set of policy areas which might be relevant to take these possible future concerns and opportunities into account in today's agricultural policy discussions in the European Parliament. These policy options will be presented in a separate document listing legal instruments at our disposal (as well as those still needing to be developed) to anticipate possible concerns and opportunities regarding PA.

Scenario 1 – Economic Optimism

This first fictive scenario, developed as an exploration tool, has the following main characteristics:

- main objective: economic growth;
- very rapid economic growth;
- rapid technological development;
- rather slow population growth;
- increasing worldwide trade globalisation/free trade;
- PA and other technologies are implemented for the sole goal of higher efficiency;
- PA develops fully, up to the point of autonomous robots and controlling farms (resulting in loss of jobs); and
- policy and legislation create open markets.

Market dynamics play a central role, trade is free and ever more global, and the company is booming. People rely heavily on technology and witness rapid technological developments. They place trust in technological development and the mechanisms of the market to solve problems, now and in the future. New technologies see fast breakthroughs, meeting little resistance, and technological innovation mainly takes place in the private sector. The market mechanism governs developments and bring about increasing risks and phenomena of economic and social inequality. Although there is free trade, the resulting differences in income determine the global access to technology. However, people have faith that technology will in the end – in combination with the market mechanisms – be able to solve issues in the environment as well as social and economic inequality. For example, global food security has improved. And, as long as they show return on investment, technological applications will continue to break through and be rolled out.

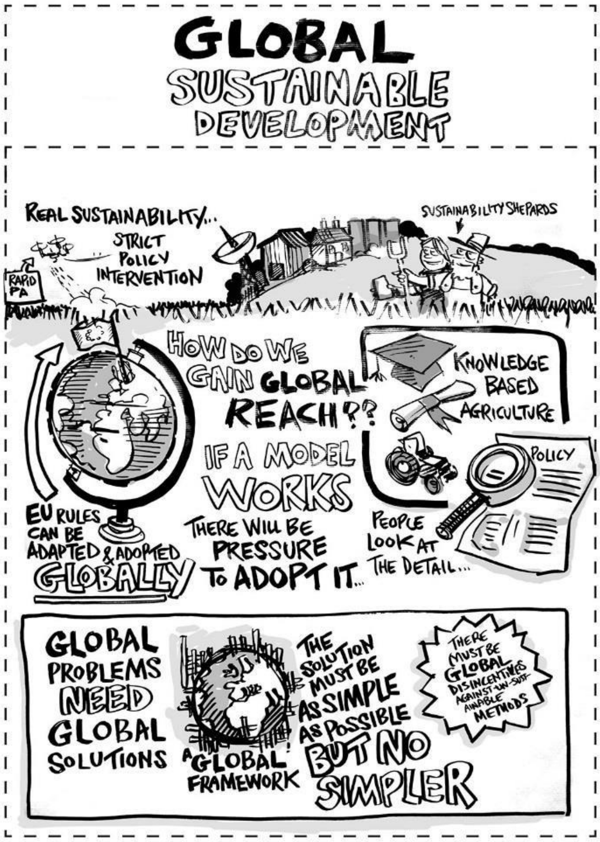
A lot of agriculture has moved outside Europe and new ‘free’ locations are being used. Agriculture left in Europe is fully automated, up to the point of autonomous robots and controlling farms, and PA and other technologies are implemented for the sole goal of higher efficiency.

Scenario 2 – 2050: Global sustainable development

This second fictive scenario, developed as an exploration tool, has the following main characteristics:

- main objective: global sustainability;
- strong economic growth;
- (relatively) slow (global) population growth;
- medium rapid technological development;
- worldwide trade/globalisation/free trade;
- strong global governance - government sets sustainability frameworks and targets;
- increasing regulation intensity;

- governments push for behavioural change;
- PA breakthroughs relate to sustainability and equality issues; and
- PA develops fast, semi-autonomous technologies on most farms (cannot take jobs – farmers in role of sustainability shepherds).



The protection of the environment and the combat of inequality are of highest importance. These targets are achieved through global cooperation, clear political frameworks, efficient technology and sometimes even behavioural change aimed at sustainability. Sustainability, equality and justice are at the core. Technology contributing to these targets will be adopted. People will therefore be mainly looking for and investing in technologies contributing to “a better world” according to these criteria There is global governance by strong international institutions and legislation but applied as frameworks and targets that are then realised by the actors “on the ground”.

PA is pushed forward and developing rapidly where it clearly drives sustainability of agriculture forward and is strongly regulated. It can be found in the city, in the shape of vertical farms, and in the countryside, where every plot of land is attributed to a specific use, be it food production or conservation of nature and biodiversity.

Scenario 3 - 2050: Regional competition

This third fictive scenario, developed as an exploration tool, has the following main characteristics:

- main objective: security;
- slow economic growth;
- rapid population growth;
- slow technological development;
- trade barriers;
- strong national governments;
- to save time and produce more, technology is pushed and accepted in PA;
- we want ‘real’ products, but when needed, to be self-sufficient, modification is allowed; and
- farmers are seen as important members of the community.

Regions (groups of countries, countries or regions within countries) have taken over. They concentrate on their own interests and regional identity, which has caused some interregional or intercultural tension and has made exploiting advantages of scale impossible.

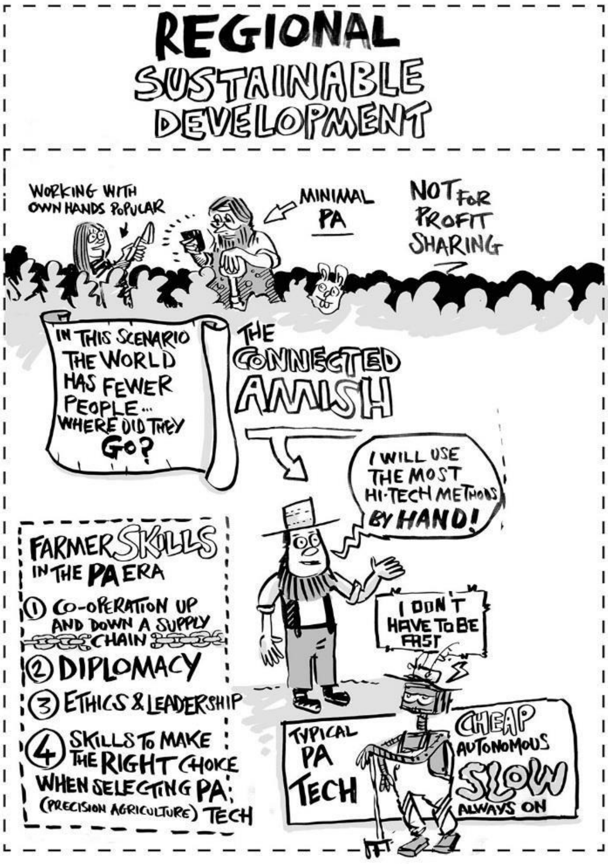
Security is paramount and technologies that have not proved themselves in this respect, or technologies promising fast and large-scale change, are not adopted. Instead, technology for efficiency and security is invested in heavily. The local food supply is, for example, based on the principle of national or local independence, with the environmental in second place.

PA is utilised to stimulate regional growth and production. Because of the regional scale being dominant and because of society´s demand for food security, some genetic manipulation of plants, soil and weather is accepted, but only when highly monitored. Farmers are regarded as the main assets to make sure we are self-sufficient as a region.

Scenario 4 - 2050: Regional sustainable development

This fourth fictive scenario, developed as an exploration tool, has the following main characteristics:

- main objective: regional sustainability;
- medium to slow economic growth;
- medium population growth;
- slow technological development;
- trade barriers;
- local management, local actors; and
- PA used for food security and sustainability goals.



For problems with the environment and social inequality, solutions are sought at the regional level. The key is a drastic change of lifestyle and decentralisation of government. Everywhere, the main focus is on one´s own region – because everyone believes that this is where sustainability can be realised. Decisions arise from idealism rather than fear, the communities are sotrong and tightly knit. Overall, the paradigm is about small-scalechange, and while this has been successful in many respects, the advantages of large (international) scales could not be realised

PA is employed to produce more sustainably and to decrease environmental impact. It has made progress, but farms are not fully automated, due to lack of scale and a generally slower technology progress

2.3. Concerns and opportunities for European policy regarding PA

2.3.1 Overall concerns and opportunities

The main concerns and opportunities for policy and legislation for PA, as identified in the foresight exercise, are presented in Table 3. They have been grouped under different issues: environmental, societal and cultural, economic, technological, and (geo-) political.

The particular scenario(s) where they are most relevant are indicated

Scenario 1 - Economic optimism,

Scenario 2 - Global sustainability,

Scenario 3 - Regional competition,

Scenario 4 - Regional sustainable development.

Concern	Opportunity	Scenarios			
		1	2	3	4
Environmental issues					
Neglect of environmental issues, loss of biodiversity and therefore potentially even higher risk of natural disasters	Use PA technology to enhance biodiversity, e.g. via mixed cropping; use PA to become more environmentally friendly; conserve back up technology and create seed banks as a back-up; and stimulate external markets	X		X	
Possible health threats because of lack of diversity as a result of monocultures or closed borders	Secure biodiversity, for example through seed banks; encourage international trade; and precision consumption: choose/control your food supply from home	X		X	X
Societal and cultural issues					
Disconnect between humans and nature, less understanding of and concern for nature	Use technology, and communication technology specifically, to give consumers insight in where food comes from (apps, websites, social media); and precision consumption: choose/control your food supply from home	X			
Social unrest because of high inequality, either between people or between regions	Use PA to create more data and better insight or information for decision making, to produce efficiently, and to create new economic growth	X		X	X
Loss of privacy (and rise of security issues)	Inform and educate people and companies about privacy issues in the context of digitalisation	X		X	X
Resistance to new technologies might be an obstacle for the uptake of PA	Inform and educate on positive possibilities, also showcasing international best practices		X		X
Loss of traditional knowledge and know-how	Use new technologies to conserve traditional knowledge and combine traditional knowledge with PA technologies	X	X	X	
Little trust in government and institutions	Keep in contact with/maintain close cooperation with farmers and grass-root organisations	X		X	X
Save traditional production	Farmes need support and skills to manage mistakes; and policy agility	X		X	X
Micro-management, because of which farming is no longer an attractive profession; and bureaucracy might slow down changes and technological breakthroughs	Avoid micro-management and overregulation; and keep in contact with/maintain close cooperation with farmers and grass-root organisations		X		

Report developed in the frame of the project "Precision Agriculture System to limit the impact on the environment, on health and on air quality of grape production WINEGROVER"- LIFE19 ENV/IT/000339

Little trust in government and institutions	Keep in contact with /maintain close cooperation with farmers and grass-root organisations	X		X	X
Economic issues					
Smaller farmers not being able to keep up with new technologies because of lack of knowledge or investment capital; large digital divide between big and small farmers	Use PA to create new business models and new economic opportunities			X	X
Monopolies, because all data is in the hands of big companies and production is focused on efficiency and economic gain	Free exchange/knowledge and idea flow in innovation, and rapid technological development	X			
Uneven access to technology because of high investments being necessary, or because of closed borders	Stimulate new forms of financing like crowd sourcing; stimulate international exchange of knowledge and ideas; encourage global collaboration; and stimulate new forms of cooperation between farmers and farms (with each partner having specialised knowledge or equipment, leading to a new concept of a cooperative enterprise)	X		X	X
Human labour disappears from farms, strong loss of jobs	More efficient production and new employment opportunities because of new technologies	X		X	X
Regional fragmentation might impact the export sector negatively; lack of scale might slow down innovation	Stimulate knowledge, data and innovation sharing, keep knowledge available; technology as a tool needs government support; and policy agility and policies that allow for regional diversification			X	X
Loss of human labour because of robots	Encourage 'smart' human-robot task-sharing	X	X		X
Strong variation between standards in sustainability	Develop a common international standard for measuring and monitoring sustainability, gain insight into which technologies really contribute (and how) to sustainability; evidence-based standards; and policy agility		X		X
Technological issues					
Big differentiation between standards and types of data	Develop a common international standard for creating and sharing data, avoid centralised data; and need for data hygiene		X		X
(Geo-)political issues					

Vulnerability to "techno-overlords"	Make sure to keep up with new developments, understand technology	X			
Lock-in effect, high dependency on technological systems	Create safe, reliable systems and contingency plans	X		X	X
Dependency on non-European countries for (production of) new technologies	Keep good relations with technology front-runners, create a supportive environment for R&D into new PA technologies, and encourage global collaboration	X		X	x
Vulnerability to cyber-attacks and hacking the food system	Invest in security and work together with hackers	X		X	X
Regional fragmentation and lack of scale result in high risks in case of extreme events	Contingency plans; dealing with variability and diversity; policy agility; protect local environmental concerns; and safety net for disasters between communities			X	X

Table 3.Concerns and opportunities in the different scenarios

2.3.2. Specific analysis regarding skills and education for PA

2.3.2.1. Skills needs in the four selected exploratory future scenarios

The specific skills that will be needed in each scenario are summarised in Table 4:

Scenarios Skills needs	1 – Economic Optimism	2 - Global Sustainable Development	3 - Regional Competition	4 - Regional Sustainable Development
Technological expertise	X	X	X	X
Legislative expertise	X	X	X	X
Local community leadership		X	X	X
Business management	X		X	X
Innovation management	X		X	X
Entrepreneurship	X		X	X
Marketing skills	X		X	X
Combine traditional and precision agriculture			X	X

Knowledge on sustainability		X		X
Security, monitoring expertise			X	
'Sustainability shepherd' role (farmer to ensure sustainability in the community)		X		
Genetics expertise	X	X		
Expertise in circular agriculture		X		
Knowledge of local ecosystems		X	X	X
Mentor farmers pass on knowledge in traditional agricultural approaches				X

Table 4. Skills needs in the scenarios

Table 4 highlights the wide range of skills a successful farmer (or combination of specialists and farmers) will need in the future. However, the portfolio of particular skills varies according to the scenario.

'Scenario 1 - Economic Optimism' is exceptional in that the profession of a farmer as we know it today hardly exists4. Most farms are highly automated with only a few low-skilled manual jobs for tasks that are not automated. A few specialists provide the skills indicated in Table 3. As well as technological and legislative expertise, the entrepreneurial skills (business management, innovation management, entrepreneurship, marketing) are particularly important in this scenario.

In 'Scenario 2 - Global Sustainability', governments heavily control farming and entrepreneurial skills are therefore less important. In addition to the three key areas of technological expertise, legislative expertise and local leadership, the various sustainability skills will be of particular importance.

In 'Scenario 3 - Regional Competition', farmers are important members of the rural community and have to produce feed efficiently and self-sufficiently. Technological, legislative, leadership and entrepreneurial skills are all required. Farmers must also be able to combine traditional and PA farming methods and be knowledgeable on both security and food security issues, and also on local ecosystems.

In 'Scenario 4 - Regional Sustainable Development', the focus is on cooperation and local sustainability. Leadership, sustainability, entrepreneurial skills, and combining traditional and PA technologies are all important. Technology and legislative expertise are required, but technological progress is limited by the focus on sustainability and also by restricted possibilities for economies of scale.

2.3.2.2. Three clusters of PA-related skills

Comparing the skills needs in the different scenarios, three key areas of expertise, or clusters of skills, become apparent. Technology expertise and legislative expertise are required in all scenarios, and local community leadership is needed in all but scenario 1. Table 5 shows more detail on the specific skills clusters that fall under each of these three key areas of expertise.

Technological expertise (relevant in all scenarios)	Legislative expertise (relevant in all scenarios)	Local community leadership (relevant in all scenarios but scenario 1)
• Work with robots/automation technology • Work with data/data skills (data science) • Choose right technologies or solutions • Low waste production • Diverse high-tech production skills	• Understanding legislation • Knowledge of the laws/anticipating changes • Dealing with bureaucracy • 'Diplomacy' and 'people skills' in working with institutions	• Knowledge of regiona potential and regional growth • Insight into local needs • Communication • People management/'people skills' • Sense of solidarity with and responsibility for the community

Table 5. Clusters of skills relevant to three key areas of expertise

2.3.2.3. Conclusions on skills and education

From the skills needs identified in the different scenarios, four main conclusions can be drawn regarding skills and education:

1. A strong push for increased education in farming, especially in high-tech skills, would be required under all scenarios in order to achieve significant progress with PA. A greater level of continuous and life-long learning would be necessary to keep up with the speed of expected technological developments.

Such an "education push" could also help to improve the image of jobs in farming, which is seen as critical to ensure that younger people are attracted to the profession. If farming is seen as being more knowledge-based and high-tech, it may become more attractive to new entrants.

As is clear from the list of skills needs in Table 5, the traditional role of farmers is changing in all scenarios and may help to attract young professionals with more diverse interests such as technology, business and the environment. Roles such as "sustainability shepherd" (where the farmer is seen as the key person to ensure sustainability in the community) or “expert on local ecosystems” may carry a high status as the person is seen as having a high level of competence in the particular field, rather than as merely a farmer in the traditional sense.

2. Not only are new skills needed, but also new forms of learning. Generally, education is undergoing a paradigm change, where new forms of learning are increasingly used. Examples are trends towards:

- virtual and blended learning (blended learning brings 'traditional' face-to-face learning and virtual learning together);
- MOOCs (Massive Open Online Courses), as offered by leading universities and independent education providers, either free or at a cost; and
- peer-to-peer learning, where anyone has the opportunity to teach a topic within their area of expertise, without having a formal teaching qualification. This is offered by, for example, Peer 2 Peer University5.

A rollout of such education forms in the agricultural sector can enable and accelerate the necessary skills push. An example is new education forms that focus on the role of experienced farmers as mentors, as indicated in Table 5. Other forms can be knowledge sharing mechanisms, or bite-sized virtual or blended training programmes (e.g. apps for learning via a smartphone, or combined forms of technology-based distance learning and traditional face-to face learning).

Such new approaches may be particularly useful for farmers and agricultural workers on smaller farms, who often find it challenging to participate in possibly costly and time-intensive traditional training forms. Access would be encouraged by targeted incentives and support programmes.

3. Overall education for agriculture and food production needs to be re-examined in order to respond to the challenges of rapid technological progress, the need for sustainability and a decline in students attending agricultural colleges and universities.

Structural changes, including the closure of agricultural colleges and mergers with other educational institutions, have changed the layout of this educational sector. Given the magnitude of the challenges for the sector and the increasing skills needs as outlined in the scenarios, this calls for the renewal of the agricultural education sector to provide the skills needed in the future.

4. There is a need to improve the education of the general public on modern agriculture and food production. Although this does not relate specifically to skills for

farming, the general public often struggles to understand and appreciate the complexity of new farming methods and the role of agriculture in society and with regard to the environment. Such a lack of understanding can lead to a tendency to disagree with the uptake of new technologies, which is a risk to the future development of European agriculture.

2.3.3. Overall remarks on opportunities and concerns

2.3.3.1. A major policy concern: future ownership of data is central

The clear main policy concern identified by the experts stems from the insight that the future of PA will probably be dominated by data exchange, and that platforms will be used for this data exchange. In this development, those who own the data can direct and control the data sets, are in the central position of power, and create the added value and earn a major share of income generated in agriculture. Thus, the most critical issue for the future of PA and farming in Europe lies in future ownership of data and control of these platforms, and, secondarily, in issues concerning privacy. These issues are relevant in every scenario. In 'Scenario 1 – Economic Optimism', big companies are in charge of the data; in 'Scenario 2 – Global Sustainable Development' it is the government; in 'Scenario 3 – Regional Competition', local governments may not own the data, but at least have access to all of the data; and in 'Scenario 4 – Regional Sustainable Development', people and businesses own their data, but also share data easily. This topic was clearly the strongest worry as it concerns power shifts in the sector, and it is listed as the top priority for policy and legislation. It was also stressed by the experts that the specific context of European farming plays a role here: European agriculture is characterised by diversified farming with many high-quality products, the value of which depends strongly on data (from food safety, tracing and tracking to brands, organic food, etc.). In addition, Europe has innovative, highly skilled farmers, and a large and leading specialised machinery industry. These characteristics and strengths combined with existing initiatives on e.g. pushing digitalisation in Europe provide a competitive starting point. At the same time, the pressure from developments in Silicon Valley or other leading high-tech regions means that a strong effort is needed in order to ensure that 'control over data' from the European agricultural sector does not lie increasingly outside of Europe.

2.3.3.2. Public perception of precision agriculture

Another major concern of the experts was the question of the image of PA and future farming, which in public discourse seems to be dominated by the idea of a farm transformed into a ‘control room’ with many computer screens and a farmer making decisions and 'running the farm from behind those screens'. What is lacking from this image is the possibility that new technologies might not be large- scale and thus costly, but rather could also be “slow and precise, plus small and cheap”, as described by one of the experts. This means that, for example, while today, machines for planting, irrigation or harvesting often still have to be controlled by farmers and thus there is a certain amount of time (per day) that these machines can operate, this could change because of autonomous systems. If the machinery becomes autonomous, they might have more time (day and night for example) to perform the same tasks, but in a more precise and maybe even slower manner. Also, while many people envision big machines and robots operating the farm, we already see, for example in drone-technology, that there are many small and relatively cheap versions available. In addition, not all forms of PA have to be machinery-based: especially in developing countries, we find examples of PA where with use of data (internet of things, data-analyses), PA is practised but the tasks of planting, harvesting, irrigation etc. are performed by people. There is thus a need to better convey those alternative images of future farming in public dialogue, while also stressing the potential e.g. for smaller farms.

2.3.3.3. Reflections on the future uptake of precision Agriculture

Looking at the portfolio of scenarios resulting from this process, it becomes clear that the pressing question currently is probably not which forms of PA or which specific technologies will be used in the future. Rather, the key question is to what extent, for what goals and for whose benefit they will be used.

Comparing the scenarios, it is obvious that the main purpose for which PA is used will change, but PA progress as such is not questioned.

PA thus has the ability to achieve a combination of economic, social and environmental objectives. For example, in 'Scenario 1 – Economic Optimism', PA is used for economic purposes, and mainly by larger, international corporations. In 'Scenario 2 – Global Sustainable Development', PA is used for environmental and sustainability purposes and is regulated strongly by the government. In 'Scenario 3 - Regional Competition', PA is mainly used to ensure food security and food safety. In 'Scenario 4 – Regional Sustainable Development', PA has to establish sustainability on a very local level in combination with traditional knowledge and human labour.

2.3.4. Possible implications for legislation

Concerning the implications or concerns for legislation, a number of aspects were highlighted:

- As highlighted above, the clear main policy concern identified by the experts stems from the insight that the future of PA will probably be dominated by data exchange and the respective platforms. It will thus be critical to create respective policies and legislation that ensure that data ownership and benefit from use of PA is directed where desired, according to political goals.
- There is a high risk that European farming becomes dependent on non-European production for technology and machinery for PA. This development is seen as very likely and a challenge resulting from all scenarios apart from 'Scenario 2 – Global Sustainable Development' (where global coordination solves the problem).
- Like every other technology, the introduction and uptake of PA will require new skills to be learned by farmers. At the very least, this comes down to an understanding of the technology and its possibilities. In 'Scenario 1 – Economic Optimism', a farmer will have to 'develop into an IT-firm' to survive. In the other scenarios, farmers need to at least know how to acquire the right services from other companies to profit from PA. In the scenarios '3 – Regional Competition' and '4 – Regional Sustainable Development', there is a need for creating a combination and synergy between PA and traditional agricultural and local knowledge. Also, in these scenarios, farmers can become local 'heroes' and community leaders. Skill sets that are of increasing importance under such conditions therefore range from technological expertise and legislative expertise to leadership skills. An education push is needed, pushing not only for a diffusion of new skills, but also utilising new forms and media for learning, thereby renewing the agricultural education sector.
- It is expected that precision agriculture and further digitalisation and automation might lead to a weaker relationship between humans and nature. However, it is also possible that new technologies lead to giving people more insight in nature and food production because it enables them to track and trace the products that they consume.
- Uptake of PA might lead to a rapidly growing digital divide between small and big farmers, because smaller farmers might lack the investment capital or knowledge to acquire PA technologies. This is obvious in 'Scenario 1 – Economic Optimism', where technologies and free market principles 'take flight'. If this is to be prevented, we expect that strong governmental intervention will be needed, like that described (in extreme form) in 'Scenario 2 – Global Sustainable Development'. However, in 'Scenario 3 – Regional Competition' and 'Scenario 4 – Regional Sustainable Development', the digital divide is less of an issue because of the regional scale and lack of economies of scale.

- The introduction and uptake of PA might lead to loss of jobs, with human labour potentially being increasingly replaced by robots and computers. In 'Scenario 1 – Economic Optimism', this is the case because human labour is too expensive in comparison to technological solutions, which could very well also be the case in 'Scenario 3 – Regional Competition'. In the scenarios '2 - Global Sustainable Development' and '4 – Regional Sustainable Development', it is very possible that sustainability goals will encourage farmers to work increasingly with machines rather than humans. In every scenario, it is very likely that machines will do dangerous and challenging physical work within ten years.

Concerning what the 'key levers' for legislation and policy are, to push for the respective directions of a scenario, several prototypical 'roadmaps' of policy and legislation directions are obvious:

- For the'Scenario 1 - Economic Optimism', legislation towards free, global trade (agreements) is a prerequisite. The principle is to 'let market mechanisms decide' and thus reduce governmental intervention to a minimum; loosened data security regulation and privacy standards play a key role. Large investments in technological innovations would be needed, as well as a strong alliance with science and technology institutes (if one wanted to push for this scenario direction, which was regarded as generally not desirable by the group of experts).
- In contrast, the 'Scenario 2 - Global Sustainable Development' relies on strengthened government, especially on strong, international political alliances. A global framework for sustainability standards would need to be developed and legislation and policy would have to push for behavioural change towards sustainability.
- 'Scenario 3 - Regional Competition' would also rely on strengthened policy and legislation influence, but on the national and regional level. The focus here would be on security and privacy, with strong measures to protect people and organisations, but allowing for differentiation in the regional implementation of policy.
- 'Scenario 4 - Regional Sustainable Development' instead relies on an alliance between government, business and academia at the local level. Here, policy and legislation would need to focus on support for local and regional developments and approaches and would have to connect with bottom-up movements, as well as to stimulate alternative forms of agriculture and to create self-sufficiency incentives.

However, as a concluding remark, we would like to stress that we regard it as critical for the next phase of 'legal backcasting' to look at the implications across the scenarios, and not only at each scenario in isolation. First and foremost, this means taking account of the main policy and legislation concerns emerging from all scenarios, which centre on future ownership of data.

In addition, we would like to suggest that the question of which direction is to be set by policy and legislation for future PA in Europe would benefit from a broader dialogue between government, industry, citizens and all other stakeholders. However, the scenarios as presented here already provide a solid overview of potential directions and skills needs concerning PA in Europe, produced via a systematic process and integrating the views of numerous leading experts. They can now be utilised for the next phase of the project, in which implications for legislation will be analysed further. Furthermore, a wealth of materials and long-term perspectives on the topic is now available and can be utilised for potential follow-up or related studies.

2.3.4.1. Possible points of attention regarding precision agriculture for CAP

- Income support or support implementation and development of precision agriculture to reduce environmental impact
- Stimulate the conversion to precision agriculture by support for advances:
  - into feasible techniques (not necessarily only large complex machines)
  - practiced by trained farmers around the world
  - irrespective of the scale of farming

Precision agriculture, and the digitalisation of agriculture, has implications for the CAP but also for other EU policy domains:

- Environmental policy (better measuring);
- Regional policy (alternative employment);
- Competition policy (platforms);
- Science and innovation policy;
- Digital policy (data ownership etc.);
- Education and training in rural areas;
- Industrial policy (machineries, Industry, Research and Energy (ITRE).

A list of legal instruments related to precision agriculture is the topic of a related Policy Briefing, published separately. In addition, the six detailed technical briefing papers as well as the detailed description of the four exploratory scenarios used to explore possible opportunities and concerns are published as an annex to this report.

2.3.5. Main conclusions

Overall, the conclusions drawn from the foresight exercise can be summarised under the four main guiding themes:

- Food security and food safety;
- Environmental sustainability of farming;

- Societal changes and technology uptake in agriculture;
- Skills and education for farmers.

Further, some reflections are included regarding the diversity of agriculture throughout the EU.

2.3.5.1. Food security and food safety

PA can actively contribute to food security and food safety

In all scenarios envisaged, whether optimistic (global sustained economic growth), pessimistic (recession, depression, end of globalisation) or disruptive (break-up of the European Union), food security and food safety were central. This is of course linked to the very essence of agriculture, which is to feed humanity.

2.3.5.1.1. Increasing global population and low EU agricultural productivity gains

The most accepted scenario was based on the UN forecast of a world population reaching 9 billion people by 2050. The main question related to this scenario was how the EU could contribute to feeding this growing population with low yield gains and declining agricultural land?

To achieve global food and nutrition security by 2050, agricultural global total factor productivity (TFP)
comparing the total outputs to the total inputs used for production of the outputs – will have to grow by an average rate of at least 1.8 % per year. According to the European Commission's DG Agriculture (DG AGRI) – based upon Eurostat data – TFP growth in EU agriculture has constantly remained below the percentage needed by the EU to contribute in a meaningful way to global food security. From 1995 to 2002, TFP grew by 1.6 % per annum in the EU-15. Thereafter, EU-15 TFP growth in agriculture dropped to just 0.3 % per annum (2002-2011).

To these low yield gains, we should add that, in the EU (also according to DG AGRI) there is a long- term decline in the number of holdings. Between 2005 and 2013, the average rate of decline was 3.7 % per year, resulting in the number of holdings being reduced by 1.2 million. The area of agricultural land also fell by 0.7 % over the same period due to increased forestry and urbanisation. Regardless of world demographics and global demand for agricultural commodities and food, it is obvious – if these trends persist – that EU agricultural productivity has to increase in order to maintain the same output.

2.3.5.1.2. PA already offers technology solutions for producing more with less

Beyond the sustainability issue, PA already offers technologies for producing more agricultural output with less input. For instance, sensor-based monitoring systems provide farmers with better information and early warnings on the status of crops, and improved yield forecasts. PA also plays a major role in animal husbandry.

A very good example is given by precision milking and feeding robots. The Netherlands, Germany and France are currently leading the shift towards automatic milking. Some 90 % of new equipment installations in Sweden and Finland, and 50 % in Germany include robotic milking. Half of the dairy herds in north-western Europe will be milked by robots in 2025. Robotic milking generates about 120 data variables per cow per day such as: movements, feed being distributed, milk being produced, quality of milk, temperature, coughs and other cattle diseases… All these technologies noticeably improve the well-being of cows and lower their stress levels.

Dairy farms fully equipped with precision milking enjoy a substantial increase in yields. While the EU average annual milk production per cow is 6 915 kg, some precision milking demo-farms produce almost double that at 12 000 kg milk per year with the same agricultural input as traditional dairy farms. This is a clear example of what PA could deliver in terms of better yields with the same level of agricultural input.

2.3.5.1.3. PA will enhance food safety and plant health

PA will contribute more and more to food safety. PA makes farming more transparent by improving tracking, tracing and documenting. Crop and livestock monitoring will give better predictions on the quality of agricultural products. The food chain will be easier to monitor for producers, retailers and customers.

It will also play a significant role in terms of plant health. Current technologies allow to monitor to different levels of resolution in precision farming. Grid level ranges from field monitoring (ca. 30 x 30m) to plant level monitoring (ca. 30 x 30 cm). Forthcoming technologies will make leaf level (ca. 3 x 3 cm) and spots on leaves (ca. 0.5 x 0.5 cm) accessible to optical automated diagnostics. Diseases undetectable by traditional means will be prevented by automated optical sensing and intelligent planning options.

2.3.5.1.4. Policy options

Irrespective of what the economic context might be in the next decades, PA will be needed by EU farmers to improve their yields on less available arable land. The strategic question here is: will the EU be one of the major global players for PA technologies?

Yet the EU has already taken some vigorous steps in addressing this challenge. The EU doubled its efforts with an unprecedented budget of nearly €4 billion, allocated to Horizon 2020 and the specific theme 'Societal Challenge 2', which partially relates to PA

Parallel to this, the EU has set Fostering knowledge transfer and innovation in agriculture, forestry and rural areas as the first priority for rural development policy in 2014-2020. Rural development programmes will finance agricultural and forestry innovation through several measures which can support creation of operational groups, innovation services, investments or other approaches. In those two EU R&D funding tools, nine programmes include PA practices as an eligible priority.

All stakeholders agreed that investments in research and development will be the key driving force for bringing about the agricultural jobs of tomorrow. Accordingly, a substantial shift from the CAP (2021- 2027) to enhanced R&D in agriculture could be envisaged, especially in a period of persistent budgetary constraints during which other policy priorities are likely to supersede CAP priorities. More money could for instance be invested in cutting-edge technologies like biosensors, robotics, and spectrographic, imagery…

2.3.6. Environmental sustainability of farming

PA supports sustainable farming

Sustainability is another central pillar of the STOA PA study and expert discussions. The concept could be found in all proposed scenarios.

As stated above, by 2050 the global population will be in excess of 9.5 billion and we will require 70- 100 percent more agricultural output to meet this global demand.

Producing more while using less through PA will be the driving force for sustainably meeting the needs of the EU's environmental policies.

2.3.6.1. Key PA technologies already in use with positive impacts on the environment

PA uses not only satellite navigation and positioning systems but also a wide range of other technologies. These covers:

- Automated steering systems, which can take over specific driving tasks such as auto-steering, overhead turning, following field edges and overlapping of rows. Automatic steering systems reduce human errors. In addition, they contribute to effective soil and site management. Automated headland turns could, for instance, already save from 2 % up to 10 % fuel consumption.

- Geo-mapping, which is used to produce maps identifying, for instance, types of soils and levels of nutrients for particular fields.
- Sensors and remote sensing, with which data can be collected from a distance to evaluate soil and crop health, measuring parameters such as moisture, nutrients, compaction, and crop diseases. These sensors can be installed on mobile machines. EU farmers already make use of a wide range of sensors for capturing variations in properties of soils and crops, weather conditions and animal behaviour. Thermal, optical, mechanical and chemical measurements by sensors are applied to quantify crop biomass, plant stress, pests and diseases, soil properties, climatic conditions and animal behaviour.
- Agricultural robots of the future will be autonomous and able to reconfigure their own architecture to perform various tasks. They will offer an enormous potential for sustainability:
  - They will ease the energy transition. Robots will be powered by electricity. The required electricity could be produced at the farm site.
  - They can minimise soil compaction due to heavy machinery. Swarm robots will be lighter and able to intervene only where they are needed, staying permanently on the fields. (note: Swarm robots are a group of simple robots, which can be coordinated in a distributed and decentralised way, in order to jointly execute more complex tasks)
  - Less work effort and resources input will be required, and robots will most likely provide greater output, as they already do in the dairy industry.
  - Robots will optimise inputs used by farmers (fertilisers, pesticides, insecticides) and reduce the impact on soils and water tables.

2.3.6.2. PA will generate sustainable productivity

The potential of PA for cost saving can be illustrated by two examples discussed during the STOA project workshop:

The Nitrogen-uptake rate is the amount of Nitrogen applied in a field that is actually absorbed in the plant. Assuming that the average Nitrogen uptake rate in small grains in Europe is 50 %, this means that the rest ends up in the air, the soil or the ground water: a 50 % uptake rate means also 50 % waste. At N-fertiliser cost of around €180 per ha6 this means a potential saving potential of €90 per ha.

FAO studies from 2009 indicate that in many countries, less than 10 % of all spray applications hit a sick plant, a weed or a parasite, which means waste of 90 %. With spray cost in small grains at approximately €190 per ha there is roughly €170 per hectare savings potential in spraying.

Combined, these two process issues represent a savings potential of €260 per ha (170 + 90). €260 compared to a gross margin of €400-€700 per ha today in the EU.

Today, PA technologies do not (yet) enable EU farmers to save €260 per hectare. However, these figures show the untapped potential of new technologies to drive sustainability in agriculture. A 25 % (€65), 33 % (€87) or 50 % (€130) improvement potential through innovation covering each production step could be realistic to achieve by 2050.

2.3.6.3. Policy options

The study recommends that PA should be one of the key issues to be addressed by the next CAP. It is of critical importance that productivity in farming continues to grow. Should productivity growth in farming fall behind productivity growth in the rest of the economy in the long run, farmers' living standards risk declining.

It is essential that the processes driving productivity growth in farming be actively encouraged by the next CAP. Progress towards high-precision farming would be part of such a process. Productivity gains require significant investments. Risk-taking attitudes should be rewarded so that progress disseminates among farming communities.

Options include:

- Enticing farmers to invest in PA technologies through Pillar 1 and a renewed greening scheme. It could take the form of a 'sustainability bonus' linked to investment in PA technologies with a proven benefit for the environment: robots, smart machines, software, sensors, intelligent solutions, managerial schemes, digitalisation… The sustainability bonus could be proposed as an alternative option to the current greening measures.
- In relation to the 'sustainability bonus', developing PA standards focusing on transparency, sustainability and interoperability through the Centre Européen de Normalisation (CEN), the International Organization for Standardization (ISO) and the European Telecommunications Standards Institute (ETSI).

These suggestions could be combined in a broader option:

- Setting-up a third pillar within the CAP (2021-2027) dedicated to environment and sustainable technologies.

2.3.7. Societal changes and technology uptake in agriculture

PA will trigger societal changes along with its uptake rate

Similarly, to the way in which PCs, internet, smart phones and satellite navigation have changed our ways of life, PA will trigger societal changes in rural communities and will initiate new business models.

2.3.7.1. New business models on the rise

One of the major contributions of the STOA PA study was to show that new business models are already on the rise and technologies will drive new ways of farming.

The study suggests a new forward-looking typography of what new farming business could be, including the following new professional profiles:

- The Geo-Engineer would specialise in carbon sequestration, alongside a food production business…
- The Energy Farmer would specialise in renewable energy production and management for the local area…
- The Web Farm Host would… give a constant, positive commentary to the outside world, explaining what is going on and often giving virtual tours to school children…
- The Animal Therapist would act as a welfare manager for farm animals … making sure that consumers buying meat or dairy products from the farm are able to access information about animal wellbeing...
- The Pharmer would use biotechnology expertise to grow and harvest plants that have been genetically engineered with foreign DNA to make them produce medicine…
- The Insect Farmer would farm large quantities of insects for use as natural predators to control the new species of insect that spread in farming areas because of climate change…

At this stage, it would be very difficult to predict which of these models will be most prevalent by 2050. However, some of these new businesses could become a subject for policymaking depending on the societal support they get (see 3.4).

2.3.7.2. PA will influence work practices and life conditions on farmland

PA will reduce the gender gap by making farming operations easier for women, especially when it comes to using heavy equipment or performing difficult physical tasks. Both will be taken over by automated systems or robots. New social interactions with broadened perspectives are expected from this societal change.

PA will also improve the quality of life of EU farmers. As we have seen, there is broad acceptance of robotics in dairy farms. In the past decade, robots have been developed to relieve farmers form heavy work like scraping manure and pushing roughage, in essence very repetitive and time-consuming tasks. By 2050, it is expected that more and more tasks will be automated, freeing up time for farmers. The latter will get easier access to the leisure society equivalent to that which urban populations enjoy.

On the other hand, PA might have a negative impact on seasonal work. Seasonal workers are low paid and low skilled. They are usually employed to assist with harvesting tasks, such as fruit picking. Over 4 million seasonal workers are in temporary employment. Two thirds of them are migrant workers coming from central and eastern Europe to western Europe during the harvesting season, and they migrate within the European Union itself, following the cycles of fruit harvesting. Many of these migrants might be replaced by PA technologies and a new generation of robots. This might then lead to reduced income for seasonal workers from some EU states, for example Poland, Bulgaria and Romania.

2.3.7.3. PA technologies are broadly available, but their uptake is still low

As described in detail in the study, a wide range of PA technologies are already available to EU farmers. Such available PA technologies are used for object identification, geo-referencing, measurement of specific parameters, global navigation satellite systems (GNSS), connectivity, data storage and analysis, advisory systems, robotics and autonomous navigation.

After 2000, the digitalisation of farming accelerated. When internet reached farmland shortly before the millennium, it allowed farmers to get access to data and information, decision-making tools and communication. A wide range of internet platforms with farmer-specific information have developed over time. Data storage services (mostly cloud-based), GIS systems and data analysis software are now available. Wireless communication via e.g. 3G, 4G and other networks became possible. Applications on internet platforms and smartphones have also recently been developed. These applications can provide farmers with specific information such as on weather conditions, status of crops, heat detection and movement of animals, and give management advice.

Despite the wide range of PA solutions being offered it is estimated that only 25 % of EU farms use technologies which include a PA component.

The critical question here was 'How can all sizes of farms – from small family farms to large agribusinesses – benefit from these technologies?'

The STOA workshop's debates showed that financial support will not be enough for setting the trend. Other tools should also be considered. Some of these tools are listed below.

2.3.7.4. Policy options

Exploring new business models

Through pillar 2 of the CAP, Horizon 2020 or Comission President Jean-Claude Juncker's investment plan, the EU could support a network of experimental/demonstration farms focused on a new fully integrated business model (i.e. the energy farmer, the 'Pharmer', the full robotic-equipped farm). Through such initiatives, the viability of specialised business PA models could be tested on a real-life scale.

Promoting PA towards trend-setters and the next generation

Pedagogic communication is definitely needed to inform the younger generations of the new opportunities offered by modern farming.

Exhibitions, advertisements, videos, cartoons, brochures to be distributed at school level could be planned, as well as the launch of a European Year of Modern Farming.

Issuing an annual report on PA uptake

Based on the USDA experience, the Commission's DG AGRI, should publish an annual PA EU uptake report.

Building the appropriate infrastructure for keeping and attracting young farmers

Without appropriate infrastructure, it will not be possible to keep or attract young farmers in the agricultural business; they will move or stay in well-connected urban, globalised areas.

Where EU support might be most needed in the coming decade(s) is for building 5G infrastructure for European farmers. The potential users are there, but the lower density of population in rural areas is a clear obstacle for the telecoms sector to invest in farming areas. It could be a clear case for EU structural funds to intervene. 5G coverage would be extremely relevant, or even critical for:

- Live mapping of soil moisture;
- Variable rate fertilisation (including N-sensing);
- Precision planting;
- Data-centric farm management;
- Connectivity to wind-farms;

- Access to world markets.

For all these uses EU agriculture needs better performing broadband service, coverage and latency. 5G technology could also greatly contribute to improve the positioning accuracy and farms' connectivity. It is a key enabler of a performing and sustainable agriculture.

2.3.8. Skills and education for farmers

PA requires new skills to be learned

Like every new technology, the introduction and uptake of PA will require new skills to be learned by farmers. The general assumption under which globalisation transformed our economies into knowledge economies is also valid for agriculture. Young farmers need to be equipped with the right mix of both job-specific and cross-cutting core skills to be able to access PA.

2.3.8.1. PA could contribute to raising employment and education levels in rural areas

Rural areas deserve special attention in terms of education. Studies show that school drop-out is a problem that is increasingly giving cause for concern, and that particularly affects children and young people in rural areas. While the EU 2020 strategy for smart, sustainable and inclusive growth is aimed at reducing school drop-out rates from 14 % for the EU to 10 % or less, the drop-out rates in in several rural areas remains far above 30 %. Moreover, rural areas present, in general, lower rates of tertiary education. As we understand, the situation in those areas is extremely challenging. Not only does the rural population have to bridge the educational gap with the urban population, but they also have to learn new skills, which are not necessarily addressed by the local education system.

However, PA technologies could really boost education levels in rural areas since they are all linked to the competencies identified by the EU for increasing competitiveness and growth. About 70 % of EU farmers have only practical agricultural skills. This group will have a slower adoption of precision farming technology than a group of trained farmers. Not surprisingly, adoption of precision farming is highest in north-western European countries where farmers are more trained than in other parts of the EU.

2.3.8.2. A brief overview of the PA skills needed in future

These skills can be divided into three categories: ICT and automation/robotics technologies, environmental and managerial.

Technological skills:

- Work with robots;
- Work with processed data;
- Choose appropriate solutions according to the farming project;
- Computer sciences;
- Advanced machinery: auto-steered equipment, drones;
- Complex apps (RTK, Satellite imagery…).

Environment skills:

- Understanding legislation;
- Expertise in circular agriculture;
- Knowledge of local ecosystems;
- Genetics expertise;

Managerial skills:

- Business management;
- Innovation management;
- Entrepreneurship;
- Marketing skills.

2.3.8.3. Policy options

Skills needs are clearly identified in all the different scenarios of the STOA PA study. All of them suggest a strong push for education in farming.

Through the European Social Fund and the CAP's Pillar 2, the EU could envisage the following options for keeping farmers up to speed with expected technological developments:

Encouraging new forms of learning:

A paradigm change in the education sector is needed to spread PA technologies by using virtual classes, e-learning, and blended training programmes (virtual and on-site learning).

Reaching out to smaller farms:

Sharing knowledge with small farms needs new educational and mentoring mechanisms. One possibility would be, for instance, to entice PhD or post-doctoral students in agronomics, with a PA background, to tour rural communities with a training package and demo-material for sharing PA knowledge and promote new technologies. These tours could be made with specially equipped buses during the winter season.

Combining traditional knowledge with PA technologies:

To avoid loss of traditional knowledge and know-how, master-apprentice relationships should be revisited, to privilege the exchange of expertise between the older and younger generations.

Promoting targeted training and advice to enhance the use of best practices (prevention of mistakes):

Agricultural products are regularly checked for compliance with health and safety standards and destroyed in case of non-compliance. In the future, more attention should be devoted to promoting good practices and offering targeted training for preventing such cases as much as possible, and in particular repeated 'mistakes' leading to problems for the farmer.

2.3.9. Final reflections

The wide diversity of agriculture throughout the EU, regarding particularly farm size, types of farming, farming practices, output and employment, presents a challenge for European policy-makers. European policy measures therefore should differentiate between the Member States, taking into account that the opportunities and concerns vary highly by country.

As demonstrated in the overview of agricultural production in the EU and the analysis of the business models of farming in Europe, the farming business across the EU-28 is very heterogeneous in many aspects:

- Business models;
- Production sectors;
- Farming practices;
- Employment in number of people;
- Education and skills;
- Output.

Some of the STOA Panel Members tend strongly to encourage support for the transition towards precision agriculture in the EU through the Common Agricultural Policy (CAP). However, MEPs also expressed concerns about possible loss of jobs in the sector in countries highly agriculture-dependent for employment, through the introduction of precision farming and automation in farming practices. However, in these countries too increased uptake of precision agriculture could bring great opportunities.

Therefore, possible measures in the next review of the CAP should differentiate between the Member States, taking into account that the opportunities and concerns differ between countries.

3 Precision agriculture in Europe: Legal, social and ethical considerations

3.1. 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 agroecological 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.

3.2. Challenges

The adoption of technologies for sustainable farming systems is a challenging and dynamic issue for farmers, extension services, agri-business and policymakers. 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 standards1 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.

3.3. Policy areas

3.3.1. 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 agrienvironment-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.2 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 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 keys texts:

- Commission Implementing Regulation 2016/1842 of 14 October 2016 amending Regulation (EC) No 1235/2008 as regards the electronic certificate of inspection for imported

organic products and certain other elements, and Regulation (EC) No 889/2008 as regards the requirements for preserved or processed organic products and the transmission of information C/2016/6502, OJ L 282, 19.10.2016, pp. 19–37

- European Parliament resolution of 7 June 2016 on technological solutions for sustainable agriculture in the EU (2015/2225(INI))
- Commission Regulation (EU) No 1312/2014 of 10 December 2014 amending Regulation (EU) No 1089/2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data services, OJ L 354, 11.12.2014, pp. 8–16
- Regulation 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007 OJ L 347, 20.12.2013, pp. 671–854
- Regulation 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009 OJ L 347, 20.12.2013, pp. 608–67
- 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 Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000,(EC) No 1290/2005 and (EC) No 485/2008 OJ L 347, 20.12.2013, p. 549–607 and Annex II
- Regulation 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005 OJ L 347, 20.12.2013, pp. 487–548
- Commission Regulation (EU) No 1253/2013 of 21 October 2013 amending Regulation (EU) No 1089/2010 implementing Directive 2007/2/EC as regards interoperability of spatial data sets and services, OJ L 331, 10.12.2013, pp. 1–267
- 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 (EU) No 102/2011 of 4 February 2011 amending Regulation (EU) No 1089/2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services, OJ L 31, 5.2.2011, pp. 13–34
- Commission Regulation (EU) No 1088/2010 of 23 November 2010 amending Regulation (EC) No 976/2009 as regards download services and transformation services, OJ L 323, 8.12.2010, pp. 1–10

- Commission Regulation (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services, OJ L 323, 8.12.2010, pp. 11–102

- 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
- Council Regulation 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers, amending Regulations (EC) No 1290/2005, (EC) No 247/2006, (EC) No 378/2007 and repealing Regulation (EC) No 1782/2003 OJ L 30, 31.1.2009, pp. 16–99
- Council Regulation (EC) No 1234/2007 of 22 October 2007 establishing a common organisation of agricultural markets and on specific provisions for certain agricultural products (Single CMO Regulation), OJ L 299, 16.11.2007, pp. 1–149
- Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) OJ L 108, 25.4.2007, p. 1–14

3.3.2. 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 are 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 behaviour. 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 being you sharing? How are the different data parts, versions and derivatives separated? Is its clear which part of the data being primary versus derived versions? Is its 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
- Regulation 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) OJ L 119, 4.5.2016, p. 1–88
- 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
- EDPS Opinion 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'(26 November 2014)

–https://secure.edps.europa.eu/EDPSWEB/webdav/site/mySite/shared/Documents/Consultation/Opinions/2014/14-11-26_Opinion_RPAS_EN.pdf

- Working Group 29 Opinion 01/2015 on Privacy and Data Protection Issues relating to the Utilisation of Drones (16 June 2015) - http://ec.europa.eu/justice/data-protection/article-29/documentation/opinion-recommendation/files/2015/wp231_en.pdf
- Commission Communication, Towards a thriving data-driven economy, COM/2014/0442 final
- Directive 2013/37/EU of the European Parliament and of the Council of 26 June 2013 amending Directive 2003/98/EC on the re-use of public sector information - text with EEA relevance, OJ L 175, 27.6.2013, p. 1–8
- Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information, OJ L 345, 31.12.2003, p. 90–96
- Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications), Official Journal L 201, 31/07/2002
- P. 0037 – 0047
- Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data, OJ L 281, 23.11.1995, p. 31–50

3.3.3. Protection of natural/agricultural environment and food safety

EP Committees: ENVI, ITRE

3.3.3.1. 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 (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 regulations. While more efficient algorithms and hardware could be developed, and even if precision agriculture has been associated with promises about increased fuel use efficiency 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:

- Directive 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (Text with EEA relevance) OJ L 239, 15.9.2015, p. 1–29
- Commission Implementing Regulation (EU) 2015/1866 of 13 October 2015 laying down detailed rules for the implementation of Regulation (EU) No 511/2014 of the European Parliament and of the Council as regards the register of collections, monitoring user compliance and best practices, OJ L 275, 20.10.2015, p. 4–19
- Regulation (EU) No 511/2014 of the European Parliament and of the Council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union Text with EEA relevance, OJ L 150, 20.5.2014, p. 59–71
- Commission Regulation (EU) No 283/2013 of 1 March 2013 setting out the data requirements for active substances, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market Text with EEA relevance, OJ L 93, 3.4.2013, p. 1–84
- Commission Regulation (EU) No 284/2013 of 1 March 2013 setting out the data requirements for plant protection products, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council concerning the placing of plant protection products on the market Text with EEA relevance, OJ L 93, 3.4.2013, p. 85–152
- 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 Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000,(EC) N 1290/2005 and (EC) No 485/2008 OJ L.347, 20.12.2013, p.549-607 and Annex II

- Commission Implementing Regulation (EU) No 607/2012 of 6 July 2012 on the detailed rules concerning the due diligence system and the frequency and nature of the checks on monitoring organisations as provided for in Regulation (EU) No 995/2010 of the European Parliament and of the Council laying down the obligations of operators who place timber and timber products on the market Text with EEA relevance, OJ L 177, 7.7.2012, p. 16–18
- Commission Communication of 29 February 2012 on the European Innovation Partnership 'Agricultural Productivity and Sustainability' (COM(2012)0079)
- Commission Communication of 13 February 2012 entitled 'Innovating for Sustainable Growth: A Bioeconomy for Europe' (COM(2012)0060)
- Commission Regulation (EU) No 188/2011 of 25 February 2011 laying down detailed rules for the implementation of Council Directive 91/414/EEC as regards the procedure for the assessment of active substances which were not on the market 2 years after the date of notification of that Directive Text with EEA relevance, OJ L 53, 26.2.2011, p. 51–55
- Commission Regulation (EU) No 547/2011 of 8 June 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards labelling requirements for plant protection products Text with EEA relevance, OJ L 155, 11.6.2011, p. 176–205
- Commission Regulation (EU) No 546/2011 of 10 June 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards uniform principles for evaluation and authorisation of plant protection products Text with EEA relevance, OJ L 155, 11.6.2011, p. 127–175
- Commission Implementing Regulation (EU) No 540/2011 of 25 May 2011 implementing Regulation (EC) No 1107/2009 of the European Parliament and of the Council as regards the list of approved active substances Text with EEA relevance, OJ L 153, 11.6.2011, p. 1–186
- Regulation 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market OJ L 295, 12.11.2010, p. 23–34
- Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC, OJ L 309, 24.11.2009, p. 1–50
- Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (Text with EEA relevance), OJ L 309, 24.11.2009, p. 71–86
- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance) OJ L 140, 5.6.2009, p.16–62
- Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway

vessels and repealing Directive 93/12/EEC (Text with EEA relevance), OJ L 140, 5.6.2009, p. 88–113

- Commission Regulation (EC) No 1077/2008 of 3 November 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 1966/2006 on electronic recording and reporting of fishing activities and on means of remote sensing and repealing Regulation (EC) No 1566/2007, OJ L 295, 4.11.2008, p. 3–23
- 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
- Commission Regulation (EC) No 1095/2007 of 20 September 2007 amending Regulation (EC) No 1490/2002 laying down further detailed rules for the implementation of the third stage of the programme of work referred to in Article 8(2) of Council Directive 91/414/EEC and Regulation (EC) No 2229/2004 laying down further detailed rules for the implementation of the fourth stage of the programme of work referred to in Article 8(2) of Council Directive 91/414/EEC (Text with EEA relevance), OJ L 246, 21.9.2007, p. 19–28
- Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97, OJ L 3, 5.1.2005, p. 1–44
- 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
- Council Regulation (EC) No 870/2004 of 24 April 2004 establishing a Community programme on the conservation, characterisation, collection and utilisation of genetic resources in agriculture and repealing Regulation (EC) No 1467/94 (Text with EEA relevance), OJ L 162, 30.4.2004, p. 18–28
- Commission Regulation (EC) No 1490/2002 of 14 August 2002 laying down further detailed rules for the implementation of the third stage of the programme of work referred to in Article 8(2) of Council Directive 91/414/EEC and amending Regulation (EC) No 451/2000 (Text with EEA relevance), OJ L 224, 21.8.2002, p. 23–48
- Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, OJ L 309, 27.11.2001, p. 22–30
- FAO, 2001, International Treaty on Plant Genetic Resources for Food and Agriculture.
- Commission Regulation (EC) No 451/2000 of 28 February 2000 laying down the detailed rules for the implementation of the second and third stages of the work programme referred to in Article 8(2) of Council Directive 91/414/EEC, OJ L 55, 29.2.2000, p. 25–52
- Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 327, 22.12.2000, p. 1–73 (Water Framework Directive or WFD)
- Council of Europe, European Landscape Convention. Reference, ETS No.176, Florence, 20. X.2000

- Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control, OJ L 257, 10.10.1996, p. 26–40
- Commission Regulation (EEC) No 3600/92 of 11 December 1992 laying down the detailed rules for the implementation of the first stage of the programme of work referred to in Article 8 (2) of Council Directive 91/414/EEC concerning the placing of plant protection products on the market, OJ L 366, 15.12.1992, p. 10–16
- Council Decision 92/583/EEC of 14 December 1992 on the conclusion of the Protocol of amendment to the European Convention for the Protection of Animals kept for Farming Purposes, OJ L 395, 31.12.1992, p. 21–21
- Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, OJ L 375, 31.12.1991, p. 1–8
- Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market, OJ L 230, 19.8.1991, p. 1–32
- Council Decision 78/923/EEC of 19 June 1978 concerning the conclusion of the European Convention for the protection of animals kept for farming purposes, OJ L 323, 17.11.1978, p. 12–13
- Council of Europe, European Convention for the Protection of Animals kept for Farming Purposes, Strasbourg, 10/03/1976, ETS No.087

3.3.3.2. 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 agroindustry, 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 manage 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 their food comes from, as it enables them to track and trace the products they consume. The spread of the Internet of Things5 may further contribute to a more efficient, near-real-time monitoring 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 agroecological farming.

Legal instruments and other key texts:

- Commission Implementing Regulation 208/2013 of 11 March 2013 on traceability requirements for sprouts and seeds intended for the production of sprouts. (Text with EEA relevance) OJ L 68, 12.3.2013, p. 16–18
- Commission Implementing Regulation 931/2011 of 19 September 2011 on the traceability requirements set by Regulation (EC) No 178/2002 of the European Parliament and of the Council for food of animal origin. (Text with EEA relevance) OJ L 242, 20.9.2011, p. 2–3
- 2005/123/EC: Commission Decision of 9 February 2005 amending Decision 2004/292/EC on the introduction of the TRACES system and amending Decision 92/486/EEC (notified under document number C(2005) 279) (Text with EEA relevance), OJ L 39, 11.2.2005, p. 53–54
- 2004/292/EC: Commission Decision of 30 March 2004 on the introduction of the Traces system and amending Decision 92/486/EEC (Text with EEA relevance) (notified under document number C(2004) 1282), OJ L 94, 31.3.2004, p. 63–64
- 2003/623/EC: Commission Decision of 19 August 2003 concerning the development of an integrated computerised veterinary system known as Traces (notified under document number C(2003) 2983), OJ L 216, 28.8.2003, p. 58–59
- Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC, OJ L 268, 18.10.2003, p. 24–28
- Regulation 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety OJ L 31, 1.2.2002, p. 1–24.

3.3.3.3. 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)6 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 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 agroecological 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.7 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.8 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 faming may also provide detailed agronomical and environmental information that could be used as a justificatory basis for mitigation measures.

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
- Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020, OJ L 140, 5.6.2009, p. 136–148

3.3.3.4. 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,9 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.

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).11 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 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)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:

- Proposal for a regulation of the European Parliament and of the Council on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and repealing Regulation (EC) No 216/2008 of the European Parliament and of the Council, COM/2015/0613 final - 2015/0277 (COD)
- Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance, OJ L 153, 22.5.2014, p. 62–106
- Regulation 1285/2013 of the European Parliament and of the Council of 11 December 2013 on the implementation and exploitation of European satellite navigation systems and repealing Council Regulation (EC) No 876/2002 and Regulation (EC) No 683/2008 of the European Parliament and of the Council
- Decision 1104/2011/EU of the European Parliament and the Council of 25 October 2011 on the rules for access to the public regulated service provided by the global navigation satellite system established under the Galileo programme (OJ L 287, 4.11.2011, p. 1).
- Regulation (EU) No 182/2011 of the European Parliament and of the Council of 16 February 2011 laying down the rules and general principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers, OJ L 55, 28.2.2011, p. 13–18
- Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (Text with EEA relevance), OJ L 309, 24.11.2009, p. 71–86
- Directive 2009/114/EC of the European Parliament and of the Council of 16 September 2009 amending Council Directive 87/372/EEC on the frequency bands to be reserved for the coordinated introduction of public pan-European cellular digital land-based mobile communications in the Community (Text with EEA relevance), OJ L 274, 20.10.2009, p. 25–27
- Directive 2009/104/EC of the European Parliament and of the Council of 16 September 2009 concerning the minimum safety and health requirements for the use of work equipment by workers at work (second individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) (Text with EEA relevance), OJ L 260, 3.10.2009, p. 5–19
- Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93 (Text with EEA relevance) , OJ L 218, 13.8.2008, p. 30–47
- Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (Text with EEA relevance), OJ L 79, 19.3.2008, p. 1–49
- Regulation 683/2008 of the European Parliament and of the Council of 9 July 2008 on the further implementation of the European satellite navigation programmes (EGNOS and Galileo) (OJ L 196, 24.7.2008, p. 1)

- Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (Text with EEA relevance), OJ L 157, 9.6.2006, p. 24–86
- Regulation (EC) No 785/2004 of the European Parliament and of the Council of 21 April 2004 on insurance requirements for air carriers and aircraft operators, OJ L 138, 30.4.2004, p. 1–6
- Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC Text with EEA relevance, OJ L 390, 31.12.2004, p. 24–37
- Regulation (EC) No 1592/2002 of the European Parliament and of the Council of 15 July 2002 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency (Text with EEA relevance), OJ L 240, 7.9.2002, p. 1–21
- Directive 2002/22/EC of the European Parliament and of the Council of 7 March 2002 on universal service and users' rights relating to electronic communications networks and services (Universal Service Directive), OJ L 108, 24.4.2002, p. 51–77
- Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive), OJ L 108, 24.4.2002, p. 33–50
- Directive 2002/20/EC of the European Parliament and of the Council of 7 March 2002 on the authorisation of electronic communications networks and services (Authorisation Directive), OJ L 108, 24.4.2002, p. 21–32
- Directive 2002/19/EC of the European Parliament and of the Council of 7 March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive), OJ L 108, 24.4.2002, p. 7–20
- Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety (Text with EEA relevance), OJ L 11, 15.1.2002, p. 4–17
- Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity, OJ L 91, 7.4.1999, p. 10–28
- Council Directive 92/58/EEC of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (ninth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC), OJ L 245, 26.8.1992, p. 23–42
- Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace (third individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC), OJ L 393, 30.12.1989, p. 18–28
- Council Directive 89/654/EEC of 30 November 1989 concerning the minimum safety and health requirements for the workplace (first individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC), OJ L 393, 30.12.1989, p. 1–12
- Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work, OJ L 183, 29.6.1989, p. 1–8

- Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, OJ L 210, 7.8.1985, p. 29–33
- Riga Declaration on Remotely Piloted Aircraft (drones) 'Framing the future of aviation', Riga,6 March 2015
- 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'

3.4. 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 agri-food 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'.14' 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 robotization 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 instrumentalization 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.

3.5. 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.

Need to take into account the specific environmental and socio-economic features of the European farming ecosystem.

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.

Need for safeguards that could properly ensure effective data ownership

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.

Need for developing equitable and fair-use 'technology use agreements' at the EU level

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.

Need to introduce security and safety safeguards

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 Européene'(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.

Need for special rules for small drones used in precision agriculture

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, 'geo-fencing' 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.

Need to adopt a 'code of best agricultural data' and to design an EU-wide independent, farmer-centric data repository

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 competiveness 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.

Need for tools and incentives to be designed especially for small and medium-sized farms

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 financialization 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.

3.6. 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.

4. Technology in precision viticulture

4.1. Introduction

In a context of growing competition on international markets, it becomes of utmost importance to achieve higher quality standards in the vineyard. This has led to a radical renewal of viticulture and a review of agricultural techniques, with the aim of maximizing quality and sustainability through the reduction and more efficient use of production inputs such as energy, fertilizers and chemicals, and minimizing input costs while ensuring the preservation of the environment. The concept of precision viticulture is a step in this direction, being a differentiated management approach aiming to meet the real needs of each parcel within the vineyard. Several authors have studied precision viticulture in Australia and in Europe. Vineyards are characterized by a high heterogeneity due to structural factors such as the pedo-morphological characteristics, and other dynamics such as cropping practices and seasonal weather.

This variability causes different vine physiological response, with direct consequences on grape quality. Vineyards therefore require a specific agronomic management to satisfy the real needs of the crop, in relation to the spatial variability within the vineyard. The introduction of new technologies for supporting vineyard management allows the efficiency and quality of production to be improved and, at the same time, reduces the environmental impact. Recent technological developments have allowed useful tools to be elaborated that help in the monitoring and control of many aspects of vine growth. Remote and proximal sensing sensors become strong investigation instruments of the vineyard status, such as water and nutrient availability, plant health and pathogen attacks, or soil conditions. Precision viticulture thus seeks to exploit the widest range of available observations to describe the vineyard spatial variability with high resolution and provide recommendations to improve management efficiency in terms of quality, production, and sustainability.

Nowadays, agriculture faces new challenges and threats, some of the most important being related to environmental and climate issues. In the specific case of viticulture, according to the International Organization of Vine and Wine, EU is the world leading producer and exporter of wine and still encompasses the largest vineyard area in the world (38%) representing 20% of total agricultural employment in the EU (being mainly composed of small producers). The critical environmental impacts of grape production come from the intense use of pesticides, from the very high variability of the amount of fertilizers and from energy consumption related to the application of fertilizers and pesticides and for irrigation, pruning and tillage which are normally done with diesel tractors. EU regulations highlight the strong need to reduce pesticides (e.g. the recent EU regulation of 13 December 2018 restricts the use of plant protection products containing copper pesticides in order to minimize the potential accumulation in soil and the exposure for not target organisms).

The impact of global warming on wine growing European regions is increasing and vast portions of the Mediterranean basin may become completely inhospitable (warmer) to grape production by 2050. In particular, changes in temperatures and humidity may increase the presence of pest and diseases as their temperature limits move poleward. In this contest, vineyards can require lots of external inputs (water, pesticides and fertilizer) to reduce biotic and abiotic stressors and to ensure grape production Moreover, it is also important to note that the intense use of fertilizers significantly contributes to the production of ammonia and to the eutrophication phenomena.

Most of EU vineyards are today based on traditional agronomy management and they have not been significantly driven by technology. The increased consumer awareness of environmental impact of viticulture and the importance of wine quality in relation to human health are encouraging the practice of alternative agronomic strategies, and the world of wine is heading towards a transformation enabling Precision Agriculture (PA) applied to viticulture. The objective is to gain in efficiency, in productivity and overall in quality of wine. New technologies can help winegrowers in the decision-making process in order to adapt their production mode in their vineyards using new devices (sensors, robots and drones) and digital techniques to monitor and optimize agriculture production processes. At the moment, a lot of progress has been made in PA development and the PA market is fully embraced by the sector and investors, but the full potential of PA has not yet been harnessed.

This chapter presents a review of technologies used in precision viticulture. It is divided in two main sections. The first one focuses on monitoring technologies, which are the basis of mapping spatial variability; the second part discusses technologies utilized to provide site-specific agronomic inputs, identified as variable-rate technologies (VRTs) and "agbot" systems.

4.2. Monitoring technologies

The primary objective of the monitoring process is acquisition of the maximum amount of georeferenced information within the vineyard. A wide range of sensors aiming to monitor different parameters that characterize the plant growth environment are employed in precision viticulture for remote and proximal monitoring of geolocated data.

4.2.1. Geolocation

Georeferencing is the process of establishing the relationship between spatial information and its geographical position. This makes a comparison possible among the different spatial data detected in the vineyard, such as soil physical properties, yield, and water or fertilizer contents. The Global Positioning System (GPS) is a space-based satellite navigation system that provides users with a highly accurate, 3D position (x, y, z) and rapid and timely information. While a GPS receiver calculates its position on earth based on the information it receives from four or more located satellites, with about 3–15 m accuracy, the differential techniques provide centi-meter location accuracy, thanks to a network of fixed, ground-based reference stations to correct the positions indicated by the satellite systems with known fixed positions. This type of GPS technology is useful in performing tasks requiring high precision, such as crop mapping, automatically driven farm vehicles, soil sampling, and distribution of fertilizers and pesticides at variable rates.

4.2.2. Remote sensing

Remote sensing techniques rapidly provide a description of grapevine shape, size, and vigor and allow assessment of the variability within the vineyard. This is image acquisition at a distance with different scales of resolution, able to describe the vineyard by detecting and recording sunlight reflected from the surface of objects on the ground.

Remotely sensed data permit the plant physiology to be described by means of vegetation indices calculation, such as the well-known normalized difference vegetation index (NDVI), which exploits the different response of vegetation to the visible (red) and near-infrared spectral bands that are closely related to crop status. Canopy reflectance, in the visible and near-infrared bands, is strongly dependent on both structural (leaf area index [LAI]) and biochemical proper-ties (chlorophyll content) of the canopy. The combination of vine-leaf biomass and photosynthetic potential has been defined as photosynthetically active biomass (PAB), and remote sensing can detect PAB through the synergetic effect of individual pixel values (photosynthetic potential) and pixel distribution (biomass) in the spectral signature. Grapevine PAB is influenced by site-specific geo-pedo-morphological conditions, and their variation within a vineyard causes a spatial variation in canopy characteristics. Vine vigor, which is traditionally measured through parameters like trunk cross-sectional area, average shoot length, and pruning weight, is reported to have a considerable effect on fruit yield and quality. The three platforms mainly used in remote sensing are satellites, aircraft, and unmanned aerial vehicles (UAVs) (Figure 1), with different application methods and types of sensors.

Figure 1. Remote sensing platforms employed in precision farming.

Notes: (A) Satellite. (B) Aircraft. (C) Unmanned aerial vehicle

Satellite:

Satellites have been used in precision farming for over 40 years, when Landsat 1 was launched into orbit in 1972. It was equipped with a multispectral sensor and provided a spatial resolution of 80 m per pixel with revisit intervals of approximately 18 days. Landsat 5 was launched in 1984 and collected imagery in the blue, green, red, near infrared, and thermal bands at a spatial resolution of 30 m. The first application of remote sensing in precision agriculture occurred when Landsat imagery of bare soil was used to estimate spatial patterns in soil organic matter content. In the meantime, there were several ongoing efforts to design higher spatial resolution satellite imaging systems with quicker revisit cycles. The spatial resolution of imaging systems has improved from 80 m with Landsat to sub-meter resolution with GeoEye and WorldView, and the frequency has improved from 18 days to 1 day with new satellite platforms, with significant advances in sensor performances.

The latest satellite, WorldView 3, successfully launched in August 2014, is even capable of providing resolutions of 0.30 m in visible spectra, 1.30 m in multispectral, and 3.70 m in short-wave infrared, with a revisit frequency between 1 and 4 days. The use of satellites in remote sensing therefore has great potential, but the spatial resolutions are not sufficient for precision viticulture due to the narrow vine spacing. Another limitation is the temporal resolution, and cloud cover that can occur at the time the satellite passes. The costs of the images are only sustainable on large areas given the size of a single image, not less than 50 ha.

Aircraft:

Aircraft allow ground monitoring with wide flight range and high payload in terms of weight and dimensions, thus providing the ability to manage a large number of sensors. The aircraft bypasses some limitations of the satellite application by programming the image time acquisition and providing higher ground resolution, depending on the flying altitude. However, the reduced flexibility of the time acquisition, due to the rigid schedule of flight planning and high operational costs, makes it economically viable only on areas of more than 10 ha. An example is the Sky Arrow 650 TC/P68, an aircraft built entirely in carbon and Kevlar, equipped with a 100 HP Rotax engine, with a flight range of about 6 hours. It is a flexible aircraft, which can take off from and land on airports and airfields with a runway length of only 500 m.

UAV:

Technological development in the field of automation has provided precision viticulture with a new solution for remote monitoring, UAVs. These fixed or rotary wing platforms are capable of flying autonomously. They are sometimes also improperly called “drones”, due to their monotonous low dull sound like the buzzing of a male bee. UAVs can be remote controlled at visual range by a pilot on the ground or fly autonomously to a user-defined set of waypoints, by means a complex system of flight control sensors (gyros, magnetic compass, GPS, pressure sensor, and triaxial accelerometers) controlled by a microprocessor. These platforms can be equipped with a series of sensors, which allow a wide range of monitoring operations to be performed. The peculiarity of UAV application in remote sensing is the high spatial ground resolution (centimetres), and the possibility of highly flexible and timely monitoring, due to reduced planning time. These features make it ideal in vineyards of medium to small size (1–10 ha), especially in areas characterized by high fragmentation due to elevated heterogeneity. Vineyards are a common target of study in wine-producing countries, such as the USA, Spain, France, Italy, and Australia. Despite these positive aspects, UAV platforms have an important limitation in terms of payload weight and operating times. Moreover, the implementation of flight regulations has been demanded by UAV stakeholders to drop the barriers for UAV certification and use for all applications involving a large group of contributing agents and institutions. UAV regulations are discussed in European RPAS Steering Group (ERSG) and Federal Aviation Administration (FAA) reports, and a comprehensive description of the most recent works is presented by van Blyenburgh, who reports the experiences of different expert groups from several countries around the world.

Remote sensing sensor and applications:

Applications of remote sensing in precision viticulture are focused mainly on reflectance spectroscopy, an optical technique based on reflectance measurement of the incident electromagnetic radiation at different wavelengths, in particular in the visible region (400–700 nm), near infrared (700–1,300 nm), and thermal infrared (7,500–15,000 nm). The relationship between the intensity of the reflected and incident radiant flux is specific to each type of surface. The spectral reflectance of a body, such as a crop or soil, is called the “spectral signature”, and is represented on an XY graph, with the reflectance value on the ordinate and the wavelength of the spectrum on the abscissa.

The most common classes of sensors are capable of detecting an alteration of transpiration or photosynthetic activity on the leaf surface. Thermal sensors are used to remotely measure leaf temperature, which increases when water stress conditions occur, and is followed by stomatal closure, which reduces the water loss and at the same time interrupts the cooling effect of evapotranspiration. Alterations in photosynthetic activity are linked to the nutritional status, health, and vigor of the plants, and can be detected with multispectral and hyperspectral sensors. Leaf reflectance is influenced by different factors in specific regions of the spectra: in the visible by the photosynthetic pigments, such as chlorophyll a, chlorophyll b, and carotenoids; in the near infrared by the structure of the leaves (size and distribution of air and water within the canopy); and in the infrared by the presence of water and biochemical substances, such as lignin, cellulose, starch, protein, and nitrogen.

Satellite and aerial images are frequently used to estimate spatial patterns in crop biomass and yield, using vegetation indices such as the NDVI. Correlation of these indices with structural or physiological characteristics of the vine is well studied. NDVI can be related with different factors, such as the LAI, the presence of nutrient deficiencies, water stress status, or health status, while the narrow-band hyperspectral vegetation indices are sensitive to chlorophyll content.

Hyperspectral remote sensing provides a powerful insight into the spectral response of soils and vegetated surfaces, collecting reflectance data over a wide spectral range at high resolution (typically 10 nm), while multispectral sensors acquire reflectance data in a reduced spectrum range focused on the blue, green, red, and near-infrared regions, with less resolution (at least 40 nm wide). Another field of application is the study of the canopy structure and biomass by light detection and ranging (LiDAR) systems, a remote sensing technology that measures distance by illuminating a target with a laser and analysing the reflected light. Figure 2 shows some of the newest remote sensing sensors used in precision viticulture.

4.2.3. Proximal sensing

Within proximal sensing applications, there are many tools available for continuous measurements carried by moving vehicles, or instruments for precise ground observations made by an operator.

Figure 2. Some kinds of sensors developed ad hoc for monitoring applications for unmanned aerial vehicle platforms.

Notes: (A) Three-band multispectral camera Tetracam ADC-Lite. (B) Six-band multispectral camera Tetracam Mini-MCA. (C) Micro-Hyperspec VNIR hyperspectral camera. (D) Ocean Optics USB4000 spectrometer. (E) FLIR TAU II. (F) YellowScan LiDAR.

Abbreviation: LiDAR, light detection and ranging.

Wireless sensor network:

Wireless sensor network (WSN) technologies provide a useful and efficient tool for remote and real-time monitoring of important variables involved in grape production, processing the data and transmitting the required information to the users. A WSN is a network of peripheral nodes consisting of a sensor board equipped with sensors and a wireless module for data transmission from nodes to a base station, where the data are stored and accessible to the end user. The nodes are energy independent and are installed in areas representative of the vineyard variability, which can be identified with information provided by a vigor map (Figure 3). A comprehensive review on the state of the art of WSN in agriculture and the food industry was written by Ruiz-Garcia et al. With regard to viticulture, Burrell et al described WSN applications and configurations for different purposes within the vineyard, while Beckwith et al56 implemented a WSN consisting of 65 motes that collected temperature measurements in a vineyard over 1 month. Matese et al proposed a wireless sensor application in precision viticulture, which enables site-specific microclimate monitoring for different vigor areas of the vineyard. In recent years, the advent of low-cost and open-source technologies has led to their wide diffusion in the scientific community. The possibilities afforded by an open-source hardware system, the most famous example being the Arduino project, include the rapid prototyping of information communication technology systems where circuit models are licensed under Creative Commons and the source codes are publicly available and customizable by the user. This leads to a coordinated development of hardware and software solutions, with ample and effective support from network communities, therefore a wide range of ready-to-use software applications is available on the Web, shortening development times. At the same time, the evolving technology provides solutions that are increasingly efficient in terms of minimal size, low cost and power supply, and improved power transmission, which allow greater distances to be covered with reduced consumption. The primary application of WSNs is the acquisition of micrometeorological parameters at vine canopy and soil level. In the last decade, the continuous innovation process has allowed the development of new kinds of sensors for plant physiology monitoring, such as dendrometers and sap-flow sensors, for the continuous measurement of plant water status for irrigation scheduling.

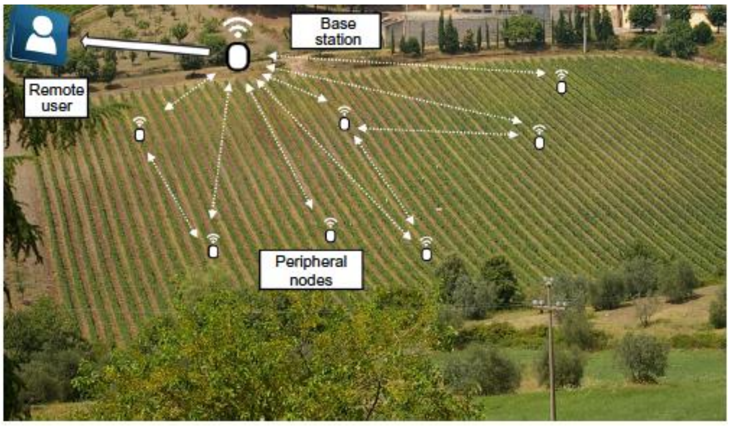


Figure 3. Wireless sensor network architecture deployed in a vineyrd at Azienda Agricola Castello di Brolio, Siena, Italy.

Soil monitoring:

An important application of innovative techniques in precision viticulture is the proximal monitoring of soil variability, which includes the use of a wide range of sensors. Measurement of the apparent electrical conductivity of the soil can be detected by mobile platforms equipped with soil electromagnetic sensors and GPS for continuous measures. It is a parameter strongly correlated with many soil properties, such as texture and depth, water retention capacity, organic matter content, and salinity. The sensors used for this type of measurement are either invasive electrical resistivity or noninvasive electromagnetic induction sensors. The first type (electrical resistivity) are used to control the resistivity, and therefore conductivity, of a given volume of soil, generating electrical currents and subsequently measuring the potential differences. Among the commercial systems available, the Veris 3100 (Veris Technologies Inc, Salina, KS, USA) and the Automatic Resistivity Profiling system (ARP) (Geocarta Ltd, Paris, France) are the most common. The operating principle of the electromagnetic induction sensors involves the generation of a magnetic field that induces electrical current in the ground, which in turn creates a second magnetic field proportional to the conductivity of the soil that is measured by the sensor. Some devices on the market are the DualEM (DualEM, Milton, ON, Canada) and EM-31 and EM-38 (Geonics Ltd, Mississauga, ON, Canada). There are also newly developed sensors for mobile platform applications, for the measurement of pH, ionic nitrogen, and potassium content, for the measurement in near-infrared and mid-infrared spectra, ground penetrating radar, and radiometers. The soil proprieties play an important role in vine growing, so knowing the spatial variability of soil characteristics within a vineyard allows improved understanding of vine physiological response variability.

Crop monitoring:

Many systems have been developed for monitoring vineyards, which provide a high-resolution screening of the canopy side across the row coupled with a GPS system for data georeferencing. In relation to crop sensors, Zhang et al point out various possibilities. One example of these sensors is GrapeSense (Lincoln Ventures Ltd, Hamilton, New Zealand), which captures a high-frequency digital image of the canopy side, collecting information on the height and texture of the vines along the row. Other systems are based on multispectral sensors like GreenSeeker® (NTECH Industries Inc, Ukiah, CA, USA) and the Cropcircle (Netherlands Scientific Inc, Lincoln, NE, USA), which supply information for vegetation indices calculation, strongly correlated with the vertical LAI and the leaves' layer density.

Figure 4. The Trimble GreenSeeker multispectral sensor for canopy monitoring, carried on a quad (practical Precision Inc., Tavistock, Canada) (A) or tractor (Avidorhightech SA, Le Mont-Pelerin, Switzerland) (B).

These sensors are designed to be mounted on machines and tractors (Figure 4), allowing the acquisition of spatial data during the daily vineyard management. Another solution in continuous development is the use of LiDAR sensors, which can provide a georeferenced 3D reconstruction of each single plant and generate spatial variability maps referring to the volumetric size of the canopy, directly correlated with the LAI. Thanks to these proximal monitoring systems, it becomes possible to analyse the spatial variability with higher resolution than provided remotely.

Yield and quality monitoring:

Many systems have been developed to obtain georeferenced yield information, especially integrated on mechanical harvesters. Varieties of solutions are now available on the market such as HarvestMaster Sensor System HM570 (Juniper Systems Inc., Logan, UT, USA), Canlink Grape Yield Monitor 3000GRM (Farmscan, Bentley, WA, Australia), and Advanced Technology and Viticulture (ATV) (Advanced Technology Viticulture, Joslin, SA, Australia). The HM570 system operating principle is based on a volumetric grape measurement on the discharge conveyor belt of the harvester; 3000GRM and ATV systems perform a direct measurement of the transported grape weight by means of load cells. These tools give the farmer the ability to map the vineyard productivity with a resolution never previously achieved (Figure 5). The yield maps realized with these sensors represent an excel-lent tool to verify the effectiveness of management practices applied in the vineyard.

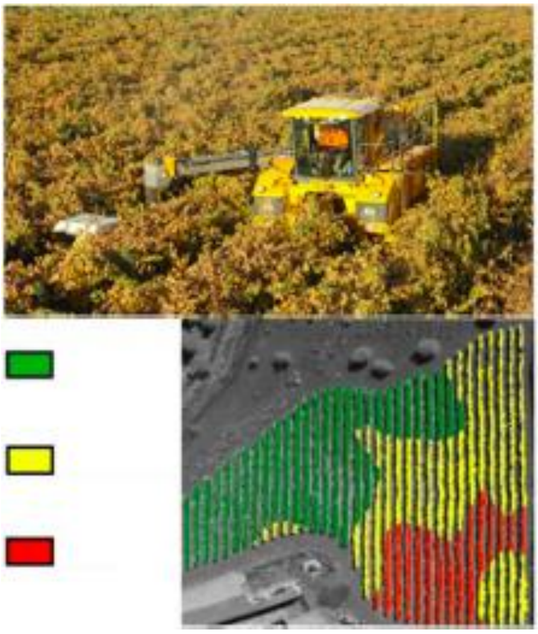


Figure 5. Harvester (GREGOIRE Group, Cognac Cedex, France) equipped with a georeferenced yield monitoring system (A) and a yield of the vineyard (B).

Nondestructive monitoring of grape quality parameters is based on optical sensors designed as “hand devices”, instruments carried by an operator, used for proximal georeferenced measurements (Figure 7). Among the most important devices available, the Spectron (Pellenc SA, Pertuis Cedex, France) is a portable spectrophotometer with integrated GPS, designed to monitor grape maturation through nondestructive measurement of parameters related to grape quality, such as the sugar, acidity, and anthocyanin concentration and water contents. The Multiplex (Force-A, Orsay Cedex, France) is a portable optical sensor that uses fluorescence to quantify polyphenols and chlorophyll content, with georeferenced noncontact measurements both on target leaves and grapes. The processing of the acquired data allows indices to be obtained relating to the concentration in flavonols, anthocyanins, chlorophyll, and nitrogen nutrition. Given its technical specifications, this tool has also been used on mobile ground vehicles.

Figure 6. Spectron (A) and Multiplex (B) hand -device sensors for grape quality proximal monitoring, which allows quality maps to be realized

4.2.4. VRTs and agbots

VRT in precision viticulture allows agronomic management to be differentiated and the inputs dosed in time and space. This technology uses software that can combine the position information, obtained by a GPS module, with prescription maps generated for each specific operation. The agronomic inputs will no longer be applied as average quantities per hectare, but according to the real needs of the vines derived from the vineyard heterogeneity.

The concurrent development of standard electronic communication in agricultural machinery has facilitated the connection between tractors and equipment. Considerable efforts have been made to develop international standards to regulate the communication protocols and exchange of information between sensors, actuators, and software from different manufacturers. Research conducted on VRT has explored many application solutions, including the differentiated distribution of fertilizers and pesticides and pruning methods. The key factors of the variable-rate strategy potential are based on the development of innovative technologies in the field of vegetation monitoring and high-performance atomization systems. The implementation of site-specific vineyard management aims to abandon the concept of the vineyard as a territorial unit and suggests a parcel and even sub-parcel management level. With engineering development, in particular in the field of satellite navigation systems, VRT will become more accurate and easier to use, with lower costs.

VRT:

Modern agricultural machines utilize automation technologies both to control the movement within the vineyard, in terms of speed and direction of travel and steering angle, and to manage the agronomic operations. Advanced board technology makes it possible to have an automatic guidance system based on the use of GPS and proximity sensors.68 At the same time, tractors have been engineered to perform site-specific operations autonomously without human intervention, thanks to the interpretation of prescription maps made with monitoring sensors mounted on board, which can monitor the plant status during the progress along the row, interpreting information and managing operations in real time. There are many commercial solutions for VRT in vineyards (Figure 7).

Figure 7. Some automated commercial solutions used in precision viticulture.

Notes: (A) Pellens Australia 600LM SP selective harvester. (B) Tecnovit Mod. III S VRT variable-rate leaf stripper. (C) Durand-Wayland SmartSpray selective atomizer with ultrasound sensors. (D) Tecnovit Mod. VRT 150 variable-rate fertilizer spreader. (E) GreenSeeker vigor monitoring system for treatments at variable rate

This technology meets the current needs of the food industry, ensuring adequate productivity and profitability in the vineyard. The resulting benefits are a substantial reduction of the work and speeded-up operations. The guidance systems can reduce operating stress, while the VRT provides a rational use of agronomic inputs, with direct impact on costs, quality, and environmental sustainability.

Robotics:

The use of robotics in precision viticulture is still at a proto-type stage, but many projects are already in the final stage of development, and some have already been put on the market.

Professor Simon Blackmore, a leading expert in precision agriculture, told at the 2014 Oxford Farming Conference in the UK that his vision was for "farming with robots in 2050", and that "farmbots" or "agbots" are the future of agriculture. If, in recent years, there has been an important effort of innovative technologies in agriculture, the coming years will see an exponential increase with higher-performance solutions and reduced costs. Automation and robotics will be accessible to small businesses, becoming widespread, but we must not forget that all this technology for monitoring and intervention is of no use without the support of the farmer's experience.

A review follows of the robotic innovations for precision viticulture. The VineRobot project coordinated by Televitis group, at the University of La Rioja in Logroño, La Rioja, Spain, has received more than €2 million financing by the European Union. The goal of the project is the development of a new agricultural robot, equipped with non-invasive sensing technologies, such as sensors, fluorescence, multispectral, RGB for machine vision, thermal infrared, and GPS. The system is designed to perform a proximal monitoring of various critical parameters such as yield, vigor, water stress, and quality of the grapes, and provides a tool for decision support to the grower to improve the management of the vineyard (Figure 8A).

The VINBOT project exploits the technology proposed by the Spanish Robotnik Automation Company.71 It has developed a robotic platform with open-source software. The system is equipped with sensors for 3D reconstruction of the leaf curtain, and multispectral cameras for vine vigor, to provide important information such as the estimation of productivity. The robot acquires data at an operating speed that can monitor a surface of 1 ha per hour; it is capable of moving on slopes of up to 45° and is powered by an electric motor with a range of 8 hours a day (Figure 8B).

The Wall-Ye robot is a product developed for vineyard monitoring by Christophe Millot. It can move independently along the rows, acquiring data on each vine, and producing a very highly detailed vineyard map. Thanks to a monitoring system based on many optical sensors, this robot cannot only perform correct displacements within the vineyard, but also carry out precision pruning, respecting the specific structure of each individual vine. Wall-Ye has an autonomy of 12 hours and can prune about 600 plants per day. It can also be monitored remotely by means of an application developed for the iPad. Thirty have already been sold to French winegrowers, at a market price of around €25,000 (Figure 8C).

Ben-Gurion University of the Negev, in Beer Sheva, Israel, developed a prototype designed for foliar applica-tions.73 The robot, called VineGuard, can move within the vineyard using a complex set of sensors, with a movement system optimized for rough terrain. In addition to this application, a robotic arm designed for grape harvesting is in development, using artificial intelligence to guide the robot in a series of operations, such as localization, assessment of the maturation state, and selection and detachment of the grapes from the vine (Figure 8D).

Vitirover is the result of a project conceived and produced by Xavier David Beaulieu, owner of Chateau Coutet (Saint Emilion, France), and received an award at the Grand Prix of Innovation in 2012 at the salon Vinitech-Sifel. This little robot is able to cut the grass up to a distance of 2–3 cm from the base of the vine, in full respect of the plant, ensuring a cutting height of between 4 and 10 cm. The robot has four drive wheels that allow it to work in steep vineyards up to a maximum gradient of 15%. The power system is completely self-sufficient thanks to a solar panel; however, the operating speed is low (500 m/h), so about 100 hours of work is needed to cover 1 ha of vineyard. The robot works independently on the basis of GPS coordinates, but can also be controlled by computer or smartphone thanks to a simple application compatible with iPhone, BlackBerry, and Android. Although the machine is able to work in a constant way, the time necessary to treat a single hectare remains high and is therefore also a function of the relatively low cost (about €5,000). The manufacturers recommend the use of multiple units for efficient vineyard management (Figure 8E).

The American company Vision Robotics Corporation (VRC) has developed a prototype able to perform a precision pruning, by means of optical sensors that perform a 3D reconstruction of the vine structure. The robot identifies the points of intervention according to the specifications provided by the harvester, and carries out very high-detail pruning cuts by means of two hydraulic shears. The prototype is still in an experimental phase, but the final product is expected to be on the market in 2016 at a base price of about €120,000 (Figure 8F).

A robot tractor prototype has been developed by Autonomous Solutions (ASI). The Forge Robotic Platform can be driven by remote or be completely autonomous but will also be available in a cab version for transporting the operator on board. It is a real tractor capable of supporting agricultural tools commonly used in vineyard management. The testing phase of this prototype is nearly over. It is intended to be marketed by the end of 2015, with a price ranging between €60,000 and €120,000, depending on the configuration (Figure 8G).

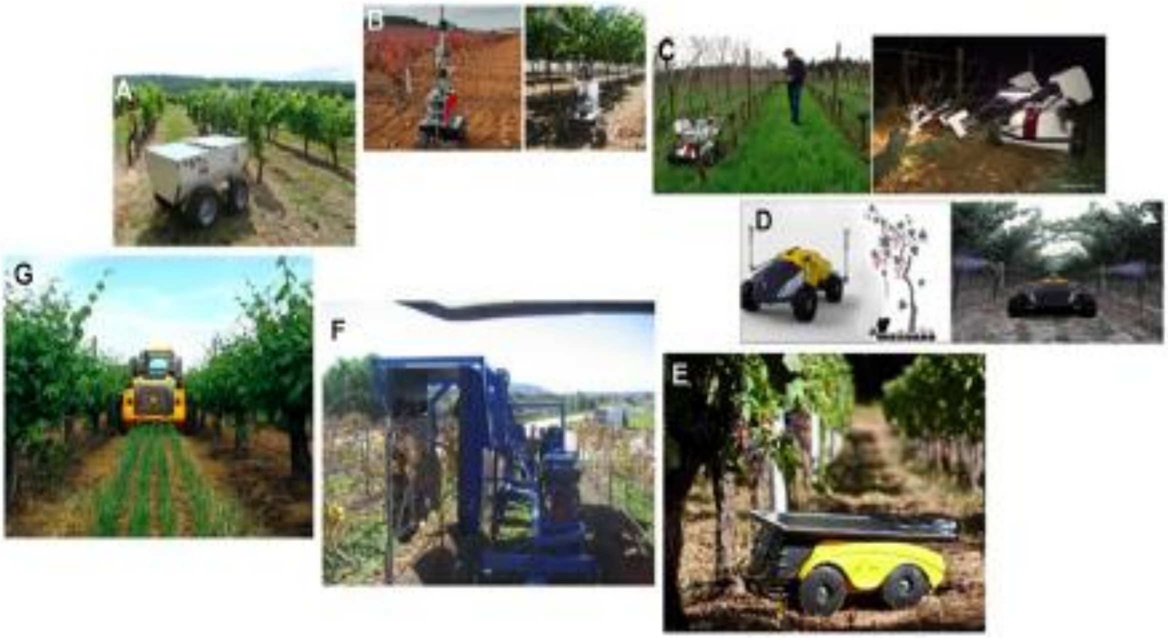


Figure 8. Some robot prototypes and commercial solutions for precision viticulture

Notes: (A) VineRobot. (B) VINBOT. (C) Wall-Ye. (D) VineGuard. (E)Vitirover. (F) Vision Robotics Corporation (VRC) robot. (G) Forge Robotic Platform

The WINEgROVER:

The WINEgROVER is an innovative precision agriculture system developed in the frame of a project financed by the EU LIFE program. The main goal of the project was the development of an Innovative Integrated System for Precision Farming integrating innovative technologies like autonomous aerial and terrestrial drones platform, monitoring system and dedicated software and a multi sensors platform. The innovative approach at the basis of WINEgROVER, is an Unmanned Ground Vehicle rover prototype developed by the company SETEL (Fig. 9).

Figure 9. The terrestrial rover prototype developed in the framework of the LIFE WINEGROVER project.

The prototype already owns a Technological Readiness Level of 6 and at the end of the project it will be integrated with other components and implemented to become a commercial product. The rover can be equipped with various non-invasive sensing technologies to monitor several parameters (grape yield, vegetative growth, water status, grape quality and composition, etc.) and also equipped with actuators capable of performing precision interventions on the plants for precision foliar drip irrigation and precision pesticides and nutrients application. The system covers the integral monitoring of vineyards over the entire season and allows to provide key information regarding vines performance parameters much faster than manual solutions and at higher resolution, in a more flexible and efficient manner and with lower costs. Final users can receive updated information concerning their vines status in the vineyard through an application (mobile, tablet, computer) as simple maps.

This precision viticultural system allows for revolutionary and conclusive decision-making to optimize vineyard management (pesticide, water and nutrition management) and to drive agronomical fundamental decisions according to yield estimation, plant growth monitoring, sanitary and water status and berry quality assessment (chemical, biological and physical traits). The project has been implemented in a pilot plants and relies on the introduction of a system of zonal vineyard management by the application of site-specific techniques in order to improve grape quality and yield and minimize the impact on the environment. The project advocates a differentiated agronomic approach to vineyard management based on the spatial-temporal variability of vegetative development, production and quality of the vineyards. The system represents a case of forefront viticulture practice requiring objective and continuous monitoring of key parameters for rational decision making using new technologies and advanced sensors applied to vineyards:

- The system monitors grapevine parameters on-the-go: yield, vegetative growth, water and sanitary status, berry chemical, biological and physical traits.
- Images acquired, and data generated are processed and sent to grape-growers.
- Final users receive real¬-time data in specifically developed app for tablets, computers and smartphone devices.
- Data are used to instruct the rover to provide reduced and precise quantities of pesticides, fertilizers and water for the vineyard management optimization improving grape quality and production.

Next phase of the project will be the testing of the solution in two different pilot vineyards in Italy and Spain in order to validate for the first time in Europe their effectiveness in real-vineyard situations, identifying the constraints and the specific cost of their implementation and integrating different technologies.

4.3. Conclusion

The aim of this review is to report the state of the art of technologies in the field of precision viticulture. In recent years, these technologies had rapid development and greater applicability due to lower costs, ease of use, and versatility. In general, the application advantage of these innovative solutions is a cost reduction in crop management, through improving crop quality and yield production, process traceability and environmental sustainability with a rational use of chemical inputs.

The rapid innovation in proximal sensing technologies involve an optimization of Decision Support System (DSS) and thus make possible the implementation of rapid intervention strategies. However, it will be necessary to choose the best remote sensing platform for each kind of application. Even if satellite and aircraft are excellent tools for producing prescription maps for variable-rate applications, satellite already has limitations due to low resolutions for precision viticulture, and aircraft imply very high operational costs. At the same time, the UAV platform presents a high ground resolution, great flexibility of use and timely intervention, but it is economically feasible only for small areas (about 10 ha) and experimentation. VRTs are well developed and widely used, especially in chemical applications.

Currently, remote and proximal monitoring technologies and variable-rate machinery are applied on a broad basis, while robotics reported in this review are in an experimental stage.

In general, there are issues to overcome before widespread adoption of these technologies can take place, which are related not only to the need to further explore the potential of these tools, but above all to the ability of farms to train technicians capable to understand and properly use this type of technology.

5. Viticulture sector in Spain.

5.1. History of wine in Spain

The wine history is lost in the history of mankind. The first crop of grapes in Spain began has made 3000 years ago (Iglesias, 1995). This section of work the evolution of the Spanish wine sector is analysed in the last 150 years, in these years happen very important facts such as: the great expansion of exports, the arrival of phylloxera, the production of quality wines in Spain, changes in demand or changes in the technological process.

In the last 150 years, production and marketing of wine has undergone great changes in the world. In the second half of the nineteenth century, the international wine market was formed, in which France had a central position, of its imports and exports. France especially exported quality wines and it was a major importer due to the phylloxera plague that devastated the vineyards.

In this context, Spain experienced a major expansion of its exports, both to France as to other destinations. The spectacular results at the outputs the wine, had its counterpart in the descent of the quality in the exported product, most of which can be considered a raw material for coupagues with French wine, that is to say, the wines with different characteristics are mixed in order to get another wine having the characteristics of the wines involved in the mix. The change of the French trade policy caused a major crisis in the sector, which was worsened by the arrival of phylloxera. The problems escalated with the low growth in consumption of the industrialized countries of northwestern Europe and protectionism in other continents.

In the first third of the twentieth century, the great work was to replant the entire vineyard which had been affected by phylloxera, without that the domestic demand produce more significant changes and with more serious consequences. The domestic demand was geared mainly to low quality wines. Still, the tariff measures taken by Spain against France generated opportunities f1or the production of quality wines in Spain. Until the late nineteenth century sherry was the great exception of quality wine and was oriented to the British market, Spanish wines were continued with a low quality. In the last decade of the century, the wineries producing good quality wines grew. The great examples and epicenters of technical change in the Spanish wine industry are: La Rioja, with table wine and the Penedes with sparkling wine.

Post-Civil War decades offer no large changes in the sector, Spain seems trapped in the production of low-quality wines, because it is in what had specialized, as a result both of the few changes in the domestic demand as the expansion of the demand for this type of wine in the international market. Consequently, Spain lost positions in international markets and misses significant changes in external demand, such as the strong growth of wine consumption in developed countries.

In the late twentieth century, the sector significantly was transformed, thanks to the technologies available for the production and the imitation of the quality Spanish producers who offered a different product for over a hundred years. Successes in the export of sparkling wine or growing share of the bottled wines of medium or high quality are the clearest signs of changes.

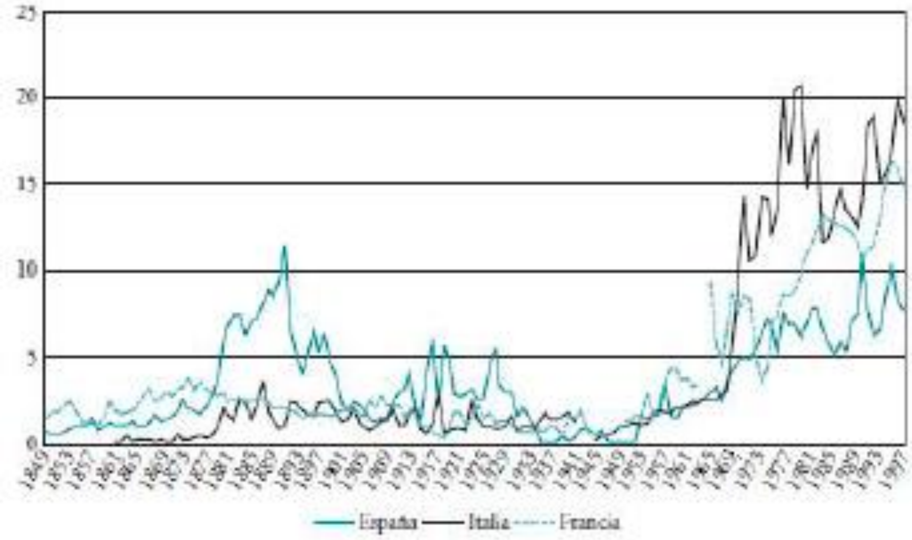


Figure 10. Spanish, Italian and French wine exports (1849-2000). In million hectolitres (Castillo and Compes, 2014)

The wine sector is evolving in an increasingly competitive international scenario characterised by the irruption of new producing countries with innovative strategies in production and trade, allowing them to occupy growing participations in the global wine market. In fact, although the chief traditional producers (France, Italy and Spain) maintain worldwide market leadership, the so-called new producer countries (mainly the United States, Australia, Chile, Argentina and South Africa) are those that largely have led the intensification of international trade occurred during the last years. These countries base their export strategy on strong brands linked to a relatively homogenous product range, supported by substantial investments in promotion and advertising, and easily identifiable by the consumer through varieties.

International positioning of new producers is also favoured by high business concentration. The top five companies control 73% of wine production in the United States, 68% in Australia and 47% in Chile, against respective figures of 13% in France, 10% in Spain and 5% in Italy. High concentration facilitates the elaboration of plans for penetration and consolidation in external markets, substantial investments in technical innovation and promotional marketing, more efficient connection with distribution networks, and access to the financial markets.

Meanwhile, the prevailing industrial organization model in Europe is sustained on product differentiation based on the territory through the recognition of Designations of Origin (DO) and Geographical Indications (GI). This has traditionally conditioned the size of enterprises and restricted them to a specific geographical area and traditional production systems, contrary to industrial production systems developed in the new world countries where volume strategies are determining. Consequently, the Mediterranean wine industry is highly atomised, where coexist companies of different size and structure, and in which specific weight of the cooperatives is rather elevated.

Another contributory factor of increasing competition on the world wine markets is the evolution of demand. In aggregate terms, the tendency towards reduction in world consumption experienced during the decades of 1980s and 1990s has been reverted in 2000 (since then, global wine demand has increased by 9%, according to OIV [5]. However, in the major producing and consuming countries the net tendency has been to decrease: between 1989 and 2004, total wine per capita consumption has fallen from 72 to 55 litres in France, from 62 to 49 litres in Italy and from 54 to 34 litres in Spain. This decrease has concerned almost exclusively table wines, whereas higher quality wines have seen their market share increasing progressively. In the European Union (EU), the proportion of quality wine consumption within total wine consumption has increased from 30% in 1986 to 46% in 2006.

Adaptive production and commercial strategies are also affected by national and supranational public regulations. In the EU, wine production has been traditionally conditioned by Common Agricultural Policy (CAP) which bases the control of vineyard production potential on the prohibition of new plantations and yield limitation in the DO areas. The Agenda 2000 represented a turning-point in the Community wine policy when it has been transformed from a price to quality-support policy [7]. The objective was not specifically to balance supply and demand but rather to adapt supply to the new quality requirements in order to improve European competitiveness and to increase exports (EC Regulation 1493/1999 of 17 May 1999). To this end, an impulse has been given to plans for vineyard restructuring and re-conversion.

The new Common Market Organisation (CMO) for wine approved in April 2008 and entered in force in August of the same year, is also inspired by this objective of improving quality and competitiveness. It has envisaged a rapid restructuring process through a program of subsidised grubbing-up coupled with medium-term suppression of plantation rights, the disappearance of traditional instruments for market intervention, and the possibility of implementing new measures like promotion in foreign markets and the modernisation and investment in wineries and vineyards, leaving in all these processes ample margins for action to Members States.2 Moreover, the new reform maintains the authorization of wine enrichment with sugar to reach sufficient alcoholic graduation. It is an allowed practice in Northern EU countries that Southern countries tried to eliminate arguing that its removal could contribute to the elimination of over-supply. It also maintains the prohibition of mixtures of European wines with wines from third countries. Mixtures could harm countries like Spain, which in such cases would face competition of countries like Argentina, producer and exporter of bulk table wines potentially usable in mixtures with French wines, for instance.

In Spain, whereas the vineyard area has experienced in the 1980s a notable reduction largely prompted by Community policy incentives to grubbing-up, over the 1990s significant improvement of the productive potential has happened through rejuvenation of old plantations and changes in production methods, with a tendency towards an increase of the irrigated surface which presently represents 25.2 % of total vineyard surface. The process has been reinforced by CAP re-conversion and restructuring programs initiated in 2000, which have concerned 126,000 hectares that have received subsidies amounting 973 million euros.

This has contributed to a substantial increase of production. Averages close to 34 million hl in the decade of 1990s have risen to more than 45 million hl over the last campaigns. This caused disequilibria between supply and demand as uses have not increased in the same proportion. In particular, domestic consumption has been declining and exports have experienced only slight increases. The result has been a significant increase in available supplies pressing downward market prices and economic results of companies. In the medium term this situation could compromise the viability of the sector in many fragile zones, with important consequences on the conservation of natural resources and rural development.

Moreover, it is worth mentioning that at the normative level, the Spanish government has approved in 2003 a new Law of wine whose main objective has been to modernise and to adapt the wine quality regulation to new market conditions. The Law established inter alia a new classification of wines, introducing two new categories: quality wines with GI and vinos de pago (equivalent to French crus), in addition to the already existing table wines vinos de la tierra (land wines) having the right to use a geographical mention and wines with DO. A controversial aspect of this Law is permitting the use of the same brand in different DO, allowing large companies to benefit from scale and branding strategies.

5.2. Types of grape varieties and wine making

This section will analyse the type of grape varieties and the process of winemaking. First will be presented, the types of major varieties of grapes in Spain and in the foreign. Then will explain in detail, the stages of the production process of red wine and white wine.

5.2.1. Types of grape varieties

The grape variety is very important to understand wine, as in some countries differ their wines through the type of grape and consequently people when they go to buy wine, they seek which is the variety used for production.

The grape varieties from Spain and some foreign varieties more important they are:

5.2.1.1. Red varieties.

- *Tempranillo:* It is the most common variety and typical of Spain. It has this name because it is collected before other varieties. It is a grape with very fruity and aromatic touch, aging well in barrel. In Ribera del Duero and Toro it is called “ink of the country” or “ink of the Toro” so you can acquire differential characteristics compared to other regions.

- *Garnacha:* This grape variety is typical in the northeast of the country such as La Rioja, Navarra, Aragon and Catalonia. It is a very fruity grape but not age so well in barrel as the tempranillo.

- *Mencía:* This type of grape is specific in Spain and only grown in the Denomination of Origin Bierzo (Leon) and the Denomination of Origin Ribeira Sacea (Ourense). It is rough and dry grapes, but it has lots of character.

- *Monastrell:* This is a typical grape of Murcia and of south of Valencia. It produces powerful wines, with great structure an alcoholic degree something above normal.

- *Cabernet Sauvignon:* It is the most widespread French grape and grape most commonly used in many of the best red wines in the world. It gives the wine a pleasant acidity and aged remarkably well in barrel therefore, it is widely used in the mixture of varieties to give more structure and duration wines.

- *Merlot:* It is characterized by its finesse and its softness without leaving of being aromatic and meaty. It is native to the region of Bordeaux, France, where it is the most cultivated variety, after the Cabernet Sauvignon.

- *Syrah:* This type of grape is French and is widespread but its characteristics vary depending on where it is grown and the climate. In Spain, for example, there are some wines from Syrah with extraordinary power and smoothness, that differ much from the French Syrah which they are more acidic and soft. In Castilla la Mancha there are wineries that have specialized in their development and in the wine production in Australia are produced very interesting wines.

5.2.1.2. White varieties.

- *Verdejo:* It is one of the best white grapes of great quality in Spain. It provides an extraordinarily aromatic wine, which often resembles the smell of tropical fruits. This type of grape is abundant in the southern province of Valladolid especially in the municipalities of Rueda, where it is considered the main variety of this Denomination of Origin.

- *Albariño:* It is a type of white grape which is only grown in Galicia, as well as the wines produced with this grape are those of the Designation of Origin Rias Baixas. It produces an acid, dry, refreshing and very particular aroma wine.

- *Godello:* It is a type of grape which is used especially in northwest Spain (Galicia and Leon). This grape is known from only a few years ago, as previously It was cultivated sparsely and has a capacity of aging in barrels of more than 10 years.

- *Xarelo:* It is a type of white grapes used for the production of cava and mixed with other varieties such as Parellada and Macabeo. The wine is usually aromatic, balanced, silky and tasty. It can be fermented in barrel, but it does not work as a young wine (Turismo de vino, 2016).

- *Parellada:* It is a type of Catalan white grape. Also, It is used for the elaboration of cava together with the Xarelo and Macabeo. Although this variety is very fine and difficult to care as it is sensitive to disease and to drought.

- *Macabeo (o Viura):* It is one of the most widespread grape varieties by Spain. It is used to produce slightly acidic, pale and light wines. Traditionally, this grape was mixed with Xarelo and Parellada to produce cava.

- *Riesling:* It is a grape variety originally from Germany. It is used for obtain dry, fruity, sweet, fresh and scented wines without the need for mixing with other varieties nor need the contribution oak barrels to produce a good wine. Its production is limited.

- *Gewurstraminer:* It is a white grape variety which has a special relevance in France and Germany. It produces dry and aromatic wines and It can produce very dry or very sweet wines These wines combine well with Asian food.

- *Pinot Gris:* It is a white grape variety of French origin, it distinguishes for its floral fragrance and offers delicate wines with citrus, creamy and spaced flavours. Depending on the maturity of the grapes and the winemaking technique, they can be lighter or stronger wines.

- *Moscatel:* From this grape you can obtain a dry, aromatic or semi-sweet wine. It can also get a liqueur wine, usually it called mistela in the Valencia area.

5.2.2. Wine Making

Since the sixties the methods of making and aging wines have undergone a major evolution. New methods have been introduced to maintain control on the grape harvest monitoring the primary aromas of the fruit or the order and hygiene that must to keep a hold. Spain in particular, became one of the countries which less investing in innovation, since many wineries were still using traditional methods. Over the years Spain has gone on to have the most modern wineries in Europe.

Each type of wine has different processing methods and different aspects that influence the final result. As: vintage, wine colour or juice extraction.

- Vintage: It is a very important process, as the first selection of the fruit is done at this stage and success will depend largely on the work carried out in this process. The harvest is done during late August, early September and mid-October, when the fruit has acquired the desired degree of maturation. The transfer of the grapes from the vineyards to wineries, also it is very important, because the grapes cannot squash neither deteriorate or break, because the grape may lose the juice in and produce undesirable primary fermentations, so it must be done carefully.

- The colour of wine: The vast majority of the grapes used in winemaking have the same coloration in its pulp, regardless of the type of grape. The main difference between the production of red and white wines are the colouring pigments, for example, in the case red wines are in the skin, why it is so important that this colouring matter present in the skins is transferred to the whole mass of the must.

- Juice extraction: Juice extraction is a common process that is performed before starting the production process, regardless of the type of wine to be obtained. The remaining clusters vintage are offloaded into a container to proceed to crushed and must be performed precisely, what for it will not tear or break the vegetables and hard elements of a cluster, such as the nugget, the rapones or stalks (vegetable cluster structure) and husks.

A viscous paste composed by crushed grape, broken skins, seeds and stems. This paste is transferred to a series of dams, where beginning the process of developing the type of wine to be obtained. This paste is transferred to a series of dams, where beginning the process of developing the type of wine to be obtained. During transfer the mixture cannot produce more breaks and the mixture cannot be in contact with air to not have a premature and unwanted fermentation.

5.2.2.1. Red wine

The process of making red wine will be divided into 8 stages:

1. Reception

First through a stripping process it has removed all stalk because in the production of red wine the entire cluster is not used, as colour extraction is carried out through maceration and the presence of herbaceous structure containing much potassium, subtracts acidity wines and can often provide unpleasant herbaceous flavours.

2. Crushing

When the grapes are separated from scratch, they are crushed to extract the juice and is formed a past where the wort is together with the grape skins. This will allow greater maceration that is when the wort and the solids are deposited in a single deposit. Both flavours such as colour, found in the skin of grapes, so that during this process wort extract colour and aromas. The aromatic and phenolic substances pass from the skins, seeds and sometimes scrapes, the fermenting juice to provide the wine varietal aromas, colour and structure, during maceration of wine. The aim is to extract the maximum nice tannins.

3. Fermentation

Red wines undergo two fermentations. The first fermentation is called alcoholic or tumiltuosa fermentation. It is a process whereby the sugar of wort becomes ethyl alcohol by the action of natural yeast present in the grape husks (skin) and other elements, plus carbon dioxide release.

Fermentation is one of the key moments in winemaking. This process begins after crushing, when the dough from which we discussed in the previous stage. It is transferred to a deposit and there begins the fermentation. The tumultuous fermentation is so named, because it has a large activity of the yeast that metabolize sugars produce a large amount of carbon dioxide.

Carbon dioxide pushes up the skins, forming a barrier called hat. This barrier should be soaked to promote dissolution of dyestuffs and other elements of the wort, to it, this liquid is withdrawn from the bottom of the deposit via hose and is introduced from the higher. In addition, for that the hat is not be made excessively compact, it must be removed from time to time, this is called punching down.

The fermentation will take more or less time depending on the type of wine to be obtained, usually between eight and twelve days between 26ºC and 29ºC temperature. Then the liquid is extracted from the deposit and moves to another.

Sulfur dioxide is usual to use it before this process, to override oxidases which are enzymes that degrade the colour of wine, it found in grapes and also help to remove the wild yeasts present on the grape skins.

The second fermentation called malolactic, begins when the liquid is transported to another deposit with wort and separate solid matter, where fermentation ends, here malic acid, which it is the stronger it becomes softer and unctuous others such as lactic acid.

This second fermentation of the wine provides fineness and softness. In this phase the wort also must be removed manually, so the liquid continues to flow, this operation is known as roll up.

4. Pressing

After fermentation, when the liquid is transferred in the reservoir a solid part stays, which are the remains of the grapes and they are steeped wine. This wort is extracted using dams. The dams force the remains until almost dry. The wine obtained is called wine press characterized by being rich in coloring matter and tannins. But, above all, this wine should not be mixed with others.

5. Racking

It is to separate the wine from the lees accumulated in the bottom of the deposits and barrels. Lees are the remains of yeasts and other solid substances, which are at the bottom of the vinarios containers. These sediments not must be much time together with wine to go decreasing the turbidity.

This process aerates the wine, as it is convenient to help a good completion of fermentation and wine stabilization. This process allows the evaporation of volatiles.

Sulfur dioxide is used for cleaning the tanks, generally, a tablet of 5 grams' sulfur is burned, to prevent the vinegary bacteria and mold.

6. Clarification

Many remains are removed from the wine during decanting, but smaller or lighter debris are not removed. these substances are removed with to added to wine the colloids substances of vegetable and animal origin.

Formerly, this process was done with animal blood or egg whites, gelatins are currently used. These gelatins are responsible drag all suspended impurities containing wine, to the bottom of the deposit. For a perfect clarification are needed three weeks.

This step sometimes is followed by a filtering, which involves passing the wine through a porous element to remove resistant particles at clarification process. With this debris are avoided in the bottom of the bottle.

7. Ageing and Upbringing

After completing the above processes, the wine is selected by qualities or bottled, if immediate trade is decided, as a young wine or wine goes into barrels to complete the precesos aging and breeding, as vintage wine, reserve wine or wine great reserve.

After completing the two fermentations, the wine is stored in oak barrels, which provide flavours and aromas to the wine, depending on the type (French, American ...) and the toasting level that he has given to the wood.

The tanks, typically, are stored stacked in in underground cellars or fresh stores, where the wine is aging, stabilizing their colour and enriching their aromas.

8. Breeding in the bottle

This process involves the permanence of the wine inside the bottle in the room from the winery. It is a reductive breeding process unlike barrel aging which is oxidative.

9. Bottling

The corking dispersed air in the wine, that causes a deterioration of wine, until once elapsed time, oxygen is taken up by wine and within months becomes stabilized.

5.2.2.2. White wine

The process of making white wine is simpler and less complex than the preparation of red wine. The process of making red wine will be divided in 4 stages:

1. Reception and separation the musts

The difference between the drafting of red wine and white wine preparation, it is that red wine should not to separate the grapes of the husk, but let it drain all together. In making white wine, the grapes must be separated from the husk of grapes and the first must obtained it is called, according to the zones, wort yolk or wort of flower or tear.

This first must obtain is of higher quality, its main features are: a great lightness and finesse, aromatic, soft, floral and fruity.

2. Drained and pressing

Once obtained the first wort, the pasta remains much stronger of fluid loss and it is subjected to pressure from increasingly strong that is called "first", "second", "third" or "musts press' intensity, this depends the pressing from which it is obtained. The musts that have been obtained, subsequently will ferment separately, to obtain different types of wines.

The remnants that remain in the press are marks, which contain sugar because they have not fermented, and they are called sweet or fresh pomace. These marks can be subjected to different processes, giving rise to marks and other alcohol derivatives.

Before starting the process of fermentation, the wort should be debourbage this process consists of to let rest the wort, but with special care, to that the wort not begin to ferment.
The solids materials are falling to the bottom by its own weight and, later, the clean musts are decanted and transferred to stainless steel deposits for fermentation, following a meticulous control.

3. Fermentation

The clean must of solid matter is fermented at a temperature ranging between 18 and 22 degrees. In this process is achieved that both the splitting of the sugars into alcohol as the release of carbon, it makes in a slow and deliberate manner.

The aim of the process is to preserve the aromas of the wine and, therefore, get a higher quality. The amount of sugar that is left in the must and the temperature is very important to control them. A rise in temperature could result the death yeast and an unwanted stop in the fermentation. This process takes between 10 and 15 days and it ends when the wine contains between 1 and 2 degrees of sugar per liter. At this point the wine is completely dry, with little presence of sugars. However, completely dry white wines are increasingly scarce, since, usually, the white wines maintained a certain proportion of residual sugars to achieve greater flavor intensity.

When the wine is fermented without the skins contact are produced very light and clean wines. This fermentation is called: fermentation in virgin. Currently the must with marc it is starting to quiet to macerate, to slow down of the fermentation with the cold. The wine obtained in this process has more body, more intense sensations and aromas more powerful. In addition, this procedure favours the evolution in the bottle and lengthens life of the wine.

4. Racking and Clarification

When the fermentation process has finished, the must is subjected to two or three rackings for to remove the solid debris that it could have. This operation must be performed low temperature, to avoid contamination by unwanted microorganisms. Because of this, the rackings must be made between the months of November and January. After selecting the wines of different qualities, itself make different mixtures with those wines, to obtain the desired wine.

The last step in making wine, before bottling is the clarification by substances to drag suspended matter, which they had been able to avoid the rackings and finally the filtering.
Finally, the wines are selected and separated by qualities, so that, through appropriate mixtures, each wine is destined for a type corresponding of desired function.

5.3. Industry Characteristics

5.3.1. The wine sector in Spain

The Spanish wine sector is of great importance because of three issues: the economic value it generates, to the population that occupies and the role for environmental conservation.

As for the area of vineyards planted in Spain, there are 963,644 hectares it ranks as the leading country in Europe and worldwide. This extension represents 30% of the total European area while France has about 23% and Italy 22%. It has been estimated that in Spain around 97.4% of the planted area is used for the manufacture of wine, 2% for table grapes, 0.3% for the production of raisins, and nurseries remaining 0.3%.

Spain is a very privileged place for producing wines with very different characteristics thanks to the geographical location, the variety of soils and climatic differences.

5.3.2. Protected Designations of Origin and Protected Geographical Indications.

Protected Designations of Origin (PDO) and protected geographical indications (PGI) form the system used to recognize the differing quality of the wines in our country. The quality is recognized by the own and differential characteristics, which are due to: the geographical location of where the raw materials are produced, where the products are developed and the influence of the human factor.

The advantages and disadvantages of belonging to a determined (PDO) or (PGI) are:

- Advantages
  - The penetration of products in both domestic and international markets is easier.
  - The advertising and the offer of the product at a national and international level increase.
  - Products and processing thereof have a certain protection at national level and for an indefinite period. That is, the (PDO) and (PGI) are used as legal framework.
  - The organization of certain productive sector is furthered and favoured.
  - A level of quality and specific a characteristic is guaranteed for the consumer
- Disadvantages
  - A brand of wine can lose value if it belongs to a (POD) or a (PGI) which is not valued.
  - The barriers to entry to belong to a (POD) or (PGI) are very strict.

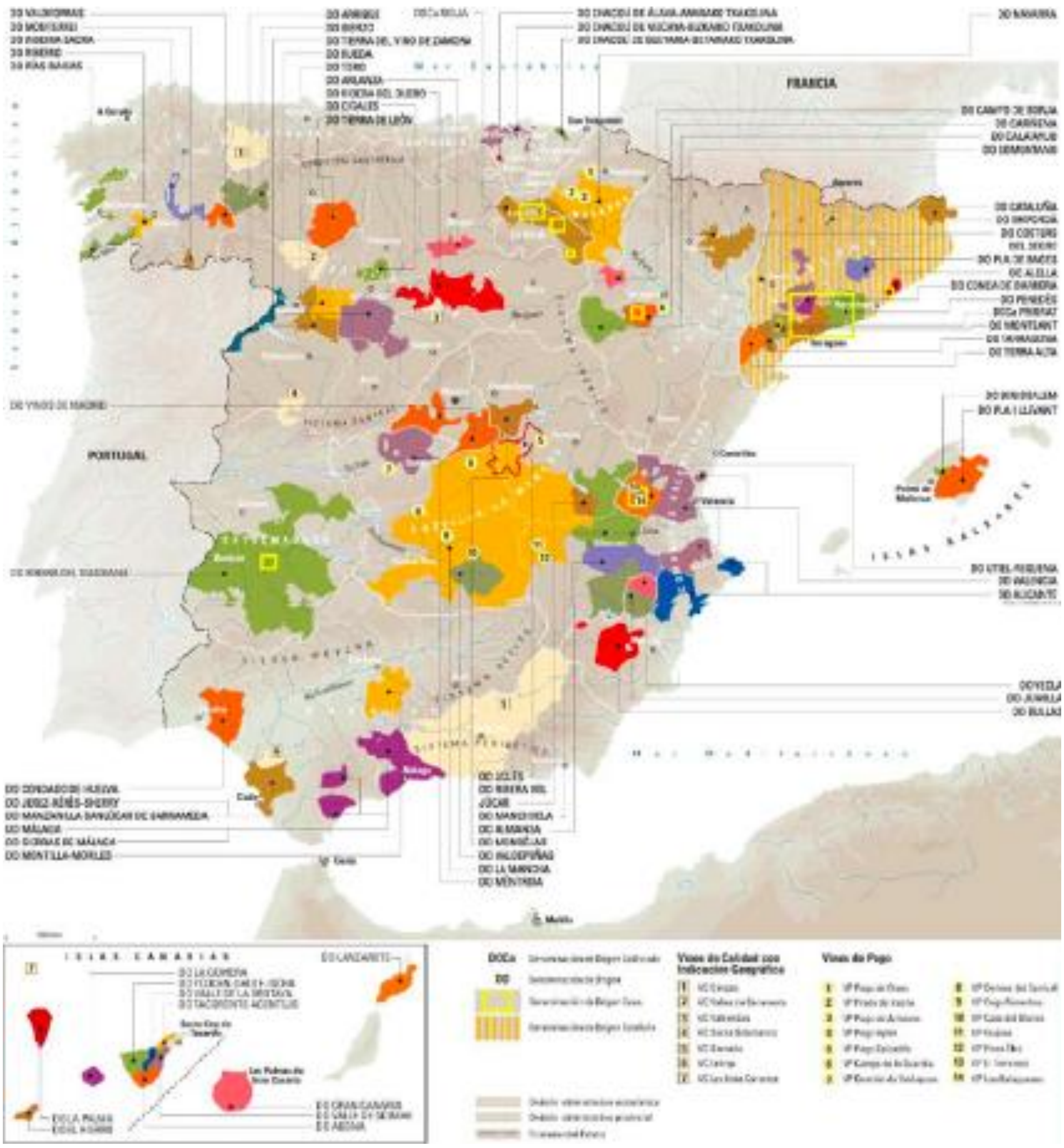


Figure 11. Protected Designation of Origin and protected Geographical Indication

Currently, the terms used to indicate that a wine belongs to a Protected Designation of Origin or a Protected Geographical Indication are:

Protected Designations of Origin

- Designation of Origin
- Qualified Designation of Origin

Quality wine with Geographical Indication

- Wine of Pago
- Qualified

5.3.2.1. Protected Designation of Origin (P.D.O)

The products listed under this name; they are protected by legislation of the European Union. This regulation ensures compliance with more requirements than other products (AEC).

The Spanish Denominations of Origin Protected most important are:

P.D.O hl	FOREING TRADE %		DOMESTIC TRADE hl%		TOTAL hl
RIOJA	**1.750.953**	**63**	**1.016.075**	**37**	**2.767.028**
CAVA	**610.778**	**34**	**1.199.105**	**66**	**1.809.883**
RUEDA	**578.528**	**86**	**55.528**	**14**	**674.056**
LA MANCHA	**441.614**	**69**	**200.767**	**31**	**642.381**
RIBERA DEL DUERO	**571.084**	**89**	**69.001**	**11**	**640.085**
VALDEPEÑAS	**338.818**	**60**	**229.535**	**40**	**568.353**
CATALONIA	**268.337**	**51**	**259.340**	**49**	**527.677**
VALENCIA	**119.888**	**26**	**338.673**	**74**	**458.561**
CARIÑENA	**106.252**	**26**	**303.257**	**74**	**409.509**
NAVARRE	**257.589**	**64**	**143.327**	**36**	**400.916**

Table 6. Distribution of the marketing of D.O.P. Spanish, campaing 2013/2014

5.3.2.2. Designation of Origin (D.O)

The Designation of Origin is the name of a place which has been legally recognized to designate wines that fulfil the following conditions.

- The wines had to be made in the region or place of the Designation of Origin with grapes exclusively from that particular geographical area.
- The wines must have special characteristics and a quality that can be obtained only thanks to the geographical environment in which they have developed.
- The wines must have a high reputation for its origin on the market.
- The wines for have the recognition of Denomination of Origin, they have had to be recognized from at least 5 years before as a product of that area.

The Denomination of Origin existing in Spain are:


•Condado de Huelva
•Jerez-Xeres-Sherry
•Malaga
•Manzanilla-Sanlucar de Barrameda
•Montilla-Moriles
•Sierras de Malaga
ANDALUSIA
• Cava
• Navarre
NAVARRE
• Benissalem
• Pla i Llevant
BALEARICS
•Almansa
•Jumilla
•La Mancha
•Manchuela
•Mentrida
•Mondejar
•Ribera del Jucar
CASTILLA LA MANCHA
• Cava
LA RIOJA
• Cava
• Ribera del Guadiana
EXTREMADURA
•Calatayud
•Campo de Borja
•Cariñena
•Cava
•Somontano
ARAGON
•Monterrei
•Rias Baixas
•Ribeira Sacra
•Ribeiro
•Valdeorras
GALICIA
• Abona
• El Hierro
• Gran Canaria
• La Gomera
• La Palma
• Lanzarote
• Tacoronte-Acentejo
• Valle de Güímar
• Valle de la Orotava
• Ycoden-Daute-Isora
CANARY
•Wines of Madrid
MADRID
•Arribes
•Arlanza
•Bierzo
•Cigales
•Ribera del Duero
•Rueda
• Tierra de León
• Tierra del Vino de Zamora
• Toro
CASTILLA Y LEON
• Bullas
• Jumilla
• Yecla
MURCIA

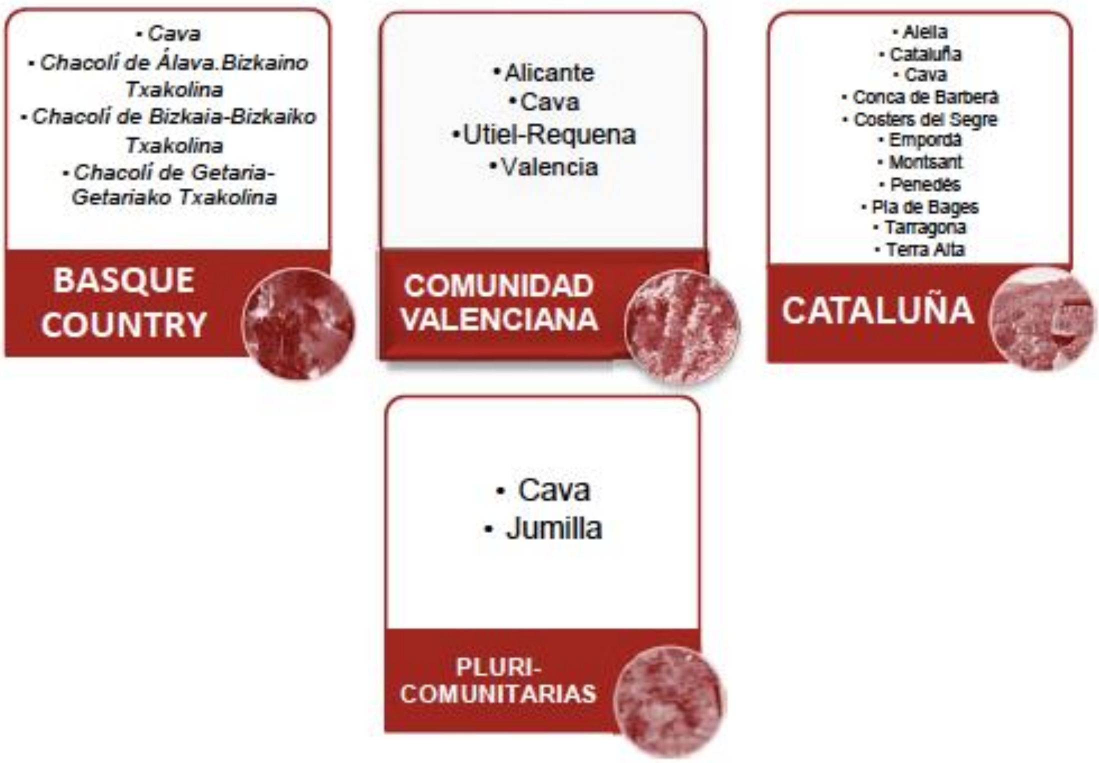


Figure 2. The Denomination of Origin existing in Spain

5.3.2.3. Qualified Designation of Origin

The wines to belong to a Qualified Denomination of Origin, on the one hand they must meet the requirements of the PDO and the following requirements:

- Ever since the mark was recognized as a designation of origin, at least 10 years have had to spend.
- All the bottled wine must be marketed from the enrolled wineries and located in the specific geographical area.
- A more comprehensive control over the quality and quantity of wine should be carried out from production to marketing the wine, with a physico-chemical and organoleptic controls of homogeneous lots to limited volume.
- The law prohibits to have wines in the same warehouse which belonging to a Denomination of Origin Qualified and other wines which not pertecen. Unless these wines are Qualified Payment located in that territory.
- Wine producers must have a cartographic delimitation, by municipalities, of land suitable to produce wines entitled to the Denomination of Origin Qualified.

In Spain there are only two Qualified Denominations of Origin: Rioja and Priorat (Vivanco).

- La Rioja gets the Qualified Denomination of Origin Qualified in 1991.

The wine region of La Rioja has three zones of production:

- Rioja Alta (municipalities of La Rioja and of the province of Burgos).
- Rioja Baja (municipalities of La Rioja and Navarre).
- Rioja Alavesa (municipalities in the province of Alava, Basque Country).

- Designation of Origin Priorat achieved in 2009 its mention as Qualified Denomination of Origin

The wine region of Priorat wines is in Tarragona and consists of nine municipalities:

- Bellmunt del Priorat
- Gratallops
- El Lloar
- El Molar
- La Morena de Montsant Poboleda
- Porrera
- Torroja del Priorat
- La Vilella Alta
- La Vilella Baixa

5.3.2.4. Quality Wines with Geographical Indication

The wines are produced and processed in the region, area, locality or place with grapes belonging to the same place. Quality, reputation or characteristics of production, reputation or aging wine have to give thanks to the geographical environment of the particular place or human factor.

5.3.2.5. Wines of Pago

The wines are original from a Pago, it is a place or rural site with different characteristics and its own microclimate, which distinguish it the wines of their environment. The wines are made with traditional and notorious forms in the cultivation of vineyards, from which wines are obtained with a unique personality and whose maximum extension are limited by the competent authority, according to the criteria of each region. If the payment name is typically used for 5 years in the market to identify the wines produced in that particular place, it is understood that there is a notorious linkage with the culture.

CASTILLA LA MANCHA	***Campo de la Guardia***
	Casa del Blanco
	Dehesa del Carrizal
	Dominio de Valdepusa
	Finca de Élez
	Guijoso
	Pago Florentino

Table 7. Areas Wines of Pago in Castilla La Mancha

NAVARRE	***Pago de Arinzano***
	Pago de Otazu
	Prado de Irache

Table 8. Areas Wines of Pago in Navarre

5.3.2.6. Wines of Qualified Pago

When wine is paid in full within a DOCa, you can get certified wine qualified payment, provided it meets the requirements of belonging to a DOCa, and is enrolled in it. The grape production, processing and bottling of wines must be made within the payment.

ANDALUCIA	***Granada***
	Lebriia

Table 9. Areas Wines of Qualified Pago in Andalucia

CASTILLA Y LEON	***Sierra de Salamanca***
	Valles de Benavente
	Valtiendas

Table 10. Area Wines of Qualified Pago in Castilla y Leon

PRINCIPADO DE ASTURIAS	***Cangas***

Table 11. Areas Wines of Qualified Pago in Principado de Asturias

6. Viticulture sector in China

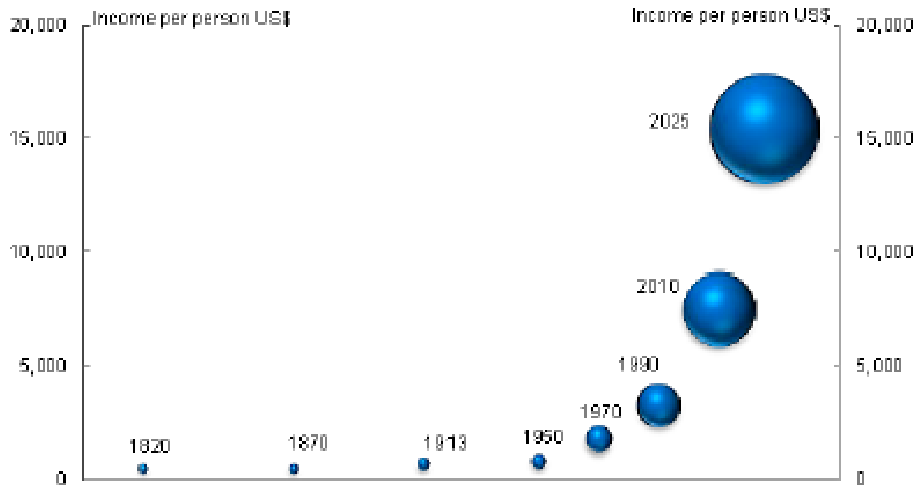
6.1. History of wine in China

Winemaking history in China can be traced back to Han Dynasty when emperor Wu intended to expand the land and defeated Hun. In around 138---119 B.C. there was a famous Chinese adventurer called Zhang Qian who had the diplomatic mission to Xiyu (the Western Regions of China) and travelled as far as Rome Empire. Thanks to this long journey he brought grape weeds and winemakers from Tashkent to China. Since then, China emerged the wine producing industry. However, this traditional Chinese wine hasn't an important role in people's daily drinking. And the real time for wine in China should be traced back to a hundred years ago.

In 1982, Cheong Fatt Tze established Yantai Changyu Pioneer Wine Company that was the first modern wine company in China. However, the development of wine industry hadn't been pushed forward until 1954. The number of wine companies grew up to over 100 in the late 1970s and the production of wine rocketed from less than 200 ton in 1949 to 64 thousand ton in 1978. The production continued to rise rapidly afterwards: it reached to 933 thousand ton in 2002 and 3.3 billion ton in 2005.

The countries of Asia are growing their economies faster than the countries of the developed world and therefore increasing their share of the world economy.

The Australia in the Asian Century white paper analysed the anticipated transformation in world markets by 2025 attributable to the rapid rise in income per head in Asian countries as illustrated in the Figure 13.



Note: Bubble area reflects the size of GDP. GDP adjusted for purchasing power parity (2011 prices). See glossary for definition of Asia and description of Treasury projections. See Appendix A for a description of Asia's resurgence to date.
Sources: Maddison (2010), Conference Board (2012), IMF (2012c) and Treasury projections.

Figure 3. Asia´s economic resurgence is set to continue

The Asian region is expected to be home to the world's fastest growing middle class, whose pursuit of an improved quality of life will see Asian economies emerge as the world's dominant consumer markets.

These more discerning and aspirational Asian middle-class consumers will increase dramatically the demand for discretionary luxury food and beverages, including wine.

China is the market where this demand surge for wine will be greatest, given that wine consumption and its growth rate is already many orders of magnitude greater than other Asian markets, as illustrated by the graphic below sourced from a presentation by Kym Anderson, University of Adelaide in August 2013.

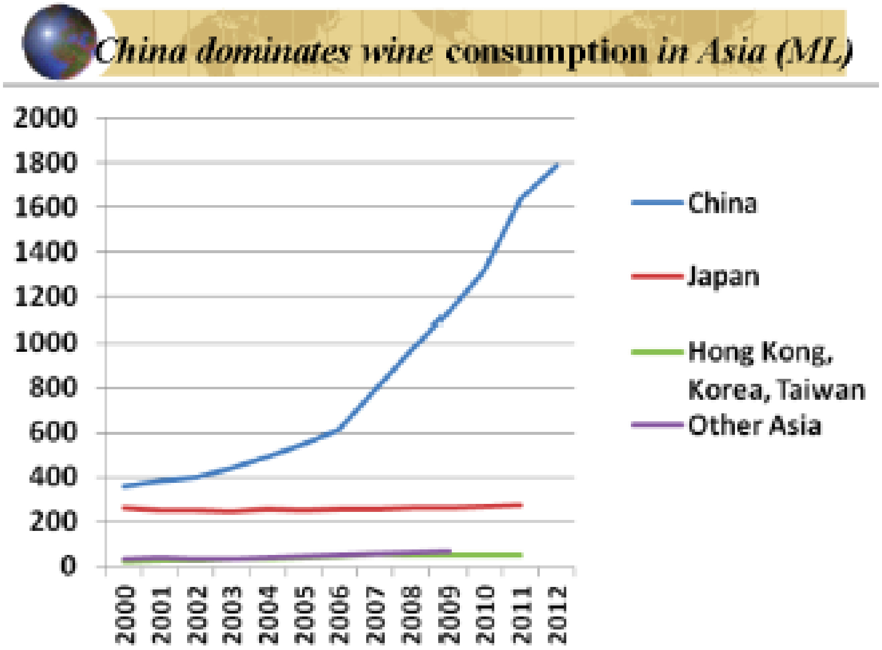


Figure 4. China dominates wine consumption in Asia

As outlined in the foregoing, the primary driver of wine demand in China has been increasing incomes and the changing demand preferences of the middle class. Western preferences have infiltrated Chinese middle class discretionary and luxury expenditure and wine has been a significant beneficiary.

Although China therefore is an enticing prospect for foreign businesses including wine, achieving success in the market is getting tougher. The Economist in a leader article headlined "China loses its allure" outlines how competition from local firms is heating up and that "Consumers will longer pay a hefty premium because a brand is foreign. Their internet savvy and lack of brand loyalty makes them the world's most demanding customers" (my emphasis).

In the business world in China where gift giving plays a vital role in developing and nurturing the relationships necessary for success, wine has been adopted as a desirable gift. In this context, wine must convey the required prestige for the gifting occasion and recipient, hence the importance of brand reputation and the provenance and scarcity from which that reputation is derived. This explains the pre-eminence in the China market of French first growth wines specifically and of premium imported wines generally.

Another factor which is a powerful driver of wine demand in China is the perceived health benefits of wine consumption, refer market research data in figure 3. Coupled with the Chinese Government's discouragement of grain-based spirits, a shift in alcohol consumption is occurring in favour of wine. Despite this wine accounts for only 12% of total alcohol consumption, so there is potentially considerable scope for wine's share to increase purely on the basis of a preference shift as distinct from the income growth factor.

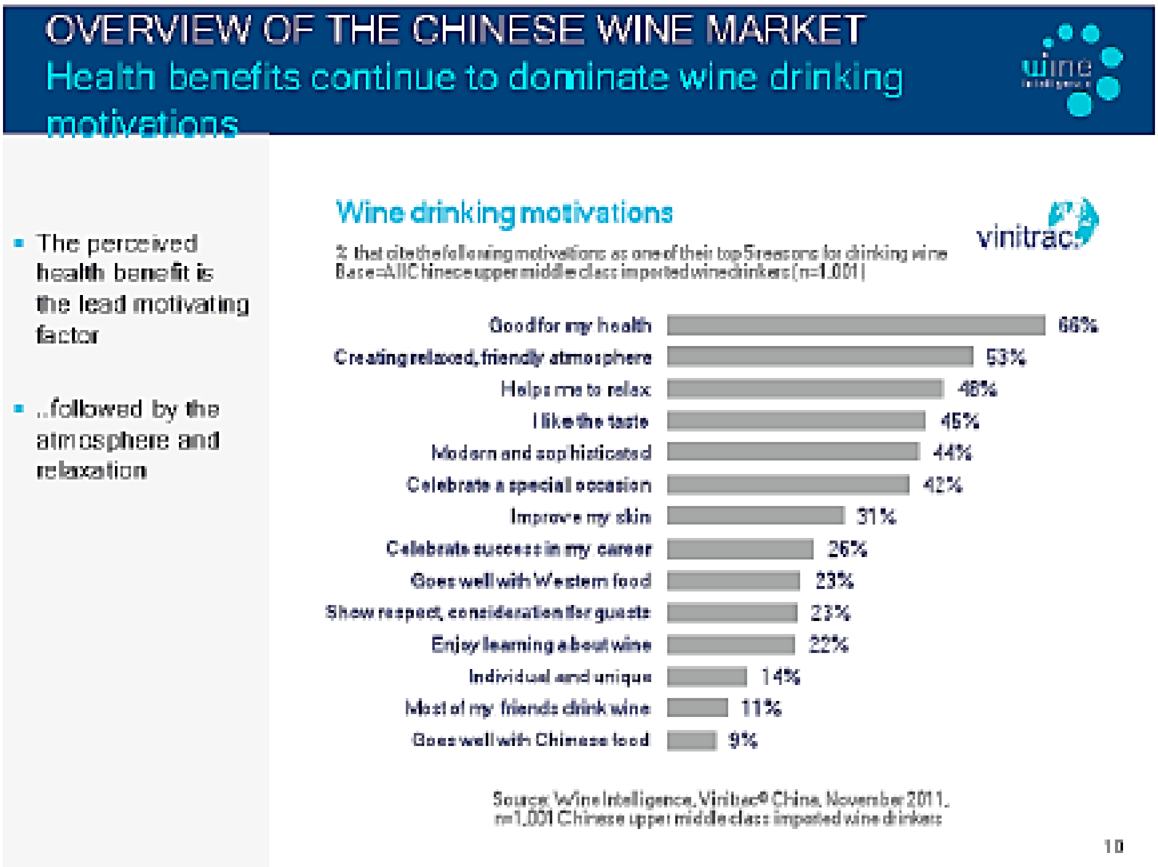


Figure 15. Overview of the Chinese wine market, health benefits

6.2. Market analysis

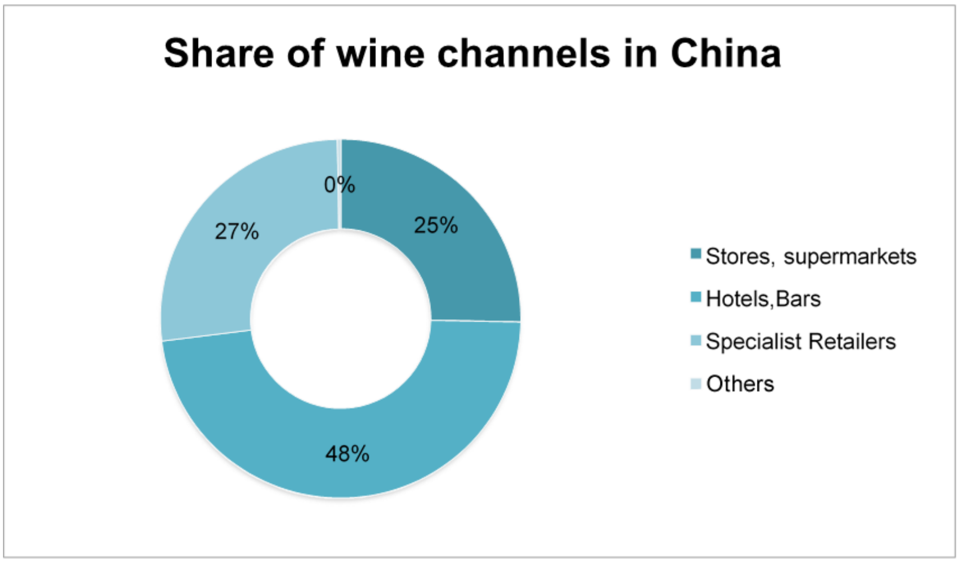
6.2.1. Regional structure of China´s wine market

The main wine market in China is concentrated in the east coastal area and metropolises like Shanghai, Beijing, Chengdu, Fuzhou, Xiamen, etc. The reason why the consumers are mainly come from big cities and in the middle class and class of bourgeois is that as for Chinese people wine culture is a new---coming foreign one and the price of wine is relatively high comparing with other alcoholic beverages like beers and Chinese traditional white spirits. In spite of the fact that wine culture has been spread into lower---tier cities and rural areas, the popularity of wine drinking is far from enough up till now. In addition, people from metropolis like Shanghai and Beijing have a higher purchasing power and mainly consume middle---high class of wine while for those from second or third---tier cities and rural areas low---middle class of wine are their first option.

6.2.2. Distribution of wine in China

Generally speaking, the circulation of wine from the factory to consumers go through distributors, dealers or restaurants and hotels, although at present many wine producers have started self-built wine shore in the main cities. 47.7% of wine consumption is through on-trade places like hotels, bars, clubs and so on; 52% of wine consumption is through specialist retailers and supermarkets/hypermarkets on behalf of the consumption model of drinking in family/party occasions and BYO(Bring your own) in hotels. All in all, wine producers can hardly involve directly in wine sales and wine will pass through a complex circulation before reaching consumers.

Figure 16. Channel process of wine in China



6.2.3. Imported wine in China

In 2009, China's wine consumption has maintained annual growth rate of 30%. In 2011,

Figure 17. Share of different wine channels in China

China's wine consumption has amounted to 45 billion RMB, becoming the world's fifth largest wine consumer. China's spectacular performance not only provides development space for domestic wine market but also attracted a large number of imported wine producers.

Imported wine expansion rate is as high as 65% a year. At present, the imported wine market in China has accounted for about 30% of the market share, and however five years ago domestic wine occupied more than 90% of the market.

"Domestic wine enterprises focus on selling products rather than the brand shaping and wine culture cultivation, which gives the imported wine a large elbow space. In the short term, the domestic wine can still keep some 'home advantage' in the market, but along with the imported wine pouring into the market and effect of wine culture promoting, imported wine and domestic wine will have equal shares in 3 to 4 years." Said by Guo Songquan5 in the interview by Guangming Daily.

Statistics by National Statistical Bureau show that in the first quarter this year, China imported 6.44 million cases of wine, with year---on---year growth of 15%. Over the same period, the cumulative yield of domestic wine industry was 279.1 thousand tons, with year---on---year growth of 6.82%. Statistics from Boston consulting group show that the number of China's overseas travel has accounted for 8% of the world, and it will become the world's second largest overseas tourists exporting countries in 2013. Most destinations for them are Europe and the United States, so that they are gradually cultivated by western food and culture. By 2015, Chinese's annual average consumption of wine will amount to 1.9 liters.

France, Australia, Spain, Chile, Italy and the United States are the leading imported wine producers. From 2002 to 2011, the annual average import volume from the above six countries accounted for 90% of the total imports of wine. French wine occupies the absolute dominant position in the Chinese market from both aspects of imports and import volume. In 2011, China imported about 117.9 thousand tons of wine from France, with year on year growth of 74.15%; the imports was 706 million US dollars, with year on year growth of 108.26%.

The movement of American wine has always been very stable in China market: the import volume rose from 820 thousand litres in 2002 all the way up to more than 13 million litres in 2011, which has increased by 15 times; the imports has been surged from more than 1 million US dollars in 2002 to 62 million US dollars in 2011, increased by 60 times.

Over the years, Chile has been one of China's largest suppliers of bulk wine. According to the Chilean wine industry association statistics, Chile exported 65.266 million US dollars of wine to China in 2011, increased by 74.6% from the previous year. The number of bulk wine (more than 2 litres capacity) accounts for 35% of the total wine imports. At the same time, Chilean bottled wine was imported 3.5 million dollars, with year---on---year growth rate of 53%.

According to Italian statistics department in 2011, Italian wine imports increased 80% in China market. According to data from administration of Australian wine in 2011, Australian exports grew by 32% to 181 million Australian Dollar to China and China has become the fastest growing export market to Australia. In terms of quantity, Spain is China's second biggest wine exporter. According to data from Spanish wine market supervision committee, in 2011, the Spanish wine export volume to China increased by 56% and the exports doubled to 78 million euros. The New Zealand wine exports to

China grew from 20.13 million dollars in 2010 to 32.96 million dollars in 2013, which increased by 64%.; export volume climbed also from 2317 tons in 2010 to 3440 tons in 2013.

In addition, South African wines boom in the China market. In 2011, the bottled wine exporting to China grew by 80%. South Africa wine, Australian wine and New Zealand wine are three countries whose exports to China increased significantly, in addition to geographical advantages, it has also something to do with its young and dynamic wine industry development and vigorous promotion.

6.2.4. Analysis of wine industry in China

A) Life cycle stage of China wine industry

Industry life cycle refers to the total period of time for an industry from emergence to complete withdrawal from social and economic activities. Industry life cycle consists of four development phases: introduction period, growth period, mature period and decline phase. Industry life cycle curve ignore specific product types, quality, specifications and other differences, and it only considers from the perspective of the whole industry. The industry life cycle stage model is summarized as shown in the chart above. According to the theory, China wine industry is still in the growth period. Reasons are as follows:

- There is still great space for wine industry to develop in China. China's current wine consumption per capita is 1 litre which is only 6% of the world average level. And thus, the industry has a larger growth space.
- The economic indicators show that China's wine industry is in the second period of industry life cycle stage model, that is, growth stage. Enterprises in the wine industry are continuing to increase and industry profits are increasing. In addition, industry revenue and profit growth begin to have a significant decline, but profitability is still in a high level. These indicators are consistent with characteristics of the growth stage.

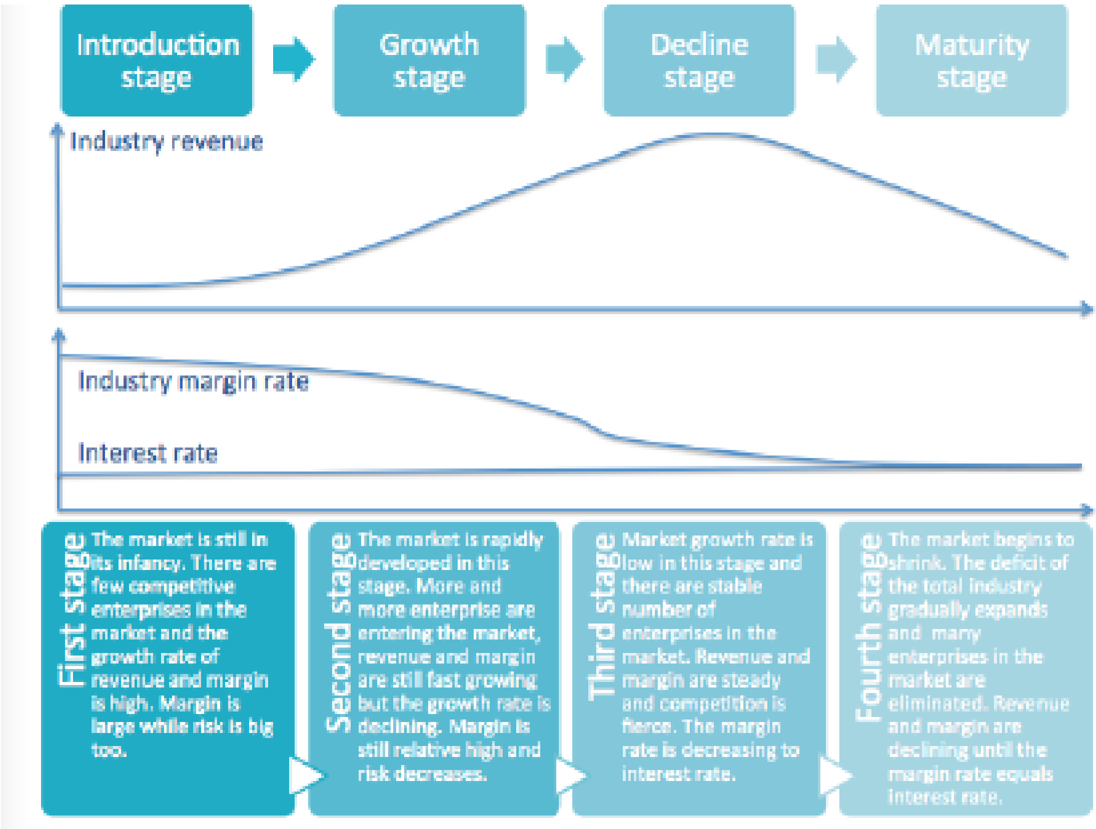


Figure 18. Life cycle stage of China wine industry

B) Porter´s five force model for wine industry in China

a) Bargain power of buyers

There are many brands on the market so space for choices is large, which to a certain extent, reduce the bargain power of buyers. With the gradual integration of wine culture into Chinese culture, it has huge potential for future development. On the analysis of the wine industry in China buyers should be represented by wine distributors as wine dealers and retailers, since sales of retailers account for 52% of market share while hotels, clubs and other trade on places accounted for 48%, mainly mastered by dealers. Moreover, food and alcoholic beverage retail market in China are scattered, which reduces bargain power of buyers. In addition, wine can not only be differentiated by vinification (e.g. dry wine, sparkling wine, etc.), but also by origin, grape variety, taste style and so on, and such differentiation makes the wine distributors provide wine as much comprehensive as possible for their customers, which reduce bargain power of buyers to some extent. However, conversion cost of choosing another product is not high and it greatly increase bargain power of buyers. As a word, threats from buyers are neutral.

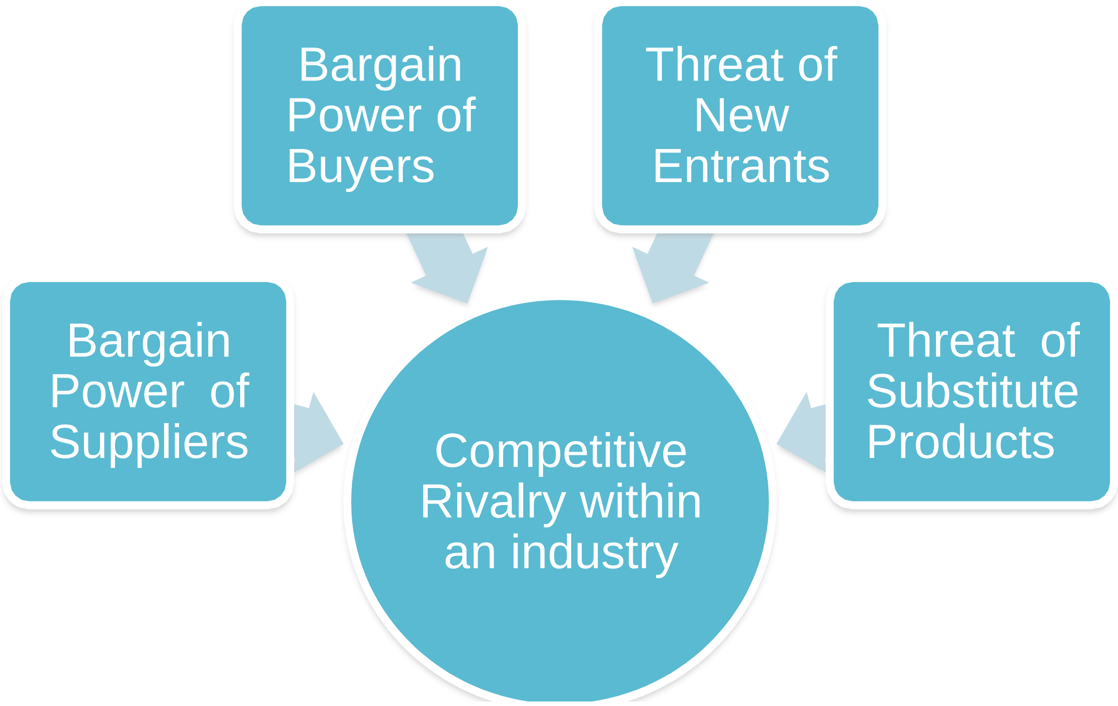


Figure 19. Porter´s five force model for wine industry in China

b) Bargain power of suppliers

The main investment of wine producers is grapes and wine bottles. With the rapid expansion of vineyards in recent years, domestic wine production industry is developing fast. The manufactory scale of main producers is big, even if their own or rent the vineyards, they still can't satisfy the demand. And thus, they need to buy grapes or grape juice from other producers. Most of the time, producers use grapes from its own vineyard to produce high-end products while using grapes or grape juice bought from a third party to make low price products. The number of grapes or grape juice suppliers is large, which weakens the bargain power of suppliers. But many independent suppliers can find other substitute market, such as fruit market, fruit sugar market, etc. All of these factors strengthen the bargain power of suppliers. In these areas, the quality of raw materials is critical, and the quality of the finished products determined greatly by the quality of grapes. All in all, threats from suppliers are no higher than neutral.

c) Threat of new entrants

The high speed of growth of wine industry in recent years will attract new competitors to enter. The way can be establishing a new company, diversify oneself into the wine industry and increase imports for imported wine producers. Government regulations such as tag management constitute main barriers to entry. In addition, although the import tariff has cut a lot after China's entering WTO, the value-added tax and consumption tax is still very high accounting for about 50% of the total importing cost.

d) Threats of substitute products

Other alcoholic beverages are all substitutes for wine. For retailers and on---trade places, conversion cost between different products is very low, price of unit volume may be higher (such as liquor) or lower (beer). It is hard to determine which one is better of wine and its substitutes. The best storage condition for white wine, champagne and beer is to be preserved in the freezer (often impossible) making a high preservation cost. More than often, liquor provides more benefits than wine and beer to sellers. However, noting selling wine will be a competitive disadvantage in a certain place in big cities in China. For consumers, they have different consumption habits to drink different kinds of alcoholic beverages. Business negotiations in China often involve luxurious banquet, and "cheers" is a popular culture. So, on this occasion, wine becomes more and more popular and begins to replace rice spirits for the sake of health care. But most of the time, the choice is decided by personal taste, so wine is vulnerable to the threat of other kinds of wine. In a word, substitution threat is high.

e) Competitive Rivalry within an industry

The concentration of China's wine industry market is relatively high, in which the top three enterprises occupy nearly 50% of industry sales and about 70% share of the profits. Powerful wine enterprises in the industry establish strong brand effects, and buyers may have a relatively low switching cost between different products, which intensify the competition. In addition, major producers not only produce high---end products but also low-middle-end products, and this means a higher investment in fixed assets deepening competition in the industry. All in all, competition rivalry with industry is neutral.