



Precision agriculture and the future of farming in Europe

Scientific Foresight Study

STUDY

Science and Technology Options Assessment

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IP/G/STOA/FWC/2013-1/Lot 7/SC5

December 2016

Abstract

Precision agriculture (PA) or precision farming, is a modern farming management concept using digital techniques to monitor and optimise agricultural production processes. Rather than applying the same amount of fertilisers over an entire agricultural field, or feeding a large animal population with equal amounts of feed, PA will measure variations in conditions within a field and adapt its fertilising or harvesting strategy accordingly. Likewise, it will assess the needs and conditions of individual animals in larger herds and optimise feeding on a per-animal basis.

PA methods promise to increase the quantity and quality of agricultural output while using less input (water, energy, fertilisers, pesticides, etc.). The aim is to save costs, reduce environmental impact and produce more and better food. The methods of PA rely mainly upon a combination of new sensor technologies, satellite navigation and positioning technology, and the Internet of Things. PA has been making its way into farms across Europe and is increasingly assisting farmers in their work.

This study intends to inform Members of the European Parliament about the current state-of-the-art, possible developments for the future, societal concerns and opportunities, and policy options for European policy-makers to consider.

In its first part, the study presents an overview of key aspects of European agriculture and PA's state-of-the-art. In the second part, it presents possible scenarios for future developments of PA developed in the context of a foresight exercise, followed by four main conclusions drawn from the analysis of these scenarios. The final part draws attention to legislative instruments through which the European Parliament can contribute to shaping the framework conditions in which these new technologies will be able to evolve.

PE 581.892

The Scientific Foresight project 'Precision Agriculture and the future of farming in Europe' has been requested by the Science and Technology Options Assessment (STOA) Panel. This report is a summary of the study and has been compiled by Lieve Van Woensel and Christian Kurrer with James Tarlton (Scientific Foresight Unit, EPRS). The technical horizon scan of the study was conducted by a team of scientists from Wageningen University and VetEffect upon the request of the STOA Panel and managed by the Scientific Foresight Unit at the European Parliament. The scenario development and foresight phase were conducted by Cornelia Daheim, Future Impacts, with Erica Bol and Silke den Hartog – de Wilde.

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LINGUISTIC VERSION

Original: EN

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To contact STOA or to subscribe to its newsletter please write to: STOA@ep.europa.eu

This document is available on the Internet at: <http://www.ep.europa.eu/stoa/>

Manuscript completed in December 2016

Brussels, © European Union, 2016

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PE 581.892

ISBN 978-92-846-0475-3

doi: 10.2861/020809

QA-06-16-365-EN-N

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Annex 1: Technical Horizon Scan

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1 Executive Summary

Precision agriculture (PA), or precision farming, is a modern farming management concept using digital techniques to monitor and optimise agricultural production processes. For example, rather than applying the same amount of fertilisers over an entire agricultural field, or feeding a large animal population with equal amounts of feed, PA will measure variations in conditions within a field and adapt its fertilising or harvesting strategy accordingly. Likewise, it will assess the needs and conditions of individual animals in larger populations and optimise feeding on a per-animal basis.

PA methods promise to increase the quantity and quality of agricultural output while using less input (water, energy, fertilisers, pesticides...). The aim is to save costs, reduce environmental impact and produce more and better food. The methods of PA rely mainly upon a combination of new sensor technologies, satellite navigation and positioning technology, and the Internet of Things. It has been making its way into farms across Europe and is increasingly assisting farmers in their work.

The present study intends to inform Members of the European Parliament about the current state-of-the-art, possible developments for the future, societal concerns, and policy options for European policy-makers to consider.

In its first part, it presents an overview of key aspects of European agriculture and the state-of-the-art in PA. In the second part, it presents possible scenarios for the future development of PA developed in the context of a [Foresight](#)¹ exercise, followed by the main opportunities and concerns drawn from the analysis of these scenarios. The final part discusses the main conclusions drawn from the foresight exercise, which are of particular interest for European policy-making:

1. **Precision agriculture can make a significant contribution to food security and safety:**
 - PA already offers technology solutions for producing more with less; and
 - PA will enhance food safety and plant health.
2. **Precision agriculture can promote more sustainable ways of farming:**
 - key PA technologies are already in use with positive impacts on the environment; and
 - PA will generate sustainable productivity gains.
3. **Precision agriculture will trigger wider societal changes:**
 - PA technologies are already widely available but their uptake is still low;
 - PA will influence work practices and life conditions on farmland; and
 - new farming business models are on the rise;
4. **Precision agriculture requires the learning of new skills:**
 - technological skills;
 - environmental skills; and
 - managerial skills.

The wide diversity of agriculture throughout the EU, particularly regarding farm size, types of farming, farming practices, output and employment, presents a particular challenge for European policy-makers. European policy measures should therefore take into account that opportunities and concerns around PA can vary greatly from one Member State to another.

¹ "Towards Scientific Foresight for the European Parliament", Lieve Van Woensel and Darja Vrščaj, EPRS, 2015 (PE 527.416)

2 The state of European agriculture in a wider context

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 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.

2.2 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.

2.3 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.

Table 1: How does precision agriculture influence policies?

| 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

2.4 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 policies 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 competitiveness of enterprises and SMEs), **Horizon 2020**, **Galileo** and **Copernicus**. The EU industrial policy also supports the protection of Intellectual Property Rights (IPR).

Property 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.

2.5 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 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 17 (Investments in physical assets)**

This measure applies to farm modernisation and intensification.

- **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.

- **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.

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.

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

| Process | Technique | Expected environmental gains |
|--|---|--|
| Timeliness of working under favourable weather conditions | Automatic machine guidance with GPS | Reduction in soil compaction Reduce carbon footprint (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 to 1 T/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 sprayers 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 |

| Process | Technique | Expected environmental gains |
|---|---|---|
| Precision irrigation | Soil texture map | Avoidance of excessive water use or water logging Reduction of fresh water use |
| Patch herbicide spraying in field crops | Weed detection (on line/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: <ul style="list-style-type: none"> - Multisensor optical detection - Airborne spores detection - Volatile sensors | Reduction of pesticide use with correct detection and good decision model (84.5% savings in pesticides possible) |
| Orchard and vineyard precision spraying | <ul style="list-style-type: none"> - Tree 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 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 fertiliser dose and fungicide use on the basis of higher disease risk in areas with high crop density |

2.6 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, 2012²). Young people have become distanced from 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 Shucksmith³ 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 DGIP 2012; Directorate-General for Internal Policies (DGIP). EU Measures to Support and Encourage New Entrants. Policy Department B Structural and Cohesion Policies. Agriculture and Rural Development. 2012.

³ Shucksmith M. How to Promote the Role of Youth in Rural Areas of Europe. Brussels: European Parliament, 2010. PE 438.620.

3 Foresight results: Scenarios helping to identify future opportunities and 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 economy 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 mechanisms govern 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 direct 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 environment in second place.

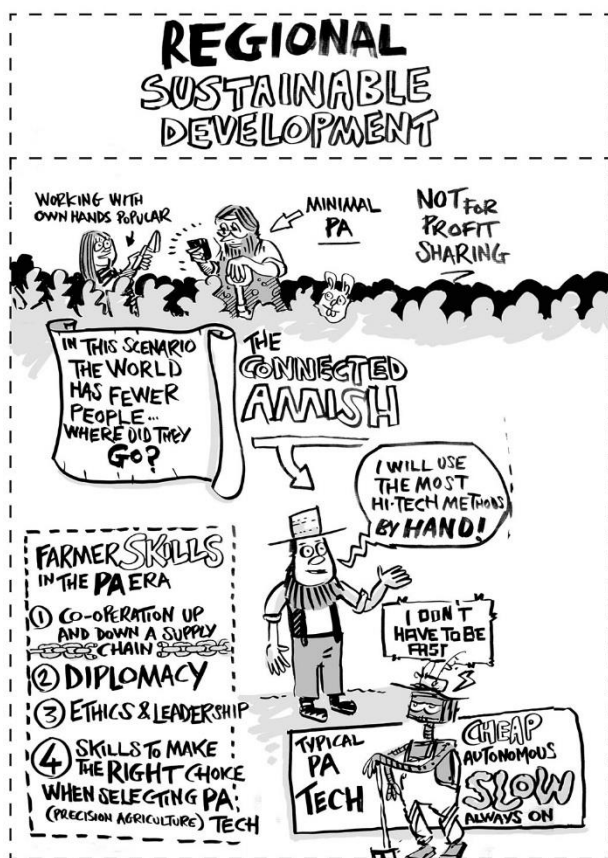
PA is utilised to stimulate regional growth and production. Because of the regional scale being dominant, and because of society's demand for food security, some genetic manipulation of plants, soil and weather is accepted, but only when highly monitored. Farmers are regarded as the main assets to make 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 strong and tightly knit. Overall, the paradigm is about small-scale change, 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.

4 Concerns and opportunities for European policy regarding PA

4.1 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)

Table 3: Concerns and opportunities in the different scenarios

| 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 | |
| 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 | | |

| Concern | Opportunity | Scenarios | | | |
|--|---|-----------|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 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 | Farmers need support and skills to manage mistakes; and policy agility | 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 |

| Concern | Opportunity | Scenarios | | | |
|---|---|-----------|---|---|---|
| | | 1 | 2 | 3 | 4 |
| 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 |

4.2 Specific analysis regarding skills and education for PA

4.2.1 Skills needs in the four selected exploratory future scenarios

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

Table 4: Skills needs in the scenarios

| Scenarios | 1 – Economic Optimism | 2 - Global Sustainable Development | 3 - Regional Competition | 4 - Regional Sustainable Development |
|---|-----------------------|------------------------------------|--------------------------|--------------------------------------|
| Skills needs | | | | |
| 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 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 is required, but technological progress is limited by the focus on sustainability and also by restricted possibilities for economies of scale.

4.2.2 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.

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

| Technological expertise <i>(relevant in all scenarios)</i> | Legislative expertise <i>(relevant in all scenarios)</i> | Local community leadership <i>(relevant in all scenarios but scenario 1)</i> |
|--|---|--|
| <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • Understanding legislation • Knowledge of the laws/anticipating changes • Dealing with bureaucracy • 'Diplomacy' and 'people skills' in working with institutions | <ul style="list-style-type: none"> • Knowledge of regional potential and regional growth • Insight into local needs • Communication • People management/'people skills' • Sense of solidarity with and responsibility for the community |

⁴ See the graphic on Economic Optimism in Chapter 3

4.2.3 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.

⁵ www.p2pu.org/en/

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.

4.3 Overall remarks on opportunities and concerns

4.3.1 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.

4.3.2 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.

4.3.3 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.

4.4 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.

4.4.1 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.

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.

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.

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.

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.

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 30 m) 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.

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...

5.2 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.

5.2.1 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 cover:

- 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.

5.2.2 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.

5.2.3 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.

⁶ Data taken from the website of the German journal DLG-Test Lebensmittel (DLG 2/2015)

5.3 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.

5.3.1 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 policy-making depending on the societal support they get (see 3.4).

5.3.2 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 from 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 automatated, 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.

5.3.3 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.

5.3.4 Policy options

Exploring new business models

Through pillar 2 of the CAP, Horizon 2020 or Commission 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.

5.4 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

5.4.1 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 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.

5.4.2 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.

5.4.3 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.

5.5 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 encouraging 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.

This study resulted in the identification of four main future opportunities and concerns regarding precision agriculture (PA), or precision farming, in the EU, on which the European Parliament could take anticipatory action now:

1. PA can actively contribute to food security and safety;
2. PA supports sustainable farming;
3. PA will trigger societal changes along with its uptake;
4. PA requires new skills to be learned.

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 Member States, taking into account that the opportunities and concerns vary highly from one country to another.

This is a publication of the Scientific Foresight Unit (STOA)
EPRS | European Parliamentary Research Service, European Parliament



PE 581.892
ISBN 978-92-846-0475-3
doi 10.2861/020809
QA-06-16-365-EN-N

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