Precision Agriculture and the Future of Farming in Europe

Technical Horizon Scan

STUDY

Science and Technology Options Assessment

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Study

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Abstract

The aim of the project "Precision Agriculture and the Future of Farming in Europe" is to identify implications for legislative pathways for precision agriculture in Europe by mapping areas of concern around future developments. The project has three phases:

1. Analyse underlying technologies and existing insights from the field, as well as the anticipated future developments
2. Identify possible development paths to 2050, construct scenarios, and map the related concerns around precision agriculture, adopting a stance of "What if..?"
3. Identify the legal instruments that may need to be modified or reviewed, including — where appropriate — areas identified for anticipative parliamentary work, in accordance to the conclusions reached within the project.

This publication is the outcome of the first phase of the foresight study and consists of six background briefing papers.

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 Panel (STOA). This technical horizon scan of the study was conducted by a team of scientists from Wageningen University and VetEffecT upon the request of the Science and Technology Options Assessment Panel and managed by the Scientific Foresight Unit at the European Parliament.

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1. Introduction

The development of agriculture in Europe is at an important crossroad. Technological developments make it possible to produce plant and animal products with increasing efficiency and less environmental impact, due to digitalization. The global demand for food is increasing due to increasing population, and the 28 EU Member States (EU28) exports reached a value of 122 billion euro and took over the leading position as exporter from the US in 2013. However, agriculture in Europe is at the same time challenged by an ageing workforce, rural exodus of young people, climate change, urbanisation, shortage of resources, land grabbing, and facing strong competition from upcoming markets in South-East Asia and South America. Because there is limited potential for increased demand on food markets of the EU itself, export of agricultural products has become a key factor for generating growth and jobs in agriculture and the food industry in the EU.

In view of the above, what are the policy concerns and options, to stimulate a flourishing European agricultural sector that offers jobs for young people and for the service industry, where farmers and population benefits from the digitalisation, metadata and the Internet of Things rather than is compromised by 'IT'. In addition, the study focuses on European farming practices respecting the environment as well as animal welfare, and all this in a competitive economical setting on the world market.

In a set of six technical reviews, key aspects of precision agriculture, concerns and future trends are discussed. These are:

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 digitalization and precision agriculture;
5. Environmental impact of precision farming and
6. Skilled workforces & precision agriculture.

The developments in precision agriculture have impact on various pieces of European legislation:

- For the CAP, Regulation (EU) No 1305/2013 - Rural development regulation; Regulation (EU) No 1307/2013 - Direct payments regulation; Regulation (EU) No 1308/2013 - Common Market Organisation (CMO) regulation; and Regulation (EU) No 1306/2013 - Horizontal regulation are relevant.
- For the Regional Policy, 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 support development of the regions.
- For the environment, the Water Framework Directive (Directive 2000/60/EC) and more particularly the Council Directive 91/676/EEC (The Nitrates Directive) is relevant, as it relates to the protection of water against pollution from agricultural sources. Also for the environment, Directive 2001/81/EC (the National Emission Ceilings Directive) sets upper limits for each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia).
- A basis for the food production lies the General Food Law Regulation (EC) 178/2002, which provides the general principles of food safety. These include the requirement on 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.

- For data protection, a relevant piece of legislation is 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, and repealing Directive 95/46/EC (General Data Protection Regulation). This Regulation aims to strengthen citizens' fundamental rights in the digital age and facilitate business by simplifying rules for companies in the Digital Single Market

The technical reviews may not cover the complete array of all possible aspects to precision agriculture. They are written to cover the major issues that are relevant for the European Parliament and for the Scientific Foresight phase of this STOA study, which explores possible future scenarios on possible concerns and opportunities (Part 2 of this project). A report on this part of the project will be published later in 2016, together with an inventory of a list of relevant legal instruments by which Members of the European Parliament could anticipate possible futures regarding farming in Europe.

BRIEFING PAPER 1

OVERVIEW OF AGRICULTURAL PRODUCTION IN THE EU

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List of abbreviations

AWU	Annual Work Unit
EC	European Commission
EU	European Union
Kg	Kilogramme
Ha	Hectare
PDO	Protected Designation of Origin
PGI	Protected Geographical Indication
SO	Standard Output
t	tonne
UAA	Utilised Agricultural Area
USDA	United States Department of Agriculture

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1. Key information

The area of land available for agriculture in the EU is gradually declining with increased forestry and urbanization, so productivity must increase to maintain or increase output.

The wide diversity of EU agriculture is due to many factors that contribute to different extents according to specific conditions. Physical factors such as climate, topography, soil type and latitude determine the agricultural potential for a given area. Management, husbandry, technological and social factors determine how this potential is realized.

Of the EU agricultural land, 60 per cent is arable, 34 per cent permanent pastures and grazing, and 6 per cent permanent crops, such as fruits, berries, nuts, citrus, olives and vineyards.

1.1. Agricultural holdings (farms)

There are 10.7 million farm holdings in the EU with an average area of 16 hectares. The average for individual Member States ranges from 1.2 hectares in Malta to 133 hectares in the Czech Republic.

Holdings with an area of less than 20 hectares comprise 86 per cent of all EU holdings but occupy just 18 per cent of the utilised agricultural area. In contrast, holdings over 20 hectares represent 14 per cent of all holdings and occupy 82 per cent of the total agricultural 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 cent 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 per cent over the same period.

Further information on holdings is provided in briefing paper 2.

1.2. Cereals

Cereals are grown on one third of EU agricultural land. The overall yield per hectare in the EU is 5.3 tonnes. The average yields achieved in different Member States varies between 9.3 and 1.7 tonnes per hectare. In the higher yielding areas, cereal yields are close to their agro-economic maximum and significant further increases will depend on technological developments, such as precision agriculture.

At the global level, the EU is the world's largest producer of wheat, barley, oats and rye; and the fourth largest maize producer. Amongst the major producing countries, it has the highest yields of wheat and barley.

The EU is self-sufficient in cereals and is a net-exporter. Over 50 per cent 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.

1.3. Vegetables

Fresh vegetables, including melons and strawberries, were cultivated on 1.6 million hectares of arable land in 2013 and accounted for just under 1 per cent of the utilised agricultural area in the EU. However, vegetables are high-value crops and contribute a greater proportion of the value of agricultural production than the proportion of total land area cultivated.

More than one vegetable crop may be grown on a given area of land in one year. Thus, the harvested area of fresh vegetables was 1.9 million hectares from 1.6 million hectares of land.

Tomatoes are the most important vegetable crop in the EU in terms of production, followed by onions, carrots and vegetables for fruit (including melons).

The average yields of vegetable crops show great variation between Member States. The variations are multi-factorial with the relevant contribution of each factor depending on the specific conditions. There are likely to be effects from climate, topography and whether crops are grown indoor or under-cover, as well as reasons connected with management and husbandry practices. Yield figures should therefore be treated with caution as they may not be like-for-like comparisons.

1.4. Grapes

Grapes are grown commercially in 19 Member States. In 2013, 3.2 million hectares were harvested to produce 25 million tonnes of grapes.

Spain, France, Italy, Portugal, Romania, Greece and Germany all produce over 0.8 million tonnes of grapes each and account for 94 per cent of 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 per cent went to produce wine.

1.5. 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 per cent of EU production. Ninety five per cent of production is used to make olive oil, with the remaining 5 per cent 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.

1.6. Meat

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

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

Annual per EU capita consumption of the main meats is consistently over 65kg (retail weight). Consumption is static although poultry is likely to take a small market share from other meats. Reasons for the static EU consumption levels include animal welfare, the environment, health concerns and the ageing EU population.

Environmental and social concerns and land availability are likely to result in differential changes in pig production between Member States. It is expected that the concerns will be mitigated by increased movements of live animals across national borders.

World meat consumption is expected to grow by 15 per cent between 2015 and 2025 due to increasing population and prosperity.

Beef production is expected to fall back slightly and exports are expected to remain stable. Pig meat production is likely to be limited to a 2 per cent increase by 2025, but nevertheless exports are expected to grow by 27 per cent between 2015 and 2025.

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

Economic uncertainty makes it difficult to predict meat prices, but feed prices are expected to remain moderate, resulting in increased production, which would keep world prices down.

1.7. 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. India produces a similar volume of cow and buffalo milk combined, but cows' milk is less than 50 per cent of the total.

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 is for increasing world demand and rising prices for milk and dairy products due to population growth and increasing preference for dairy products. Prices are currently low due to increased supply coupled with reduced exports. World imports are expected to increase by 2.4 per cent (over 1.4 million tonnes) per year with China remaining the main importer.

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

DG AGRI expects milk yields per cow to increase due to a number of factors including genetics, wider use of robots, improved pasture management and increased use of concentrate feeds. As average yield increases, the number of dairy cows is expected to fall.

Until 2020, the average EU raw milk price is expected to remain between 32 and 33 euro cents per kilogram. Thereafter the price is expected to rise in line with other prices.

2. Farm types and agricultural land use

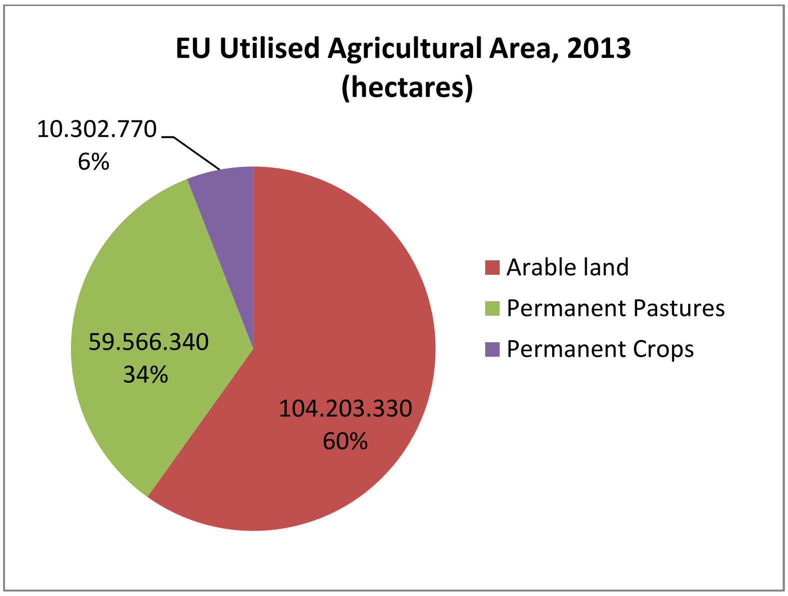
2.1. Utilised Agricultural Area

Table 1 shows the EU utilised agricultural area (UAA) in 2013. The UUA is broken down into four main types of land use: arable land, permanent pastures, permanent crops and kitchen gardens.

Table 1. Utilised agricultural area in the EU by type of land use, 2013

EU-28	hectares	% of UAA
Utilised Agricultural Area (UAA)	174 358 310	100.0%
Arable land *including:*	104 203 330	59.8%
Cereals	57 940 310	33.2%
Fodder crops	20 830 160	11.9%
Industrial crops	12 546 490	7.2%
Potatoes	1 593 440	0.9%
Fresh vegetables	1 593 320	0.9%
Sugar beet	1 577 360	0.9%
Pulses	1 413 210	0.8%
Permanent pastures, meadow and rough grazing	59 566 340	34.2%
Permanent crops *including:*	10 302 770	5.9%
Olives	3 867 450	2.2%
Vineyards	2 912 960	1.6%
Kitchen gardens	285 770	0.2%

Source: Eurostat [ef_oluft]



Source: Eurostat [ef_oluft]

The total utilised agricultural area is 174 million hectares (ha), which comprises 40 per cent of the EU land area. Of the total used for agriculture, 59.8 per cent is designated as arable land; 34.2 per cent as permanent pastures, meadow, and rough grazing; 5.9 per cent as permanent crops and 0.2 per cent as kitchen gardens.

The total utilised agricultural area in the EU is slowly decreasing due mainly to increased forest area and urbanisation.

Arable land in the EU is used to grow cereals, pulses, potatoes, sugar beet, fodder crops, 'industrial' crops (including hops, cotton and oilseeds), fresh vegetables and flowers (including under glass) and seeds.

Pastures, meadows and rough grazing provide permanent grazing for livestock and are distinct from fodder crops grown on arable land. Permanent crops include fruits and berries, nuts, citrus, olives and vineyards.

Kitchen gardens are principally for domestic use and will not be considered further in this study. Other minor types of land use are not included in Table 1 and have also been excluded from the study, although they may cause small but insignificant variations in the statistics[1].

These summary figures do not show the variation in land use in different Member States due to factors such as climate, topography, soil types and environmental, social and economic considerations. For example, high value cropping areas such as fruit and vegetables, vineyards and olive groves may be of particular importance in some Member States. Further details are available in the following chapters, in the annex to this briefing paper and in other briefing papers.

The main sources of information in this briefing paper are Eurostat and DG AGRI market reports. Any other sources are indicated.

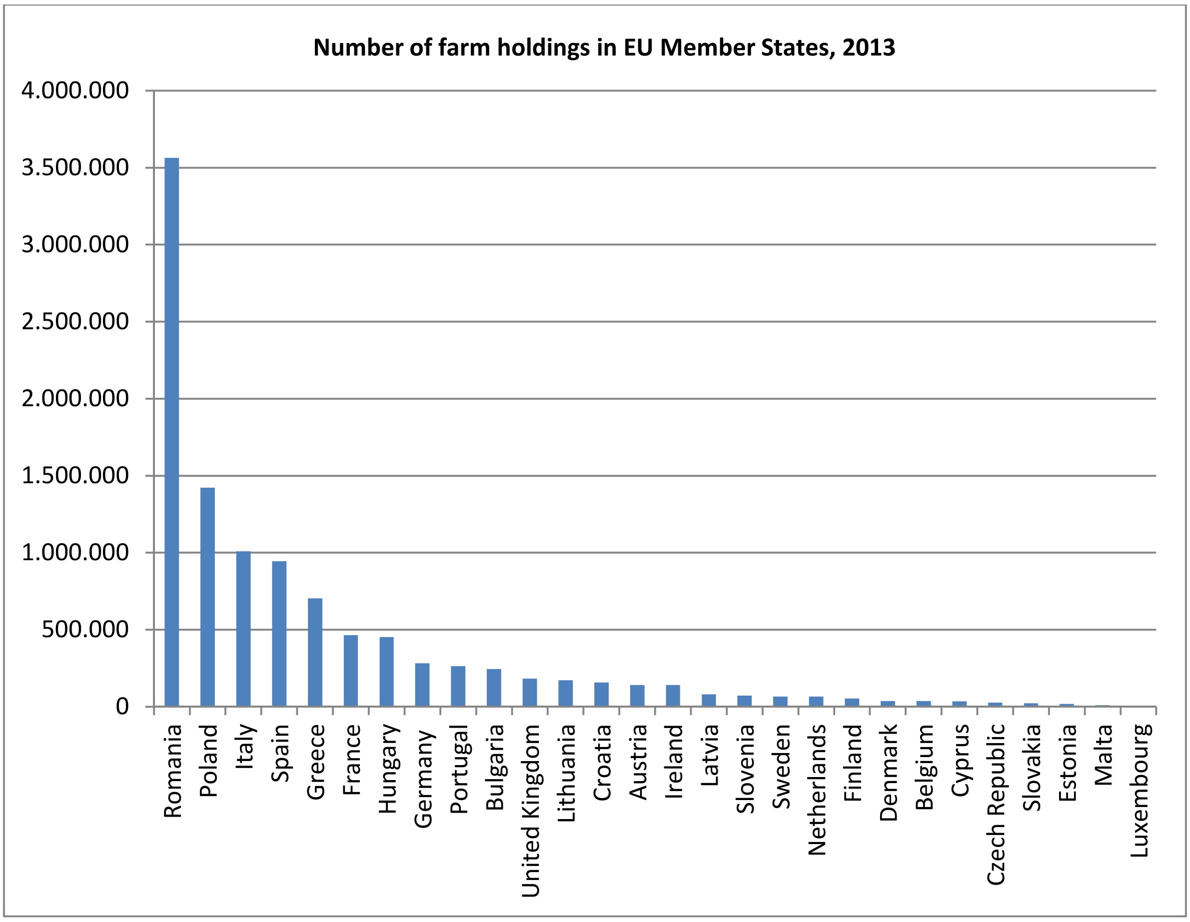
2.2. Agricultural holdings (farms)

Table 2. Distribution of agricultural holdings by area, 2013

Area of holding	Number of holdings[2]	% of total holdings	Utilised Agricultural Area (ha)	% of Utilised Agricultural Area
< 2 ha	4 706 370	44.1%	3 578 030	2.0%
2 - 4.9 ha	2 307 300	21.6%	7 313 240	4.2%
5 - 9.9 ha	1 277 230	12.0%	8 940 870	5.1%
10 - 19.9 ha	888 540	8.3%	12 442 190	7.1%
Sub-total <20 ha	*9 179 440*	*86%*	*32 274 330*	*18%*
20 - 29.9 ha	374 870	3.5%	9 134 540	5.2%
30 - 49.9 ha	387 730	3.6%	14 974 730	8.6%
50 - 99.9 ha	388 680	3.6%	27 264 410	15.6%
>100 ha	336 740	3.2%	90 965 810	52.1%
Sub-total =>20 ha	*1 488 020*	*14%*	*142 339 490*	*82%*
Total	**10 667 460**	**100.0%**	**174 613 820**	**100.0%**

Source: Eurostat [ef_kvaareg]

[1] The small difference in the utilised agricultural area in **Annex Table 1** and **Error! Reference source not found.** is due to differences in the way figures are calculated as well as rounding errors. Similar differences may be seen in other figures, but should be too small to affect the general findings.
[2] 173 480 holdings occupying zero hectares have been omitted from the table.

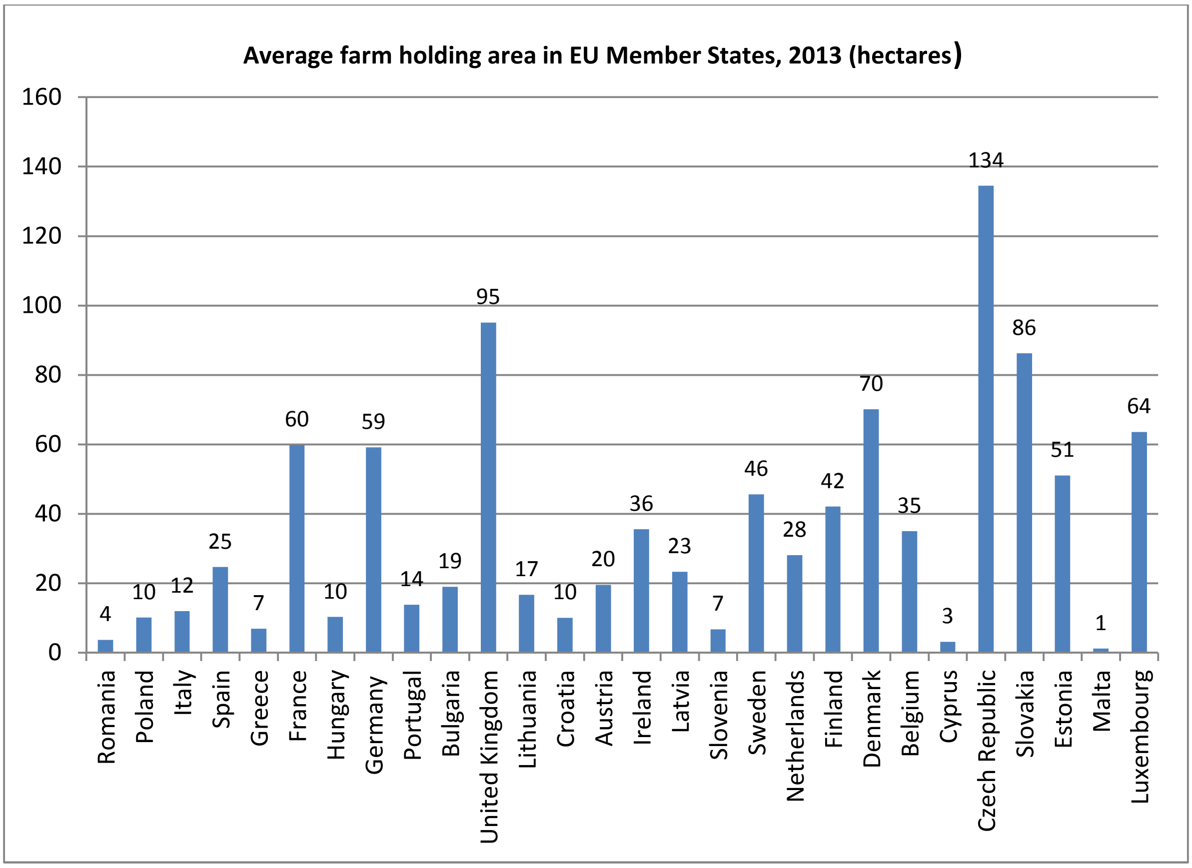


Source: Eurostat [ef_kvaareg]

The EU has 10.7 million agricultural holdings with an average area of 16 hectares. There is a very wide distribution and size range between Member States. Five states (Romania, Poland, Italy, Spain and Greece) account for 72 per cent of all holdings. One third of holdings are in Romania.

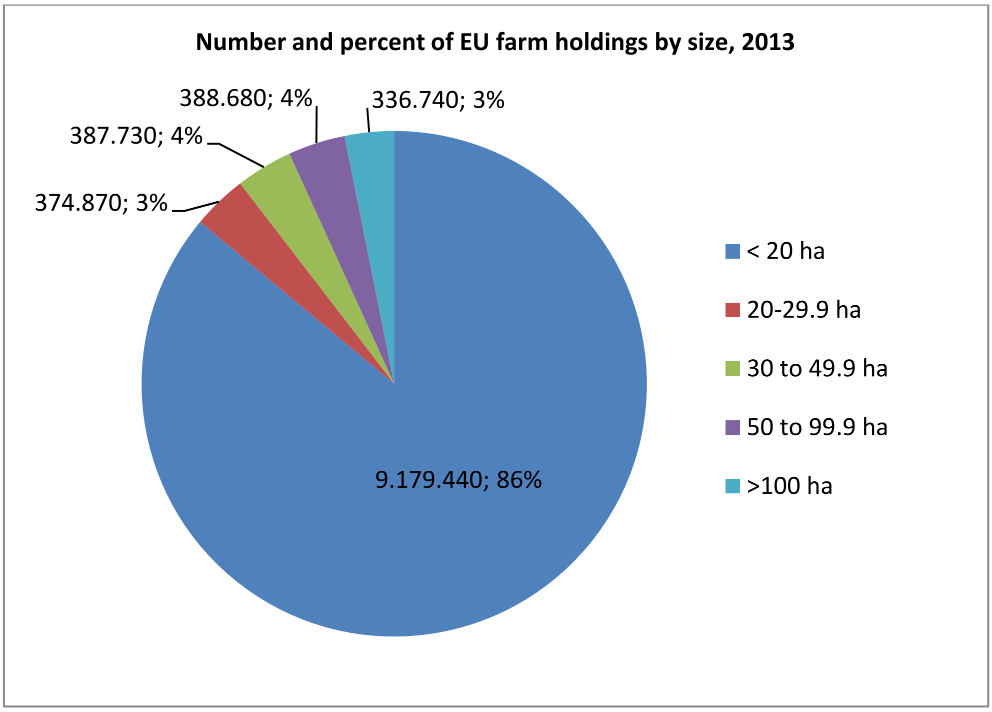
Average holding area and the size distribution vary between Member States:

- 8 Member States have an average holding area over 50 hectares: Czech Republic (134 ha), United Kingdom (95 ha), Slovakia (86 ha), Denmark (70 ha), Luxembourg (64 ha), France (60 ha) Germany (59 ha) and Estonia (51 ha);
- 7 Member States have an average holding area between 20 and 50 hectares: Sweden (46 ha), Finland (42 ha), Ireland (36 ha), Belgium (35 ha), the Netherlands (28 ha), Spain (25 ha), and Latvia (24 ha);
- 8 Member States have an average holding area between 10 and 20 hectares: Austria (20 ha), Bulgaria (19 ha), Lithuania (17 ha), Portugal (14 ha), Italy (12 ha), Hungary (10 ha), Poland (10 ha) and Croatia (10 ha);
- 5 Member States have an average holding area below 10 hectares: Greece (7 ha), Slovenia (7 ha), Romania (4 ha), Cyprus (3 ha) and Malta (1 ha).



Source: Eurostat [ef_kvaareg]

The holdings with an area of less than 20 hectares comprise 86 per cent of EU holdings but occupy just 18 per cent of the utilised agricultural area. In contrast, holdings over 20 hectares represent 14 per cent of all holdings and occupy 82 per cent of the total agricultural area. Further details on individual Member States are available in the annex tables.



Source: Eurostat [ef_kvaareg]

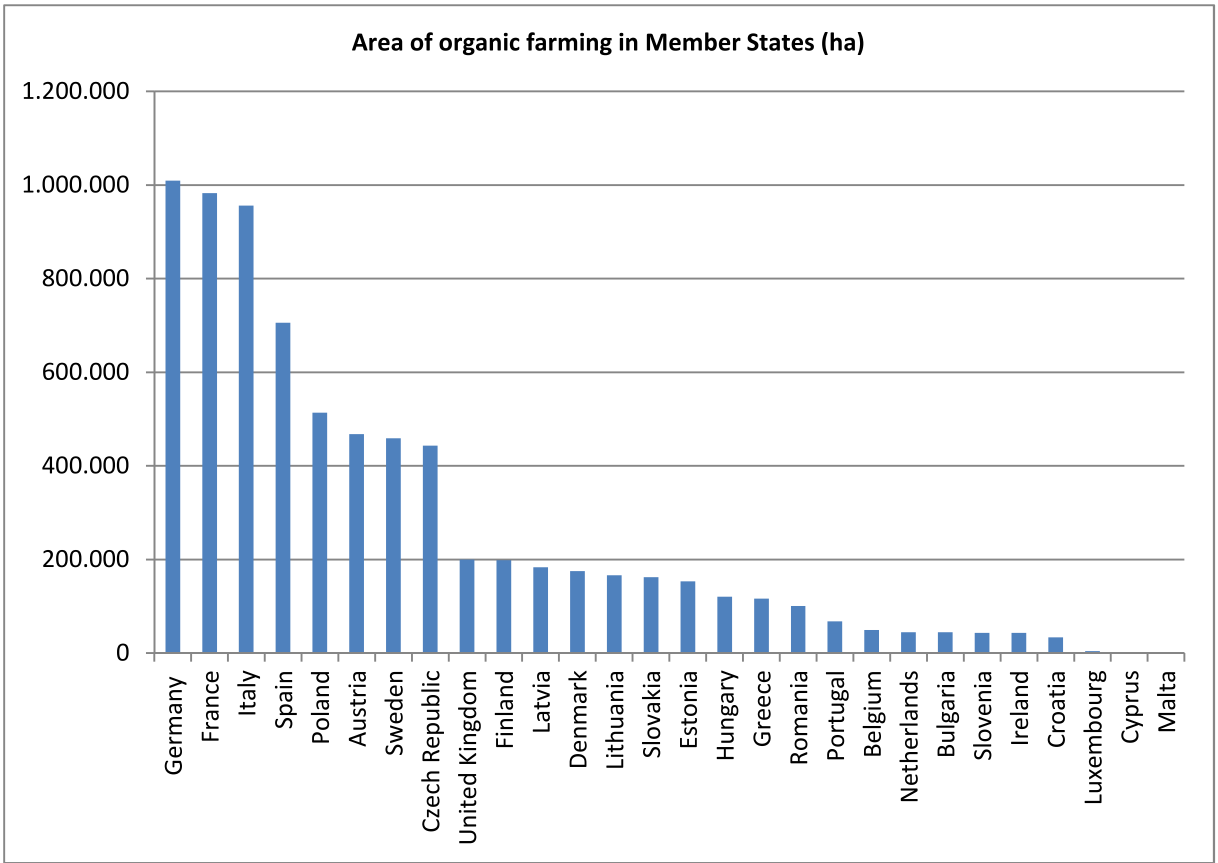
2.3. Organic production

Table 3 shows the production of selected organic crops and livestock.

Table 3. EU organic holdings and utilized agricultural area, 2013[3]

EU-28	Holdings		Utilised Agricultural Area	
	1000	%	1000 ha	%
EU farm holdings	10 841	100.0%	174 289	100.0%
Organic crops				
Cereals	71	0.7%	1 454	0.8%
Fresh vegetables, melons, strawberries	23	0.2%	85	0.0%
Pastures, meadows, excluding rough grazing	113	1.0%	3 561	2.0%
Olives	49	0.5%	332	0.2%
Vineyards	24	0.2%	216	0.1%
Organic livestock	1000	%	1000 head	%
Bovine animals	60	0.6%	3 422	2.0%
Pigs	11	0.1%	681	0.4%
Sheep and goats	26	0.2%	4 037	2.3%
Poultry	25	0.2%	25 118	14.4%

Source: Eurostat, [ef_mporganic]



Source: Eurostat, [ef_mporganic]

[3] This data differs from other Eurostat tables, such as [org_cropap]

The main agricultural crops and the structure of livestock production are considered in the next two sections.

3. Main agricultural crops

The briefing paper focuses on cereals, vegetable crops (including melons and strawberries), grapes and olives.

3.1. Production of cereal crops

Table 4 shows the production of the main cereal crops.

Table 4. EU production of main cereal crops, 2013

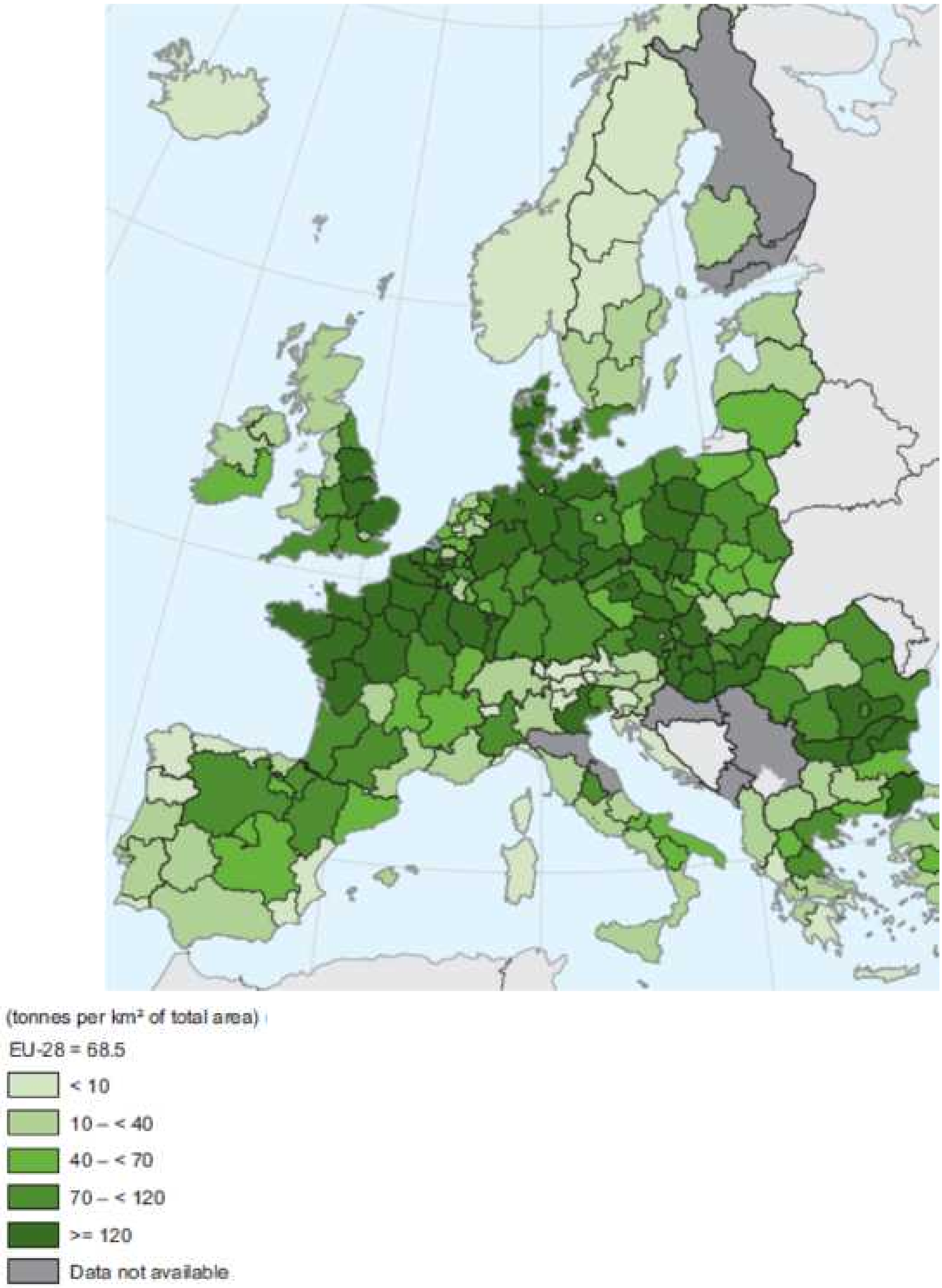
EU-28	Cereal area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Yield range between Member States	
				Highest (t/ha)	Lowest (t/ha)
Cereals* for grain *including:*	57 942	309 108	5.3	9.3	1.7
Common wheat	23 382	136 220	5.8	9.1	1.8
Barley	12 712	61 108	4.8	8.4	1.8
Grain maize (& corn-cob mix)	9 770	67 037	6.9	12.0	4.5
Rye	2 774	10 867	3.9	6.0	0.9
Oats	2 668	8 408	3.2	7.2	1.2
Durum wheat	2 383	8 049	3.4	6.1	1.9

Source: Eurostat [apro_acs_a]
*The total cereal figures shown here include rice. Rice is omitted from some other tables.

Cereal grain crops are cultivated on 57.9 million hectares and account for one third of the utilised agricultural area in the EU. They are grown on 5.5 million (51 per cent) of the 10.7 million agricultural holdings with an average area of 10.6 hectares of cereals per holding[4].

[4] See annex table

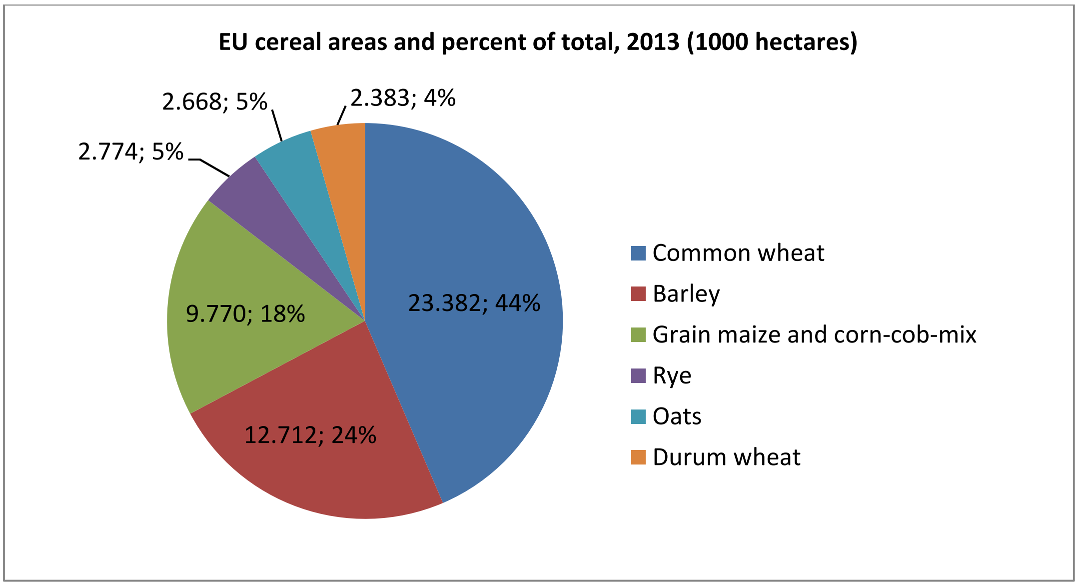
Harvested production of cereals (including rice), by NUTS level 2 region, 2013



Source: Eurostat (online data codes: agr_r_crops, apro_cpp_crop and demo_r_d3area)

Common wheat provides 44 per cent of EU cereal production. Over half of the wheat crop is produced by France, Germany and the United Kingdom. Wheat is grown in all Member States except Cyprus and Malta.

Barley accounts for 24 per cent of the EU cereal area and 20 per cent of production. Over two thirds is produced by five countries: Germany, France, Spain, United Kingdom and Poland. Barley is grown in all Member States except Malta.

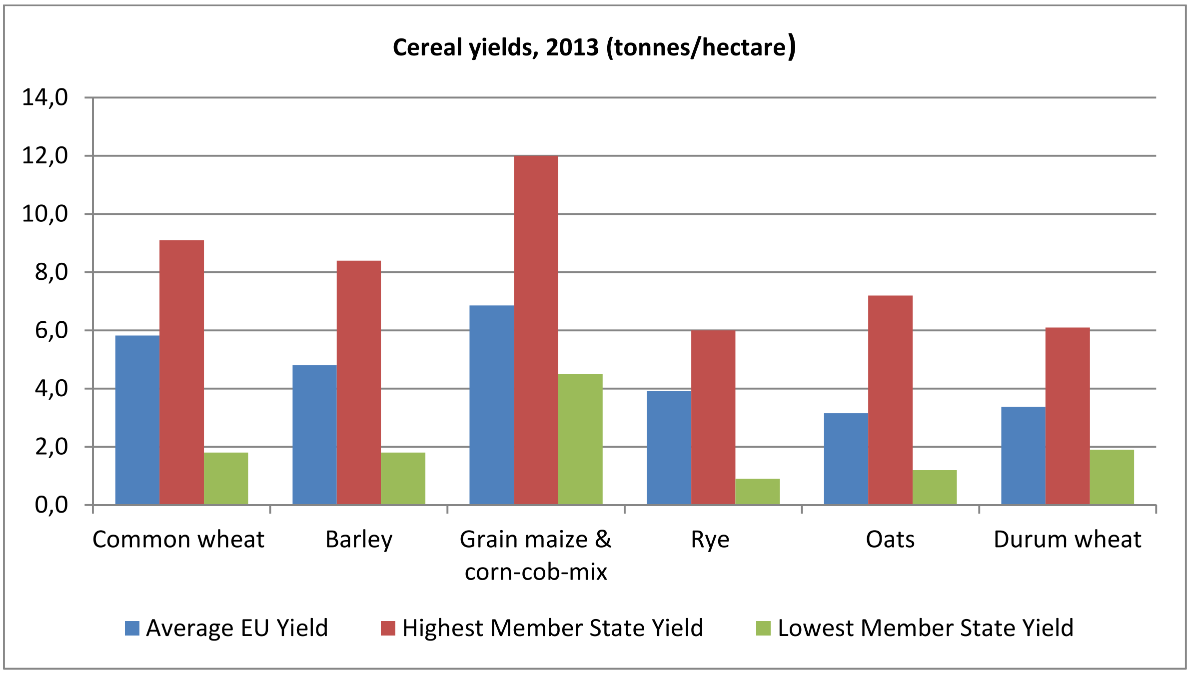


Source: Eurostat [apro_acs_a]

Production details for wheat, barley and maize (including corn-cob mix) by Member State are shown in annex tables together with statistics for total cereal grain production.

Yield per hectare of cereal crops varies considerably between Member States. The top five Member States in terms of yield per hectare for total cereals are Belgium, the Netherlands, Ireland, Germany and France. The combined average yield of cereals for these five states is 7.3 tonnes per hectare. In contrast, the average yield for the 14 Member States with the lowest yields is 4.0 tonnes per hectare. The statistics are similar for wheat and barley yields.

For maize yield, Greece, Spain and Luxembourg fall within the top five, along with Belgium and the Netherlands.



Source: Eurostat [apro_acs_a]

None of the top five Member States in terms of yield in any of the crop categories are in the top five with regards to holding size. However, Member States with high yields of wheat and barley tend to have higher proportions of cereal areas over 20 hectares. The statistics do not contain sufficient information to draw any clear conclusions on relationships between crop area and yield.

3.2. Production of vegetables

Fresh vegetables, including melons and strawberries, are cultivated on 1.6 million hectares of arable land and account for just under 1 per cent of the utilised agricultural area in the EU. However, vegetables are high-value crops and contribute a greater percentage of the value of agricultural production.

Table 5 shows the EU production of the main vegetable crops, including melons and strawberries, by harvested area.

The table shows 1 912 000 hectares were harvested for fresh vegetables, which is greater than the utilised agricultural area for vegetables shown in Table 1. The explanation is that more than one vegetable crop may be grown on a given area of land during a single year. Thus, the harvested area can exceed the utilised area. It should also be noted that these statistics include crops grown both in the open and under cover, and this means that the average figures are not always directly comparable.

Table 5. EU production of main fresh vegetable crops including melons and strawberries, 2013

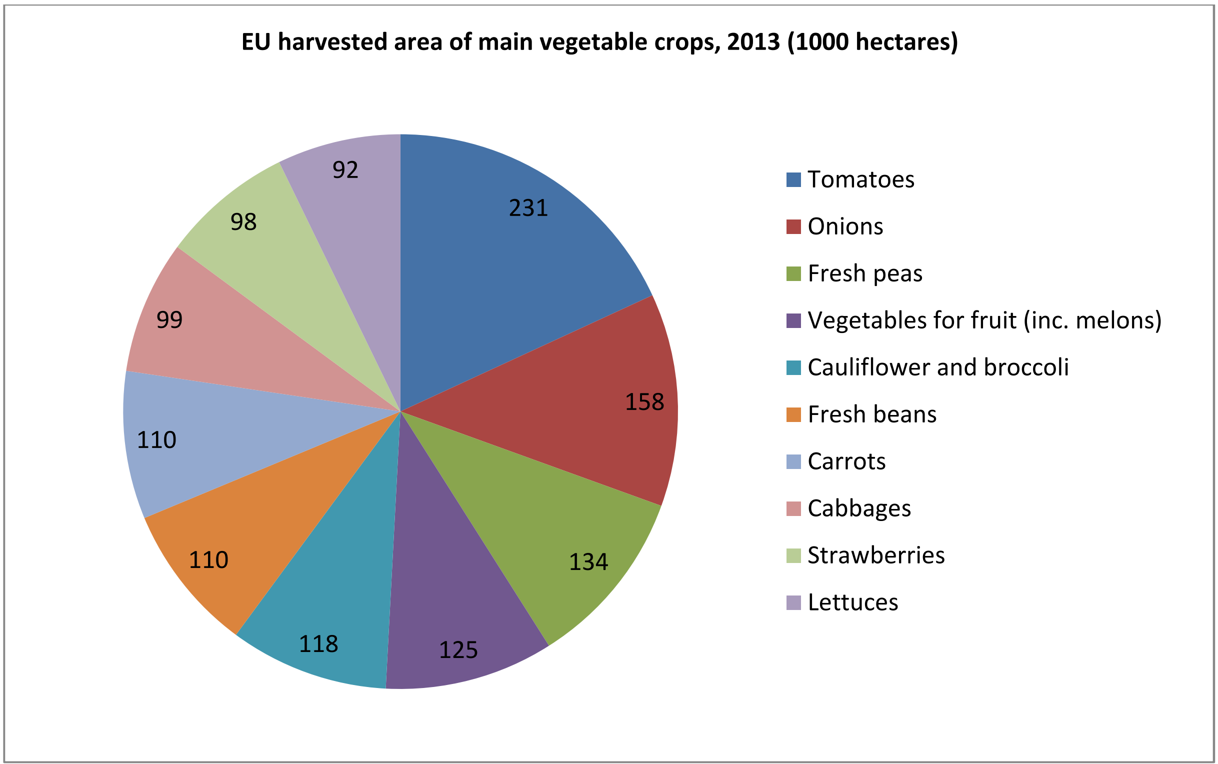
EU-28	Harvested area (1000 ha)	Harvested production (1000 t)	Yield* (t/ha)	Yield range between Member States	
				Highest (t/ha)	Lowest (t/ha)
Fresh vegetables, melons and strawberries, including:	1 912	29 691	15.5	64.8	0.1
Tomatoes	231	15 078	65.4	483.1	18.1
Onions	158	5 748	36.4	55.2	10.7
Fresh peas	134	816	6.1	13.5	1.9
Vegetables for fruit (inc. melons)	125	4 881	39.0	386.2	16.6
Cauliflower and broccoli	118	2 176	18.4	45.3	6.0
Fresh beans	110	1 081	9.9	17.7	2.0
Carrots	110	5 140	46.9	63.7	15.2
Cabbages	99	3 391	34.3	83.8	19.0
Strawberries	98	1 149	11.8	39.2	2.4
Lettuces	92	2 309	25.2	43.0	10.8

Source: Eurostat [apro_acs_a]

*Note that average yields and the highest and lowest figures should be treated with caution as they do not take into account of variations in production methods, such as open/under cover. For this reason they may be taken as indications rather than as precise figures.

Table 5 lists ten crops that account for 1 273 000 hectares or 67 per cent of the harvested area of fresh vegetables. Tomatoes are the main vegetable crop grown in the EU in terms of harvested area and production, followed by onions[5]. These are followed in terms of production by carrots and vegetables for fruit (including melons).

[5] See annex tables for further details of fresh vegetable production in Member States



Source: Eurostat [apro_acs_a]

The average yields of each crop (see annex tables) show great variations between Member States, but as mentioned above, the variations are multi-factorial with the relevant contribution of each factor depending on the specific conditions. There are likely to be effects from climate, topography and whether crops are grown indoor or under-cover, as well as reasons connected with management and husbandry practices.

3.2.1. Tomatoes

The harvested area of tomatoes accounts for 12 per cent (231 thousand hectares) of the total harvested area of fresh vegetables. The majority of tomatoes (92 per cent of the harvested area and 82 per cent of the production) are cultivated in open fields, whilst the remaining 8 per cent of the area and 18 per cent of production are cultivated under cover.

The average open-field yield is 58 tonnes per hectare, with a range from 17 to 80 between Member States. The average yield under cover is 152 tonnes per hectare, with a range from 23 to 483 tonnes per hectare.

Five Member States (Italy, Spain, Portugal, Greece and the Netherlands) account for 81 per cent of EU production of tomatoes. Production in the Netherlands is wholly under cover, whilst the Mediterranean countries are predominately outdoor producers.

3.2.2. Onions

Onions account for 8 per cent (158 thousand hectares) of the harvested area of fresh vegetables. The Netherlands and Spain have the largest harvested areas and each account for over 20 per cent of EU onion production. These two plus Poland, Germany and France are the top five Member States in terms of production.

The average yield for all Member States is 36 tonnes per hectare, ranging between 11 and 55 tonnes per hectare for individual countries.

3.2.3. Fresh peas

Fresh peas, whilst occupying third place with 7 per cent (134 thousand hectares) of the harvested area of fresh vegetables, have a lower yield than the other main fresh vegetable crops. France, United Kingdom, Spain, Belgium and Italy are the top five producers contributing 73 per cent of total production.

The average yield across the EU is 6.1 tonnes per hectare, with a range from 1.9 to 13.5 tonnes per hectare.

3.3. Production of grapes

Grape production is carried out in 19 Member States with a total harvested area of 3.2 million hectares in 2013[6], which produced 25 million tonnes of grapes.

Spain is the EU's leading grape grower by area, cultivating 0.947 million hectares in 2013. However, Italy has the most production at 8.0 million tonnes.

Spain, France, Italy, Portugal, Romania, Greece and Germany all produce over 0.8 million tonnes of grapes each and account for 94 per cent of grape production.

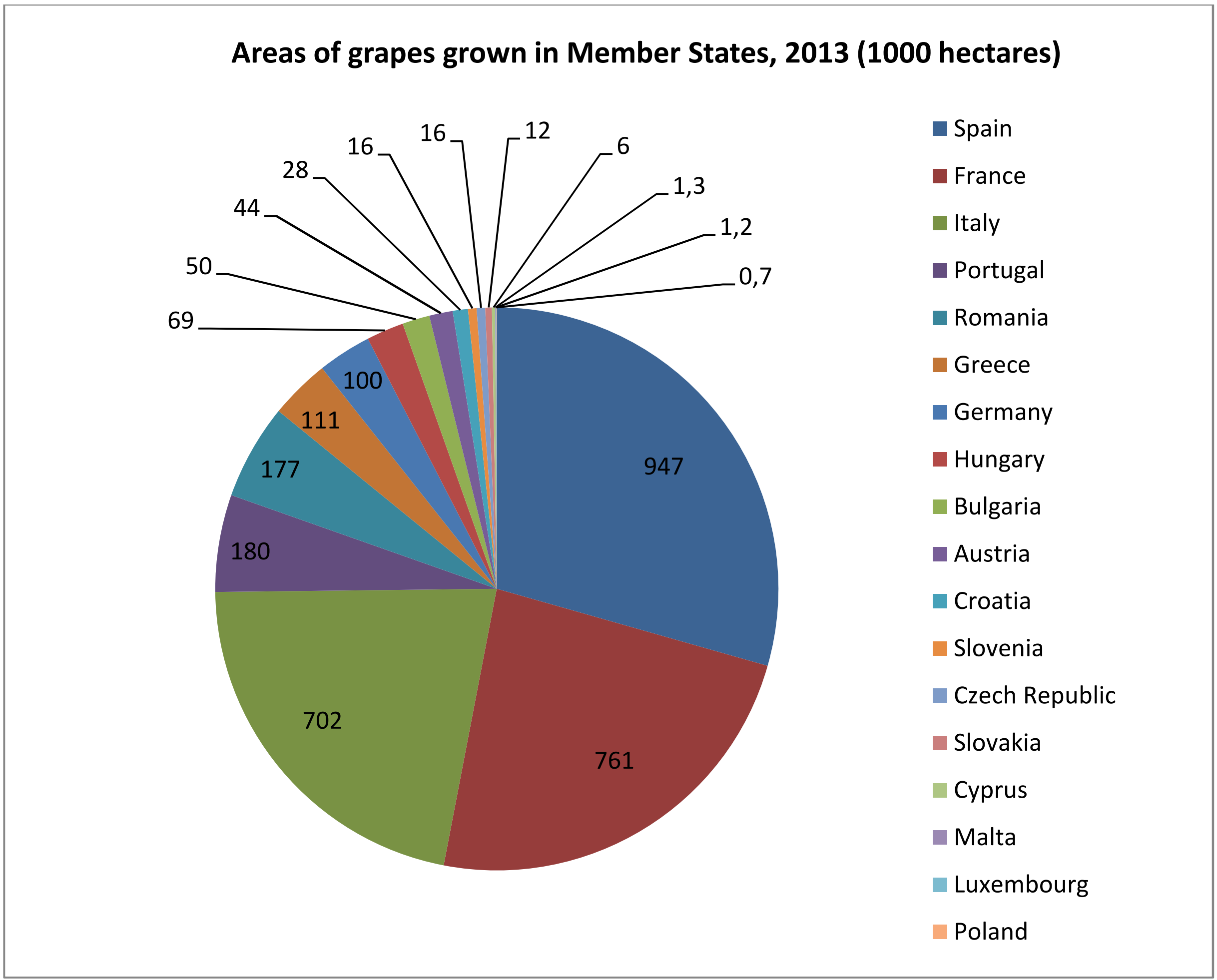
Of the total EU grape production, 92 per cent went to produce wine. Of the grapes produce for wine, 41 per cent were cultivated under Protected Designation of Origin (PDO) status and 21 per cent under Protected Geographical Indication (PGI) status.

Table 6. EU production of grapes, 2013

EU-28	Grape area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Highest MS yield (t/ha)	Lowest MS yield (t/ha)
All grapes	3 221	25 331	7.9	11.5	3.4
of which:					
Wine	3 090	23 350	7.6	11.5	3.1
of which:					
PDO wine	1 537	9 479	6.2	11.5	0.2
PGI wine	618	4 984	8.1	10.5	3.9

Source: Eurostat, [apro_acs_a]

[6] Note: Grape area does not correspond with the vineyard area in Table 1 or the harvested area in Briefing Paper 2



Source: Eurostat, [apro_acs_a]

3.4. Production of olives

The total harvested area of olives in 2013 was 4.9 million hectares[7] producing 13.6 million tonnes of olives.

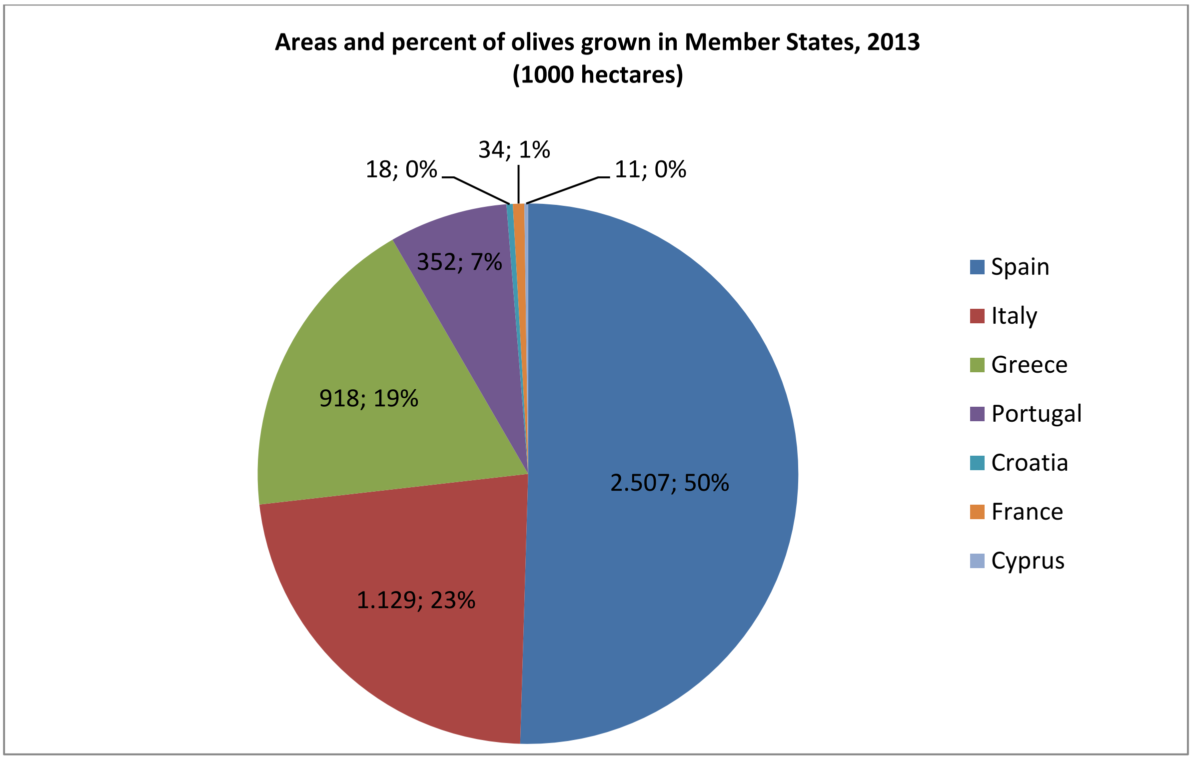
Table 7. EU production of olives, 2013

EU-28	Olive area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Highest MS yield (t/ha)	Lowest MS yield (t/ha)
All olives	4 976[8]	13 644	2.7	3.7	0.8
of which:					
Olives for table use	341	682	2.0	3.0	0.8
Olives for oil	4 635	12 962	2.8	3.7	0.8

Source: Eurostat, [apro_acs_a]

Olives were grown in seven Member States in 2013. Spain is the leading producer, cultivating 2.5 million hectares and producing 9.3 million tonnes of olives. The other major producers are Italy, Greece and Portugal. Between them these four Member States account for 99 per cent of EU production.

[7] Note: Olive area does not correspond with Table 1
[8] Note that this area does not correspond with the harvested area reported in Briefing Paper 2



Source: Eurostat, [apro_acs_a]

4. Livestock production

4.1. Meat production

Most meat produced in the EU comes from cattle, pigs, sheep and goats, and chickens[9]. The relative importance of each species varies between Member States.

EU production of meat from these species is shown in Table 8.

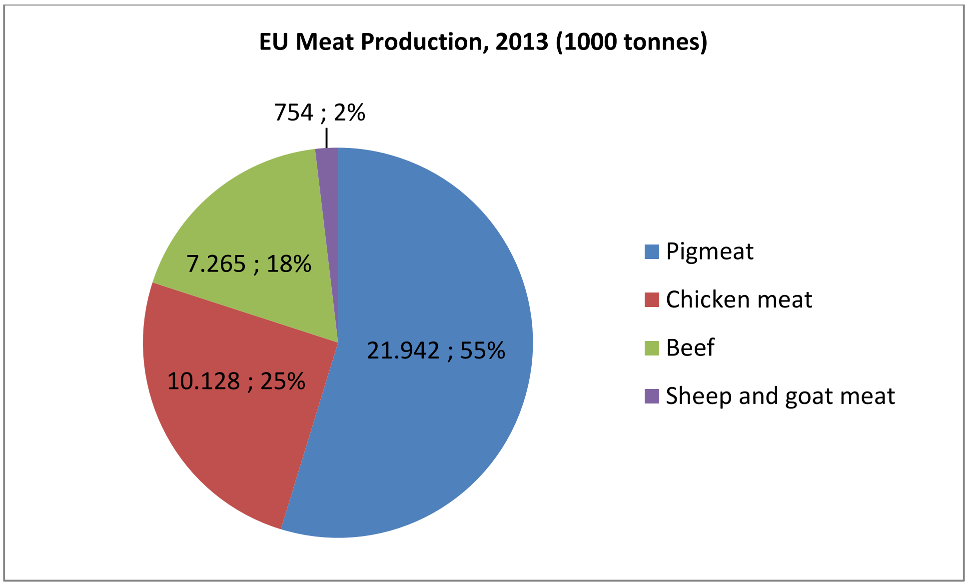
Table 8. EU meat production, 2013

EU-28	Head slaughtered (1000)	Meat production (1000 tonnes)	% of total meat production	Yield kg/head
Meat production from slaughterhouses:		40 090	100%	
Beef	25 277	7 265	18%	287
Pig meat	246 571	21 942	55%	89
Sheep and goat meat	49 106	754	2%	15
Chicken meat	6 419 009	10 128	25%	1.6

Source: Eurostat [apro_mt_pann]

[9] Note that some statistics, including in **Error! Reference source not found.**, are for chicken, whilst others are for poultry meat

Total meat production in EU slaughterhouses from the main meat species in 2013 was 40 million tonnes. Pig meat comprised 55 per cent of the total, followed by chicken meat (25 per cent), beef (18 per cent), and sheep and goat meat (2 per cent).



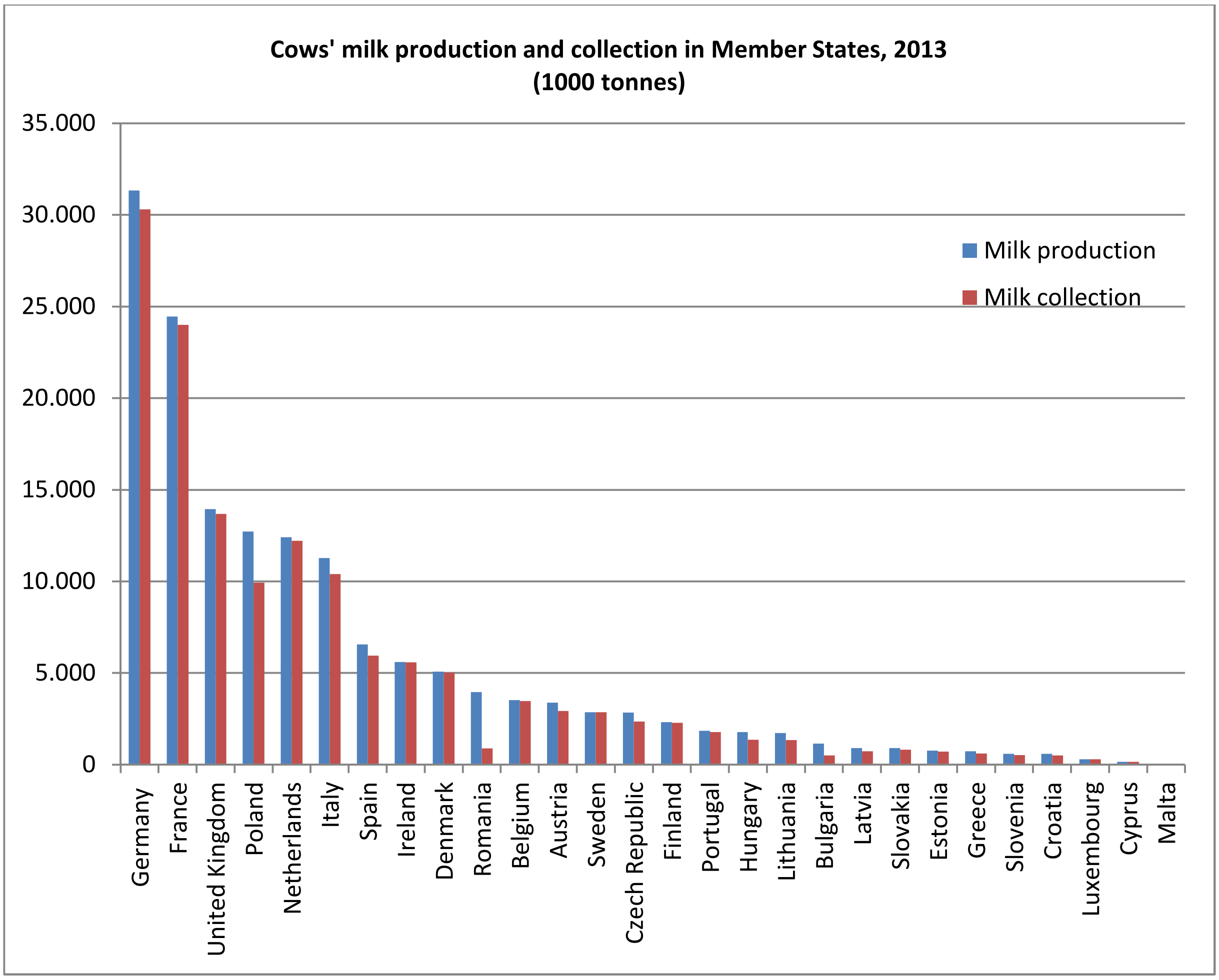
Source: Eurostat [apro_mt_pann]

4.2. Milk production

This paper focuses on milk from cows as opposed to other species, and particularly on dairy cow milk production.

Cows' milk accounts for around 97 per cent of milk produced from all species in the European Union. Total EU production of cows' milk in 2013 was 154 million tonnes of fresh milk, of which 141 million tonnes (92 per cent of production) was delivered to dairies, with the remaining 8 per cent used on farms.

Germany was the highest milk producer in 2013, followed by France, the United Kingdom, Poland and the Netherlands. These five Member States produced over 60 per cent of total EU milk production.



Source: Eurostat [apro_mk_farm], [apro_mk_pobta]

The average EU milk yield per cow in 2013 was 6 626 litres per year. Denmark was the Member State with the highest milk yield of 8 727 litres per cow per year. Yields vary considerably across the EU, partly due to climatic and soil conditions, but also due to management practices.

There are a total of 1.48 million holdings with dairy cows in the EU, which comprise 65 per cent of all the 2.28 million holdings with cattle. The average number of dairy cows per holding in the EU is 16, ranging from 2 in Romania to 158 in Denmark.

Table 9. Utilisation of milk by dairies, EU-28, 2013 (1000 tonnes)

EU-28	Products obtained*	Utilisation of whole milk
Cheese	9 274	36%
Butter	2 137	28%
Drinking milk	31 880	12%
Cream for direct consumption	2 587	12%
Milk powder	2 090	3%
Other products	-	8%
	47 968	**100%**

*Estimates, excluding Luxembourg and Malta
Source: Eurostat, Agriculture, forestry and fishery statistics, 2014 [based on data code: apro_mk_pobta]

Table 9 shows the utilisation of the 141 million tonnes of whole milk collected by EU dairies in 2013. Cheese used the most whole milk (36 per cent) followed by butter (28 per cent), drinking milk (12 per cent), cream for direct consumption (12 per cent) and milk powder (3 per cent). Various other fresh and manufactured products used the remaining 8 per cent.

Whole milk is utilised differently across individual Member States. For example, the United Kingdom produces a disproportionately large amount of drinking milk and Germany, Italy and the Netherlands produce large proportions of cheese.

5. Intra-eu trade, external trade and self-sufficiency[10]

5.1. Cereals

Table 10. EU cereals market balance, 2011-2016 (million tonnes)

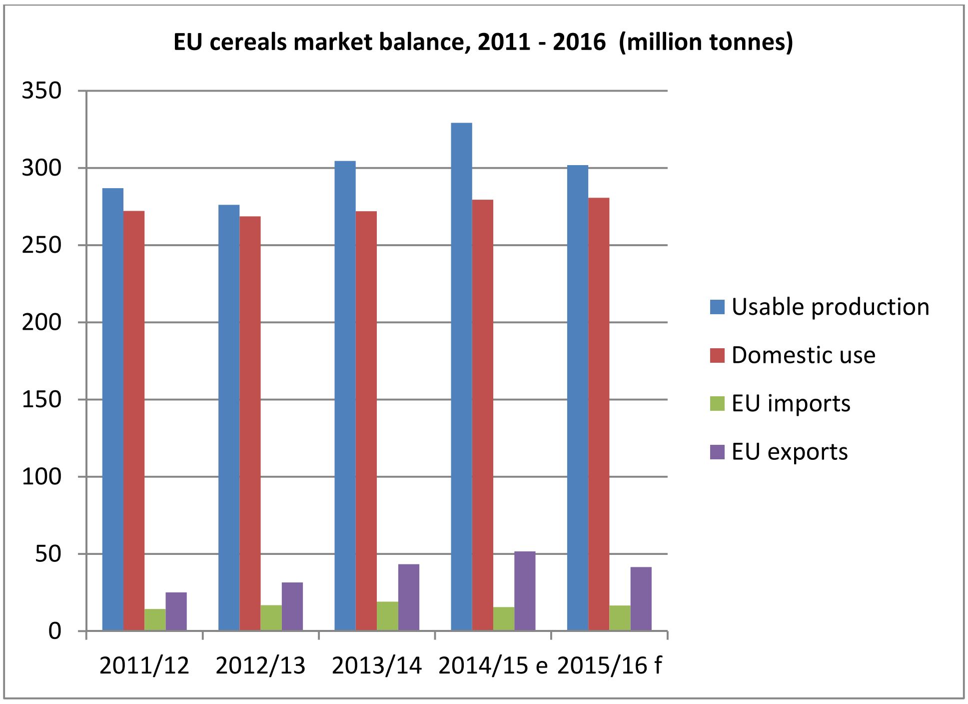
Marketing year (July-June)	EU-27		EU-28		
	2011/12	2012/13	2013/14	2014/15 e	2015/16 f
Production and use					
Usable production	286.9	276.2	304.5	329.2	301.9
Domestic use	272.2	268.8	272.0	279.5	280.8
of which human consumption	*65.4*	*65.5*	*65.7*	*65.7*	*65.8*
of which animal feed	*167.0*	*163.2*	*164.9*	*172.0*	*173.1*
Net domestic balance	14.7	7.4	32.5	49.7	21.1
Self-sufficiency rate	105%	103%	112%	118%	108%
External trade					
EU imports	14.4	16.9	19.2	15.6	16.6
EU exports	25.2	31.6	43.5	51.7	41.5
Net export balance	10.8	14.7	24.3	36.1	24.9

Source: Short-Term Outlook, Autumn 2015
e-estimate, f-forecast

Table 10 shows that the EU is self-sufficient in cereals and is a net exporter. Over 50 per cent of cereal production is fed to livestock.

Production of wheat and barley exceeds domestic use by around 25 per cent, with the surplus being exported. Maize production is generally in deficit, apart from 2014/15 which was a record year for cereal production in the EU.

[10] Unless otherwise indicated, information in this chapter is obtained from DG AGRI market reports



Source: Short-Term Outlook, Autumn 2015
e-estimate, f-forecast

5.2. Fresh vegetables

Table 11. EU-27: Intra-EU and external trade in vegetables, 2011-2013 (1000 tonnes)

EU-27	2011	2012	2013
Intra-EU trade			
Vegetables	11 793	12 011	12 561
of which, tomatoes	2 488	2 530	2 635
EU imports			
Vegetables	1 694	1 541	1 531
of which, tomatoes	450	431	431
EU exports			
Vegetables	1 474	1 597	1 762
of which, tomatoes	206	272	371
Net EU export balance			
Vegetables	-220	56	231
of which, tomatoes	-244	-159	-60

Source: DG AGRI, Markets Statistical Information, December 2014

Table 11 shows EU intra-trade and external trade in total vegetables and in tomatoes, the largest vegetable crop.

Over 40 per cent of all vegetable production is subject to intra-EU trade, as is 17 per cent of tomato production. These relatively high proportions are consistent with the uneven production of different vegetable crops across the EU (see annex tables).

The amounts of vegetables subject to EU import-export trade are considerably lower than those for EU intra-trade: about 5-6 per cent of total vegetables and 2-3 per cent of tomatoes are traded externally. Of course, the range of vegetables is very wide and many of the imported vegetables will be different types to those subjected to intra-EU trade, for climatic and other reasons.

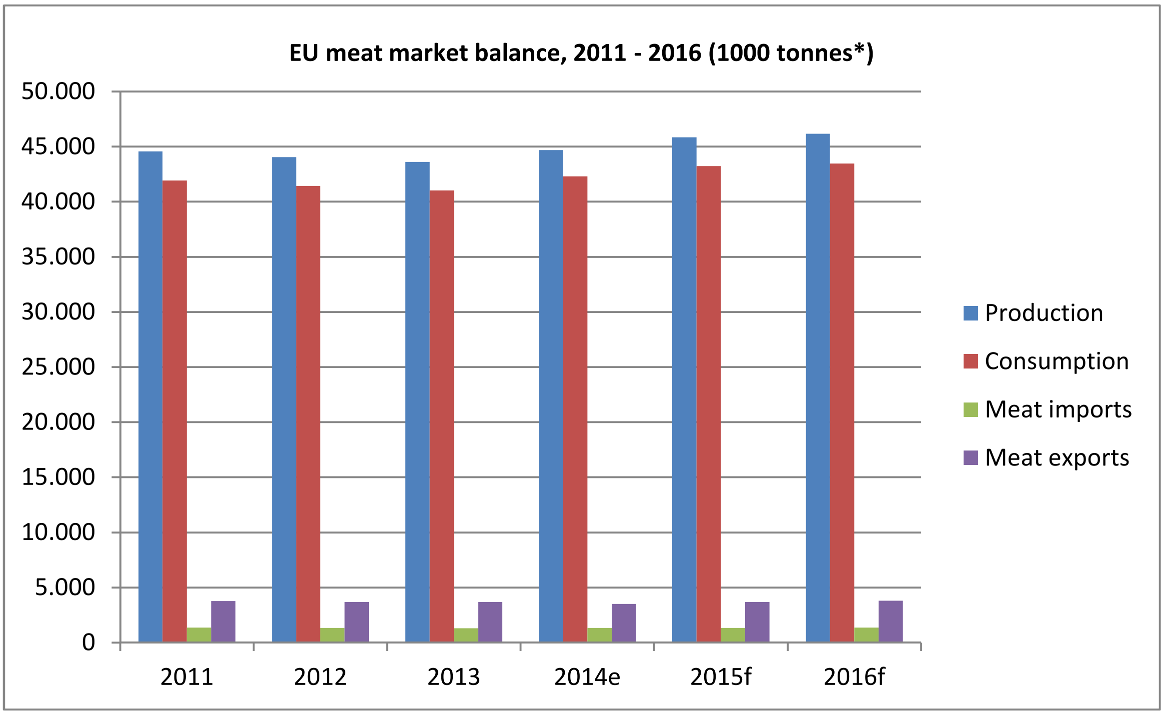
5.3. Meat

Table 12 shows the EU market balance for the main meats: beef and veal; pig meat; sheep and goat meat; and poultry meat[11].

Table 12. EU meat market balance, 2011-2016 (1000 tonnes*)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Net production	44 585	44 041	43 601	44 683	45 838	46 165
Consumption	41 920	41 435	41 036	42 306	43 231	43 479
Net domestic balance	2 665	2 606	2 565	2 377	2 607	2 686
Self-sufficiency rate	106%	106%	106%	106%	106%	106%
Per capita consumption** (kg/year)	66.0	65.2	64.5	66.3	67.6	67.9
External trade						
Net live animal exports (less imports)	239	231	178	195	238	248
Meat imports	1 357	1 326	1 311	1 326	1 334	1 361
Meat exports	3 783	3 702	3 698	3 507	3 702	3 799
Net export balance	2 665	2 607	2 565	2 376	2 606	2 686

Source: Short-Term Outlook, Autumn 2015
*carcass weight equivalent, **retail weight, e - estimate, f - forecast



Source: Short-Term Outlook, Autumn 2015
*carcass weight equivalent, e - estimate, f - forecast

[11] Note that **Error! Reference source not found.** shows figures for poultry meat whereas **Error! Reference source not found.** shows chicken meat.

The EU is self-sufficient in total meat production. However, it produces only 80-90 per cent of its consumption of sheep and goat meat. Beef and veal production is about the same as consumption, pig meat production is 11 per cent in excess of consumption and poultry meat is 4 per cent in excess of consumption[12].

Annual per EU capita consumption of the main meats is consistently over 65kg (retail weight).

5.4. Milk and dairy products

The EU is self-sufficient in milk and dairy production and exports the excess mainly in the form of dairy products[13]. Most of the surplus is exported as cheese and milk powder.

Table 13 shows EU milk production from 2011 with forecasts to 2016, together with the main dairy products obtained. More detailed data is presented in annex tables.

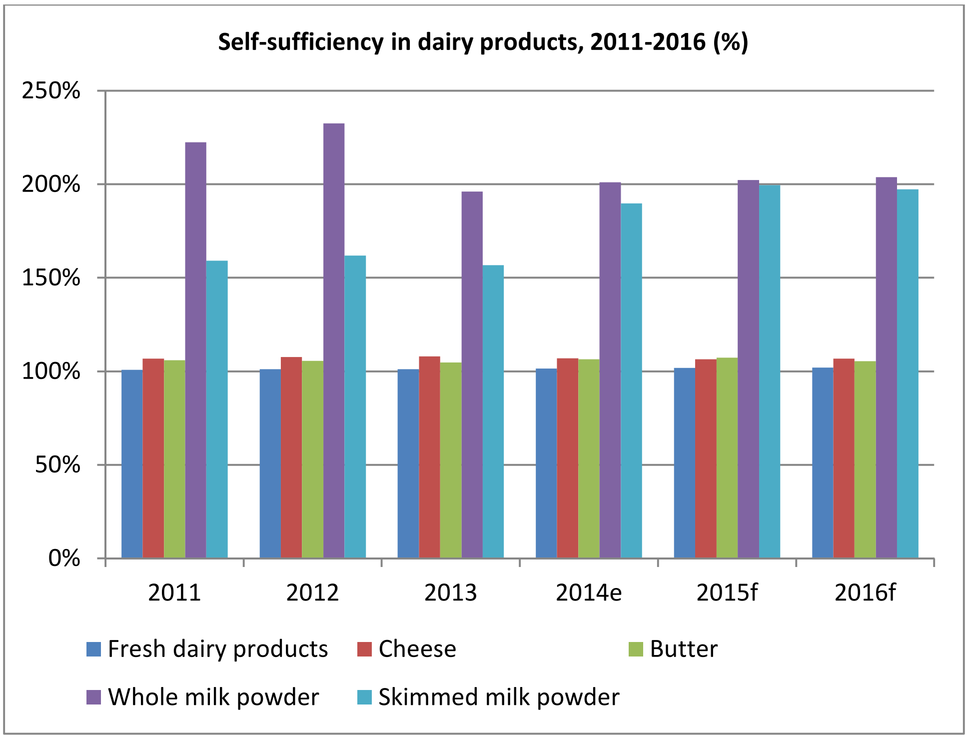
[12] See annex tables for details of each of the main species

[13] See annex tables for more detailed information

Table 13. EU milk production and dairy products market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Milk production						
Dairy cows (milllion)	23.1	23.0	23.3	23.4	23.4	23.2
Milk yield (kg/dairy cow/year)	6 444	6 472	6 480	6 727	6 800	6 915
Total cow milk production	151 900	152 100	153 800	160 100	161 900	163 400
Delivered to dairies	140 000	140 400	141 200	147 800	149 400	150 400
Dairy products						
Fresh dairy products						
Production*	46 801	46 707	47 061	46 879	46 634	46 747
Self-sufficiency rate (%)	101%	101%	101%	102%	102%	102%
EU exports	399	532	577	727	836	961
Cheese						
Production**	9 398	9 610	9 687	9 941	10 044	10 169
Self-sufficiency rate (%)	107%	108%	108%	107%	106%	107%
EU exports	673	768	787	720	687	729
Butter						
Production***	2 102	2 167	2 120	2 228	2 336	2 362
Self-sufficiency rate (%)	106%	106%	105%	106%	107%	105%
EU exports	124	124	116	134	152	165
Whole milk powder						
Production	703	672	757	770	736	752
Self-sufficiency rate (%)	222%	233%	196%	201%	202%	204%
EU exports	388	386	374	389	373	384
Skimmed milk powder						
Production	1 096	1 109	1 108	1 400	1 511	1 533
Self-sufficiency rate (%)	159%	162%	157%	190%	200%	197%
EU exports	516	520	407	646	678	726

Source: Short-Term Outlook, Autumn 2015
*Includes drinking milk, cream, acidified milk (yoghurts, etc.), buttermilk, milk drinks
**Includes goat, sheep and buffalo milk and net exports of processed cheese
***Includes butter, butter oil and other yellow fat products
e-estimate, f-forecast



Source: Short-Term Outlook, Autumn 2015

Table 13 shows that milk production has been increasing since 2011. The end of milk quotas in April 2015 appears to have been an incentive to increase production.

The quantity of fresh dairy products has fluctuated slightly over the period. Domestic consumption has declined slightly and the surplus of 1-2 per cent over domestic consumption has been exported.

Cheese production has increased slightly as has domestic consumption. Surplus production is around 6-8 per cent and has been exported. The situation with butter is similar: both production and consumption have increased slightly and the surplus of 5-7 per cent has been exported.

Both whole and skimmed milk powder are produced in excess of consumption with the surplus destined for export. The amount of whole milk powder exported has fluctuated slightly, whereas the export of skimmed milk powder has shown an upward trend.

Whilst there are imports in all categories (shown in annex tables), they are a small fraction of exports in all cases.

6. Agricultural market trends[14]

6.1. Cereals[15]

The cereal area has also fallen slightly and this trend is expected to continue in line with the gradual decline in the utilised agricultural area. Common wheat is expected to increase at the expense of other cereals.

In general, DG AGRI foresees only modest changes in yields and harvested areas over the next decade. EU cereal yields are already close to their agro-economic maximum and higher than those of other major

[14] Unless otherwise indicated, information in this chapter is obtained from DG AGRI market reports

[15] Includes information from the JRC October 2015 workshop: Medium-term outlook for the EU agricultural commodity market,

producers (see Table 14). The EU maize yield is likely to show a higher increase due to gains in a number of Member States where yield is currently below average.

This situation of modest yield increase could be enhanced by significant technological developments, such as precision agriculture, that increase yields whilst keeping costs down.

Within the EU, demand for cereals depends to a large extent on the animal feed market, which is expected to grow due to increased milk and meat production.

Recent relatively low cereal prices compared to the peak of 2012 have been offset by low energy prices, which have kept production costs down.

Cereal prices are expected to remain in the range of 150-180 euro/tonne for the medium-term. Wheat prices are expected to remain strong due to competitiveness on world markets. World demand for barley is also expected to be maintained, although this depends on continuation of the current preference in China for barley over other cereals.

6.2. Meat

World meat consumption is expected to grow by 15 per cent between 2015 and 2025 due to increasing population and prosperity[16].

Economic recovery and slightly lower prices have resulted in a forecasted increase in EU per capita meat consumption in 2015 and 2016. However this is likely to fall back slightly to 66.7 kg (retail weight) by 2025, with poultry meat taking a small market share from other meats. Reasons for the static EU consumption levels include animal welfare, the environment, health concerns and the ageing EU population.

Around two thirds of EU beef comes from the dairy herd and production therefore depends on trends in the dairy sector. Increased dairy slaughter numbers and dairy restructuring have resulted in an increase in beef production to 7.9 million tonnes in 2015 and 2016[17]. However beef production is projected to fall back slightly to 7.6 million tonnes in 2025.

EU beef exports are expected to remain reasonably stable over the period, although there may be changes in the export destinations. Economic uncertainty means that it is difficult to predict prices, but moderate feed prices are expected to result in increased production in the USA, Brazil and Argentina, which would tend to push the world price down.

EU pig meat production is expected to increase by less than 2 per cent by 2025. EU consumption is expected to fall slightly and environmental and social concerns are likely to limit increases in production for export. Nevertheless, exports are expected to grow by 27 per cent between 2015 and 2025, driven by world demand (particularly from China) and gradual price increases.

Environmental and social concerns and land availability are likely to result in differential changes in pig production between Member States. It is expected that the concerns will be mitigated by increased movements of live animals across national borders.

Sheep and goat meat production is expected to increase by 0.1 per cent per year to 2025, although this figure covers significant variation between Member States. Although world demand for sheep and goat meat is expected to increase, EU exports are likely to remain stable to traditional live animal and meat markets, with expansion limited by strong competition from Australia and New Zealand.

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[16] EU Agricultural Outlook, Prospects for EU agricultural markets and income, 2015-2025, December 2015, DG AGRI

[17] See annex table

EU poultry meat production is projected to grow by 4 per cent between 2015 and 2025, due mainly to increasing world demand with a slight increase in domestic demand. Exports are projected to increase by 1.4 per cent per year to 2025. However competition from Brazil and the USA will put pressure on prices. World-wide demand for poultry meat is strong due to its wide acceptability, health image and cheap price compared to other meats.

6.3. Milk and dairy products

Prices for milk and dairy products are currently low due to increased supply coupled with reduced exports to China and an import ban in Russia. Prices are expected to recover moderately in the short-term and then to rise further to an average 360 euro per tonne by 2025.

7. Global factors[18]

7.1. Cereals

The European Union is the world's largest producer of wheat, barley, oats and rye; and the fourth largest maize producer (USDA figures[19]).

Table 14. Wheat production and yields in major producing areas, 2015

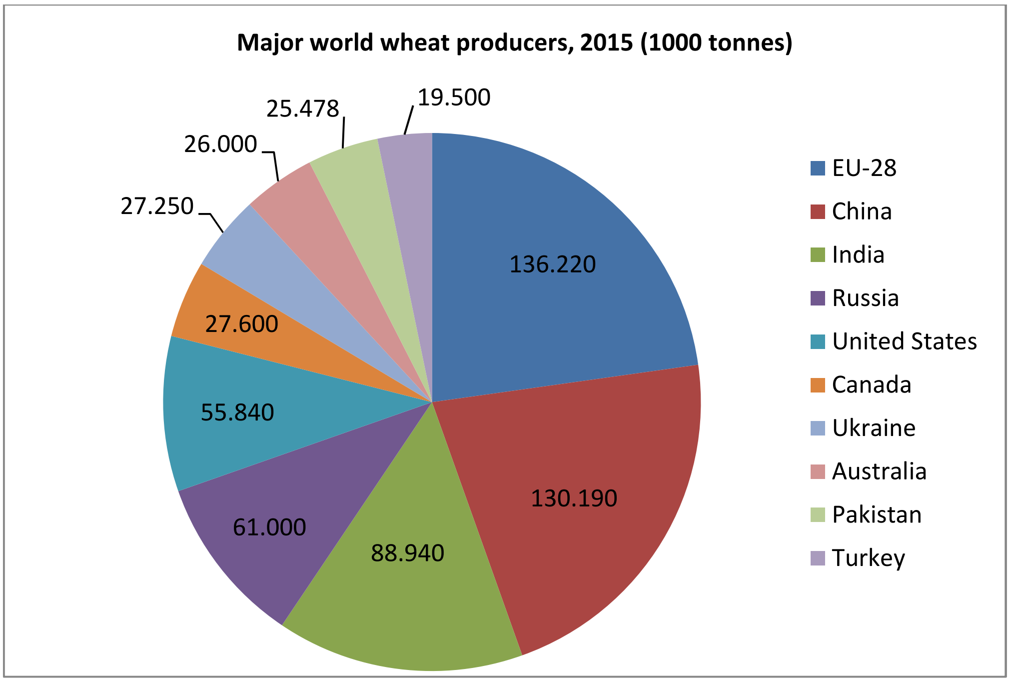
Wheat	Area (1000 ha)	Production (1000 t)	% of world production	Yield (t/ha)
World		735 770		
EU-28	23 382	136 220	19%	5.8
China	24 150	130 190	18%	5.4
India	30 600	88 940	12%	2.9
Russia	25 500	61 000	8%	2.4
United States	19 058	55 840	8%	2.9
Canada	9 600	27 600	4%	2.9
Ukraine	7 000	27 250	4%	3.9
Australia	13 800	26 000	4%	1.9
Pakistan	9 100	25 478	3%	2.8
Turkey	7 860	19 500	3%	2.5
	170 050	**598 018**	**81%**	**3.5**

Sources:
USDA - https://www.worldwheatproduction.com
CGIAR World Food Atlas based on USDA data - http://wheatatlas.org
Eurostat [apro_acs_a] (EU data)

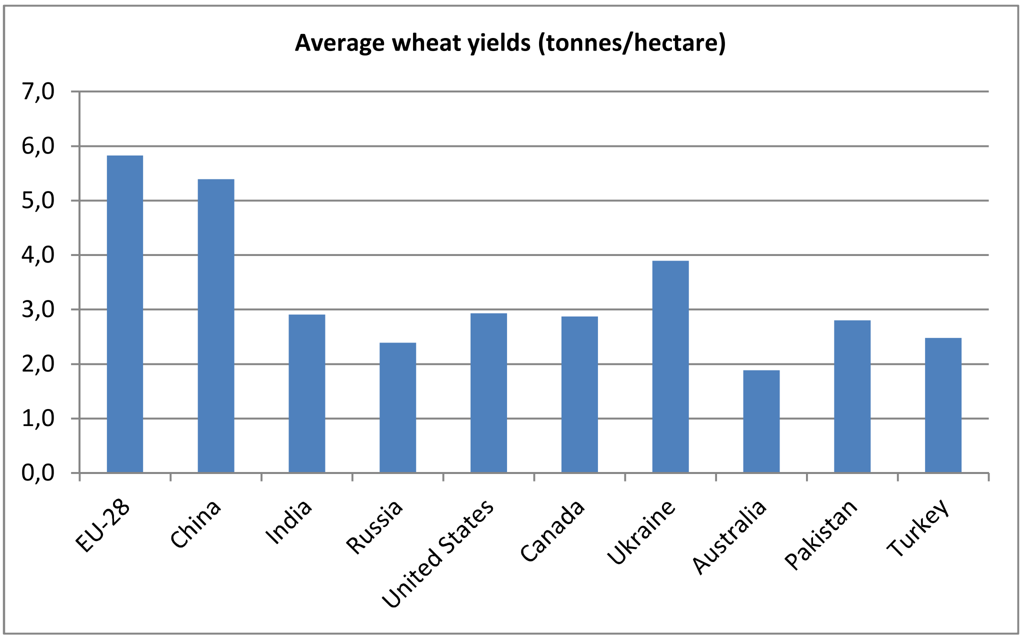
The European Union produced 19 per cent of world wheat supply in 2015 (Eurostat and USDA figures). The EU also has the highest average wheat yield per hectare amongst the major producers (New Zealand has also amongst the world's highest yields, but is not a major producer).

China is the world's second largest wheat producer after the EU, and also has the second highest yield. Other major producers are India, Russia and the United States, but they all have lower yields per hectare.

[18] Unless otherwise indicated, information in this chapter is obtained from DG AGRI market reports
[19] http://www.indexmundi.com/agriculture



Sources: USDA - https://www.worldwheatproduction.com
CGIAR World Food Atlas based on USDA data - http://wheatatlas.org
Eurostat [apro_acs_a] (EU data)



Sources: USDA - https://www.worldwheatproduction.com
CGIAR World Food Atlas based on USDA data - http://wheatatlas.org
Eurostat [apro_acs_a] (EU data)

The EU is also the world's largest barley producer, with a level of production 3.5 times that of the next largest, Russia. It also has the highest yield (4.8 tonnes per hectare) among the major producers.

The United States is by far the world's largest maize producer with 345 000 tonnes, followed by China, Brazil and the EU. The USA also has one of the highest maize yields at 11 tonnes per hectare; exceeded only by Chile and equal to New Zealand.

7.2. Meat

Economic uncertainty means that it is difficult to predict prices, but moderate feed prices are expected to result in increased beef production in the USA, Brazil and Argentina, which would tend to push the world price down.

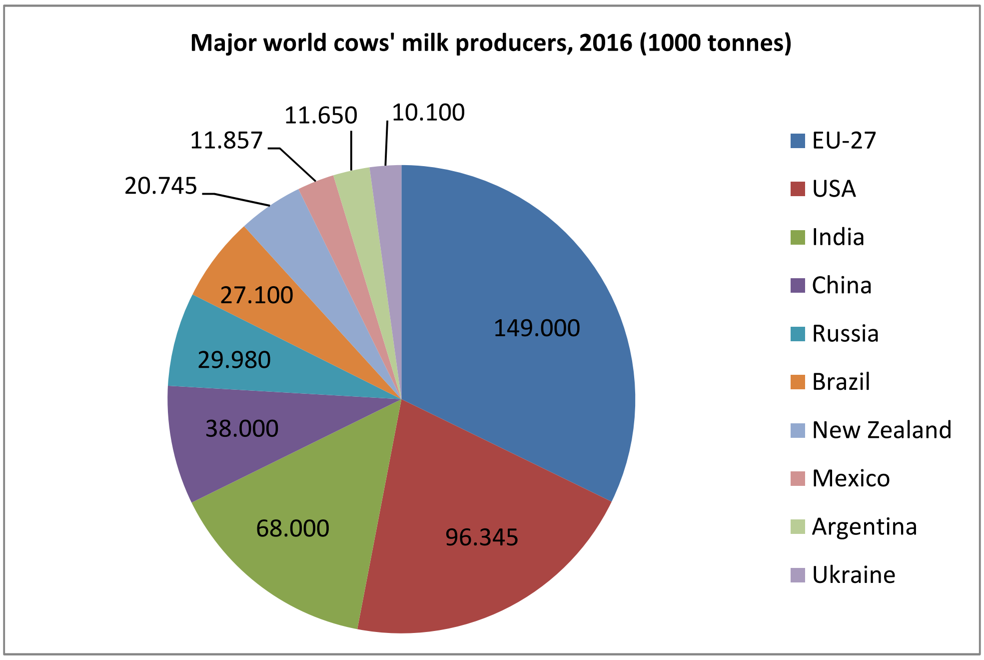
7.3. Milk and dairy products

The main world producers of milk and dairy products are shown in Table 15.

Table 15. Main cows' milk producers and yields, 2016 estimates

	Production (1000 tonnes)	Milking cows (1000)	Yield (kg/cow)
EU-27[20]	149 000	23 550	6 327
USA	96 345	9 305	10 354
India	68 000	54 500	1 248
China	38 000	8 500	4 471
Russia	29 980	7 585	3 953
Brazil	27 100	17 680	1 533
New Zealand	20 745	5 100	4 068
Mexico	11 857	6 450	1 838
Argentina	11 650	1 815	6 419
Ukraine	10 100	2 200	4 591

Source USDA - http://www.indexmundi.com/agriculture

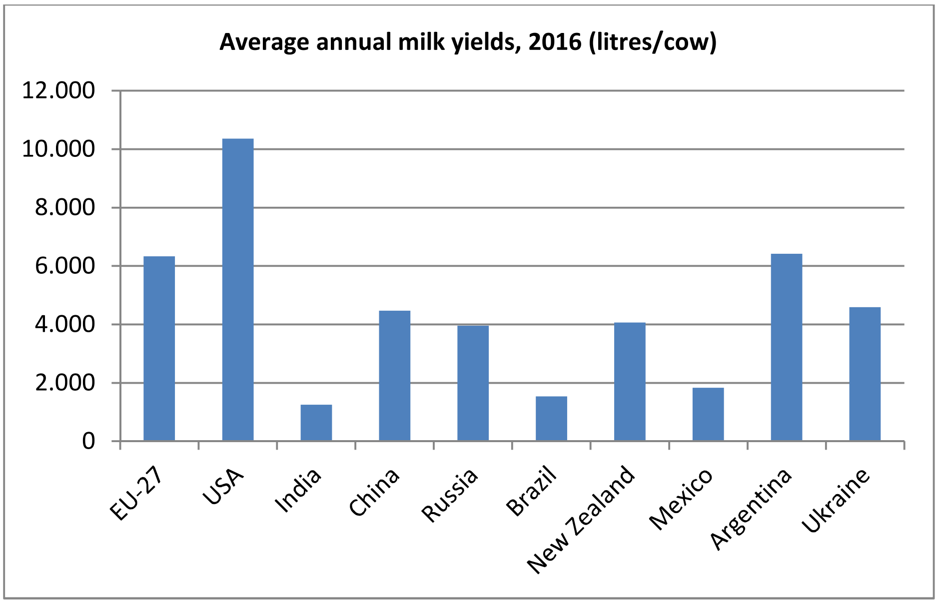


Source USDA - http://www.indexmundi.com/agriculture

The EU is the world's largest producer of cows' milk. India produces a similar volume of cow and buffalo milk combined, but cows' milk is less than 50 per cent of the total.

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-27 with 6 327 kg/cow.

[20] Index Mundi tables are still based on the EU-27



Source USDA - http://www.indexmundi.com/agriculture

Tables 16 and 17 show the product balances of the main importers and exporters. Import-export data for all the main milk producers is available in annex tables.

Table 16. Main importers of liquid milk and dairy products, 2016 estimates (1000 tonnes)

		Liquid milk	Cheese	Butter	Whole milk powder	Skimmed milk powder
China	**Net balance**	**-450**	**0**	**0**	**-358**	**-210**
	Import	475			360	210
	Export	25			2	
Russia	**Net balance**	**-240**	**-195**	**5**	**-34**	**-115**
	Import	260	220		35	117
	Export	20	25	5	1	2
Mexico	**Net balance**	**-30**	**-113**	**8**	**2**	**-230**
	Import	42	118		8	230
	Export	12	5	8	10	

Source USDA - http://www.indexmundi.com/agriculture

Table 17. Main exporters of liquid milk and dairy products, 2016 estimates (1000 tonnes)

		Liquid milk	Cheese	Butter	Whole milk powder	Skimmed milk powder
New Zealand	**Net balance**	**198**	**277**	**529**	**1 358**	**381**
	Import	2	8	1	1	4
	Export	200	285	530	1 359	385
EU-27	**Net balance**	**650**	**640**	**200**	**394**	**758**
	Import	10	65	10	1	2
	Export	660	705	210	395	760
USA	**Net balance**	**91**	**147**	**-7**	**7**	**565**
	Import	4	156	40	8	2
	Export	95	303	33	15	567

Source USDA - http://www.indexmundi.com/agriculture

The main milk and dairy product importers are China, Russia and Mexico. The main exporters are New Zealand, the EU, and the United States.

Despite being a large producer, India has an insignificant import-export trade. Its production is consumed internally and it does not import. This situation is not expected to change in the medium-term. Production will increase but will be consumed domestically.

Milk production in China is projected to grow, but not as fast as the increase in consumption. China is therefore expected to import an increasing amount of milk and dairy products.

Russian cheese imports have halved since the introduction of the import ban in August 2014. However it is not anticipated that imports will return to previous levels when the ban is lifted, due to financial constraints and increased domestic production.

The medium-term outlook is for increasing world demand and rising prices for milk and dairy products due to population growth and increasing preference for dairy products. World imports are expected to increase by 2.4 per cent (over 1.4 million tonnes) per year with China remaining the main importer.

New Zealand is expected to remain the largest exporter with 31 per cent of world trade (measured as milk equivalent), followed by the EU with 28 per cent of the market by 2025. World trade in milk and dairy products represents only a small proportion of production (7.5 per cent in 2025).

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

DG AGRI expects milk yields per cow to increase due to a number of factors including genetics, wider use of robots, improved pasture management and increased use of concentrate feeds. As average yield increases, the number of dairy cows is expected to fall.

Until 2020, the average EU raw milk price is expected to remain between 32 and 33 euro cents per kilogram. Thereafter the price is expected to rise in line with other prices.

Annex Table 1. Utilised Agricultural Area by Member State, 2013

	EU-28	Utilised Agricultural Area (1000 ha)	Arable land (1000 ha)	Permanent pastures (1000 ha)	Permanent crops (1000 ha)	Kitchen gardens (1000 ha)
1	France	27 739	18 466	8 242	1 024	6.5
2	Spain	23 300	11 295	7 962	4 042	1.2
3	United Kingdom	17 096	6 269	10 792	36	0.0
4	Germany	16 700	11 876	4 621	200	2.9
5	Poland	14 410	10 760	3 206	412	31.8
6	Romania	13 056	8 198	4 398	302	157.4
7	Italy	12 099	6 728	3 316	2 032	21.8
8	Ireland	4 959	1 042	3 916	2	0.1
9	Greece	4 857	1 817	2 102	929	8.5
10	Hungary	4 657	3 801	703	139	14.4
11	Bulgaria	4 651	3 279	1 271	95	5.2
12	Portugal	3 642	1 101	1 817	709	15.4
13	Czech Republic	3 491	2 492	960	39	0.2
14	Sweden	3 036	2 582	449	5	0.0
15	Lithuania	2 861	2 278	560	23	0.0
16	Austria	2 727	1 364	1 296	65	1.6
17	Denmark	2 619	2 397	195	27	0.0
18	Finland	2 258	2 223	31	4	0.0
19	Slovakia	1 902	1 363	518	19	0.9
20	Latvia	1 878	1 204	654	7	12.7
21	Netherlands	1 848	1 038	773	37	0.0
22	Croatia	1 571	878	618	73	1.8
23	Belgium	1 308	800	487	22	0.0
24	Estonia	958	628	325	3	1.2
25	Slovenia	486	173	285	27	1.0
26	Luxembourg	131	63	67	2	0.0
27	Cyprus	109	80	2	27	0.1
28	Malta	11	9	0	1	1.0
	Total	**174 358**	**104 203**	**59 566**	**10 303**	**286**
	% of total	100%	60%	34%	6%	0.2%

Source: Eurostat [ef_oluft]

Annex Table 2. Average holding size and distribution of holdings by size in Member States, 2013

	EU-28	Utilised Agricultural Area (ha)	Number of holdings	Average holding size (ha)	Number of holdings by size				
					< 20 ha	20 to 29.9 ha	30 to 49.9 ha	50 to 99.9 ha	>100 ha
1	Czech Republic	3 491 470	25 960	134.5	14 130	2 360	2 370	2 460	4 630
2	United Kingdom	17 326 990	182 170	95.1	67 510	17 810	23 420	32 470	40 980
3	Slovakia	1 901 610	22 050	86.2	17 440	770	730	790	2 310
4	Denmark	2 619 340	37 380	70.1	15 800	3 950	4 360	5 380	7 880
5	Luxembourg	131 040	2 060	63.6	680	120	210	600	450
6	France	27 739 430	463 710	59.8	193 730	31 610	47 440	93 330	97 600
7	Germany	16 699 580	282 160	59.2	125 330	28 920	42 530	50 220	35 160
8	Estonia	957 510	18 760	51.0	13 220	1 400	1 180	1 150	1 790
9	Sweden	3 035 920	66 560	45.6	36 500	6 650	7 220	8 160	8 030
10	Finland	2 282 400	54 230	42.1	19 920	8 190	10 940	10 580	4 610
11	Ireland	4 959 450	139 570	35.5	59 580	24 570	30 290	20 350	4 770
12	Belgium	1 307 900	37 340	35.0	16 880	4 930	6 810	6 530	2 190
13	Netherlands	1 847 570	65 790	28.1	36 250	6 890	10 980	9 280	2 390
14	Spain	23 300 220	944 300	24.7	737 430	51 550	53 550	49 960	51 820
15	Latvia	1 877 720	80 720	23.3	65 660	5 320	4 140	2 700	2 890
16	Austria	2 726 890	139 610	19.5	96 970	16 680	14 660	8 730	2 570
17	Bulgaria	4 650 940	244 860	19.0	229 110	3 210	3 410	2 960	6 160
18	Lithuania	2 861 250	171 730	16.7	149 860	6 520	5 560	5 100	4 680
19	Portugal	3 641 590	263 580	13.8	239 980	6 750	6 150	4 660	6 040
20	Italy	12 098 890	1 009 450	12.0	879 590	44 690	39 870	30 180	15 100
21	Hungary	4 656 520	453 080	10.3	423 020	8 350	7 490	6 590	7 640
22	Poland	14 409 870	1 421 560	10.1	1 287 550	62 040	40 440	20 570	10 950
23	Croatia	1 571 200	157 100	10.0	146 220	3 880	3 030	2 610	1 350
24	Greece	4 856 780	703 590	6.9	670 520	15 080	11 120	5 430	1 450
25	Slovenia	485 760	72 280	6.7	68 620	2 050	1 070	420	110
26	Romania	13 055 850	3 563 770	3.7	3 524 700	10 260	8 470	7 260	13 080
27	Cyprus	109 330	35 150	3.1	34 240	310	290	210	110
28	Malta	10 880	9 000	1.2	9 000	10	0	0	0
	Total	**174 613 900**	**10 667 520**	**16.4**	**9 179 440**	**374 870**	**387 730**	**388 680**	**336 740**
	% of total holdings		100%		86%	4%	4%	4%	3%

Source: Eurostat, [ef_kvaareg]

Annex Table 3. Cereal production* in Member States, ranked by yield per hectare, 2013

	EU-28	Cereal crop area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Number of holdings growing cereals	Cereal area per holding (ha)	Rank by crop area per holding	% of crop area on agricultural holdings <20 ha	% of crop area on agricultural holdings =>20 ha
1	Belgium	338	3 156	9.3	21 980	15.4	15	11%	89%
2	Netherlands	210	1 823	8.7	14 010	15.0	16	11%	89%
3	Ireland	307	2 401	7.8	12 520	24.5	11	4%	96%
4	Germany	6 534	47 757	7.3	184 140	35.5	8	5%	95%
5	France	9 473	67 323	7.1	256 410	36.9	6	2%	98%
6	United Kingdom	3 035	20 022	6.6	50 240	60.4	2	1%	99%
7	Denmark	1 426	9 051	6.3	26 800	53.2	5	4%	96%
8	Luxembourg	29	173	6.0	1 340	21.7	14	2%	98%
9	Austria	784	4 590	5.9	62 010	12.6	18	15%	85%
10	Croatia	584	3 188	5.5	101 440	5.8	23	44%	56%
11	Czech Republic	1 413	7 513	5.3	14 940	94.6	1	2%	98%
12	Italy	3 460	18 212	5.3	418 880	8.3	21	35%	65%
13	Sweden	976	4 993	5.1	26 500	36.8	7	3%	97%
14	Hungary	2 820	13 610	4.8	208 880	13.5	17	16%	84%
15	Greece	984	4 670	4.7	191 490	5.1	24	56%	44%
16	Slovenia	99	457	4.6	35 830	2.8	26	56%	44%
17	Bulgaria	2 007	9 154	4.6	77 580	25.9	10	5%	95%
18	Slovakia	760	3 412	4.5	14 040	54.1	4	4%	96%
19	Portugal	315	1 364	4.3	85 900	3.7	25	25%	75%
20	Spain	6 268	25 373	4.0	271 330	23.1	13	9%	91%
21	Romania	5 409	20 897	3.9	2 105 480	2.6	27	42%	58%
22	Poland	7 480	28 455	3.8	1 115 190	6.7	22	50%	50%
23	Finland	1 100	4 063	3.7	40 130	27.4	9	7%	93%
24	Lithuania	1 213	4 475	3.7	101 390	12.0	19	16%	84%
25	Latvia	578	1 949	3.4	23 590	24.5	12	7%	93%
26	Estonia	311	976	3.1	5 470	56.9	3	3%	97%
27	Cyprus	31	52	1.7	3 630	8.5	20	28%	72%
28	Malta	0	0	0.0	0	0.0	28	0%	0%
	EU-28	**57 942**	**309 108**	**5.3**	**5 471 140**	**10.6**		**18%**	**82%**

Source: Eurostat [apro_acs_a], [ef_oluft]
*including rice

Annex Table 4. Wheat production in Member States, ranked by yield per hectare, 2013

	EU-28	Wheat crop area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Number of holdings growing wheat	Wheat area per holding (ha)	Rank by crop area per holding	% of crop area on agricultural holdings <20 ha	% of crop area on agricultural holdings =>20 ha
1	Belgium	202	1 844	9.1	15 320	13.2	17	6%	94%
2	Ireland	61	545	9.0	2 970	20.4	11	2%	98%
3	Netherlands	153	1 335	8.7	9 890	15.5	15	8%	92%
4	Germany	3 120	24 966	8.0	138 530	22.5	10	4%	96%
5	France	4 983	36 867	7.4	188 700	26.4	9	1%	99%
6	United Kingdom	1 615	11 921	7.4	31 600	51.1	2	1%	99%
7	Denmark	568	4 145	7.3	14 610	38.9	3	2%	98%
8	Luxembourg	14	91	6.4	1 070	13.3	16	1%	99%
9	Sweden	323	1 869	5.8	10 810	29.9	6	2%	98%
10	Czech Republic	829	4 701	5.7	12 780	64.9	1	2%	98%
11	Austria	285	1 535	5.4	32 410	8.8	19	9%	91%
12	Italy	632	3 342	5.3	120 290	5.3	21	38%	62%
13	Croatia	203	994	4.9	52 260	3.9	22	28%	72%
14	Hungary	1 076	4 993	4.6	67 050	16.0	14	12%	88%
15	Slovakia	357	1 637	4.6	10 480	34.1	5	4%	96%
16	Poland	2 138	9 485	4.4	554 820	3.9	23	40%	60%
17	Slovenia	32	138	4.4	18 630	1.7	26	51%	49%
18	Lithuania	667	2 871	4.3	59 990	11.1	18	11%	89%
19	Bulgaria	1 302	5 464	4.2	44 630	29.2	7	5%	95%
20	Latvia	369	1 435	3.9	13 620	27.1	8	5%	95%
21	Spain	1 782	6 812	3.8	96 110	18.5	13	7%	93%
22	Finland	228	869	3.8	11 610	19.6	12	4%	96%
23	Romania	2 093	7 284	3.5	722 580	2.9	25	30%	70%
24	Greece	175	581	3.3	55 770	3.1	24	57%	43%
25	Estonia	124	407	3.3	3 210	38.7	4	3%	97%
26	Portugal	51	89	1.8	9 480	5.4	20	13%	87%
27	Cyprus	0	0	0.0	40	0.0	27	8%	25%
28	Malta	0	0	0.0	0	0.0	28	0%	0%
	EU-28	**23 382**	**136 220**	**5.8**	**2 299 260**	**10.2**		**12%**	**88%**

Source: Eurostat [apro_acs_a], [ef_oluft]

Annex Table 5. Barley production in Member States, ranked by yield per hectare, 2013

	EU-28	Barley crop area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Number of holdings growing barley	Barley area per holding (ha)	Rank by crop area per holding	% of crop area on agricultural holdings <20 ha	% of crop area on agricultural holdings =>20 ha
1	Belgium	47	391	8.4	7 370	6.3	19	23%	77%
2	Ireland	219	1 663	7.6	11 020	19.9	7	13%	87%
3	Netherlands	30	208	6.9	3 870	7.8	18	25%	74%
4	Germany	1 570	10 344	6.6	123 280	12.7	12	28%	72%
5	France	1 636	10 315	6.3	120 060	13.6	11	8%	92%
6	United Kingdom	1 213	7 092	5.8	34 740	34.9	2	6%	94%
7	Denmark	689	3 950	5.7	23 360	29.5	4	26%	74%
8	Luxembourg	8	42	5.5	920	8.4	17	8%	93%
9	Austria	143	734	5.1	33 400	4.3	21	42%	58%
10	Sweden	388	1 940	5.0	17 130	22.6	5	14%	86%
11	Czech Republic	349	1 594	4.6	10 370	33.7	3	38%	62%
12	Hungary	262	1 062	4.1	26 240	10.0	13	67%	33%
13	Slovenia	17	69	4.0	16 500	1.0	27	90%	10%
14	Finland	494	1 904	3.9	26 510	18.6	8	19%	81%
15	Croatia	54	201	3.7	46 110	1.2	26	90%	10%
16	Bulgaria	197	729	3.7	14 230	13.9	10	65%	35%
17	Italy	237	873	3.7	84 130	2.8	25	72%	28%
18	Slovakia	121	446	3.7	7 420	16.3	9	70%	29%
19	Poland	1 161	4 180	3.6	296 460	3.9	22	83%	17%
20	Spain	2 784	10 004	3.6	134 450	20.7	6	40%	60%
21	Estonia	133	441	3.3	3 350	39.7	1	29%	70%
22	Lithuania	209	686	3.3	48 310	4.3	20	75%	25%
23	Romania	495	1 542	3.1	128 520	3.8	23	92%	8%
24	Greece	129	395	3.1	42 960	3.0	24	82%	18%
25	Latvia	84	233	2.8	8 800	9.6	14	49%	51%
26	Portugal	18	33	1.8	1 980	9.3	15	58%	42%
27	Cyprus	24	36	0.0	2 790	8.4	16	82%	18%
28	Malta	0	0	0.0	0	0.0	28	0%	0%
	EU-28	**12 712**	**61 108**	**4.8**	**1 274 280**	**10.0**		**57%**	**43%**

Source: Eurostat [apro_acs_a], [ef_oluft]

Annex Table 6. Grain maize and corn-cob-mix production in Member States, ranked by yield per hectare, 2013

	EU-28	Maize crop area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Number of holdings growing maize	Maize area per holding (ha)	Rank by crop area per holding	% of crop area on agricultural holdings <20 ha	% of crop area on agricultural holdings =>20 ha
1	Netherlands	21	253	12.0	2 450	8.6	8	33%	67%
2	Greece	181	2 134	11.8	50 640	3.6	17	59%	41%
3	Belgium	74	838	11.3	9 900	7.5	12	27%	73%
4	Spain	442	4 888	11.1	59 270	7.5	13	19%	81%
5	Luxembourg	0.24	2	9.0	30	8.0	9	0%	96%
6	Germany	497	4 387	8.8	37 160	13.4	6	9%	91%
7	Italy	908	7 900	8.7	123 280	7.4	14	34%	66%
8	Portugal	112	930	8.3	68 870	1.6	20	45%	55%
9	France	1 840	15 031	8.2	108 370	17.0	4	3%	97%
10	Austria	202	1 639	8.1	27 500	7.3	15	18%	82%
11	United Kingdom	11	85	7.5	1 450	7.8	10	1%	99%
12	Lithuania	17	127	7.4	630	27.3	3	3%	97%
13	Czech Republic	97	675	7.0	1 340	72.3	1	1%	99%
14	Poland	614	4 040	6.6	92 850	6.6	16	24%	76%
15	Croatia	288	1 874	6.5	92 200	3.1	18	51%	49%
16	Bulgaria	428	2 739	6.4	41 400	10.3	7	5%	95%
17	Denmark	13	76	5.9	870	14.7	5	1%	99%
18	Sweden	1	7	5.7	0	0.0	22	0%	0%
19	Hungary	1 243	6 756	5.4	160 960	7.7	11	18%	82%
20	Slovenia	42	227	5.4	24 670	1.7	19	57%	43%
21	Slovakia	222	1 123	5.1	4 940	44.8	2	3%	97%
22	Romania	2 516	11 305	4.5	1 858 320	1.4	21	57%	43%
23	Cyprus	0	0	0.0	20	0.0	23	67%	0%
24	Estonia	0	0	0.0	0	0.0	24	0%	0%
25	Finland	0	0	0.0	0	0.0	25	0%	0%
26	Ireland	0	0	0.0	0	0.0	26	0%	0%
27	Latvia	0	0	0.0	0	0.0	27	0%	0%
28	Malta	0	0	0.0	0	0.0	28	0%	0%
	EU-28	**9 770**	**67 037**	**6.9**	**2 767 120**	**3.5**		**26%**	**74%**

Source: Eurostat [apro_acs_a], [ef_oluft]

Annex Table 7. Fresh vegetables, including melons & strawberries - agricultural area in Member States, ranked by harvested production , 2013

EU-28		Utilised Agricultural Area						Harvested area	
		Crop area for fresh vegetables (1000 ha)	Number of holdings growing fresh vegetables	Crop area per holding (ha)	Rank by crop area per holding	% of crop area on agricultural holdings <20 ha	% of crop area on agricultural holdings =>20 ha	Harvested area* (1000 ha)	Harvested production (1000 t)
1	Italy	249.4	79 710	3.1	13	48%	52%	354.8	12 229
2	France	196.8	36 350	5.4	9	19%	81%	189.8	5 364
3	Netherlands	83.3	8 050	10.3	2	16%	84%	75.6	4 900
4	Romania	69.1	203 120	0.3	27	82%	18%	170.5	2 162
5	Portugal	41.3	27 130	1.5	16	41%	59%	48.9	1 990
6	Austria	15.4	3 790	4.1	12	17%	83%	18.2	625
7	Bulgaria	22.7	64 720	0.3	26	70%	30%	24.1	451
8	Spain	238.5	109 240	2.2	14	37%	63%	347.0	312
9	Denmark	11.1	1 120	9.9	3	7%	93%	11.9	299
10	Finland	12.3	2 780	4.4	11	24%	76%	16.8	264
11	Lithuania	9.0	97 030	0.1	28	67%	33%	13.7	235
12	Czech Republic	9.2	1 040	8.8	5	9%	91%	9.6	181
13	Poland	187.1	141 890	1.3	18	64%	36%	228.0	166
14	Germany	123.9	13 310	9.3	4	10%	90%	140.2	150
15	United Kingdom	117.9	6 760	17.4	1	7%	93%	5.0	94
16	Slovakia	6.7	1 400	4.8	10	12%	88%	8.4	87
17	Cyprus	3.8	4 280	0.9	22	64%	36%	2.2	62
18	Greece	48.7	42 910	1.1	19	78%	22%	92.1	47
19	Belgium	39.4	5 810	6.8	8	23%	77%	47.6	36
20	Sweden	20.0	2 380	8.4	6	6%	94%	2.2	14
21	Ireland	4.5	640	7.0	7	13%	87%	9.9	8
22	Hungary	60.8	32 440	1.9	15	31%	69%	77.2	6
23	Croatia	8.6	14 130	0.6	25	70%	30%	6.3	3
24	Luxembourg	0.1	50	1.4	17	57%	43%	0.1	2
25	Estonia	2.2	2 480	0.9	21	41%	59%	2.7	1
26	Latvia	8.4	13 190	0.6	24	60%	40%	4.4	1
27	Malta	2.0	2 110	0.9	20	99%	1%		1
28	Slovenia	1.7	2 000	0.9	23	72%	26%	4.9	
		1 593.9	**919 860**	**1.7**		**37%**	**63%**	**1 911.8**	**29 691**

Source Eurostat [apro_acs_a], [ef_alarableecs]

*Note that the harvested area may be greater than the agricultural area due to multiple cropping on the same land during one year

Annex Table 8. Production of tomatoes in Member States, ranked by yield, 2013

	EU-28	Tomatoes - total harvested area				Tomatoes - under cover		
		Crop area (ha)	Harvested production (t)	Yield (t/ha)	% of EU production	Crop area (ha)	Harvested production (t)	Yield (t/ha)
1	Netherlands*	1 770	855 000	483	5.7%	1 770	855 000	483
2	Belgium*	520	249 800	480	1.7%	520	249 800	480
3	Ireland*	10	4 660	466	0.0%	10	4 660	466
4	Sweden*	40	15 100	378	0.1%	40	15 100	378
5	Finland*	120	38 340	320	0.3%	120	38 340	320
6	Denmark*	40	12 500	313	0.1%	40	12 500	313
7	Austria*	180	53 330	296	0.4%	180	53 330	296
8	Germany*	330	69 260	210	0.5%	330	69 260	210
9	France	5 920	775 630	131	5.1%	2 110	567 010	269
10	Spain	46 620	3 776 800	81	25.0%			
11	Hungary	1 740	135 800	78	0.9%			
12	Portugal	15 630	1 186 840	76	7.9%	1 170	26 340	23
13	Greece	16 660	1 110 680	67	7.4%	2 980	358 200	120
14	Poland	11 800	761 500	65	5.1%			
15	Cyprus	210	13 280	63	0.1%			
16	Italy	95 190	5 321 250	56	35.3%	6 910	432 470	63
17	Croatia	450	20 740	46	0.1%			
18	Bulgaria	3 800	117 900	31	0.8%	600	40 600	68
19	Czech Republic	310	8 290	27	0.1%			
20	Slovakia	440	9 730	22	0.1%	10	400	40
21	Lithuania	600	11 800	20	0.1%			
22	Romania	28 070	509 220	18	3.4%	1 470	58 500	40
26	Malta		12 290		0.1%			
24	Latvia		6 400		0.0%			
23	Estonia		1 500		0.0%			
25	Luxembourg							
27	Slovenia							
28	United Kingdom							
	EU-28	**230 450**	**15 077 640**	**65**	**100%**	**18 260**	**2 781 510**	**152**
	% of total harvested					**8%**	**18%**	

Source Eurostat [apro_acs_a]

*In these states, all tomatoes were grown under under cover

Annex Table 9. Production of onions in Member States, ranked by yield, 2013

	EU-28	Crop area (ha)	Harvested production (t)	Yield (t/ha)	% of EU production
1	Spain	22 010	1 214 500	55	21.1%
2	Sweden	1 010	49 600	49	0.9%
3	Austria	3 040	143 960	47	2.5%
4	Netherlands	28 620	1 310 000	46	22.8%
5	Belgium	1 810	79 030	44	1.4%
6	Denmark	1 110	48 360	44	0.8%
7	Germany	11 700	492 840	42	8.6%
8	Ireland	90	3 650	41	0.1%
9	United Kingdom	9 000	354 000	39	6.2%
10	Cyprus	170	6 560	39	0.1%
11	France	10 900	416 620	38	7.2%
12	Greece	6 790	250 740	37	4.4%
13	Italy	11 510	351 030	30	6.1%
14	Hungary	1 990	59 880	30	1.0%
15	Portugal	1 460	41 340	28	0.7%
16	Poland	20 000	538 600	27	9.4%
17	Slovakia	680	14 930	22	0.3%
18	Czech Republic	1 530	32 820	21	0.6%
19	Finland	1 120	22 980	21	0.4%
20	Croatia	920	16 850	18	0.3%
21	Lithuania	1 500	22 600	15	0.4%
22	Romania	19 320	251 370	13	4.4%
23	Latvia	400	4 500	11	0.1%
24	Bulgaria	1 200	12 800	11	0.2%
27	Malta		8 290		0.1%
25	Estonia		140		0.0%
26	Luxembourg				
28	Slovenia				
	EU-28	**157 880**	**5 747 990**	**36**	**100%**
	Source Eurostat [apro_acs_a]				

Annex Table 10. Production of fresh peas in Member States, ranked by yield, 2013

	EU-28	Crop area (ha)	Harvested production (t)	Yield (t/ha)	% of EU production
1	Cyprus	60	810	13.5	0.1%
2	Greece	2 210	24 050	10.9	2.9%
3	France	29 460	243 370	8.3	29.8%
4	Belgium	9 410	73 360	7.8	9.0%
5	Spain	11 870	85 600	7.2	10.5%
6	Austria	1 730	11 260	6.5	1.4%
7	Portugal	620	3 980	6.4	0.5%
8	Denmark	2 840	17 440	6.1	2.1%
9	Germany	4 620	26 380	5.7	3.2%
10	Poland	4 800	25 900	5.4	3.2%
11	Hungary	12 890	67 650	5.2	8.3%
12	Italy	14 160	71 090	5.0	8.7%
13	Croatia	470	2 300	4.9	0.3%
14	Ireland	510	2 430	4.8	0.3%
15	United Kingdom	25 440	120 850	4.8	14.8%
16	Netherlands	3 900	18 000	4.6	2.2%
17	Bulgaria	900	3 900	4.3	0.5%
18	Czech Republic	1 180	3 590	3.0	0.4%
19	Lithuania	300	800	2.7	0.1%
20	Slovakia	890	2 270	2.6	0.3%
21	Finland	2 780	6 240	2.2	0.8%
22	Romania	2 600	4 820	1.9	0.6%
23	Malta		110		0.0%
24	Luxembourg		10		0.0%
25	Slovenia				
26	Latvia				
27	Estonia				
28	Sweden				
	EU-28	**133 640**	**816 210**	**6.1**	**100%**

Source Eurostat [apro_acs_a]

Annex Table 11. Production of olives in EU Member States, ranked by harvested production, 2013

EU-28	Total olives			Olives for table use			Olives for oil		
	Olive area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Olive area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Olive area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)
Spain	2 507	9 251	3.7	164	484	3.0	2 343	8 767	3.7
Italy	1 129	2 941	2.6	34	88	2.6	1 102	2 853	2.6
Greece	918	728	0.8	117	90	0.8	801	638	0.8
Portugal	352	652	1.9	9	18	2.0	343	634	1.8
Croatia	18	34	1.9	0	0		19	34	1.8
France	34	27		17	1	0.03	17	26	1.5
Cyprus	11	13	1.2	0.2	3	14.8*	10	10	0.9
	4 969	**13 644**	**2.7**	**341**	**682**	**2.0**	**4 635**	**12 962**	**2.8**

*This figure may not be reliable

Source: Eurostat, [apro_acs_a]

Annex Table 12. Production of grapes in EU Member States, ranked by harvested production, 2013

EU-28	All grapes			Grapes for wines			Grapes for PDO wines			Grapes for PGI wines		
	Grape area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Grape area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Grape area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)	Grape area (1000 ha)	Harvested production (1000 t)	Yield (t/ha)
Italy	702.1	8 010.4	11.4	656.2	6 902.0	10.5	204.3	2 149.1	10.5	232.5	2 445.3	10.5
Spain	947.0	7 480.0	7.9	930.8	7 224.0	7.8	474.3	2 446.8	5.2	92.4	672.3	7.3
France	760.6	4 277.4	5.6	755.2	4 239.5	5.6	522.4	2 660.9	5.1	192.5	1 258.9	6.5
Germany	99.5	1 139.5	11.5	99.5	1 139.5	11.5	99.5	1 139.5	11.5			
Greece	110.9	1 059.9	9.6	65.9	598.5	9.1	13.2	118.3	9.0	15.0	137.1	9.1
Romania	176.9	988.1	5.6	169.0	932.8	5.5	20.9	119.1	5.7	21.1	134.3	6.4
Portugal	179.5	827.8	4.6	177.0	810.3	4.6	119.0	385.2	3.2	38.1	224.9	5.9
Hungary	69.3	451.1	6.5	66.0	434.0	6.6						
Bulgaria	50.2	325.6	6.5	47.4	305.9	6.5	15.1	3.2	0.2	21.1	83.2	3.9
Austria	43.6	318.9	7.3	43.6	318.9	7.3	39.1	286.0	7.3	1.3	9.4	7.3
Croatia	28.0	182.2	6.5	28.0	182.2	6.5						
Slovenia	16.1	100.2	6.2	16.1	100.2	6.2	16.1	100.2	6.2			
Czech Republic	15.7	74.7	4.8	15.7	74.7	4.8	11.8	56.4	4.8	3.5	16.6	4.8
Slovakia	12.0	53.2	4.4	11.9	52.8	4.5						
Cyprus	5.9	20.4	3.4	5.3	16.5	3.1						
Luxembourg	1.2	13.4	10.8	1.2	13.4	10.8	1.2	13.4	10.8			
Malta		5.3		0.6	4.9		0.6	1.2		0.1	1.6	
Poland	0.7	3.1	4.4									
United Kingdom	1.4		0.0	1	0							
Belgium												
Denmark												
Estonia												
Ireland												
Latvia												
Lithuania												
Netherlands												
Finland												
Sweden												
	3 221	**25 331**	**7.9**	**3 090**	**23 350**	**7.6**	**1 537**	**9 479**	**6.2**	**618**	**4 984**	**8.1**

Source: Eurostat, [apro_acs_a]

Annex Table 13. EU meat production by Member State and main species, 2013, (1000 tonnes carcass weight)

	EU-28	Total meat production (1000 tonnes)	Meat production by species (1000 tonnes)			
			Bovine	Pigs	Sheep & goats	Chicken
1	Germany	7 511	1 106	5 474	20	911
2	Spain	5 261	581	3 431	127	1 121
3	France	4 511	1 408	1 939	87	1 078
4	Poland	3 466	339	1 684	1	1 443
5	Italy	3 421	855	1 625	37	903
6	United Kingdom	3 337	848	833	290	1 366
7	Netherlands	2 621	379	1 307	14	921
8	Denmark	1 864	125	1 589	2	148
9	Belgium	1 762	250	1 131	2	379
10	Ireland*	923	518	239	57	109
11	Austria**	853	221	528	8	95
12	Portugal	686	84	346	11	245
13	Romania	664	29	308	0	326
14	Hungary	595	23	337	0	236
15	Sweden	492	136	234	5	117
16	Czech Republic	443	65	234	0	144
17	Greece	422	50	109	86	178
18	Finland	378	80	194	1	102
19	Lithuania	187	37	67	0	83
20	Croatia	176	47	80	0	49
21	Bulgaria	128	6	52	0	70
22	Slovenia	104	32	19	0	53
23	Cyprus	80	5	49	5	22
24	Latvia	69	16	26	0	27
25	Slovakia	62	10	52	1	0
26	Estonia	45	8	37	0	0
27	Luxembourg	19	8	11	0	0
28	Malta	11	1	6	0	4
		40 090	**7 265**	**21 942**	**754**	**10 128**

Source: Eurostat [apro_mt_pann]

*Ireland chicken data is from 2010, ** Austria beef data is from 2012

Annex Table 14. Production and collection of cows' milk in EU Member States, 2013

	EU-28	Cows' milk production (1000 tonnes)	% of EU production	Cows' milk collection (1000 tonnes)	Collection as % of production	Number of dairy cows	Milk yield per cow (litres)
1	Germany	31 324	20.4%	30 301	96.7%	4 251 420	7 368
2	France	24 460	15.9%	23 994	98.1%	3 737 180	6 545
3	United Kingdom	13 943	9.1%	13 687	98.2%	1 766 960	7 891
4	Poland	12 718	8.3%	9 922	78.0%	2 343 530	5 427
5	Netherlands	12 408	8.1%	12 213	98.4%	1 552 920	7 990
6	Italy	11 281	7.3%	10 397	92.2%	1 762 460	6 401
7	Spain	6 559	4.3%	5 949	90.7%	876 070	7 487
8	Ireland	5 601	3.6%	5 581	99.7%	1 163 200	4 815
9	Denmark	5 082	3.3%	5 026	98.9%	582 340	8 727
10	Romania	3 966	2.6%	882	22.2%	1 147 320	3 457
11	Belgium	3 529	2.3%	3 475	98.5%	464 830	7 592
12	Austria	3 393	2.2%	2 933	86.4%	536 000	6 330
13	Sweden	2 870	1.9%	2 870	100.0%	344 020	8 341
14	Czech Republic	2 849	1.9%	2 358	82.8%	369 980	7 702
15	Finland	2 328	1.5%	2 287	98.2%	283 120	8 222
16	Portugal	1 848	1.2%	1 777	96.2%	264 790	6 979
17	Hungary	1 773	1.2%	1 364	77.0%	241 010	7 356
18	Lithuania	1 720	1.1%	1 339	77.9%	318 140	5 405
19	Bulgaria	1 149	0.7%	511	44.5%	314 670	3 651
20	Latvia	912	0.6%	736	80.7%	166 560	5 476
21	Slovakia	912	0.6%	827	90.6%	145 520	6 267
22	Estonia	772	0.5%	706	91.4%	96 050	8 033
23	Greece	731	0.5%	607	83.0%	133 260	5 483
24	Slovenia	596	0.4%	517	86.8%	103 850	5 734
25	Croatia	588	0.4%	504	85.7%	172 920	3 400
26	Luxembourg	296	0.2%	287	97.0%	46 200	6 404
27	Cyprus	163	0.1%	157	96.2%	21 670	7 534
28	Malta	41	0.0%	41	100.0%	6 240	6 558
		153 809		**141 247**	**91.8%**	**23 212 230**	**6 626**

Source: Eurostat [apro_mk_farm], [apro_mk_pobta]

Annex Table 15. EU-28 wheat market balance, 2013/14-2015/16 (million tonnes)

EU-28			
Marketing year (July-June)	**2013/14**	**2014/15 e**	**2015/16 f**
Production and use			
Usable production	135.1	148.7	144.6
Domestic use	106.2	115.5	115.3
of which human consumption	*48.0*	*48.0*	*48.0*
of which animal feed	*42.9*	*52.4*	*52.0*
Net domestic balance	28.9	33.2	29.3
Self-sufficiency rate	127%	129%	125%
External trade			
EU imports	1.8	2.9	3.0
EU exports	30.0	33.3	27.9
Net export balance	28.2	30.4	24.9

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

Annex Table 16. EU-28 barley market balance, 2013/14-2015/16 (million tonnes)

EU-28			
Marketing year (July-June)	**2013/14**	**2014/15 e**	**2015/16 f**
Production and use			
Usable production	60.6	60.2	59.0
Domestic use	48.5	47.8	47.5
of which human consumption	*0.4*	*0.4*	*0.4*
of which animal feed	*36.6*	*35.9*	*35.6*
Net domestic balance	12.1	12.4	11.5
Self-sufficiency rate	125%	126%	124%
External trade			
EU imports	0.0	0.1	0.3
EU exports	8.8	12.7	9.0
Net export balance	8.8	12.6	8.7

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

Annex Table 17. EU-28 maize market balance, 2013/14 -2015/16 (million tonnes)

EU-28			
Marketing year (July-June)	**2013/14**	**2014/15 e**	**2015/16 f**
Production and use			
Usable production	66.5	77.9	58.4
Domestic use	75.6	75.4	77.8
of which human consumption	*4.9*	*5.0*	*5.0*
of which animal feed	*60.6*	*60.0*	*62.3*
Net domestic balance	-9.1	2.5	-19.4
Self-sufficiency rate	88%	103%	75%
External trade			
EU imports	15.0	9.4	11.0
EU exports	3.1	4.0	3.0
Net export balance	-11.9	-5.4	-8.0

Source: Short-Term Outlook, Autumn 2015
e - estimate, f - forecast

Annex Table 18. EU beef and veal market balance, 2011-2016 (1000 tonnes*)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	8 200	7 867	7 502	7 664	7 857	7 913
Consumption	8 012	7 773	7 536	7 650	7 765	7 809
Net domestic balance	188	94	-34	14	92	104
Self-sufficiency rate	102%	101%	100%	100%	101%	101%
Per capita consumption** (kg/year)	11.1	10.7	10.4	10.5	10.7	10.7
External trade						
Net live animal exports (less imports)	147	159	109	114	174	183
Meat imports	286	275	304	307	301	304
Meat exports	327	210	161	207	219	226
Net export balance	188	94	-34	14	92	105

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

*carcass weight equivalent, **retail weight

Annex Table 19. EU pig meat market balance, 2011-2016 (1000 tonnes*)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	23 058	22 554	22 385	22 834	23 441	23 557
Consumption	20 862	20 384	20 173	20 895	21 371	21 424
Net domestic balance	2 196	2 170	2 212	1 939	2 070	2 133
Self-sufficiency rate	111%	111%	111%	109%	110%	110%
Per capita consumption** (kg/year)	32.2	31.4	31.0	32.0	32.7	32.7
External trade						
Net live animal exports (less imports)	62	36	26	36	23	24
Meat imports	18	19	16	15	15	15
Meat exports	2 151	2 154	2 201	1 918	2 062	2 124
Net export balance	2 195	2 171	2 211	1 939	2 070	2 133

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

*carcass weight equivalent, **retail weight

Annex Table 20. EU sheep and goat meat market balance, 2011-2016 (1000 tonnes*)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	969	928	917	917	926	929
Consumption	1 154	1 067	1 047	1 036	1 059	1 066
Net domestic balance	-185	-139	-130	-119	-133	-137
Self-sufficiency rate	84%	87%	88%	89%	87%	87%
Per capita consumption** (kg/year)	2.0	1.9	1.8	1.8	1.8	1.8
External trade						
Net live animal exports (less imports)	22	27	34	36	33	33
Meat imports	222	190	200	188	190	193
Meat exports	15	25	36	32	24	24
Net export balance	-185	-138	-130	-120	-133	-136

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

*carcass weight equivalent, **retail weight

Annex Table 21. EU poultry meat market balance, 2011-2016 (1000 tonnes*)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	12 359	12 691	12 798	13 268	13 614	13 766
Consumption	11 892	12 210	12 280	12 725	13 036	13 180
Net domestic balance	467	481	518	543	578	586
Self-sufficiency rate	104%	104%	104%	104%	104%	104%
Per capita consumption** (kg/year)	20.7	21.2	21.3	22.0	22.5	22.7
External trade						
Net live animal exports (less imports)	8	9	9	10	9	9
Meat imports	831	841	791	816	828	849
Meat exports	1 290	1 313	1 300	1 350	1 397	1 425
Net export balance	467	481	518	544	578	585

Source: Short-Term Outlook, Autumn 2015

e - estimate, f - forecast

*carcass weight equivalent, **retail weight

Annex Table 22. EU fresh dairy products market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production*	46 801	46 707	47 061	46 879	46 634	46 747
Domestic use**	46 446	46 217	46 513	46 168	45 811	45 795
Net domestic balance	355	490	548	711	823	952
Self-sufficiency rate	101%	101%	101%	102%	102%	102%
Per capita consumption (kg/year)	92.0	91.0	92.0	91.0	90.0	90.0
External trade						
EU imports	44	42	28	16	12	10
EU exports	399	532	577	727	836	961
Net export balance	355	490	549	711	824	951

Source: Short-Term Outlook, Autumn 2015

*Includes drinking milk, cream, acidified milk, buttermilk, milk drinks

**Includes stock changes

e-estimate, f-forecast

Annex Table 23. EU cheese market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production*	9 398	9 610	9 687	9 941	10 044	10 169
of which from cows' milk	8 382	8 551	8 618	8 821	8 915	9 030
Domestic use**	8 800	8 921	8 975	9 297	9 433	9 517
Net domestic balance	598	689	712	644	611	652
Self-sufficiency rate	107%	108%	108%	107%	106%	107%
Per capita consumption (kg/year)	16.8	17.0	17.0	17.5	17.8	18.0
External trade						
EU imports	75	78	75	76	76	76
EU exports	673	768	787	720	687	729
Net export balance	598	690	712	644	611	653

Source: Short-Term Outlook, Autumn 2015

*Includes goat, sheep and buffalo milk and net exports of processed cheese

**Includes stock changes

e-estimate, f-forecast

Annex Table 24. EU butter market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production*	2 102	2 167	2 120	2 228	2 336	2 362
Domestic use**	1 983	2 051	2 025	2 094	2 177	2 242
Net domestic balance**	119	116	95	134	159	120
Self-sufficiency rate	106%	106%	105%	106%	107%	105%
Per capita consumption (kg/year)	3.9	4.0	4.0	4.1	4.3	4.4
External trade						
EU imports	34	29	21	25	3	10
EU exports	124	124	116	134	152	165
Net export balance	90	95	95	109	149	155

Source: Short-Term Outlook, Autumn 2015

*Includes butter, butter oil and other yellow fat products

**Includes stock changes

e-estimate, f-forecast

Annex Table 25. EU whole milk powder market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	703	672	757	770	736	752
Domestic use*	316	289	386	383	364	369
Net domestic balance	387	383	371	387	372	383
Self-sufficiency rate	222%	233%	196%	201%	202%	204%
External trade						
EU imports	2	3	3	1	1	1
EU exports	388	386	374	389	373	384
Net export balance	386	383	371	388	372	383

Source: Short-Term Outlook, Autumn 2015

*Includes stock changes

Annex Table 26. EU skimmed milk powder market balance, 2011-2016 (1000 tonnes)

EU-28	2011	2012	2013	2014e	2015f	2016f
Domestic balance						
Production	1 096	1 109	1 108	1 400	1 511	1 533
Domestic use*	689	685	707	738	757	777
Net domestic balance	407	424	401	662	754	756
Self-sufficiency rate	159%	162%	157%	190%	200%	197%
External trade						
EU imports	0	2	5	2	5	5
EU exports	516	520	407	646	678	726
Net export balance	516	518	402	644	673	721

Source: Short-Term Outlook, Autumn 2015

*Includes stock changes

BRIEFING PAPER 2

BUSINESS MODELS OF FARMING IN EUROPE

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List of abbreviations

AWU	Annual Work Unit
EC	European Commission
EU	European Union
Kg	Kilogramme
Ha	Hectare
PDO	Protected Designation of Origin
PGI	Protected Geographical Indication
SO	Standard Output
t	tonne
UAA	Utilised Agricultural Area
USDA	United States Department of Agriculture

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1. Main policy issues

The wide diversity of agriculture to be found throughout the EU, regarding particularly farm size, types of farming and employment presents a challenge to the widespread uptake of precision agriculture. Large-scale, highly commercialized arable and intensive livestock enterprises are likely to be well-suited to adopting precision farming techniques, but they represent a minority of farms. The challenge is to find ways for small and medium-sized farms, perhaps with difficult typology, to benefit from the new technology.

One constraint that small farmers in particular may face is lack of resources to invest in precision farming. It will be necessary to demonstrate the cost/benefit of new techniques as well as find appropriate ways of funding their introduction.

There is a long-term decline in the number of farms in the EU (decline between 2005 and 2013 was 3.7 per cent) and a gradual consolidation to form larger farms. As part of the consolidation process, the number of regular agricultural workers is declining (decline between 2010 and 2013 in number of regular agricultural workers was 12.8 per cent).

EU farms are becoming more financially productive, shown by an increase of 21 per cent between 2010 and 2013 of the standard output per holding[1], which is more than the increase in land area per holding over the same period.

Traditionally, technical innovations have been provided to farmers by equipment manufacturers and farm suppliers. The advances in machinery, information technology and biotechnology that are a part of precision farming may result in a wider range of providers offering an increasing array of equipment, inputs and services to farmers. Some issues may need to be addressed regarding the commercial arrangements for precision agriculture, for example concerning data ownership and data protection.

The level of training of farmers in the EU is generally low. It seems likely that farmers will need to be better trained with access to independent advice to apply precision farming techniques.

2. Introduction

This section describes the structure of farm businesses, employment, demographic trends, training and farm economics.

Most of the information that is presented is based on Eurostat data and DG AGRI reports. More detailed statistics are available in the annex tables. Any other data sources are specifically referenced.

3. Farm business types across the EU

In 2013, there were 10.8 million farm holdings (farms) in the EU, occupying 174 million hectares[2].

The Member States with the largest number of farms are Romania (3.6 million), Poland (1.4 million), Italy (1.0 million), Spain (0.9 million) and Greece (0.7 million). Together, these five account for over 70 per cent of all EU farms.

The average EU farm size was 16 ha, although this average covers wide differences between Member States. The Czech Republic has the largest average area at 133 ha, followed by the United Kingdom (94 ha), Slovakia (81 ha), Denmark (67 ha) and Luxembourg (63 ha). In contrast the Member States with the smallest average farm areas are Malta (1.2 ha), followed by Cyprus (3.1 ha) and Romania (3.6 ha).

[1] Farm output is measured as standard output (SO) and expressed in euro
[2] See annex tables for detailed information for each Member State

Table 1. Number and area of EU farm holdings by legal type, 2013

EU-28	Number*	%	Area (ha)	%	Average area (ha)
Total holdings	10 841 000	100%	174 613 900	100%	16
of which:					
Sole holder	10 469 580	97%	117 328 820	67%	11
Legal Entity	298 250	3%	48 031 240	28%	161
Group holding	73 180	1%	9 253 000	5%	126

Source: Eurostat [ef_kvaareg]

*The number includes farms of zero hectares – mainly pig and poultry farms

Table 1 shows that farms with a sole holder (principally family farms) account for 97 per cent of the total number, but they occupy a smaller proportion (67 per cent) of agricultural land and have an average area of 11 ha. The UK has the largest average size of sole holder farms at 80 ha, followed by Denmark (66 ha) and Luxembourg (58 ha). Malta (1.1 ha), Romania (2.0 ha) and Cyprus (2.7 ha) have the smallest average farm size for sole holders.

Farms that are legal entities (including cooperatives) account for 3 per cent of the total, but occupy 28 per cent of agricultural land with an average area of 161 ha. In most Member States the average area is much larger than the average for sole holder farms. Greece (1 861 ha), Ireland (921 ha) and the Czech Republic (837 ha) have the highest average areas for legal entities. Malta (4.8 ha), Luxembourg (18 ha) and the Netherlands (25 ha) have the smallest average areas. France stands out in having 25 per cent of farms as legal entities. Belgium (13 per cent), Slovakia (12 per cent), Estonia (12 per cent) and Czech Republic (11 per cent) also have significant proportions of farms as legal entities.

Group holdings (owned, rented or managed by more than on natural person in partnership) account for 1 per cent of farms and 5 per cent of agricultural land with an average area of 126 ha. Group holdings are recorded by Eurostat in eight Member States. France has 38 920 with an average area of 149 ha. Germany has 23 720 group holdings with an average area of 121 ha. Bulgaria, Latvia, Austria, Finland, Luxembourg and Malta have fewer.

4. Farm sizes and structures

Types of farming have been discussed in Briefing Paper 1. This section focuses on the agricultural labour force.

4.1. Regular agricultural labour force

In 2013, the regular agricultural labour force (excluding seasonal workers) in the EU comprised some 22.2 million people.

Labour is measured as annual work units (AWU). One annual work unit is equivalent to the full-time employment of one person for a year. This measure takes into account that many people work on farms on a part-time basis.

Table 2. Regular agricultural labour force in the EU per unit area and per farm holding, 2013

Total labour force (1000 persons)	22 210
Total labour force (1000 AWU*)	8 734
Utilised agricultural area (1000 ha)	174 614
Area/person (ha)	7.9
Area/AWU (ha)	20.0
Number of farm holdings (1000)	10 841
Persons/ holding	2.0
AWU/ holding	0.8
Average holding area (ha)	16.1

Source: Eurostat [ef_kvaareg], [ef_olfaa]
*AWU = Annual Work Unit

Romania has the EU's largest farm work force with 6.6 million people regularly employed. It is followed by Poland (3.6 million), Italy (2.1 million), Spain (1.8 million), and Greece (1.2 million). Together, these five Member States employ over 70 per cent of the EU agricultural labour force.

Most farm work is carried out by farmers and their families. Although the farm work is regular, it is mostly not full-time. The 22.2 million people regularly working on farms provide the equivalent of 8.7 million full-time jobs (AWU). On average, therefore, people working on farms spend 39 per cent of their time on farm work. In reality this average means that some people work full-time and others will do very little farm work.

The average number of people working on each farm is 2.0, giving an average 7.9 ha per person. Expressed as annual work units, this is an average 0.8 AWU per farm and 20 hectares per AWU.

Member States with higher average holding areas tend to have a higher number of hectares per person. This also applies to AWU. Table 3 shows that the Czech Republic has the largest average farm holding area in the EU at 133 ha and has an average of 5.0 persons regularly employed on each holding (26.6 ha per person). Slovakia has an average holding area of 81 ha with 3.4 people per farm (23.8 ha per person).

There are some exceptions to this tendency. Netherlands has the third highest average number of people per farm at 2.9, but its average farm size is relatively lower at 27 ha, giving 9.3 ha per person. In contrast, Slovenia has an average of 2.8 persons per farm and 2.4 ha per person.

Apart from the Czech Republic and Slovakia, other Member States have an average of 2.5 or less persons regularly employed per farm. The UK has the second largest average farm area at 94 ha, but just 2.3 people working on each farm (40.8 ha per person).

Table 3. Number of persons regularly employed per farm holding in the EU, 2013

EU-28	Total labour (1000 persons)	Per cent of total labour force*	Number of farm holdings (1000)	Average holding area (ha)	ha/ person	Persons/ holding
Czech Republic	132	2,5%	26	133,0	26,4	5,0
United Kingdom	435	1,3%	185	93,6	39,9	2,3
Slovakia	80	2,9%	24	80,7	23,8	3,4
Denmark	81	2,8%	39	67,5	32,3	2,1
Luxembourg	5	2,0%	2	63,0	26,5	2,4
France	907	3,2%	472	58,7	30,6	1,9
Germany	706	1,7%	285	58,6	23,6	2,5
Estonia	44	6,5%	19	49,9	21,7	2,3
Sweden	131	2,6%	67	45,2	23,2	1,9
Finland	120	4,5%	54	42,0	19,0	2,2
Ireland	270	12,5%	140	35,5	18,4	1,9
Belgium	75	1,5%	38	34,6	17,5	2,0
Netherlands	193	2,2%	67	27,4	9,6	2,9
Spain	1.783	7,7%	965	24,1	13,1	1,8
Latvia	174	17,2%	82	23,0	10,8	2,1
Austria	338	7,8%	140	19,4	8,1	2,4
Bulgaria	558	16,5%	254	18,3	8,3	2,2
Lithuania	298	20,3%	172	16,7	9,6	1,7
Portugal	626	11,9%	264	13,8	5,8	2,4
Italy	2.139	8,5%	1.010	12,0	5,7	2,1
Poland	3.559	20,5%	1.429	10,1	4,0	2,5
Croatia	388	21,1%	157	10,0	4,0	2,5
Hungary	1.060	24,5%	491	9,5	4,4	2,2
Greece	1.238	25,6%	710	6,8	3,9	1,7
Slovenia	201	19,9%	72	6,7	2,4	2,8
Romania	6.578	71,5%	3.630	3,6	2,0	1,8
Cyprus	77	17,8%	35	3,1	1,4	2,2
Malta	15	7,9%	9	1,2	0,7	1,6
	22.210	**9,2%**	**10.841**	**16,1**	**7,9**	**2,0**

*Including employed and unemployed persons
Source: Eurostat [ef_kvaareg], [lfsi_act_a]

Figure 1 shows the regular farm labour force (1000 persons) in Member States. The figures in brackets are the farm labour as a percentage of the total labour force in each Member State. These figures are derived from Table 3

Figure 1. Regular farm labour force in Member States, 2013 (1000 persons and percentage of total Member State labour force)

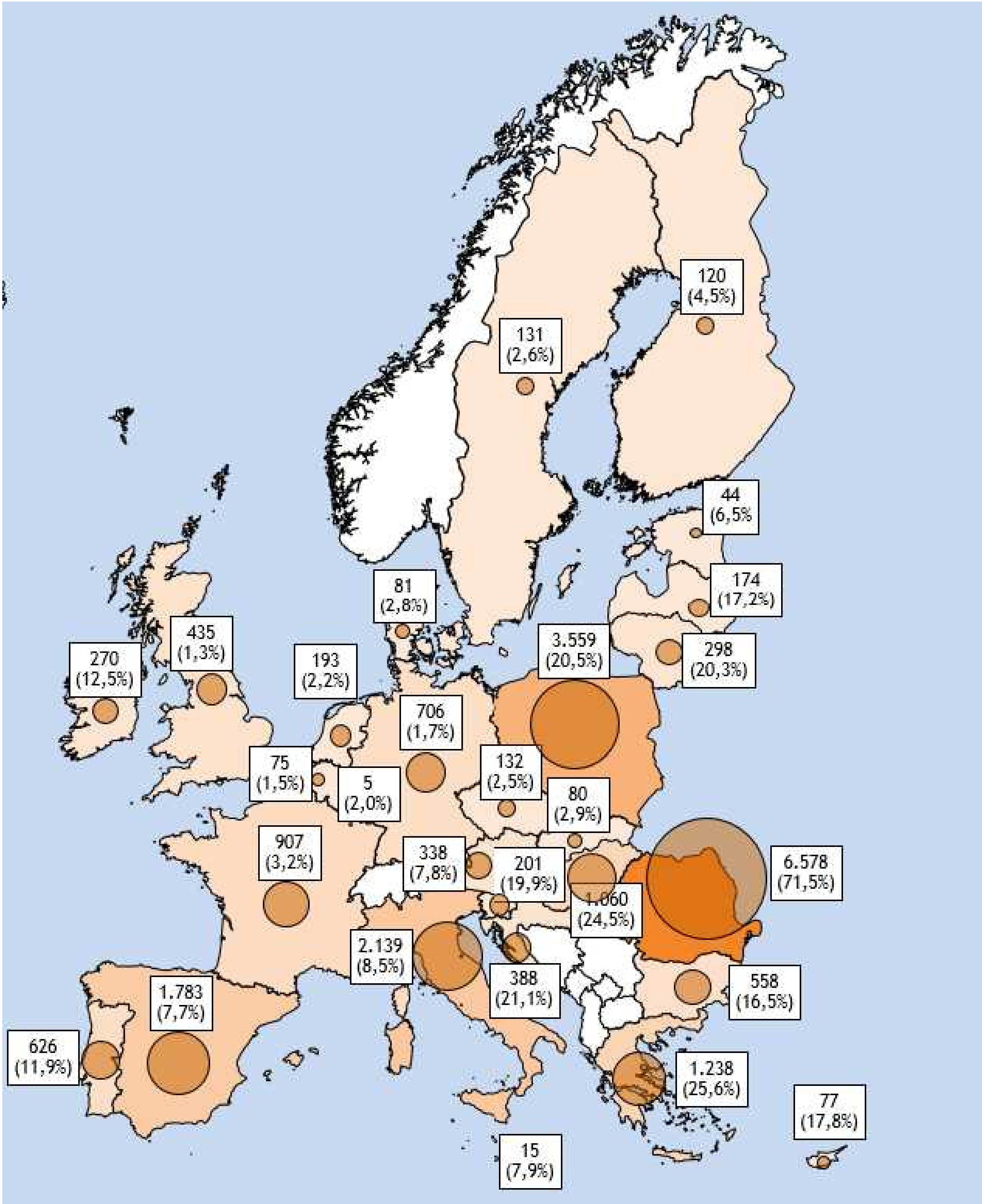


Figure 2 shows the average holding area in Member States, ranging from the Czech Republic (1st rank) with an average holding area of 133 hectares to Malta (28th) with an average holding area of 1.2 hectares. It also shows the relationship between hectares per regular farm worker and the average holding area in different Member States.

Figure 2. Average holding area and hectares per regular farm worker in Member States, 2013

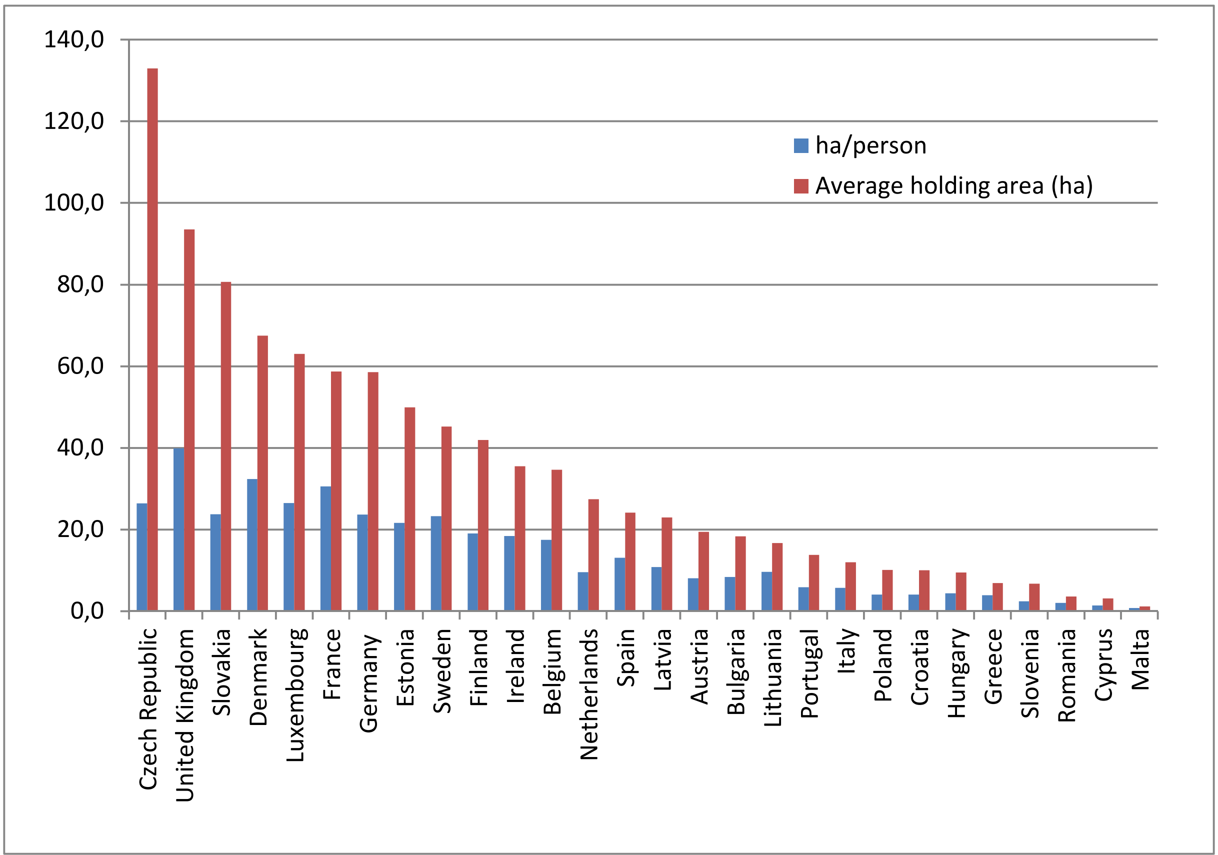


Figure 3. Persons and AWU per holding in Member States, 2013

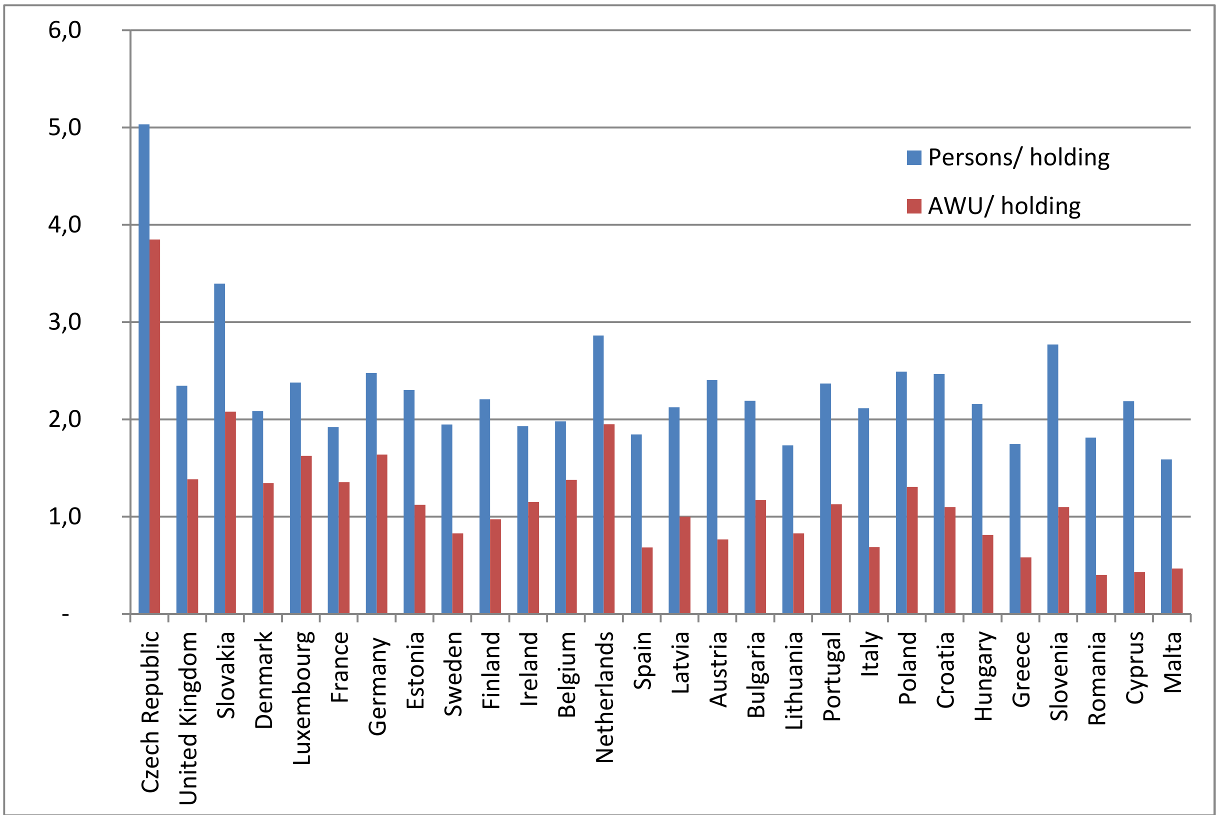


Figure 3 illustrates the number of persons and AWU per holding in Member States ranked by average holding area (from 133 hectares in the Czech Republic to 1.2 hectares in Malta).

The relationship between the number of persons per holding and the holding area in different Member States seems less distinct than the number of hectares per farm worker and average holding area shown in Figure 2.

The number of persons per holding is only modestly higher in Member States with higher average holding areas. The Czech Republic and Malta are at the extreme end of the range of average holding size in Member States (Table 3). The Czech Republic has on average three times as many persons per holding as Malta (5.0 compared to 1.6), but its average holding area is 111 times higher (133 hectares compared to 1.2 hectares).

In terms of AWU, the Czech Republic has 3.9 AWU per holding, eight times more than Malta's 0.5 AWU per holding[3]. These ratios may be partly explained by the different range of crops grown in different Member States and also on farms of different size.

Large farms have more hectares per person, and their work forces are more fully employed than on small farms. It is necessary to consider the range of different types of farming in individual Member States when looking at reasons behind the number of people employed per holding and per hectare.

4.2. Declining regular agricultural labour force in the EU

Most of the EU regular agricultural labour force works on small farms: 81 per cent of persons work on farms of less than 20 ha, 17 per cent work on farms over 20 ha and 2 per cent work on farms of zero ha (mostly pig and poultry farms)[4].

In terms of AWU, 68 per cent of all farm work is done on farms of less than 20 ha, 30 per cent on farms over 20 ha and 2 per cent on farms of zero ha.

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

The number of regular agricultural workers fell 12.8 per cent from 25 million in 2010 to 22 million in 2013. However, the number of full-time equivalent jobs (AWU) fell by just 4.4 per cent 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.

5. Demographics and training

5.1. Demographics

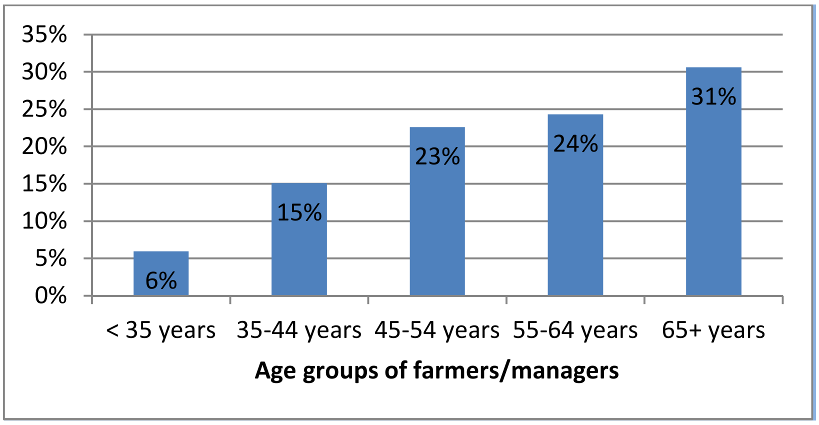
EU farmers and farm managers have a high age profile compared to other sectors of the economy. Thirty one per cent of farmers are older than 65 years, whilst 6 per cent are less than 35 (Figure 4).

Although the overall number of farmers is declining, the proportion in the different age groups remains relatively constant.

[3] See annex tables

[4] See annex tables

Figure 4. EU farmers/ farm managers by age group, 2013



Source: Eurostat [ef_mptrainman]

Poland, Austria, France, Luxembourg and Finland have the highest proportions of managers below 35 years, whilst Portugal, Romania, Cyprus, Italy and Bulgaria have the highest proportions over 65 years.

5.2. Training

Most farmers in the EU have not been formally trained in agriculture: 70 per cent only have practical experience, 20 per cent have received basic training[5] and 8 per cent have attended a full agricultural training[6] course. However, these averages do not reveal wide differences between Member States[7].

In Italy, 91 per cent of farmers have received basic training and 6 per cent full training. In the Netherlands, 64 per cent have basic training and 8 per cent full training. In Germany, 53 per cent have received basic training and 15 per cent full training.

The Member States where the highest proportions of farmers have received full training are Luxembourg (50 per cent), Czech Republic (35 per cent), France (29 per cent), Latvia (28 per cent) and Poland (28 per cent).

The countries where the highest proportions have received no training are Romania (96 per cent), Greece (94 per cent), Bulgaria (93 per cent), Cyprus (93 per cent, and Malta (87 per cent).

At EU level, a higher proportion of farmers over 65 years (80 per cent) have no training. Sixty per cent of farmers below 35 years have received no training, 20 per cent have basic training and 20 per cent have full training.

[5] Basic agricultural training: any training courses completed at a general agricultural college and/or an institution specialising in certain subjects. A completed agricultural apprenticeship is regarded as basic training

[6] Full agricultural training: any training course continuing for the equivalent of at least two years full time training after the end of compulsory education and completed at an agricultural college, university or other institute of higher education.

[7] See annex tables

6. Farm economics

6.1. Standard output

Farm output, measured as standard output (SO), varies widely between Member States, as would be expected from the wide range in agricultural areas and types of farming. Five Member States: France, Germany, Italy, Spain and the UK produce 62 per cent of EU standard output from 56 per cent of the utilized agricultural area.

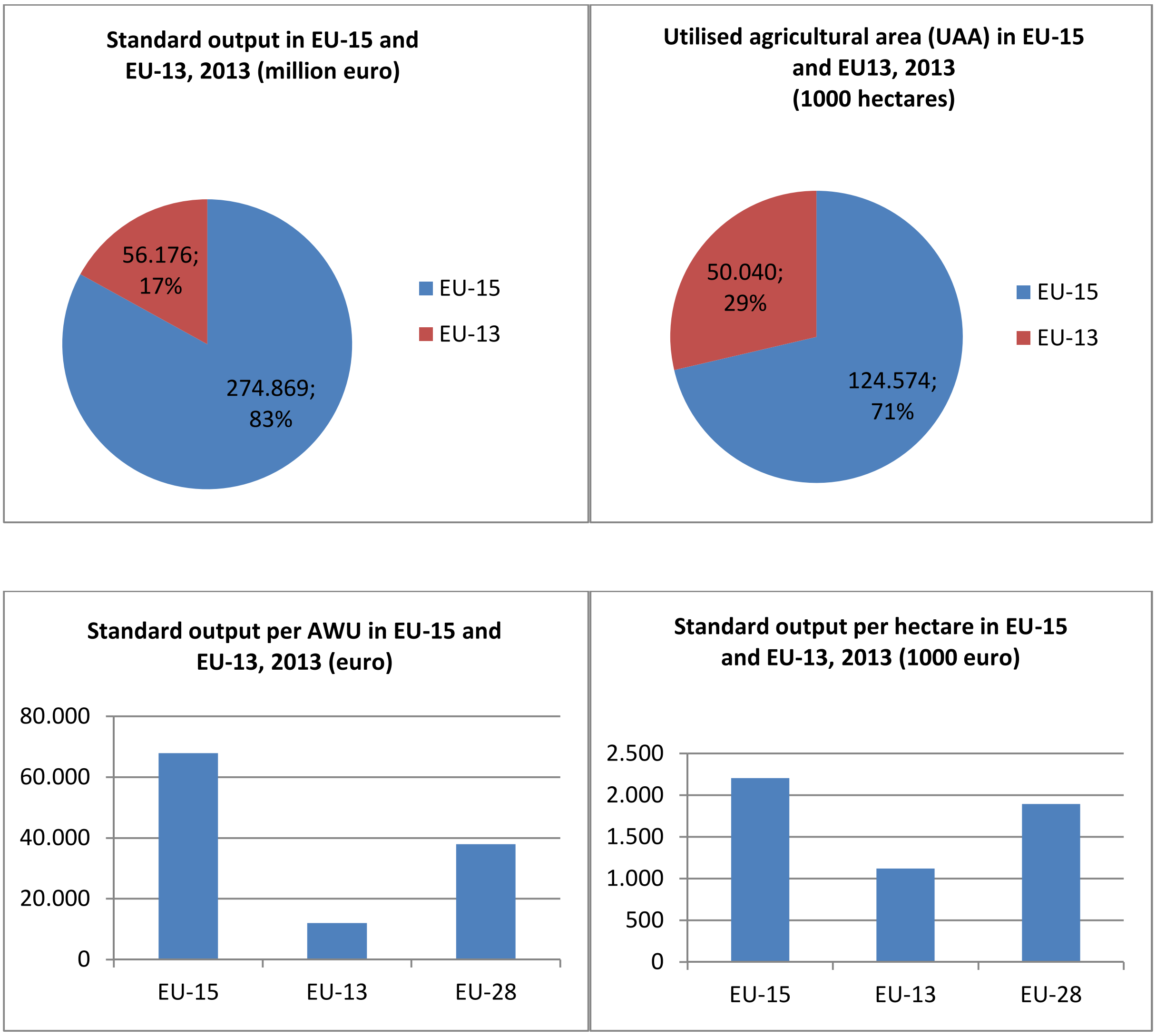
In terms of standard output per hectare, the Netherlands has a far higher financial productivity than other Member States. Malta, despite having the EU's smallest agricultural area and standard output, has the second highest standard output per hectare, followed by Belgium, Cyprus and Denmark. The financial value of the commodity produced per hectare will greatly influence this indicator, but it can also be influenced by higher yields (see 7.2).

Table 4. Standard Output (SO) in Member States, 2013

EU Member States	Standard Output (million euro)	Total utilised agricultural area (1000 ha)	SO per hectare (1000 euro)	Total labour (1000 AWU)	Population (1000)
France	56 914	27 739	2 052	640	62 297
Germany	46 252	16 700	2 770	467	79 705
Italy	43 767	12 099	3 617	696	60 225
Spain	35 979	23 300	1 544	661	46 146
UK	21 819	17 327	1 259	257	62 988
Poland	21 797	14 410	1 513	1 866	36 586
Netherlands	20 498	1 848	11 095	132	16 622
Romania	11 990	13 056	918	1 452	20 002
Denmark	9 580	2 619	3 657	52	5 609
Belgium	8 407	1 308	6 428	52	11 125
Greece	8 070	4 857	1 662	412	10 921
Austria	5 671	2 727	2 080	108	8 330
Hungary	5 578	4 657	1 198	400	9 724
Ireland	5 013	4 959	1 011	161	4 602
Sweden	4 679	3 036	1 541	56	9 502
Portugal	4 509	3 642	1 238	299	10 449
Czech Republic	4 447	3 491	1 274	101	10 521
Finland	3 398	2 282	1 489	53	5 418
Bulgaria	3 336	4 651	717	298	7 242
Croatia	2 029	1 571	1 291	173	4 253
Lithuania	1 919	2 861	671	142	2 960
Slovakia	1 812	1 902	953	49	5 411
Slovenia	1 009	486	2 078	79	2 059
Latvia	990	1 878	527	82	1 996
Estonia	676	958	706	22	1 316
Cyprus	495	109	4 531	15	828
Luxembourg	314	131	2 395	3	517
Malta	97	11	8 896	4	414
EU-28	**331 044**	**174 614**	**1 896**	**8 734**	**497 764**
EU-15	274 869	124 574	2 206	4 049	394 453
EU-13	56 176	50 040	1 123	4 685	103 311

Source: Eurostat [ef_kvftaa], [ef_olfaa], [lfsi_act_a]

Figure 5. Standard output comparisons in EU-15 and EU-13 Member States



Source: Eurostat [ef_kvftaa], [ef_olfaa]

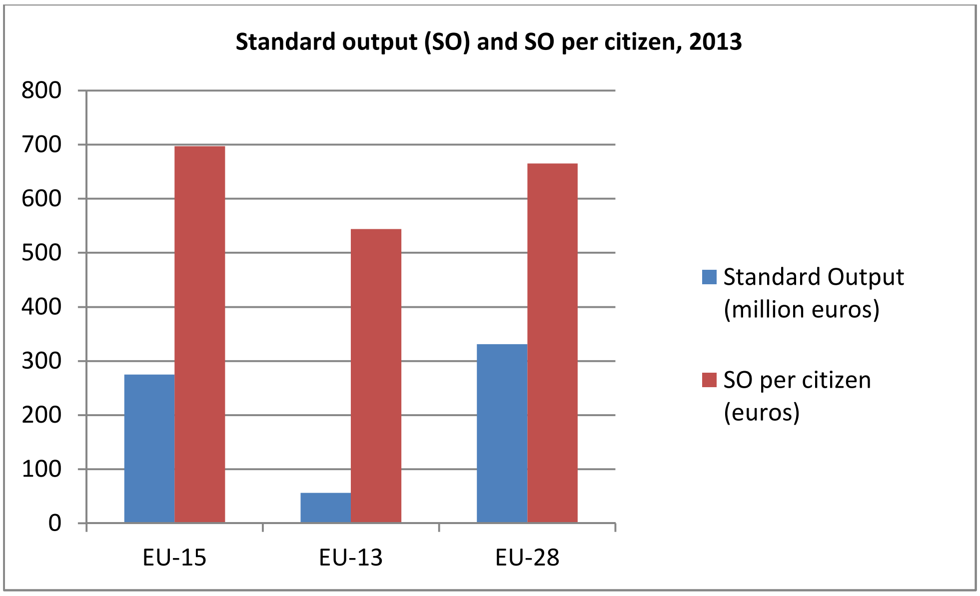
The EU-15 Member States[8] had a total standard output of 274 869 million euro in 2013, compared to the 56 176 million euro in the EU-13. However, to put these figures in perspective, the utilised agricultural area (UAA) in the EU-15 is 124.5 million hectares compared to 50 million hectares in the EU-13 (Figure 5).

The standard output per unit of agricultural labour (AWU) is much lower in the EU-13, as is the standard output per hectare.

However, the much higher population of 394 million citizens in the EU-15 compared to 103 million in the EU-13 means that the difference in standard output of agriculture per citizen is much less. Figure 6 shows the EU-15 to have a standard output per citizen of 697 euro, compared to 544 euro for the EU-13. This is an important observation for food security in the EU-13.

[8] The EU-15 were the EU Member States before May 1st 2004 and comprised Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom. The EU-13 comprise Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia, joining the EU in or after 2004

Figure 6. Standard output per citizen in EU-15 and EU-13 Member States, 2013



Source: Eurostat [ef_kvftaa], [ef_olfaa]

Regarding different types of farming, dairying produces the most standard output, followed by cereals, oilseeds and protein crops (see Table 5 and annex tables).

In terms of output per hectare, intensive types of production give the highest income. Indoor horticulture is by far the highest, followed by pigs, poultry and outdoor horticulture[9]. Together these four activities produce 23 per cent of standard output from 3 per cent of the utilised agricultural area.

However, it has to be taken into account that intensive livestock units consume feed that was grown on additional land, so comparisons per hectare are not really valid for these particular activities. Nevertheless the total standard output figures show the importance of intensive livestock to the agricultural economy.

Table 5. Standard output (SO) for specialist types of farming in the EU, 2013

EU-28	Standard Output (million euro)	Utilised agricultural area (1000 ha)	Standard Output per hectare (euro)
Dairying	53 128	19 444	2 732
Cereals, oilseed and protein crops	36 897	44 784	824
Pigs	31 753	2 823	11 247
Poultry	22 498	1 082	20 789
Vineyards	20 189	3 429	5 887
Indoor horticulture	15 380	332	46 377
Cattle rearing/ fattening	15 162	15 773	961
Sheep, goats, grazing livestock	14 862	15 904	934
Fruit and citrus fruit	11 789	2 797	4 215
Outdoor horticulture	6 000	546	10 999
Olives	4 008	3 153	1 271
Utilised agricultural area	**331 044**	**174 614**	**1 896**

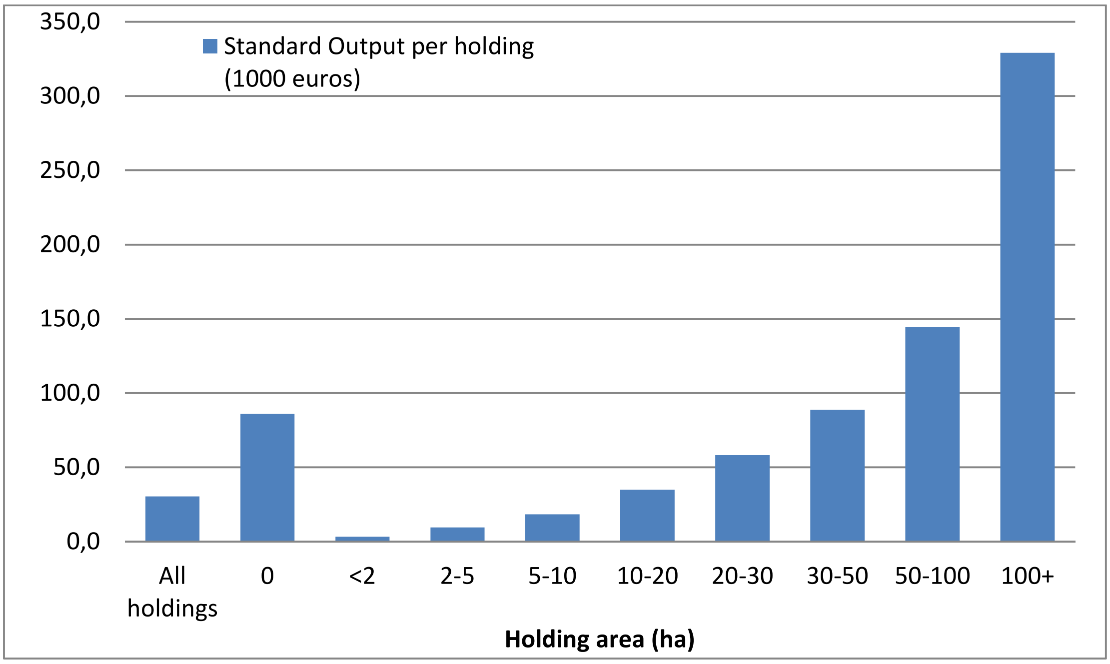
Source: Eurostat, [ef_kvftaa]

[9] Note that horticulture includes flowers and ornamental plants as well as food crops.

6.2. Standard output per holding

Figure 7 shows the standard output of holdings according to their size.

Figure 7. EU Standard Output (SO) of EU holdings by holding area, 2013 (1000 euro)

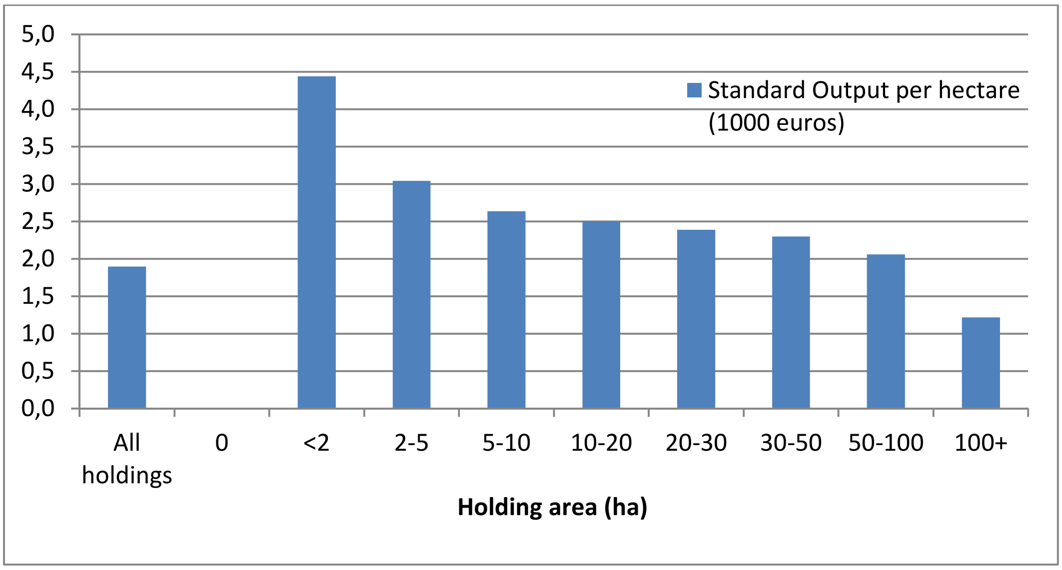


Source: Eurostat, [ef_mpmanaa]

Not surprisingly, standard output increases with the size of holding. Between 2010 and 2013, standard output per holding increased by 21 per cent, which is more than the increase in land area per holding over the same period[10], indicating that EU farms are becoming more financially productive.

Figure 8 gives the standard output per hectare for the same size groups and shows that smaller farms tend to have higher output per hectare. Holdings with zero hectares are mainly intensive pig and poultry units.

Figure 8. Standard Output (SO) per hectare of EU holdings by holding area, 2013 (1000 euro)



Source: Eurostat, [ef_mpmanaa]

[10] Average EU holding area increased from 14.4 to 16.1 ha from 2005 to 2013 (See Briefing Paper 1)

Holdings of less than two hectares have a standard output of 3 376 euro per holding, but as their average size is 0.8 hectares, the output on a per hectare basis is 4 441 euro. One possible reason for the inverse relationship between output per hectare and farm size is that more intensive activities are concentrated on smaller farms.

In contrast, holdings of over 100 hectares have a standard output per hectare of 1 218 euro, indicating less intensive activities such as livestock grazing and the growing of cereals, oilseeds and protein crops.

Details of the areas and standard outputs of these specialist types of farming for individual Member States are provided in annex tables.

6.3. Standard output by legal type of holding

Table 6 shows statistics on standard output by legal type of holding.

In terms of output per hectare, group holdings generate 2 218 euro standard output per hectare, compared to sole holders at 1 939 euro per hectare and legal entities at 1 729 euro per hectare (Figure 9).

In terms of standard output per labour unit (AWU), group holdings generate 97 059 euro per AWU, compared to 72 044 euro per AWU for legal entities and 27 930 euro per AWU for sole holders (Figure 10).

Table 6. Standard output by legal type of holding, 2013

EU-28	All holdings	Sole holder	Legal entity	Group holding
Number (1000)	10 841	10 470	298	73
Area (1000 ha)	174 614	117 329	48 031	9 253
Labour (1000 AWU)	9 509	8 144	1 153	211
Area/AWU (ha)	18	14	42	44
Standard output (million euro)	331 044	227 471	83 050	20 523
Standard output per ha (euro)	1 896	1 939	1 729	2 218
Standard output per AWU (euro)	34 815	27 930	72 044	97 059

Source: Eurostat [ef_kvaareg]

Figure 9. Legal types of holding; standard output per hectare, 2013 (euro)

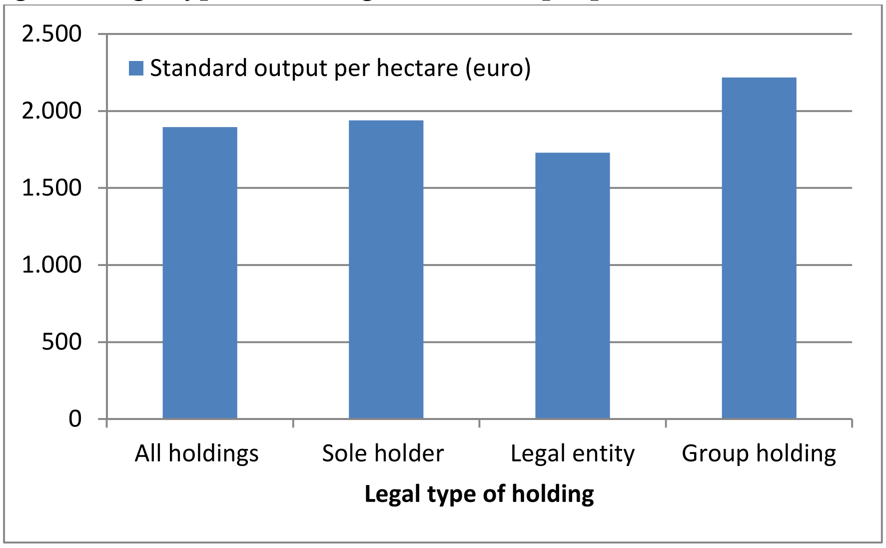
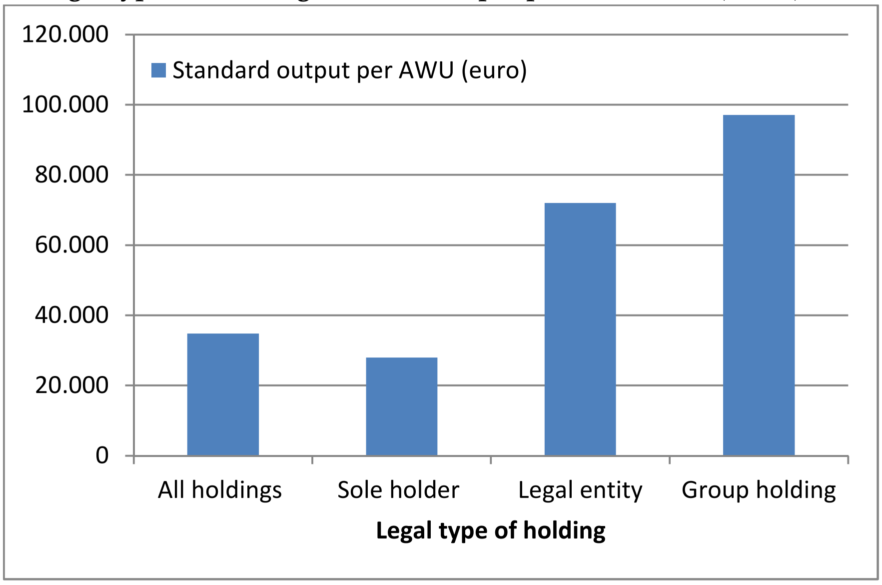


Figure 10. Legal types of holding: standard output per labour unit (AWU), 2013 (euro)



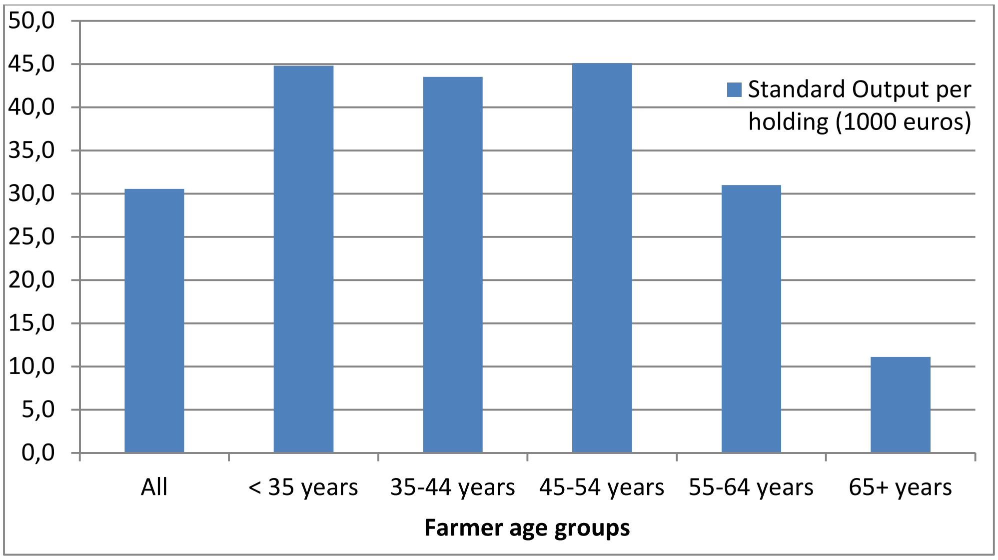
6.4. Standard output by age of farmer

Figure 11 shows the standard output of holdings according to the age of the farmer. Standard output is similar for holdings managed by farmers in age groups up to 55 years, but is less for older farmers.

However, older farmers tend to have smaller holdings, and this accounts to a large extent for their lower standard output.

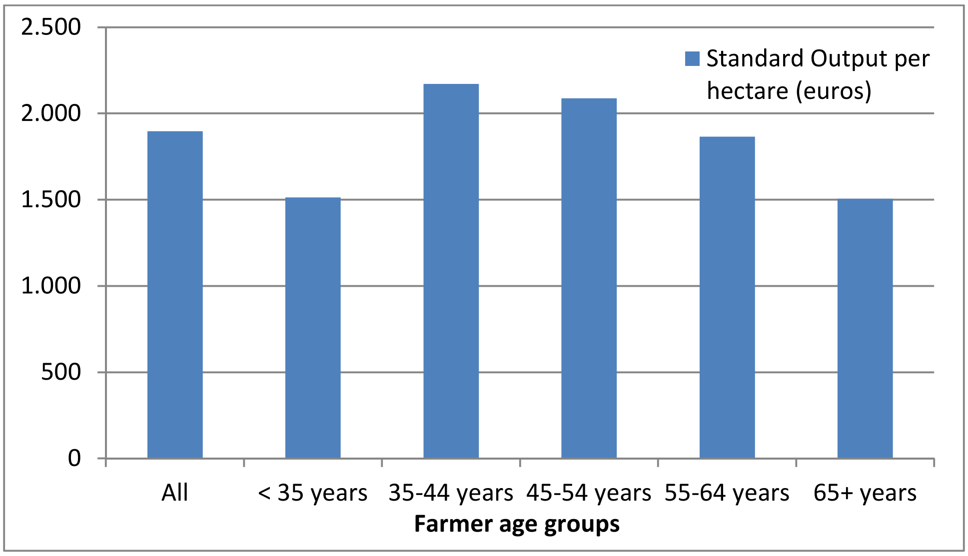
Farmers below 35 years have an average holding area of 29.6 hectares, well above the EU average. Average holding area falls as the age group becomes higher, so farmers over 65 years have an average holding area of 7.4 hectares. However, Figure 12 shows that, on a standard output per hectare basis, farmers over 65 have virtually the same standard output per hectare as farmers below 35 years.

Figure 11. Standard Output of EU holdings by age of farmer, 2013 (1000 euro)



Source: Eurostat, [ef_mptrainman]

Figure 12. Standard Output per hectare by age of farmer, 2013



6.5. Standard output by Member State

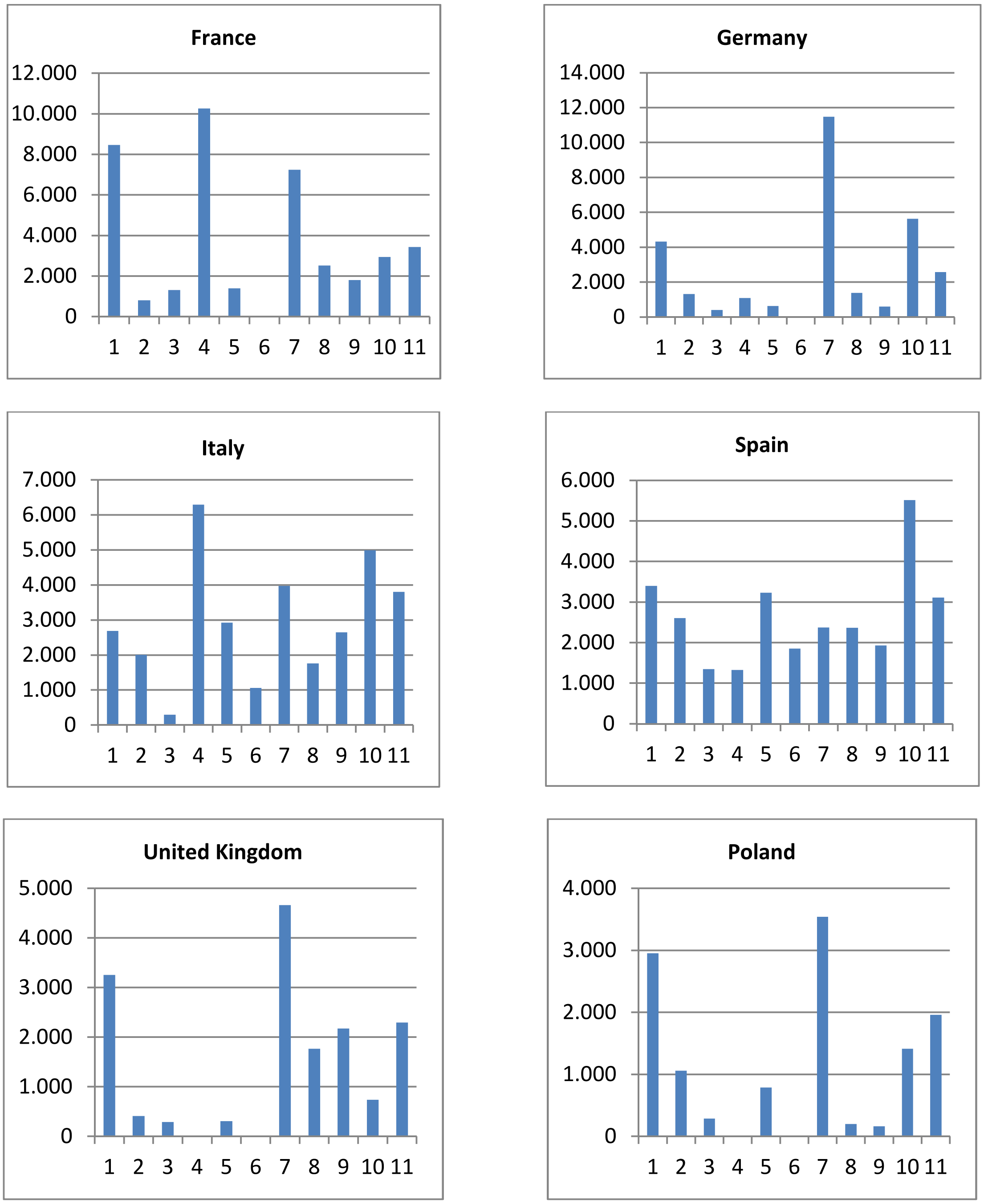
Figure 13 shows the standard output (in million euro) for 11 specialist types of farming in Member States. The total standard output for each Member State is shown in Table 4 and the total EU standard output for each type of farming is shown in Table 5. Full data for each Member State and source references are shown in Annex Table 9.

The numbers on the X-axes of the Figure 13 charts correspond to the types of farming shown in the legend.

Figure 13. Standard output for specialist types of farming in Member States, 2013 (million euro)

Legend for X-axes in Figure 13 (Y-axes are million euro)

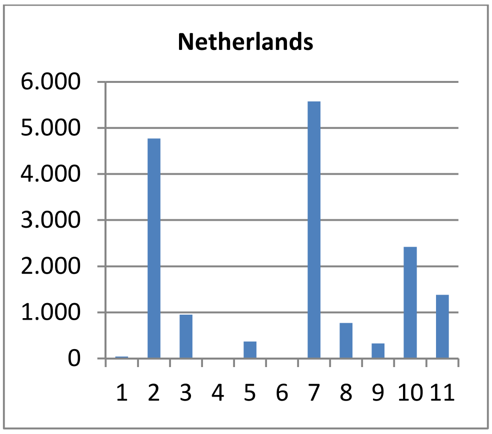
1. Cereals, oilseed, protein crops
2. Indoor horticulture
3. Outdoor horticulture
4. Vineyards
5. Fruit and citrus fruit
6. Olives
7. Dairying
8. Cattle rearing/ fattening
9. Sheep, goats, grazing livestock
10. Pigs
11. Poultry

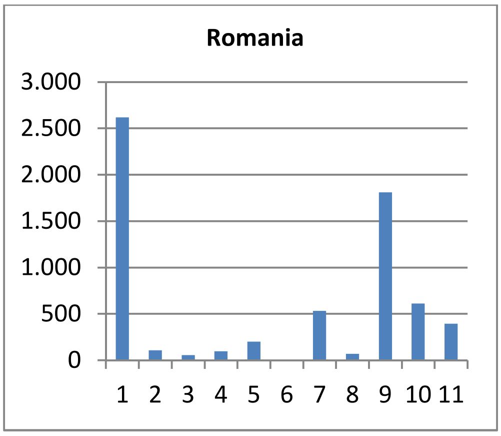


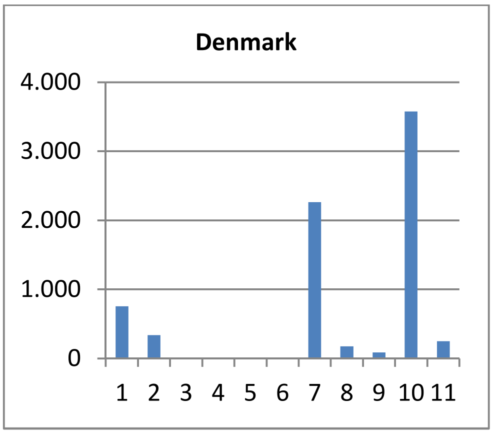
Legend for X-axes in Figure 13 (Y-axes are million euro)

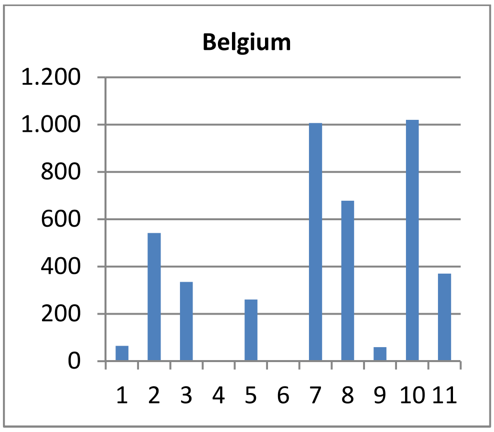
7. Cereals, oilseed, protein crops
8. Indoor horticulture
9. Outdoor horticulture
10. Vineyards
11. Fruit and citrus fruit
12. Olives

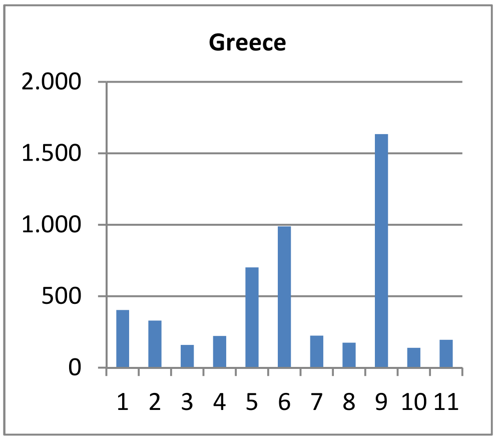
7. Dairying
8. Cattle rearing/ fattening
9. Sheep, goats, grazing livestock
10. Pigs
11. Poultry

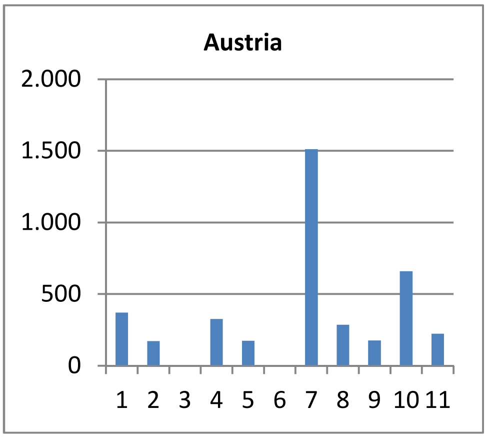












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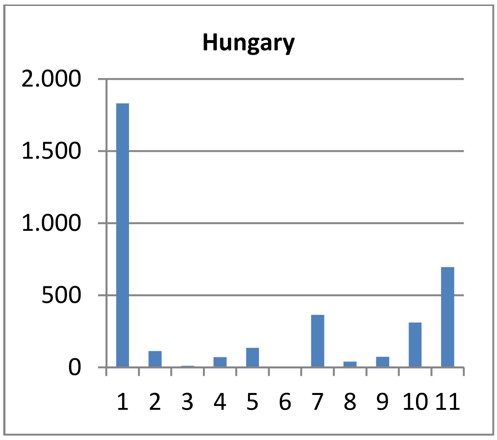

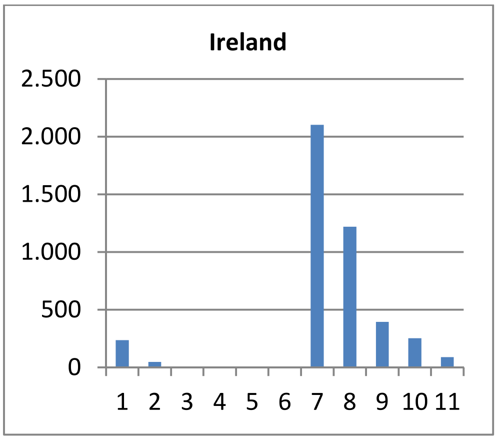

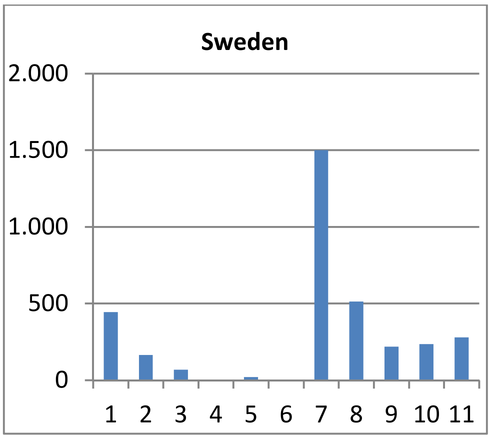

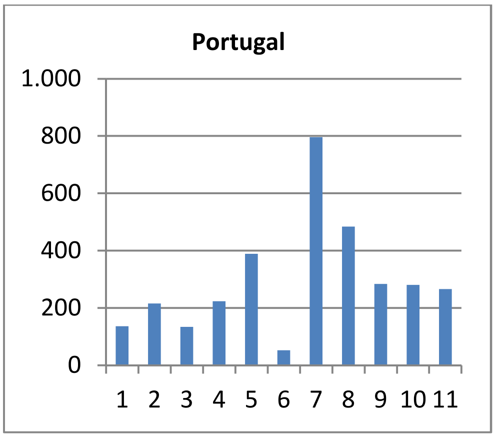

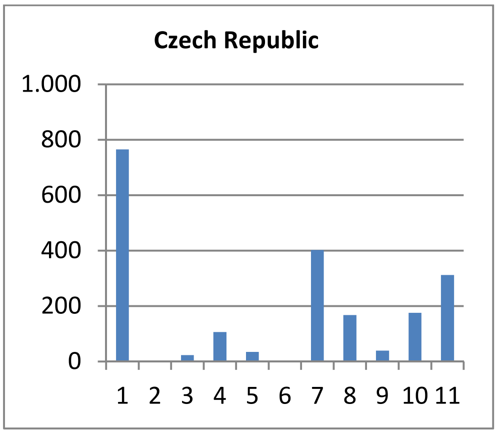

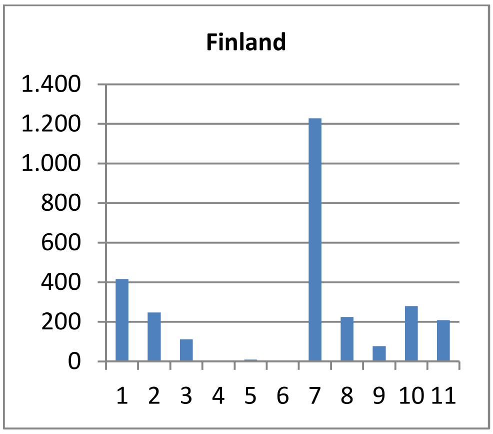

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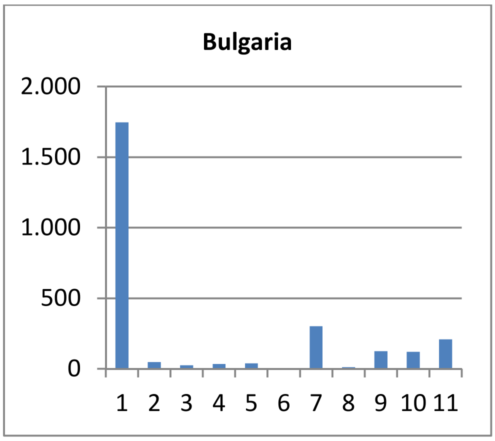

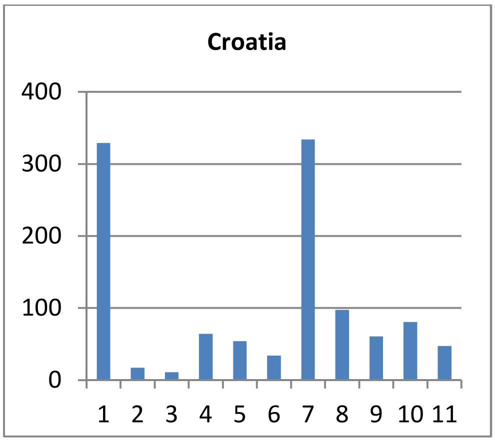

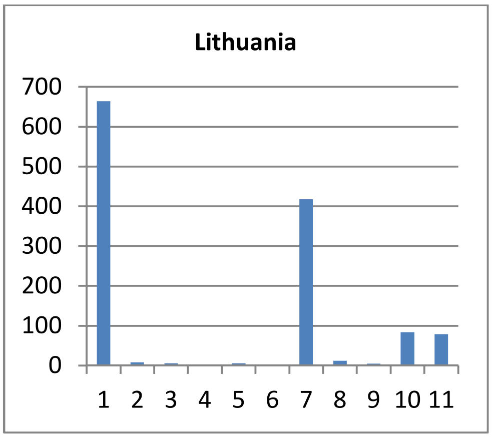

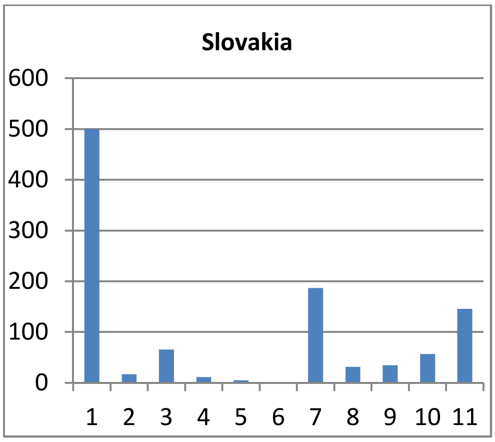

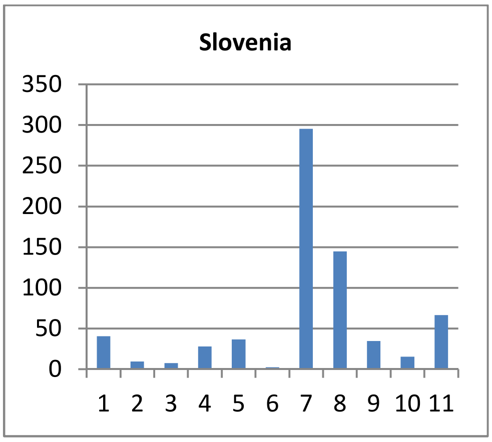

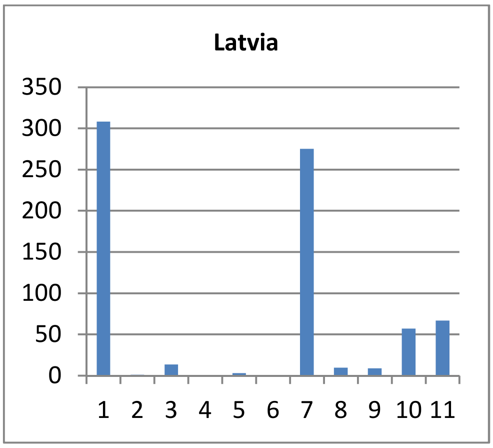

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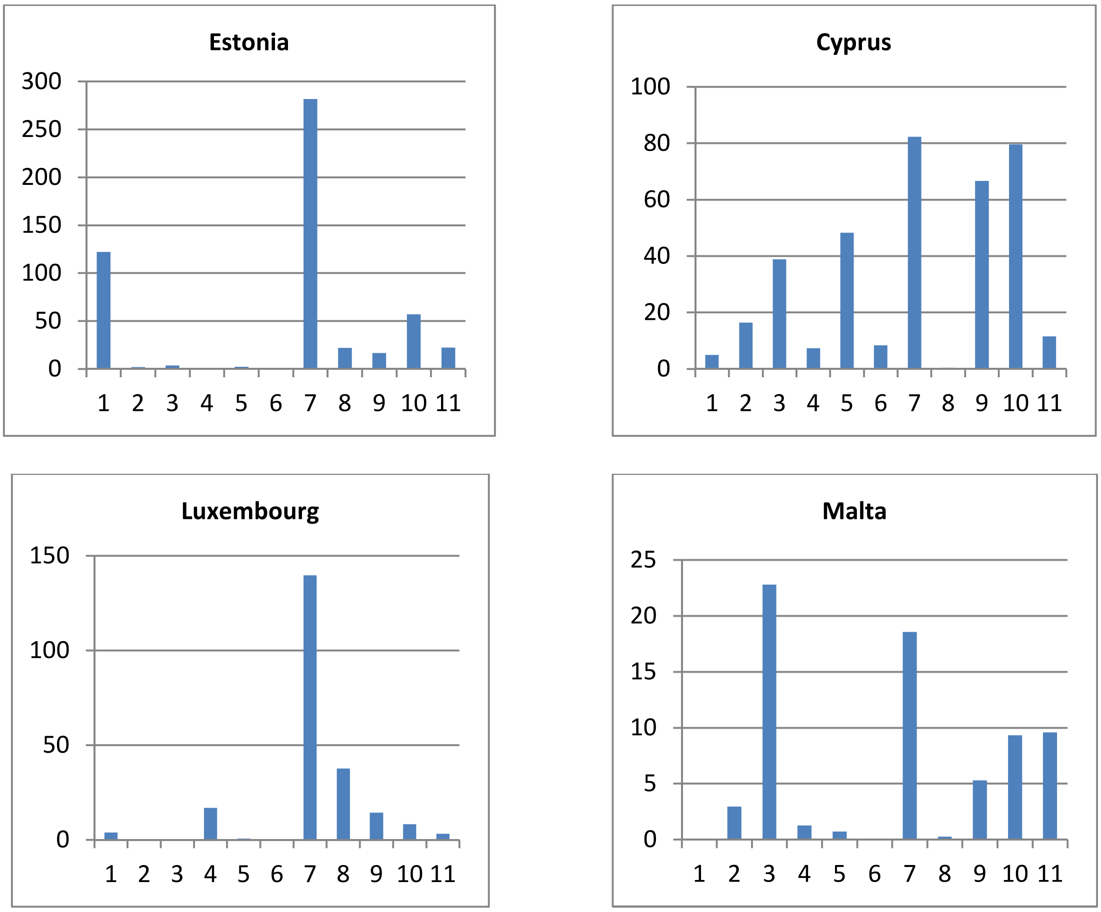

7. Summary

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 some 22.2 million people.

7.1. Employment

The average number of people working on each farm is 2.0, giving an average 7.9 ha per person. Expressed as annual work units, this is an average 0.8 AWU per farm and 20 hectares per AWU.

Most of the regular labour force works on small farms: 81 per cent of persons work on farms of less than 20 ha, 17 per cent work on farms over 20ha and 2 per cent work on farms of zero ha (mostly pig and poultry farms).

Large farms have more hectares per person, and their work forces are more fully employed than on small farms. It is necessary to consider the range of different types of farming in individual Member States when looking at reasons behind the average number of people employed per holding and per hectare.

Farms with a sole legal holder employ 86 per cent of labour units (AWU). Farms that are legal entities employ 12 per cent and group holdings employ 2 per cent of AWU.

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

The number of regular agricultural workers fell 12.8 per cent from 25 million in 2010 to 22 million in 2013. However, the number of full-time equivalent jobs (AWU) fell by just 4.4 per cent 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.

EU farmers and farm managers have a high age profile compared to other sectors of the economy. Thirty one per cent of farmers are older than 65 years, whilst 6 per cent are less than 35.

Although the overall number of farmers is declining, the proportion in the different age groups remains relatively constant.

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

7.2. Farm economics

Farm output, measured as standard output (SO), varies widely between Member States. On an area basis, average standard output in different Member States varies from 527 to 11 095 euro 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 euro per hectare across the EU, whereas cereals, oilseed and potato crops generate 824 euro per hectare on average. However there are large variations between Member States in standard output per hectare for each type of activity.

Smaller farms tend to have higher output per hectare than larger farms, indicating a concentration of more intensive activities on smaller farms and vice versa.

For legal entities, group holdings generate 2 218 euro standard output per hectare, compared to sole holders at 1 939 euro per hectare and legal entities at 1 729 euro per hectare. However more dramatic differences are evident between legal types in terms of output per labour unit (AWU). Group holdings generate 97 059 euro per AWU, compared to 72 044 euro per AWU for legal entities and 27 930 euro per AWU for sole holders.

Standard output varies with the age of the farmer. Standard output per holding is similar for holdings managed by farmers in age groups up to 55 years, but is less for older farmers. However, older farmers tend to have smaller holdings, and this accounts to a large extent for their lower standard output. On a per hectare basis, farmers over 65 have virtually the same standard output per hectare as farmers below 35 years.

Standard output varies greatly between individual Member States according to the size of the utilized agricultural area, the range of different types of farming and their productivity.

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.

Annex Table 1. Number and area of EU holdings by legal type, 2013

EU-28	Total holdings			Sole holder			Legal entity			Group holding		
	Number	UAA (ha)	Ave ha	Number	UAA (ha)	Ave ha	Number	UAA (ha)	Ave ha	Number	UAA (ha)	Ave ha
Romania	3 629 660	13 055 850	3.6	3 601 780	7 271 010	2.0	27 880	5 784 840	207.5			
Poland	1 429 010	14 409 870	10.1	1 425 390	13 103 040	9.2	3 620	1 306 830	361.0			
Italy	1 010 330	12 098 890	12.0	995 870	10 837 350	10.9	14 460	1 261 540	87.2			
Spain	965 000	23 300 220	24.1	903 390	16 211 780	17.9	61 610	7 088 440	115.1			
Greece	709 500	4 856 780	6.8	708 700	3 368 010	4.8	800	1 488 770	1 861.0			
Hungary	491 330	4 656 520	9.5	482 520	2 467 620	5.1	8 820	2 188 900	248.2			
France	472 210	27 739 430	58.7	315 420	10 495 210	33.3	117 860	11 446 360	97.1	38 920	5 797 860	149.0
Germany	285 030	16 699 580	58.6	256 050	10 897 150	42.6	5 270	2 921 050	554.3	23 720	2 881 380	121.5
Portugal	264 420	3 641 590	13.8	253 490	2 351 320	9.3	10 930	1 290 270	118.0			
Bulgaria	254 410	4 650 940	18.3	248 440	1 766 230	7.1	5 920	2 877 220	486.0	40	7 480	187.0
United Kingdom	185 190	17 326 990	93.6	179 160	14 349 510	80.1	6 040	2 977 480	493.0			
Lithuania	171 800	2 861 250	16.7	171 110	2 482 280	14.5	680	378 130	556.1			
Croatia	157 450	1 571 200	10.0	154 400	1 050 170	6.8	3 050	521 030	170.8			
Ireland	139 600	4 959 450	35.5	139 100	4 498 870	32.3	500	460 580	921.2			
Austria	140 430	2 726 890	19.4	131 950	2 382 160	18.1	4 060	263 580	64.9	4 420	81 150	18.4
Latvia	81 800	1 877 720	23.0	80 450	1 640 620	20.4	140	19 960	142.6	1 210	217 150	179.5
Slovenia	72 380	485 760	6.7	72 180	459 680	6.4	200	26 080	130.4			
Netherlands	67 480	1 847 570	27.4	63 220	1 740 730	27.5	4 260	106 840	25.1			
Sweden	67 150	3 035 920	45.2	61 960	2 377 480	38.4	5 190	658 440	126.9			
Finland	54 400	2 282 400	42.0	48 120	1 955 350	40.6	1 630	78 310	48.0	4 650	248 740	53.5
Denmark	38 830	2 619 340	67.5	37 010	2 437 290	65.9	1 820	182 040	100.0			
Cyprus	35 380	109 330	3.1	34 920	95 330	2.7	470	14 000	29.8			
Belgium	37 760	1 307 900	34.6	32 760	1 111 800	33.9	5 000	196 110	39.2			
Czech Republic	26 250	3 491 470	133.0	23 350	1 063 750	45.6	2 900	2 427 730	837.1			
Slovakia	23 570	1 901 610	80.7	20 820	368 960	17.7	2 740	1 532 650	559.4			
Estonia	19 190	957 510	49.9	16 880	424 530	25.1	2 310	532 970	230.7			
Malta	9 360	10 880	1.2	9 220	10 300	1.1	40	190	4.8	110	390	3.5
Luxembourg	2 080	131 040	63.0	1 920	111 290	58.0	50	900	18.0	110	18 850	171.4
Total	10 841 000	174 613 900	16.1	10 469 580	117 328 820	11.2	298 250	48 031 240	161.0	73 180	9 253 000	126.4
% of total number	100%			97%			3%			1%		
% of total UAA		100%			67%			28%			5%	

Source: Eurostat [ef_kvaareg]

Annex Table 2. Labour force and Standard Output (SO) of EU holdings by legal type, 2013

EU-28	Total holdings		Sole holder		Legal entity		Group holding	
	Labour* (AWU)	SO (million euro)	Labour* (AWU)	SO (million euro)	Labour* (AWU)	SO (million euro)	Labour* (AWU)	SO (million euro)
France	724 690	56 914	302 610	18 206	308 820	28 542	113 260	10 165
Germany	522 730	46 252	382 850	30 672	59 820	6 046	80 060	9 534
Italy	816 920	43 767	778 400	39 862	38 520	3 904		
Spain	813 550	35 979	612 750	21 912	200 800	14 067		
United Kingdom	275 370	21 819	254 790	19 992	20 580	1 827		
Poland	1 918 550	21 797	1 885 990	19 854	32 560	1 944		
Netherlands	153 310	20 498	116 710	16 092	36 590	4 406		
Romania	1 552 630	11 990	1 472 260	8 451	80 370	3 538		
Denmark	54 470	9 580	46 290	8 376	8 180	1 204		
Belgium	56 730	8 407	44 090	6 431	12 640	1 976		
Greece	463 860	8 070	461 080	7 701	2 780	369		
Austria	111 160	5 671	102 130	5 249	5 290	223	3 740	199
Hungary	433 700	5 578	344 470	2 715	89 230	2 863		
Ireland	163 690	5 013	162 310	4 852	1 380	161		
Sweden	59 320	4 679	46 880	3 150	12 440	1 529		
Portugal	323 470	4 509	278 610	2 746	44 850	1 763		
Czech Republic	105 080	4 447	33 230	1 013	71 850	3 434		
Finland	57 550	3 398	45 190	2 613	3 770	402	8 580	384
Bulgaria	320 230	3 336	274 050	1 729	46 050	1 605	130	2
Croatia	175 050	2 029	165 520	1 505	9 530	524		
Lithuania	144 770	1 919	129 850	1 493	14 910	426		
Slovakia	50 600	1 812	15 510	315	35 090	1 497		
Slovenia	82 450	1 009	80 120	908	2 330	102		
Latvia	82 090	990	76 090	793	850	15	5 150	182
Estonia	22 060	676	11 110	198	10 950	478		
Cyprus	16 550	495	14 510	305	2 040	190		
Luxembourg	3 530	314	2 880	258	270	6	380	50
Malta	4 450	97	4 010	79	280	11	150	6
Total	**9 508 560**	**331 044**	**8 144 290**	**227 471**	**1 152 770**	**83 050**	**211 450**	**20 523**
% of total labour			86%		12%		2%	
% of total SO				69%		25%		6%

Source: Eurostat [ef_kvaareg]

*Labour force directly employed by the holding, measured in Annual Work Units (AWU)

Annex Table 3. Regular EU agricultural labour force per unit area and per holding in Member States, 2013

EU-28	Regular labour (1000 persons)	Regular labour (1000 AWU*)	Utilised agricultural area (1000 ha)	ha/ person	ha/ AWU	Number of holdings (1000)	Persons/ holding	AWU/ holding	Average holding area (ha)
Romania	6 578	1 452	13 056	2.0	9.0	3 630	1.8	0.4	3.6
Poland	3 559	1 866	14 410	4.0	7.7	1 429	2.5	1.3	10.1
Italy	2 139	696	12 099	5.7	17.4	1 010	2.1	0.7	12.0
Spain	1 783	661	23 300	13.1	35.2	965	1.8	0.7	24.1
Greece	1 238	412	4 857	3.9	11.8	710	1.7	0.6	6.8
Hungary	1 060	400	4 657	4.4	11.6	491	2.2	0.8	9.5
France	907	640	27 739	30.6	43.3	472	1.9	1.4	58.7
Germany	706	467	16 700	23.6	35.8	285	2.5	1.6	58.6
Portugal	626	299	3 642	5.8	12.2	264	2.4	1.1	13.8
Bulgaria	558	298	4 651	8.3	15.6	254	2.2	1.2	18.3
United Kingdom	435	257	17 327	39.9	67.5	185	2.3	1.4	93.6
Croatia	388	173	1 571	4.0	9.1	157	2.5	1.1	10.0
Austria	338	108	2 727	8.1	25.3	140	2.4	0.8	19.4
Lithuania	298	142	2 861	9.6	20.1	172	1.7	0.8	16.7
Ireland	270	161	4 959	18.4	30.9	140	1.9	1.2	35.5
Slovenia	201	79	486	2.4	6.1	72	2.8	1.1	6.7
Netherlands	193	132	1 848	9.6	14.0	67	2.9	2.0	27.4
Latvia	174	82	1 878	10.8	23.0	82	2.1	1.0	23.0
Czech Republic	132	101	3 491	26.4	34.5	26	5.0	3.9	133.0
Sweden	131	56	3 036	23.2	54.5	67	1.9	0.8	45.2
Finland	120	53	2 282	19.0	43.1	54	2.2	1.0	42.0
Denmark	81	52	2 619	32.3	50.1	39	2.1	1.3	67.5
Slovakia	80	49	1 902	23.8	38.8	24	3.4	2.1	80.7
Cyprus	77	15	109	1.4	7.2	35	2.2	0.4	3.1
Belgium	75	52	1 308	17.5	25.1	38	2.0	1.4	34.6
Estonia	44	22	958	21.7	44.4	19	2.3	1.1	49.9
Malta	15	4	11	0.7	2.5	9	1.6	0.5	1.2
Luxembourg	5	3	131	26.5	38.8	2	2.4	1.6	63.0
	22 210	**8 734**	**174 614**	**7.9**	**20.0**	**10 841**	**2.0**	**0.8**	**16.1**

Source: Eurostat [ef_kvaareg] *AWU = Annual Work Unit

Annex Table 4. Regular EU agricultural labour force by farm size, 2013 (1000 persons)

EU-28	Regular labour (1000 persons)	Regular labour by holding size (1000 persons)								
		Zero ha	<2 ha	2-4.9 ha	5-9.9 ha	10-19.9 ha	20-29.9 ha	30-49.9 ha	50-99.9 ha	100 ha +
Romania	6 578	106	4 431	1 396	412	112	23	19	17	62
Poland	3 559	21	742	1 073	781	546	166	113	58	57
Italy	2 139	3	523	635	367	260	108	100	83	61
Spain	1 783	37	436	426	257	211	96	101	95	124
Greece	1 238	11	578	329	165	88	30	23	12	3
Hungary	1 060	76	662	89	55	45	20	19	20	74
France	907	19	81	91	71	82	58	89	183	233
Germany	706	9	32	25	84	120	61	96	125	156
Portugal	626	4	275	159	74	47	17	16	14	22
Bulgaria	558	19	365	62	25	17	8	9	9	44
United Kingdom	435	6	8	18	47	55	36	48	75	142
Croatia	388	1	136	118	63	34	11	9	7	8
Austria	338	2	28	60	58	78	44	39	23	7
Lithuania	298	3	35	100	61	36	11	10	12	29
Ireland	270	0	4	12	26	61	47	62	46	12
Slovenia	201	0	45	66	50	25	7	4	2	2
Netherlands	193	6	20	27	25	26	18	30	30	12
Latvia	174	2	31	31	33	32	11	10	7	17
Czech Republic	132	4	6	5	11	10	5	5	8	76
Sweden	131	2	2	11	27	24	12	14	17	23
Finland	120	0	2	4	11	21	17	24	26	14
Denmark	81	5	1	2	11	11	6	7	10	28
Slovakia	80	3	11	13	6	4	2	2	2	38
Cyprus	77	1	55	12	4	2	1	1	1	1
Belgium	75	1	3	7	9	12	10	13	14	6
Estonia	44	2	3	7	7	6	3	2	2	12
Malta	15	1	11	2	1					
Luxembourg	5	0	0	0	0	0	0	0	1	1
Total persons	22 210	343	8 530	4 778	2 743	1 965	825	865	899	1 263
% of total	100%	2%	38%	22%	12%	9%	4%	4%	4%	6%
Total AWU*	8 734	156	2 022	1 673	1 200	1 021	472	541	626	1 023

Source: Eurostat [ef_olfaa] *AWU = Annual Work Units

Annex Table 5. Regular EU agricultural labour force by farm size, 2013 (1000 AWU)

EU-28	Regular labour (1000 AWU*)	Regular labour (1000 AWU) by holding size								
		Zero ha	<2 ha	2- 4.9 ha	5-9.9 ha	10-19.9 ha	20-29.9 ha	30-49.9 ha	50-99.9 ha	100 ha +
Poland	1 866.5	13.2	284.0	498.2	433.8	350.1	115.0	81.0	42.4	48.8
Romania	1 451.9	18.2	758.6	396.2	146.1	48.0	11.5	10.5	10.6	52.2
Italy	696.2	1.7	96.1	161.0	125.5	114.3	54.6	54.6	49.7	38.7
Spain	661.1	26.1	117.4	117.1	80.8	81.1	43.2	52.5	55.9	87.0
France	640.5	13.7	35.9	42.8	38.9	53.0	40.3	67.4	148.4	200.1
Germany	466.8	6.7	16.9	14.5	36.1	61.2	37.8	66.9	94.1	132.7
Greece	412.5	8.4	114.9	118.4	77.5	48.8	18.1	15.4	8.5	2.5
Hungary	400.0	27.6	189.8	34.6	25.4	22.7	11.0	11.7	13.9	63.4
Portugal	298.6	2.9	114.2	71.5	36.3	26.2	10.0	10.7	9.6	17.2
Bulgaria	298.4	12.9	168.6	33.1	14.3	11.2	5.1	6.2	7.0	39.9
United Kingdom	256.7	2.3	4.3	7.8	16.9	24.9	18.8	27.9	49.5	104.3
Croatia	173.3	0.9	47.4	50.6	31.9	19.4	6.4	5.9	4.7	6.1
Ireland	160.6	0.1	1.6	4.9	12.4	33.5	28.3	39.9	31.2	8.7
Lithuania	142.5	2.5	11.6	37.2	27.3	18.7	6.6	6.6	8.4	23.7
Netherlands	131.8	4.2	13.3	16.1	15.9	17.3	12.6	21.4	22.0	9.0
Austria	107.7	0.4	5.2	11.4	15.4	25.8	16.9	17.2	11.3	4.2
Czech Republic	101.1	3.9	2.8	2.4	4.9	5.5	3.3	3.6	6.2	68.6
Latvia	81.8	1.1	8.7	11.4	14.8	15.7	6.1	5.7	4.8	13.6
Slovenia	79.5	0.1	11.9	24.5	21.6	12.9	3.8	2.3	1.1	1.4
Sweden	55.7	0.9	1.5	2.4	6.2	6.9	4.4	6.3	9.8	17.5
Finland	53.0	0.3	1.7	1.0	2.5	6.0	6.5	11.2	14.4	9.5
Denmark	52.3	3.7	1.0	1.2	3.7	4.5	2.8	3.9	7.0	24.6
Belgium	52.0	0.5	2.1	4.1	5.4	7.9	6.7	9.9	11.0	4.5
Slovakia	49.0	1.6	3.4	4.1	2.1	1.8	0.7	1.0	1.3	33.0
Estonia	21.6	1.3	0.8	1.7	2.0	2.1	1.0	1.1	1.3	10.2
Cyprus	15.2	0.5	6.1	3.3	1.9	1.4	0.6	0.6	0.5	0.4
Malta	4.4	0.3	2.4	1.1	0.5	0.1				
Luxembourg	3.4	0.0	0.1	0.2	0.3	0.3	0.1	0.3	1.0	1.2
Total AWU	8 734	156	2 022	1 673	1 200	1 021	472	541	626	1 023
% of total	100%	2%	23%	19%	14%	12%	5%	6%	7%	12%

Source: Eurostat [ef_olfaa] *Annual Work Units

Annex Table 6. Number of EU farmers/farm managers by age group, 2013 (1000)

EU-28	Number of farmers/managers (1000)					
	Total	**< 35 years**	**35-44 years**	**45-54 years**	**55-64 years**	**65+ years**
Romania	3 629.7	172.0	504.8	614.6	851.2	1 487.1
Poland	1 429.0	173.6	339.1	431.8	346.9	137.7
Italy	1 010.3	45.7	109.6	218.6	235.8	400.7
Spain	965.0	35.7	122.9	241.6	243.0	321.8
Greece	709.5	36.9	104.3	169.7	176.4	222.2
Hungary	491.3	30.2	73.2	95.5	143.7	148.8
France	472.2	41.6	90.3	154.4	127.3	58.5
Germany	285.0	19.5	56.1	106.0	84.8	18.6
Portugal	264.4	6.5	19.1	44.0	62.4	132.4
Bulgaria	254.4	16.3	33.7	47.0	64.1	93.3
United Kingdom	185.2	7.2	20.5	49.2	51.7	56.7
Lithuania	171.8	9.7	23.8	44.0	35.9	58.4
Croatia	157.5					
Austria	140.4	15.4	34.3	51.2	27.5	12.1
Ireland	139.6	8.7	23.3	35.1	35.5	37.0
Latvia	81.8	4.1	11.9	21.5	19.8	24.6
Slovenia	72.4	3.5	10.4	19.1	21.1	18.3
Netherlands	67.5	2.1	11.0	22.1	18.1	14.2
Sweden	67.2	2.9	8.6	16.7	18.8	20.2
Finland	54.4	4.6	12.0	16.4	15.9	5.5
Denmark	38.8	1.0	5.7	12.1	10.7	9.3
Belgium	37.8	1.5	5.7	12.4	10.1	8.0
Cyprus	35.4	0.6	2.4	7.6	10.6	14.1
Czech Republic	26.3	1.2	3.9	6.2	8.9	6.0
Slovakia	23.6	1.9	3.6	5.9	7.1	5.1
Estonia	19.2	1.4	3.2	4.5	4.2	5.8
Malta	9.4	0.4	1.2	2.3	3.1	2.4
Luxembourg	2.1	0.2	0.4	0.7	0.6	0.3
	10 841	**644**	**1 635**	**2 450**	**2 635**	**3 319**
	100%	**6%**	**15%**	**23%**	**24%**	**31%**

Source: Eurostat [ef_mptrainman]

Annex Table 7. Number of EU farmers/farm managers achieving different levels of training, 2013

EU-28	Total farmers/ managers (1000)	Practical experience only		Basic training		Full agricultural training	
		1000	%	1000	%	1000	%
Italy	1 010.3	31.3	3%	917.3	91%	61.8	6%
Netherlands	67.5	19.0	28%	43.3	64%	5.2	8%
Germany	285.0	91.0	32%	151.7	53%	42.3	15%
Luxembourg	2.1	0.8	38%	0.3	12%	1.0	50%
France	472.2	181.6	38%	152.3	32%	138.4	29%
Czech Republic	26.3	12.3	47%	4.9	19%	9.1	35%
Slovenia	72.4	36.2	50%	27.6	38%	8.5	12%
Austria	140.4	70.4	50%	31.8	23%	38.2	27%
Ireland	139.6	70.3	50%	35.6	26%	33.7	24%
Finland	54.4	27.8	51%	20.9	38%	5.7	10%
Poland	1 429.0	746.1	52%	288.8	20%	394.0	28%
Latvia	81.8	47.8	58%	10.8	13%	23.2	28%
Belgium	37.8	22.3	59%	7.5	20%	8.0	21%
Estonia	19.2	11.6	60%	2.7	14%	4.9	26%
Lithuania	171.8	112.3	65%	33.1	19%	26.4	15%
United Kingdom	185.2	126.4	68%	30.2	16%	28.6	15%
Sweden	67.2	46.5	69%	7.7	12%	12.9	19%
Slovakia	23.6	17.8	76%	3.6	15%	2.2	9%
Hungary	491.3	403.6	82%	70.7	14%	17.0	3%
Spain	965.0	793.6	82%	155.7	16%	15.7	2%
Portugal	264.4	218.7	83%	39.2	15%	6.5	2%
Malta	9.4	8.2	87%	1.1	12%	0.1	1%
Cyprus	35.4	32.7	93%	2.5	7%	0.2	1%
Bulgaria	254.4	236.3	93%	3.4	1%	14.8	6%
Greece	709.5	666.3	94%	39.1	6%	4.2	1%
Romania	3 629.7	3 498.9	96%	113.8	3%	17.0	0%
Denmark	38.8	38.8	100%				
Croatia	157.5						
	10 841.0	**7 568.6**	**70%**	**2 195.2**	**20%**	**919.8**	**8%**

Source: Eurostat [ef_mptrainman]

Annex Table 8. Areas of specialist types of farming in Member States, 2013 (1000 hectares)

EU-28	Total utilised agricultural area	Cereals, oilseed and protein crops	Indoor horticulture	Outdoor horticulture	Vineyards	Fruit and citrus fruit	Olives	Dairying	Cattle rearing/ fattening	Sheep, goats, grazing livestock	Pigs	Poultry
France	27 739	7 579.5	38.8	67.9	1 116.1	227.6	7.5	3 818.6	3 411.3	1 767.8	278.3	325.1
Spain	23 300	6 803.4	60.9	136.1	879.9	885.2	1 862.4	499.1	2 601.9	2 192.9	387.4	45.2
UK	17 327	2 947.9	13.8	15.3	1.3	46.9		1 368.8	2 115.4	5 112.1	77.6	136.6
Germany	16 700	3 604.7	8.8	19.6	114.3	64.3		3 964.9	942.4	641.1	740.1	131.1
Poland	14 410	3 853.4	58.4	88.4		352.7		1 960.5	203.1	190.2	328.8	106.3
Romania	13 056	4 722.6	10.3	12.3	84.3	130.2		379.1	54.0	1 027.3	26.9	84.6
Italy	12 099	2 228.3	72.7	22.1	826.1	497.6	606.2	820.3	910.9	1 489.2	137.3	42.8
Ireland	4 959	258.1	1.6	0.8		0.8		873.9	2 123.4	782.9	8.2	7.9
Greece	4 857	526.5	14.2	18.2	54.8	149.3	505.2	42.1	53.7	703.2	3.9	4.8
Hungary	4 657	2 506.1	9.8	1.7	49.1	67.7		202.1	125.7	110.3	25.2	32.4
Bulgaria	4 651	2 882.6	3.8	7.3	29.4	33.2		145.3	26.8	99.8	10.9	8.2
Portugal	3 642	151.9	5.1	15.3	160.2	198.8	151.0	136.9	896.1	617.5	17.5	4.7
Czech Republic	3 491	870.5		0.7	16.8	14.7		289.0	394.7	83.2	4.6	5.2
Sweden	3 036	656.8	1.5	14.4		2.6		591.9	565.5	284.0	52.9	25.0
Lithuania	2 861	1 189.4	2.7	7.9		12.4		531.5	42.9	23.4	7.0	5.2
Austria	2 727	394.2	1.8	0.4	56.4	17.3		617.8	249.1	119.0	116.6	23.3
Denmark	2 619	684.2	1.9	1.5		3.8		518.0	93.4	55.2	413.1	21.8
Finland	2 282	884.2	5.1	21.4		3.4		487.5	185.7	64.8	72.1	32.5
Slovakia	1 902	639.8	1.8	1.7	7.7	3.4		221.6	107.0	98.3	5.0	5.3
Latvia	1 878	620.5	0.3	7.6		9.3		399.4	53.8	41.8	8.1	2.9
Netherlands	1 848	29.6	12.1	54.5	0.2	20.8		825.8	128.0	102.9	45.0	15.8
Croatia	1 571	345.8	1.2	1.9	16.7	17.2	13.8	136.3	43.8	167.9	7.5	1.3
Belgium	1 308	44.1	3.9	17.0		17.1		215.1	238.1	22.1	39.6	8.3
Estonia	958	305.5	0.3	3.4		3.6		238.0	69.3	44.8	4.6	3.2
Slovenia	486	35.3	0.4	0.6	10.3	8.0	0.6	99.0	111.5	38.2	2.4	2.7
Luxembourg	131	4.0	0.0	0.0	1.4	0.1		52.4	25.3	6.8	1.7	0.3
Cyprus	109	14.6	0.7	4.8	4.0	9.1	6.4	9.1	0.1	16.6	0.6	0.1
Malta	11		0.1	2.7	0.4	0.2	0.1	0.4	0.0	0.9	0.1	0.1
Total	**174 614**	**44 784**	**332**	**546**	**3 429**	**2 797**	**3 153**	**19 444**	**15 773**	**15 904**	**2 823**	**1 082**

Source: Eurostat, [ef_kvftaa]

Annex Table 9. Standard output (SO) for specialist types of farming in Member States , 2013

EU-28	Standard output (million euros)											
	Utilised agricultural area	Cereals, oilseed and protein crops	Indoor horticulture	Outdoor horticulture	Vineyards	Fruit and citrus fruit	Olives	Dairying	Cattle rearing/ fattening	Sheep, goats, grazing livestock	Pigs	Poultry
France	56 914	8 468	805	1 306	10 256	1 398	8	7 246	2 514	1 795	2 938	3 430
Germany	46 252	4 330	1 328	412	1 096	641		11 482	1 386	597	5 627	2 580
Italy	43 767	2 684	2 006	292	6 292	2 921	1 061	3 974	1 758	2 646	4 989	3 805
Spain	35 979	3 398	2 602	1 349	1 328	3 228	1 853	2 372	2 364	1 934	5 513	3 108
UK	21 819	3 256	413	293	5	310		4 663	1 765	2 174	740	2 296
Poland	21 797	2 954	1 058	287		786		3 542	198	163	1 414	1 962
Netherlands	20 498	44	4 771	953	2	368		5 578	771	326	2 422	1 378
Romania	11 990	2 618	106	57	97	200		534	70	1 812	611	393
Denmark	9 580	758	339	7		16		2 262	177	87	3 575	248
Belgium	8 407	65	541	335		260		1 006	677	59	1 020	369
Greece	8 070	405	329	160	221	701	990	225	175	1 634	139	195
Austria	5 671	371	173	4	327	173		1 512	286	175	659	223
Hungary	5 578	1 832	114	11	72	136		366	42	73	313	695
Ireland	5 013	237	48	3		3		2 104	1 220	395	254	89
Sweden	4 679	444	164	69		21		1 500	512	220	236	279
Portugal	4 509	136	215	134	223	389	52	796	484	283	281	266
Czech Republic	4 447	765		23	106	34		403	168	40	175	312
Finland	3 398	415	248	112		10		1 229	225	78	281	209
Bulgaria	3 336	1 746	48	25	35	38		302	11	124	120	208
Croatia	2 029	329	17	11	64	54	34	334	98	61	81	47
Lithuania	1 919	664	8	6		6		418	12	4	84	79
Slovakia	1 812	500	17	65	11	5		187	31	35	56	146
Slovenia	1 009	40	10	7	28	37	3	296	145	35	15	67
Latvia	990	308	1	14		3		275	10	9	57	67
Estonia	676	122	2	4		2		282	22	17	57	22
Cyprus	495	5	16	39	7	48	8	82	0	67	80	11
Luxembourg	314	4	0	0	17	1		140	38	14	8	3
Malta	97		3	23	1	1	0	19	0	5	9	10
Total	**331 044**	**36 897**	**15 380**	**6 000**	**20 189**	**11 789**	**4 008**	**53 128**	**15 162**	**14 862**	**31 753**	**22 498**

Source: Eurostat, [ef_kvftaa]

Annex Table 10. Standard output (SO) per hectare for specialist types of farming in Member States , 2013

EU-28	Standard output per hectare (euros)											
	Utilised agricultural area	Cereals, oilseeds, protein crops	Indoor horticulture	Outdoor horticulture	Vineyards	Fruit and citrus fruit	Olives	Dairying	Cattle rearing/ fattening	Sheep, goats, grazing livestock	Pigs	Poultry
Netherlands	11 095	1 494	395 580	17 506	11 663	17 717		6 755	6 024	3 171	53 767	87 486
Malta	8 896		29 382	8 317	2 960	3 856	469	45 264	8 850	5 870	116 469	106 661
Belgium	6 428	1 469	138 808	19 668		15 148		4 677	2 846	2 683	25 753	44 708
Cyprus	4 531	343	22 197	8 082	1 829	5 320	1 314	9 101	3 887	4 016	128 310	164 107
Denmark	3 657	1 107	180 375	4 346		4 119		4 367	1 897	1 574	8 655	11 388
Italy	3 617	1 204	27 605	13 201	7 616	5 871	1 750	4 845	1 930	1 777	36 333	89 008
Germany	2 770	1 201	151 550	21 009	9 592	9 982		2 896	1 470	931	7 603	19 689
Luxembourg	2 395	984			12 152	6 627		2 664	1 491	2 098	4 826	12 614
Austria	2 080	942	98 586	8 630	5 790	10 001		2 448	1 150	1 474	5 649	9 575
Slovenia	2 078	1 145	25 562	13 311	2 725	4 604	4 243	2 986	1 299	912	6 345	24 376
France	2 052	1 117	20 741	19 241	9 190	6 143	1 030	1 898	737	1 015	10 556	10 553
Greece	1 662	768	23 099	8 752	4 039	4 693	1 959	5 353	3 259	2 324	36 102	40 270
Spain	1 544	499	42 692	9 913	1 509	3 647	995	4 752	909	882	14 230	68 814
Sweden	1 541	675	109 070	4 752		7 841		2 534	906	773	4 461	11 147
Poland	1 513	766	18 125	3 251		2 228		1 807	976	859	4 299	18 457
Finland	1 489	470	48 758	5 220		2 992		2 521	1 212	1 200	3 892	6 435
Croatia	1 291	951	14 655	6 002	3 843	3 149	2 465	2 450	2 228	363	10 761	36 267
Czech Republic	1 274	879		34 892	6 304	2 336		1 393	425	475	37 926	59 825
UK	1 259	1 104	29 940	19 139	4 022	6 608		3 407	835	425	9 537	16 807
Portugal	1 238	896	42 652	8 728	1 392	1 955	346	5 817	540	459	16 012	56 997
Hungary	1 198	731	11 701	6 841	1 461	2 009		1 811	332	665	12 398	21 491
Ireland	1 011	919	29 483	4 200		3 227		2 408	575	504	30 863	11 338
Slovakia	953	781	9 571	37 517	1 482	1 445		842	294	354	11 346	27 487
Romania	918	554	10 354	4 644	1 147	1 534		1 407	1 300	1 764	22 691	4 652
Bulgaria	717	606	12 777	3 450	1 190	1 142		2 081	428	1 245	11 002	25 322
Estonia	706	400	7 424	1 079		660		1 184	319	371	12 405	6 948
Lithuania	671	558	2 838	707		453		787	274	189	11 885	15 284
Latvia	527	497	4 282	1 803		332		689	183	212	7 117	23 229
Average SO	**1 896**	**824**	**46 377**	**10 999**	**5 887**	**4 215**	**1 271**	**2 732**	**961**	**934**	**11 247**	**20 789**

Source: Eurostat, [ef_kvftaa]

Annex Table 11. Standard Output (SO) of EU holdings by holding area, 2013

EU-28	All holdings	Holding area (ha)								
		Zero ha	<2 ha	2-4.9 ha	5-9.9 ha	10-19.9 ha	20-29.9 ha	30-49.9 ha	50-99.9 ha	100 ha +
Holdings (1000)	10 841	173	4 706	2 307	1 277	889	375	388	389	337
Utilised Agricultural Area (1000 ha)	174 614	0	3 578	7 313	8 941	12 442	9 135	14 975	27 264	90 966
Standard Output (million euros)	331 044	14 916	15 890	22 260	23 565	31 174	21 827	34 454	56 162	110 796
Average holding size (ha)	16.1	0	0.8	3.2	7.0	14.0	24.4	38.6	70.1	270.1
SO per holding (euros)	30 536	85 983	3 376	9 648	18 450	35 085	58 226	88 862	144 493	329 025
SO per hectare (euros)	1 896		4 441	3 044	2 636	2 506	2 390	2 301	2 060	1 218

Source: Eurostat, [ef_mpmanaa]

Annex Table 12. Standard Output (SO) of EU holdings by age of farmer, 2013

EU-28	Farmer age group					
	All farmers	< 35 years	35-44 years	45-54 years	55-64 years	65+ years
Holdings (1000)	10 841	644	1 635	2 450	2 635	3 319
Utilised Agricultural Area (1000 ha)	174 614	19 087	32 764	52 957	43 792	24 442
Standard Output (million euros)	331 044	28 874	71 150	110 509	81 672	36 811
Average holding size (ha)	16.1	29.6	20.0	21.6	16.6	7.4
SO per holding (euros)	30 536	44 816	43 516	45 102	30 994	11 091
SO per hectare (euros)	1 896	1 513	2 172	2 087	1 865	1 506

Source: Eurostat, [ef_mptrainman]

BRIEFING PAPER 3

TRENDS IN PRECISION AGRICULTURE IN THE EU

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List of abbreviations

3-G, 4-G	Third and fourth generation telecom network
AIOTI	Alliance of Internet of Things Innovation
App	Applications of electronic information
CAP	Common Agricultural Policy of EU
CEMA	association of Agricultural Machinery industry in Europe
CTF	Controlled Traffic Farming
DSS	Decision Support Systems
EC	European Commission
EU	European Union
EPCIS	Electronic Product Code Information Services
FI-space	F-space is Future Internet B2B internet collaboration platform
FMIS	Farm Management Information Systems
GAP	Good Agricultural Practices
GNSS	Global Navigation Satellite Systems
GS1	Global Standards One; Worldwide organization on standardization in telecom
ICAR	International Committee for Animal Recordings
ICT	Information and Communication Technologies
IoT	Internet of Things
MAP	Monitoring Agri-trade Policy
MRL	Market Readiness Level
MEP	Members of the European Parliament
LoRaWAN	Lang Range Wide Area Network, telecom network
PA	Precision Agriculture
PF	Precision Farming
PLF	Precision livestock farming
QR-code	Quick Response Code
RFID	Radio-frequency identification
RPAS	Remotely Piloted Aerial Systems (drones)
RTK	Real Time Kinemetic
STEEPED	Social, Technological, Economic, Environmental, Political/legal, Ethical, Demographic
STOA	Science and Technology Options Assessment
ToR	Terms of Reference
TRL	Technology Readiness Level
UAA	Utilised Agricultural Area
VRA	Variable Rate Application
VRT	Variable rate technology
WP	Work packages

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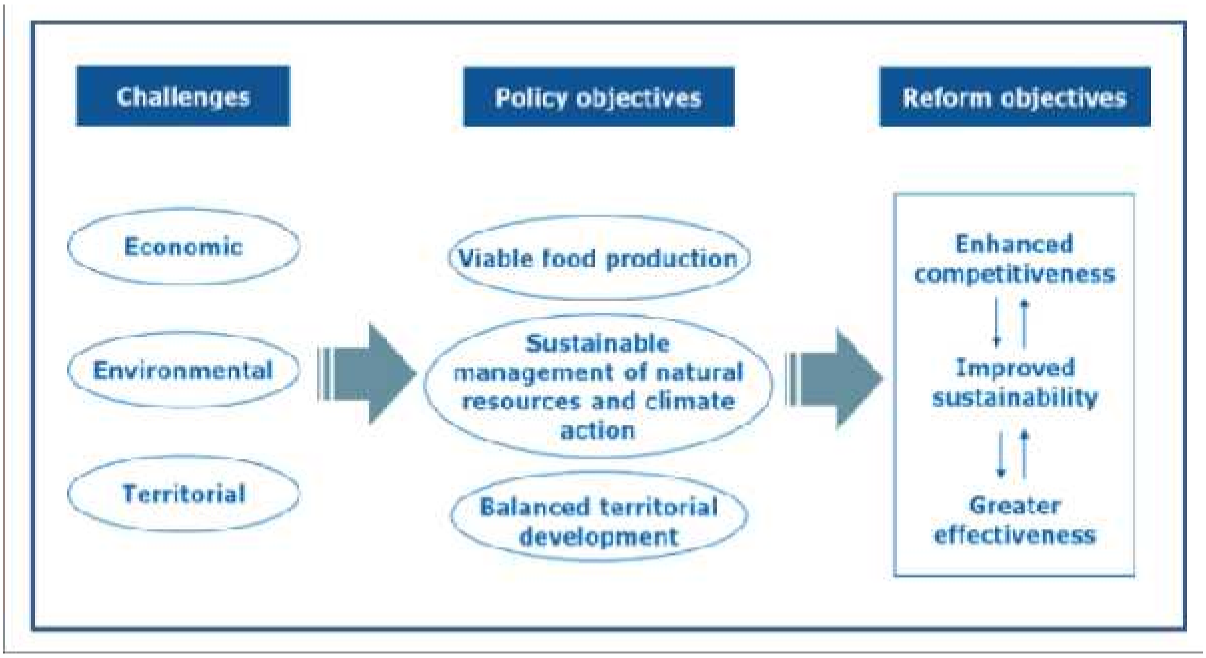
1 Main Policy issues

We start this briefing paper with a summary chapter on enabling technologies for future and current implementations of Precision Farming (PF), and how EU policies may be influenced by these implementations in agri-food chains. In Chapter 2 we describe enabling technologies and how they pave the way for Precision Agriculture (PA), and we describe first implementations. In Chapter 3 we give an outlook on opportunities and barriers for (the next level of) PA and relations with EU policies and regulations.



The EU agricultural policy is described in the Common Agricultural Policy (CAP) of 2013[1]. The box shows that the CAP objectives are divided over 3 themes: economic, environmental and territorial. Key objectives formulated in the CAP are viable food production, sustainable resource management of natural resources and climate action, and balanced terrestrial development.

In Table 1 we summarize specific CAP policy issues, and described how they are expected to be influenced by the adoption of precision farming (PF) technology. The rationale under Table 1 is that PA will produce 'More with Less' compared to common practice agriculture by using innovative enabling technologies from different domains in agri-food chains, with the aim to better capture variation in crops and livestock, in order to give plants and animals the most optimal treatments at the right time and smallest scales possible. More means higher yield and better quality. Less means less use of natural resources, agro-chemicals, energy and water, and less adverse environmental and social side-effects.

A wide range of enabling technologies for PA are available (Chapter 2.1). 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 PF practices are recognized in arable, vegetable and dairy farming (Chapter 2.2). PA technologies can also be applied to other sectors. At the moment, much

[1] http://ec.europa.eu/agriculture/cap-post-2013/

progress has been made in PF development, and PA market is fully embraced by the sector and investors, but the full potential of PA is not yet harvested.

In Chapter 3, an outlook is given on implementation of PA and interaction with EU policies and regulations. Barriers for implementation of PF technologies are related to relatively high level of skills required for farmers and farm advisors to apply PF, a lack of independent data on cost-benefit effects of PF, technical issues with implementation of specific technologies at the farm level, standardization problems, and need for specific sensors that allow accurate detection of specific soil, crop and animal conditions. The interaction between implementation of PA and some EU policies, regulations and directives is discussed.

Table 1. EU policy issues and the expected effect by precision agriculture, evaluated by the authors

How does precision agriculture influence policies ?		
Policy issue	**Description**	**Effect on policy objective***
Competitiveness of EU farming	Farm holdings will apply PF 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. 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 implementation of PF technologies, especially on farms where still a lot of work is done by low skilled workforces.	-
Skilled workforces	PA requires more skilled (ICT) farmers and 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 PF market grows.	++
Multi-functional agriculture	Farm holdings will be less diverse 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 EU for better life in cities because it creates new business opportunities and work for high skilled persons.	+
Food security	Sensor based monitoring systems and DSS will provide farmers and stakeholders better information and early warning on 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 better information and early warning on quality of food products.	++
Transparency of agri-food chains	See food safety.	++
Sustainable production	PF technologies allow production of 'more with less'. Use of natural resources, agrochemicals, anti-biotics and energy will reduce to the benefit of both farmers, the environment, and thus 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 apply mitigation	+

*++ and + are positive, = is neutral or unknown, - and -- are negative effects

2 Current precision agriculture practices

2.1 Precision farming and its enabling technologies

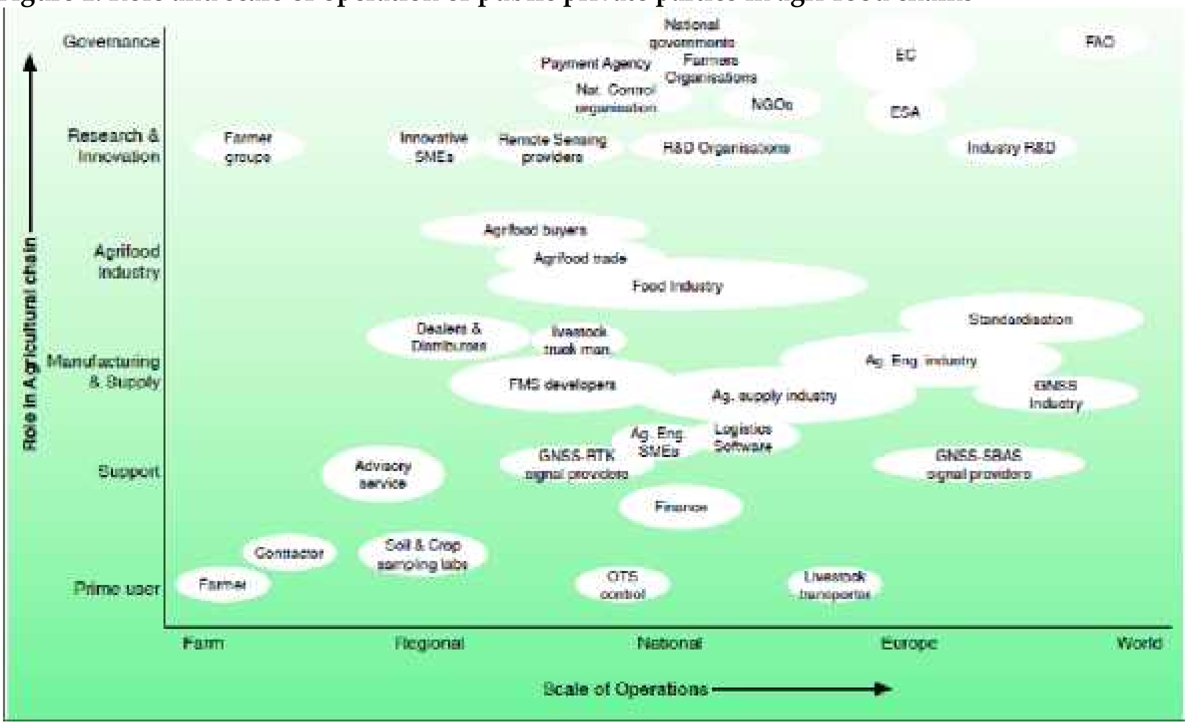
EU Agriculture today is an economic sector of around 11 million farm holdings that use 174 million hectares (ha) of agricultural land to produces a wide range of agricultural products (food, feed, flowers, fuel, fiber, fun). Farm gate value of the produce is in order of 200 billion euro per year (assuming 1000 euro per ha per year). EU farm holdings employs over 20 million persons, which is ca. 2 persons per holding[2]. It provides food security and safety to over 500 million EU inhabitants. Details are provided in Briefing Papers 1 and 2.

The agri-food business in the EU is much larger than the aforementioned farm gate value. Figure 2 shows an overview of the agri-food business in the EU. The figure shows the diversity of the agri-food sector and the development of precision agriculture industry.

Arable farms, which grow wheat, maize, oil seed, potatoes, sugar beet, pulses or field grown vegetables), use 60 per cent of the agricultural land in the EU, being the largest agricultural sector in the EU in terms of acreage and variety of products. Dairy farming, using grassland for feed production for livestock, is the second important sector in terms of acreage, using 34 per cent of the agricultural land. Milk is produced in every single EU Member State and is the EU best single product sector in terms of value at approximately 15 per cent of agricultural output (Eurostat data).

In the next chapters, we describe the development, status, and challenges on two main sectors for precision agriculture in the EU: arable farming and dairy farming. Permanent crops (ca. 6 per cent of agricultural land use in EU) and greenhouse crops are not included in this study.

Figure 1. Role and scale of operation of public private parties in agri-food chains



Source: Zarco-Tejada et al., 2014

Trends in EU agriculture relevant for PF have already been described in the first two briefing papers. They are shortly summarized as: (1) the number of persons working on farms in the EU is decreasing,

[2] http://ec.europa.eu/eurostat/data/database

and (2) average holding size in the EU is increasing. These trends favor introduction of precision farming technology, providing that finances and skills are not limiting. PF technologies require training in technology. About 70 per cent of the EU farmers only have 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 West European countries where farmers are more trained then in other parts of the EU (EIP-Agri Focus Group, 2015). In Figure 3 we show an artist impression of PF in the EU.

Before describing PF practices in chapter 2.2, we described what we mean by PF and summarize its enabling technologies in chapters 2.2.1-2.2.6. Precision farming (PF) aims at giving crops and livestock the right treatment at the right time and smallest scale possible in order to optimize inputs and yield in a more sustainable (for people, planet, profit) way. In other words, PF is a farming management concept based on observing, measuring and responding to inter- and intra-field variability in crops and livestock. PF requires technology to capture the variation. The following groups of technology enabled the development and implementation of precision farming: Object identification technology, sensors, Global Navigation Satellite Systems, Connectivity and other Information and Communication technology, robotics and autonomous navigation. We expect more technologies will enter the agri-food sector in years to come to make precision farming more sustainable. Figure 3 is an artist impression of PF.

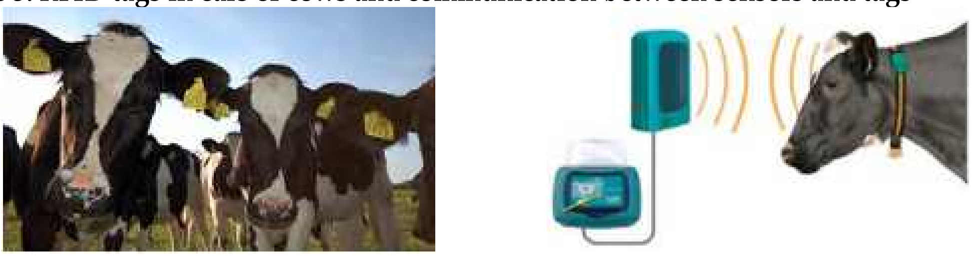
Figure 2. Artist impression of precision farming

Source: ZLTO, The Netherlands, 2014

2.1.1 Object identification technology

Several technologies have become available for object identification. They are used in agriculture to track and trace fresh and processed agricultural products, animals and supply chain products. Radio-frequency identification (RFID) is the oldest technology being used, starting in the 1960s. RFID uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves. Active tags have a local power source such as a battery and may operate at hundreds of meters from the RFID reader (see Figure 3). More recently adopted technologies are barcoding and QR-coding. A barcode is an optical machine-readable representation of data relating to the object to which it is attached. QR-code (abbreviated from Quick Response Code) is the trademark for a type of matrix barcode (or two-dimensional barcode) first designed for the automotive industry in Japan.

Figure 3. RFID tags in ears of cows and communication between sensors and tags



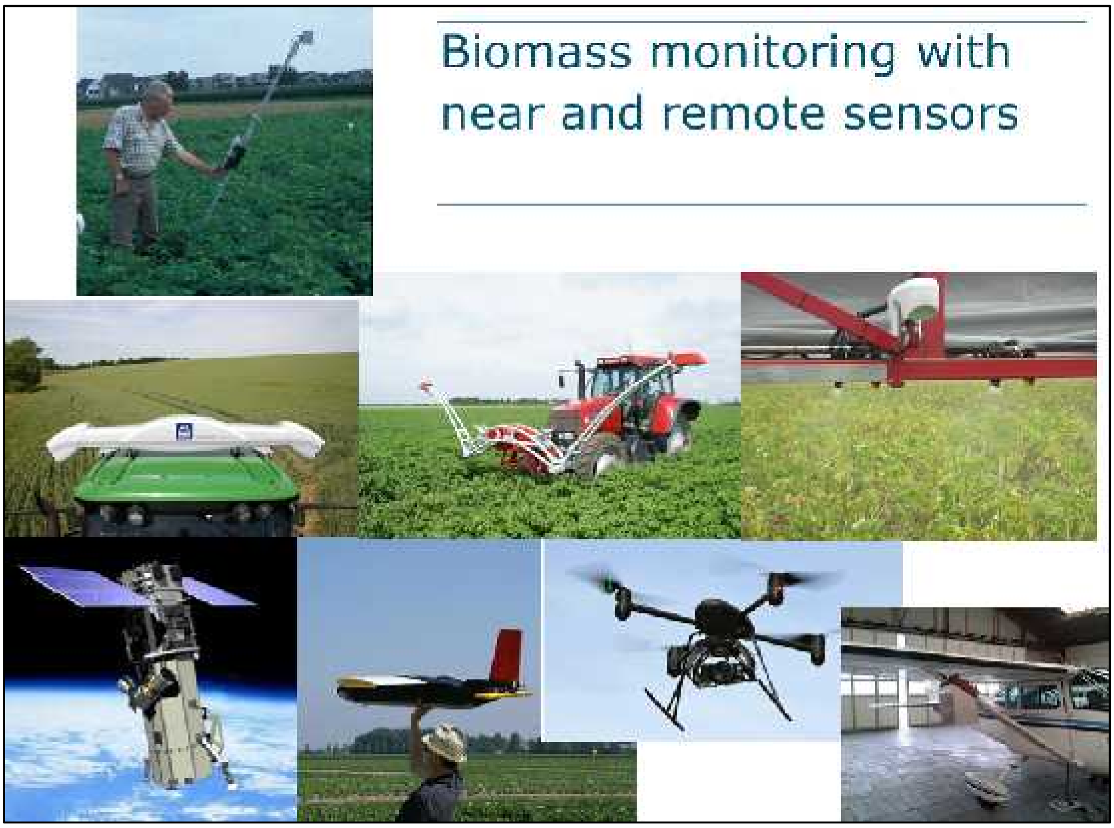
Aforementioned technologies require a tag on the object. Identification of untagged objects in agriculture is an expected next step. This requires sensor (see also 2.1.2) and image analysis / mathematical pattern-recognition (see 2.1.4) technologies. They allow identification and geo-localization of stationary and/or moving objects based on detectable features of the object. An example is Iris-scanner technology for unique identification of human beings, being used on e.g. airports. In agriculture, technology for identification of animals and plants is by far not mainstream technology yet (see Annex 1). Sensors for detection of weed plants and diseases of plants have a so-called Technology Readiness Level (TRL) of 5-6.

Technology Readiness Level (TRL) is measured on a scale of 1 – 9, and 7 or higher means efficacy demonstrated under practical conditions. We expect breakthrough technologies on this subject in the coming years, e.g. near-real time detection of specific plant and animal diseases.

2.1.2 Sensor technology

PF requires sensors that capture the relevant spatial and temporal variation in the agro-eco environment. A sensor is an object that can detect events or changes in its environment, and then provide a corresponding output, preferably as digital data. Farmers can make use of a wide range of sensors. Table A-1 in the Annexes contains a summary of sensors that are used or being developed for use in precision farming for capturing variation in soils, crops, climate and animal behaviour. The table illustrates the diversity in technologies applied in sensors to measure different properties. Thermal, optical, mechanical, chemical measurements are applied to quantify crop biomass, plant stress, pests and diseases, soil properties, climatic conditions and animal behaviour. The table also shows technology and market readiness of the sensors. Sensors can be positioned far away from the object (camera's on satellites or airplanes) or near the object (camera's mounted on field equipment or in stables) (Figure 4). Some of these sensors have reached TRL 8-9 and are used in practice with proven added value and good accuracy (see Annex 1 and Figure 6). Others are still in development. Presently, sensors for quantification of aboveground crop biomass, some important soil and climate properties and animal behaviour allow the implementation of the first precision farming applications (Figure 6). Other sensors, like sensors for detection of pests and diseases, soil nutrients and crop/product quality, still require further development before they can be used in precision farming applications. We expect that investments in sensors for precision farming will grow in the coming years.

Figure 4 Illustrations of proximal (near by) and remote crop (on RPAS, manned airplane or satellite) biomass sensors



Source: Kempenaar, 2015.

2.1.3 Global Navigation Satellite Systems and connectivity

PF requires an GNSS for geo-referencing of the spatial variation captured by sensors. GNSS means global satellite navigation systems. America, Russia, EU and China developed an GNSS (GPS, GLONASS, Galileo or Beidou, resp.). GNSS signal receivers on farms are used to geo-reference data. The GNSS systems were developed in the 20th century, mainly to help military personnel find their way, but civilian and agricultural applications soon became numerous. In Table 2 agricultural applications now possible with GNSS are summarized. Some of them already have become mainstream in agriculture. Multinational machine companies have developed and marketed GNSS receivers and services for controlled traffic farming. This allows farmers to drive on planned so-called "tram lines'' on the field and reduce overlay in field interventions. Farmer's groups have also developed GNSS services, like 06-GPS[3], in order to get better coverage of GNSS signals and to become brand independent. Introduction of GNSS hardware and services started around 2005. Van der Wal estimated that 10 per cent of EU farms used GNSS for controlled traffic farming in 2012/2013 (see Figure 5, (Van der Wal, 2013)). In the Netherlands, the percentage was already at 47 per cent those years. Today, the use of GNSS on farms is already higher than the statistics shown in Fig 5. In Europe, the use of Real Time Kinemetic (RTK) GNSS (which is a GNSS with accuracy of +/-2 cm) is highest. This is because EU agriculture is quite diverse and requires higher precision than agriculture in other continents.

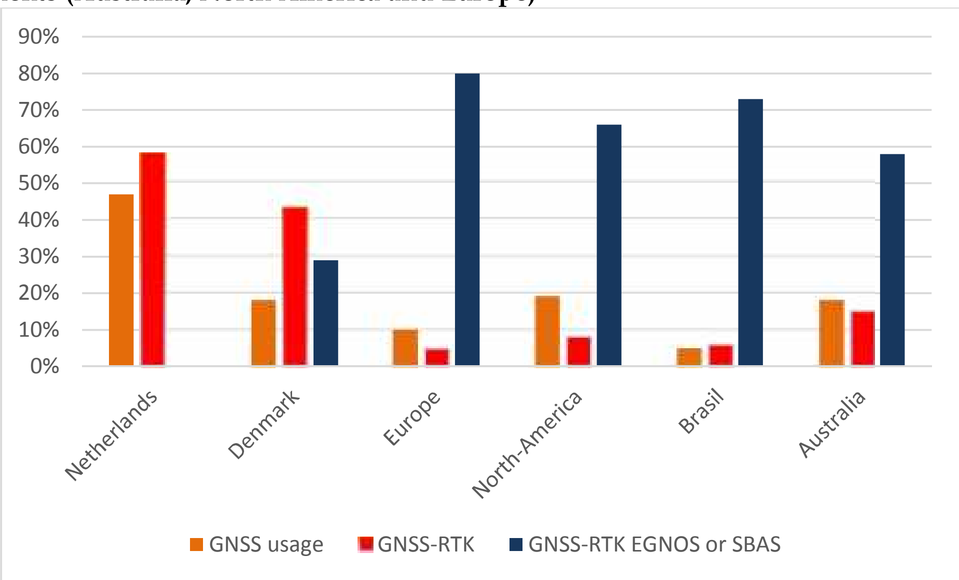
[3] http://www.06-gps.nl

Table 2. GNSS applications in different agricultural processes

	Position	Position, Time	Position, Time and Navigation
Production Efficiency	Mapping; Variable Rate Application; Field work optimisation; sampling;	Harvest monitoring; animal tracking;	Machine Guidance; Robotics; UASs
Farm Management	Mapping, Crop Rotation, Daily Planning; contracting.	Farm machine movement; Registration of field work; animal tracking; virtual fencing;	
Logistics	Unique parcel ID;	Track&Trace (produce, livestock, manure, etc.)	Harvest pick-up; Transport.
License to Operate	Mapping; CAP declaration; Area Measurement; Control; Eco Focus	Livestock Welfare in Transport; Spraying logbook;	

Source: Van der Wal, 2013

Figure 5. Use of GNSS on arable farms in some countries (The Netherlands, Denmark and Brazil) and continents (Australia, North America and Europe)*



Source: Van der Wal, 2015

*RTK: Real Time Kinematic; EGNOS: European Geostationary Navigation Overlay Service; SBAS: Satellite Based Augmentation System

Figure 6 shows grid level ranges from normal (ca. 30 x 30 m), plant level (ca 30 x 30 cm), leaf level (ca. 3 x 3 cm) to spots on leaves level (ca. 0.5 x 0.5 cm). Crop biomass grid monitoring is used in practice, while leaf and disease monitoring not yet.

Figure 6. Different levels of resolution in precision farming.

Source: Nieuwenhuizen & Kempenaar, 2012

2.1.4 Information and communication technology

Farmers started to use Farm Management Information Systems (FMIS) in the 1980s when stand-alone computers became mainstream. A FMIS is a system for collecting, processing, storing and disseminating of data in the form of information related to production parameters to support the farm management. Adoption of FMIS by EU farmers differs from country to country, ranging from 6 per cent (Greece) to 70 per cent (Finland) (Kempenaar, 2014). Besides bookkeeping, farmers started to apply electronical Decision Support Systems (DSS) for crop and livestock management.

After 2000, the digitalization of farming became widespread (Wolfert et al., 2012, Tops et al., 2015). Hereafter we only summarize main events. When internet became mainstream shortly before 2000, it allowed farmers to have access to data and information, decision making and communication. A wide range of internet platforms with farmer specific information has been developed over time. Data storage services (mostly cloud-based), GIS systems and data analysis software became available Wireless communication via e.g. 3-G, 4-G and LoraWAN[4] networks, etc. became possible. DSS became easily available as apps on internet platforms and smartphones. These apps can provide farmers specific information such as on weather conditions, status of crops, heat detection and movement of animals, and give management advices. Service companies deliver climate data and satellite data to farmers via Apps on computers and smart phones. Early warning systems are introduced in farming, e.g. warning for presence of specific diseases. Farm machine manufactures cooperating in CEMA have developed standards for machine to machine communication, e.g. ISOBUS standard. Software service companies and stakeholders cooperation in GS1[5], Alliance of Internet of Things Innovation (AIOTI) and AgGateway[6], are also working on standardization, e.g. EPCIS and FI-space. A whole new industry is developing around these new opportunities.

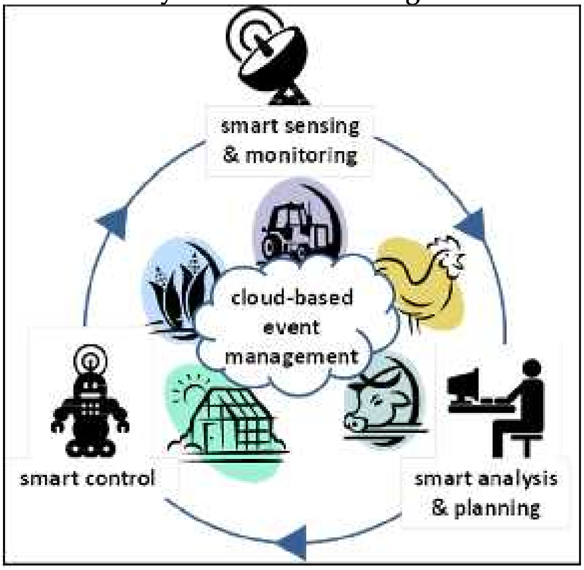
[4] LoraWAN™: this is a crowd sourced city-wide Internet of Things data network; https://thethingsnetwork.org/

[5] GS1: Global Standards One; worldwide organization focussed in standardization in telecom

[6] AgGateway is a non-profit consortium of businesses serving the agriculture industry, with the mission to promote, enable and expand eBusiness in agriculture; http://www.aggateway.org/Home.aspx

This all facilitates the PF processes cycle of 'Smart sensing & Monitoring, or Sensing', 'Smart analysis & planning, or Thinking', and 'Smart control, or Acting' (see Figure 7)

Figure 7. Sense, Analyse and Control cycle in smart farming.



Source: Wolfert et al., 2012

Berger[7], a consultant, estimated the global market for PA to be 2.3 billion euro at the end of 2014, and to be 4.5 billion euro in 2020. The PA market consists of hardware devices (automation and control systems, sensing and monitoring devices), software and services (farm management software, cloud-based, software services, etc.), technology (GPS, GIS, remote sensing, variable rate technology etc.), hardware applications (yield monitoring, field mapping, soil monitoring etc.), and software applications (crop management, financial management, farm inventory management, weather tracking and forecasting etc.). Berger estimated the EU PA market on 0.4 and 1.0 billion euro in 2014 and 2020, resp. Rabobank estimated in 2015 the total market of data-intensive PA, including big data and IoT, on 8 - 9 billion euro[8]. At the farm level, the market for crop monitoring was estimated by Piper Jaffray Bank on 5 euro per ha per year, and the market for data analytics and advice in agriculture on 30-50 euro per ha per year (Precision Farming Software Primer, 2014). The estimates by Piper Jaffray Bank are indicative for what farmers are willing to pay for digital services in PA. The estimates do not include investments in hardware.

2.1.5 Robotics in agriculture

PF comes in three steps: Sensing, Thinking and Acting, or actuation. This last step, sometimes called robotics, requires advanced technology that implements a task at the right place, time and intensity, if possible autonomously. We cannot describe all relevant technologies here because of the many technologies applied. For a state of art overview, we refer to the International Federation of Robotics, in particular the Book on Advances in robot technologies (Caverot, 2015). Although most investments are done in car-industry robots, significant developments also took place in farm equipment.

The farm equipment industry consist of several multinational and family owned companies. They have a long relation with farming of over 100 years, dedicated to deliver customized machine solutions for work what was done by 'hand' or animals in the past. Since the 1980s, we see a dawn of machines designed to implement tasks with high precision at relatively small scales. They require mechatronics

[7] http://www.rolandberger.com/press_releases/market_for_smart_agriculture_applications_growing.html
[8] http://hugin.info/133178/R/1965336/717569.pdf

that steer the implements of machines with no or very little human intervention, besides an optimized hardware design. The task of the operator becomes more and more a supervisor task.

Today, farmers can implement technology that allow them to apply variable rate technology in soil tillage, seeding, fertilizer application, weed control, crop protection and irrigation. Figure 8 shows an illustration of a variable rate seeder with processor and controller. Further advances are expected towards machines with even more precision. Selective harvest methods and selective storage are expected in years to come. In the dairy sector, we see introduction of automated feeding systems, milk robots, and cleaning machines. Some of these technologies are elaborated in the chapter on PF practices.

Figure 8. Prototype autonomous tractor and variable rate precision sprayer

Source: Kempenaar, 2013

2.1.6 Autonomous vehicles

The last group of enabling technologies we shortly address, is the group of autonomous vehicles. Currently, we see two types of autonomous vehicles: (1) vehicles such as tractors or especially designed mobile platforms mounted with different technologies being able to navigate over a field or in farm buildings to do specific interventions, and (2) aerial systems that can do monitoring activities and provide data for interventions. Several technologies integrated in these autonomous systems were already mentioned in the chapters 2.1.1-2.1.5. A few notes are given hereafter to better understand and evaluate the technologies. For both autonomous vehicles and drones, EU governments are currently in the process of developing rules and guidelines that guarantee safety for bystanders, operators, other traffic and the environment.

Autonomous tractors/platforms:

- Universities, start-up companies and multinationals have developed small size platforms that can navigate in a crop or in a barn and do specific interventions (Bakker, 2012; Caverot, 2015).

In Figure 9, we show an image of an autonomous platform that can navigate within a grassland field and can selective drill out *Rumex* weed plants[9].

- Multinational farm machine companies have developed intermediate systems in which one operator controls several tractors and operations on a field. E.g., one operator controls two tractors which both do soil tillage operations. These systems are called Master – Slave systems.
- Teach and play back systems. These systems are successfully applied on golf courts for mowing of grass since ca. 2010. With these systems, you have to teach the board computer with specific software and a GNSS one time all the actions on a field you want the machine to execute. The computer of the system can play back the stored instructions any time later on, allowing the machine to drive over the field autonomously and implement the instructed interventions. These systems still need an operator who remotely supervises the operation.
- Autonomous cars attract much attention these days. Multinational farm machine companies have also developed autonomous tractors which use all kinds of sensors that can safely control the machine in the agro-eco environment. Technologies used in car industry are also applied in this farm machines industry. Autonomous tractors still require operators nearby who can take over control in risky situations, as for the Teach and Play back Systems. Autonomous tractors are not yet marketed because of uncertainty of how they will perform in real life situations on farms and what the risk will be.

Figure 9. Image of an autonomous weeding robot

Source: van Evert, 2012[6]

Aerial systems for crop monitoring (See also Fig. 4):

- Crop monitoring with Remotely Piloted Aerial Systems (RPAS) is possible since circa 5 years. Expectations of use of RPAS (sometimes called drones or unmanned airplanes) in agriculture are high (Precision Farming Software Primer, 2013; [7, 8, 10]). RPAS technology is rapidly developing, and we see several start-up companies offering RPAS services to farmers and farm advisors. They combine RPAS technology with sensor technology, big data analytics, other ICT and DSS, in order to give information to farmers and farm advisors on crop status and need for interventions. Multi- and hyper spectral cameras are mounted on the RPAS. They capture the variation in crop conditions at high resolution, and the information is used to give site specific recommendations to farmers[10].

[9] http://www.ruud.wur.nl/index.php/EN
[10] http://www.precisielandbouw.eu/dossiers/171-gewasmonitoring-met-drones

- Larger RPAS are also being developed and tested for being able to carry up to 100 kg small actuators that allow crop interventions. First examples are RPAS that carry small sprayers that can treat individual plants with fertilizers and/or control agents.
- Crop monitoring is also possible with small manned airplanes. They apply sensors that can do similar observations as RPAS can do.

2.2 Current PA practices

2.2.1 Arable farming

In this chapter, we describe applications of precision farming technology in arable farming in the order of decreasing level of adoption (see e.g. www.precisielandbouw.eu).

Controlled traffic farming was one of the first precision applications in arable farming (Van der Wal, 2013). Since 2004, farmers apply GNSS receivers on farm equipment in order to drive on fixed paths ("tram lines") in the field. Knowing where you are on the field, allows reduction of overlay, saving on use of energy, water and agro-chemicals. This reduction is in order of 5 to 10 per cent. Investments in receivers and services are required. Also contractors use this technology in their field operations. Adoption can be as high as 80 per cent on modern farms in specific regions of EU. Farmers use the tram lines in next crop intervention operations.

Figure 10. Applications of GNSS in controlled traffic ploughing, seeding and yield mapping

Source: Kempenaar et al., 2014

Yield mapping is a second precision farming application on arable farms with high adoption. Combine harvesters allow wheat yield mapping. Corn harvesters are also equipped with yield mapping technology. The maps give farmers better understanding of variation in performance of fields and crops. Uses beyond visualization of the yield variation are still limited.

Farmers started using Decision Support Systems (DSS) to optimize crop management in the 1980s (see 2.1.4). The first applications of geo-data in DSS for crop management are only 10 years old. Worldwide we see several irrigation advisory systems that use satellite data. These DSS are used successfully to optimize timing of irrigation. For DSS in fertilizer use and crop protection, see section on variable rate technology.

Precision seeders and planters are used on modern farms, allowing to have accurate positioning of plants. Additional features are variable rate seeding, allowing to vary plant density between rows and, in this way, to further optimize crop growth. An example of such a machine is shown in Figure 8. Savings on planting material are in order of 5 to 10 per cent.

Variable rate technology (VRT) for fertilizers and crop protection products was first applied about ten years ago (Kempenaar et al., 2014b and 2014c, Haverkort et al., 2016). Modern spreaders and sprayers have features that allow to vary the rate according to a controller that uses with (near) real-time data. A first example of application of such a technology is variable rate potato haulm killing (Kempenaar et al., 2014b), where the herbicide dose is varied on the basis of sensors that determine the site specific condition of the potato canopy. Other VRA systems use soil maps as input. Farmers can choose from a wide range of VRT. Savings are in the order of 20-30 per cent when this VRT is applied at a scale of 30 – 50 M^2 (see grid application in Figure 6). Investments are higher when higher precision is to be applied. Savings in agro-chemicals will increase with higher precision.

Selective weed control in arable crops using sensors that detect the weeds and actuator that selectively kill the weed are still in early adopter phase. The same applies for the *Rumex* weeder on grassland (see Figure 9). Only in specific crops, this technology is economic today (see chapter 2.2.2). Also for control of volunteer potato plants in arable crops, farmers are interested in this technology. Volunteer plant means a plant grown from seeds that are left on the field after harvest and produce a new plant in the next crop. Volunteer potato plants are unwanted because they cause phytosanitary problems.

2.2.2 Vegetable production

In this chapter, we describe three applications of precision farming technology in field grown vegetable farming. These applications are only used in specific crops because of their unique nature or because of high net returns per ha allowing investments.

The first we describe is selective non-chemical weed control in vegetable crops. The nature and cropping systems of some specific crops allow selective non-chemical weed control. The sensor technology in combination with weeding actuators is applied in weed control programs on organic farms. This technology is also used in fenotyping of crop and weed plants, e.g. counting the number of plants per ha.

Another innovation in vegetable production is selective harvesting. Figure 12 shows a picture of a machines that determines the quality of the broccoli head and only harvest the head if it has reached the right quality.

And third application of precision farming technology in field grown vegetable farming is a tractor that navigates itself over a strawberry plot or through an orchard, pulling a precision sprayer that automatically sprays only where necessary, of which a prototype is shown in Figure 8. This prototype is used by a small group of farmers in practice, resulting in more than 30 per cent reduction in pesticide use and saving labour.

Figure 11. Sensor technology used on machines for selective weed control and fenotyping

Source: Pekkeriet et al., 2013.

Figure 12. Selective broccoli harvesting with sensor technology on harvester

Source: Blok et al., 2015

2.2.3 Dairy farming and forage production

Developments in the Information and Communication Technology already contribute to the innovative character of the dairy sector for 40-50 years now. However, continuous developments in ICT outside the dairy sector urges the dairy sector to think, decide and act on using these developments for improving their farming systems. In general cows and farmers have seen benefits in their welfare, farm sizes have increased, and farmers have become more integrated (or reliable) in the transparent dairy chain.

In the past ISO standardization on electronic identification for cows, sheep and goats, and ICAR[11] approved milk meters contributed to important innovations in the dairy sector. Breeding improvement and feeding and housing innovations could be stimulated. Also the development of automatic concentrate feeders and automatic milking systems were integrated in farming systems in Europe and are accepted widely.

Sensors are already integrated in process control systems. Trend is now that sensors are developed to support specific tasks and are able to observe more precise and specific cow behavior in their environment. Rutten et al. (2013) gives a good overview of scientific papers which support the idea that there is much progress and activity on sensor development, but hardly or no developments on the integrated decision support. Sensor developments benefit mainly from wireless communication, calculation power and improved battery life. Modern data loggers for cattle not only detect movement and can serve for heat detection, but can also indicate the location of the cow on the farm, and health indicators (coughing by neck-based collars) are under development.

Developments on management information systems for cow records were mainly seen in the 1990s. The biggest change is that these systems have become Internet based, which makes maintenance much more efficient. Integration and connection of data from different devices, such as from the feeding robot, the milking robot and data from the animal itself to improve productivity and animal health is now being explored.

Up to some years ago, dairy farmers put more efforts in optimization of milk production per cow than on optimization of forage or roughage (grass, maize) production per ha. Of course machines for mowing and harvesting were developed. However, measuring grass and forage production is now becoming a

[11] International Committee for Animal Recording (ICAR) ; www.icar.org

hot topic, and is stimulated by the discussion on the need for grazing cows and for the environmental restrictions on phosphate. In experiments also development of virtual fence applications is actual. Harvester machines with sensors for yield mapping and quality monitoring are now marketed or being developed.

Robotics in dairy farming is accepted for milking. The last decade also robots were developed mainly by industry to relieve farmers form heavy work like scraping manure and pushing roughage (Figure 13). In essence very simple tasks. Attempts for automatic feeding of roughage have been made, but are not fully developed yet to be accepted in practice.

Figure 13. Example of feeding robot on dairy farm

3 Outlook on Precision Agriculture

3.1.1 Opportunities and barriers

Chapter 2 of this briefing paper showed that a wide range of enabling technologies is available for the development of PA. In chapter 2.1 enabling technologies for object identification, geo-referencing, measurement of specific parameters, GNSS, connectivity, data storage and analysis, advisory systems, robotics and autonomous navigation were shown and discussed, all prerequisite for implementation of PA. And first implementations of PF practices were shown in chapters 2.2. We conclude that many innovations took place in the last 10 years, and that the economic potential is recognized by the sector and investors. However, the full potential of PA is not yet harvested. We only see a first series of PF practices implemented on small number of farms. These PF are making farming more easy rather than giving crop plants and animals the optimal treatment at the right time and lowest scale possible. For the latter, the adoption rate is still very low.

In 2014, the EIP AGRI focus group Mainstreaming Precision farming was established[12]. A total of eight different panels were created within the Focus Group, assessing individually aspects related to:

(i) *empowerment of farmers* in order to improve technology transfer, overcoming the perceived complexity of PF solutions;

(ii) the critical *support for advisors* considering their role as a direct link with farmers;

(iii) assessment of the *cost-benefit* analysis to improve the awareness of the potential benefit for farmers under different scenarios;

(iv) issues related to *strategies in small and medium sized farm holdings* to assess profitability under such case;

(v) issues related to *technical solutions*;

(vi) evaluating *data management and compatibility* for mainstreaming Precision Farming, as one of the current main limitations is due to non-standard software and data format solutions available, and also the important issue about farmer's rights and permissions on data collected in the field;

(vii) *research needs* to ensure innovation and knowledge transfer in Precision Farming.

The focus group concluded that barriers for implementation of PF technologies are related to relatively high level of training required for farmers and farm advisors to apply PF, lack of independent data on cost-benefit of PF, technical issues with implementation of specific technologies at the farm level, standardization problems, and need for specific innovations that allow accurate detection of specific parameters. The group also gives recommendations on how to lower the barriers, e.g. by setting up training programs, demonstration farms, cooperatives for PF on small and medium size farms, stimulation of standardization of software and machine to machine communication, development of missing technologies for specific PF practices and phenotyping, public financial support for PF components in which private companies are reluctant to invest (e.g. in DSS for advisory systems, IP is hard to protect), and stimulation of big data technologies, regulations and use.

[12] https://ec.europa.eu/eip/agriculture/en/content/mainstreaming-precision-farming

3.1.2 EU policies, Regulations and Directives and PA

In Table 1 we showed that implementation of PA will support EU CAP policies. There is a wide range of EU Regulations and directives influencing agriculture, and so, PA. Four important regulations from CAP are: (1) Regulation (EU) No 1305/2013 - Rural development regulation, (2) Regulation (EU) No 1307/2013 - Direct payments regulation, (3) Regulation (EU) No 1308/2013 - Common Market Organization (CMO) regulation, and (4) Regulation (EU) No 1306/2013 - Horizontal regulation. Besides, we mention environmental protection directives, such as the drinking water directive, water framework directive and air quality framework directive. Finally, we mention policies on Energy use reduction, Animal welfare, and Innovation. Hereafter, we shortly discuss what implementation of PA technology means for the policies, regulations and directives.

CAP Regulations

Table 1 showed that implementation of PA will have a positive effect on demographic and rural development. It will create new business opportunities and jobs, slowing down or reversing the trend of depopulation of several rural areas of the EU. PA needs more skilled workforce. A point of attention that PA requires investments from farmers, which could slow down investments in other functions of agriculture, like blue and green services (multifunctional agriculture).

Food security and safety

PA will contribute to EU policies on food safety and security. PA will make farming more transparent and will improve tracking and tracing. Crop and livestock monitoring will give better predictions on yield and quality of agricultural products. And the quality of food products in agri-food chains can better be monitored. Losses in agri-food chains will be reduced due to better planning options.

Environmental protection directives, energy use and climate change

The EU has several policies, regulations and directives on environmental protection. PA will lead to less use of water, fertilizers and crop protection products. This means that the quality of water, soils and air will increase, contributing e.g. to better surface and ground water for drinking water and other purposes.

PA will also lead to less energy use in agriculture. Less energy use will contribute to the EU policy on sustainable energy use. Less energy use and less fertilizer use will contribute to less emission of greenhouse gasses, slowing down climate change and contributing to global objectives on this topic.

Animal welfare

Farmers can better monitor conditions and behaviour of livestock with PA technology. This means that they have faster alerts in case animals need specific attention, not only on the farm but also during transport. This means that PA has the potential to improve animal welfare, and so, will contribute to EU policies on this topic.

Innovation

Horizon2020, the implementation of the innovation policy of the EU, should further support the development of precision agriculture and the development of smart agri-food chains. See also the recommendations made by EIP AGRI focus group MPF in chapter 3.1.1.

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Annex 1. Overview of sensors studied or used in agriculture

Type of measurement/sensor and description		Technology Readiness Level (TRL)	Market Readiness Level (MRL)								
		(0-9)	Innovation adaptation (0-5)			Proven added value			Accuracy		
			Pasture	Potato	Maize	Pasture	Potato	Maize	Pasture	Potato	Maize
Crop parameter											
Crop height	Grass height meters, handheld	9	2			+			+		
Crop height	Nearby, Ultrasonic or Laser	9	1	1	1	+	?/+	?/+	+	?	?/+
Crop height	Remote, Optical, Lidar radar	4-6	1	1	1	?/+	?/+	?/+	-/+	-/+	-/+
Aboveground biomass	Nearby, Optical, Various brands	9	1-2	1-2	1-2	+	+	+	+	+	+
Aboveground biomass	Nearby, Optical, Various satellite types	8	1	2	1	+	+	+	-/+	-/+	-/+
Aboveground biomass	Hyperspectrale cameras (RPAS or manned)	8	1	1	1	-/+	-/+	-/+	+	+	+
Aboveground biomass	Remote sensing (radar)	4	0	0	0	-/+	-/+	-/+	-/+	-/+	-/+
Aboveground biomass	Remote sensing (lidar)	6	0	0	0	-/+	-/+	-/+	-/+	-/+	-/+
Crop yield	Harvested product per ha	6-9	1	1	3	-/+	-/+	-/+	-/+	-/+	-/+
Crop temperature	Heat sensor	8-9	1	1	1	-/+	-/+	-/+	-/+	-/+	-/+
Crop growth stage	Remote sensing (optical, radar, lidar)	4-6	0	0	0	-/+	-/+	-/+	-/+	-/+	-/+
Plant stress	Fluorescence	4-6	0	1	1	?	+	?	-/+	-/+	-/+
Nitrogen content	Chlorofyl content	8-9	1-2	2	1	+	+	+	+	+	+
Dry matter content	NIRS	5-6	1	0	1	?	?	?	?	?	?
Protein content	NIRS	4-6	1	0	1	?	?	?	?	?	?
Nutrient content	NIRS	4-6	1	0	1	?	?	?	?	?	?

Type of measurement/sensor and description		**Technology Readiness Level (TRL)**	**Market Readiness Level (MRL)**								
Weeds	Image analyser, structure analysis	5-8	1	1	1	?	?	?	+	+	+
Diseases	Image analyser, hyperspectral	4-6	0	0	0	?	?	?	-/+	-/+	-/+
Quality parameter											
Dry matter	NIRS	5-6	1		1	?		?	?		?
Protein	NIRS	4-6	1		1	?		?	?		?
Quality of harvested products	NIRS	4-6	1		1	?		?	?		?
Composition of manure	NIRS	4-6	1		1	?		?	?		?
Climate											
Weather data	Precipitation, temperature, etc.	9	2		2	+		+	+		+
Micro-climate	Weather stations in field or building	9	2		2	+		+	+		+
Grazing											
Accelerometer	Cow behaviour	6-9	2			+			+		
Neck pressure sensor	Eating, cow behaviour	4-5	0			-/+			-/+		
Neck microphone	Eating, cow behaviour	6-7	1			-/+			-/+		

Source: Hoving et al., 2015

BRIEFING PAPER 4

THE ECONOMICS AND GOVERNANCE OF DIGITALISATION AND PRECISION AGRICULTURE

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List of abbreviations

AKIS	Agricultural Knowledge and Innovation Systems
CAP	Common Agricultural Policy
DMCA	Digital Millennium Copyright Act
EDI	Electronic Data Interchange
EFR	Electronic Farm Record
EIP-AGRI	European Innovation Partnership for Agricultural productivity and sustainability
ERP	Enterprise Resource Planning
EU	European Union
FBN	Farmers Business Network
FI-PPP	Future Internet Public Private Partnership
FIspace	A business-to-business collaboration platform
FSS	Farm Structure Survey
GAP	Good Agricultural Practice
GIS	Geographic information system
GNNS	Global Navigation Satellite System
GPS	Global Positioning System
IACS	Integrated Administration and Control System
ICT	Information and Communications Technology
IPR	Intellectual Property Rights
IoT	Internet of Things
LINUX	A computer operating system assembled under the model of free and open-source software development and distribution.
LUCAS	Land Use and Cover Area frame statistical Survey
NGO	Non-Governmental Organisation
OEM	Original Equipment Manufacturer
p.a.	per annum
PDO	PHP Data Objects (PHP is a server-side scripting language designed for web development and used as a general purpose programming language)
RFID	Radio-frequency identification
SME	Smart and Medium sized Enterprise
TTIP	Transatlantic Trade and Investment Partnership
USD	United States dollar
WTO	World Trade Organisation

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1 Main policy issues

Agriculture and the food chain become more and more data-driven by the use of ICT. Precision farming is a good example. The digitalisation of agriculture will have effects on the organisation and functioning of markets for products. Not only on existing markets for products, but also on markets for new products and services, and markets for new software and data as well as on the labour market. Digitalisation stimulated by precision agriculture can be a key contributor to solving problems in agriculture with regards to the environment, the working conditions, food safety and other public interests. However there will also be effects on the organisation of the food chain including the family farm, potentially shifting decision making from the farm and encouraging farm enlargement and chain integration. This could have negative effects on rural employment.

As for the moment the balance seems to be positive, the development and adoption of ICT could be encouraged through the European Innovation Partnership, a public policy of Open data and using up to date ICT by the Managing Authorities (Paying Agency) that integrate data exchange with platforms in the food industry. Environmental policy and Food Safety policy could also benefit from ICT and stimulate it.

Special attention is needed for establishing an open data exchange in and around the food chain, with adequate standards and platforms for data exchange that have a governance structure that prevents misuse of natural monopolies or lock-in effects. Making farmers owner of their data (although judicially speaking that is a difficult concept) and providing opportunities to control the flow of their data to stakeholders by authorisations should 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 band wide in the internet (4G / 5G) and help to find new forms of employment in case agriculture becomes less labour intensive.

2 Introduction

Following a mechanical and a 'green' (genetics and chemicals) revolution, agriculture is now confronted with an ICT-revolution. The digitalization of agriculture is based on a number of technologies coming from outside the agricultural sector, like global positioning systems, cloud computing, drones, Internet of Things (IoT) etc. In essence these technologies support very detailed data capturing that in principle can easily be shared (cloud technology) and interpreted with big-data techniques. The European satellite programs Galileo (navigation) and Copernicus (earth observation) contribute to this. For agriculture the Copernicus program is great news because two satellites provide detailed field imagery to enable precision agriculture applications and one satellite provides imaging capacity at 250 m for global agricultural monitoring. And the Galileo program delivers Europe's own satellite navigation system which is unique in its civil governance compared to the military systems. Although signal receivers claim to be ready for Galileo, its delay in launching spacecrafts results in reduced applicability. Nevertheless, Global Navigation Satellite Systems (GNSS) are a key enabler for many precision agriculture techniques. Augmented by ground stations, it enables farmers to navigate their machines at 2 cm accuracies, even when revisiting the field a week later. This enables auto-guidance of tractors and implements and facilitates precision seeding, precision weeding, precision fertilising and precision harvesting (amongst other applications). This ICT-revolution results in what is known as smart farming or precision agriculture (see briefing paper 3 in this series (Kempenaar and Lokhorst, 2016) for an overview).

In this briefing paper we describe the effects of digitalisation of precision agriculture on management and business models, the organisation of food supply chains, the markets, governance issues, and current relevant government policies, as these effects influence the future of farming, and should be taken into account in a foresight technology assessment, to which this briefing paper aims to contribute.

We base our description on scientific literature, as well as documents like the strategic agenda of the ERANet ICT-AGRI (Lötscher, 2012), work from the EU's Future Internet PPP, several technology scans / foresights and a briefing paper we prepared for the OECD (Van der Wal et al., 2015).

3 Digitalisation of agriculture: macro-economics and ICT-markets

Messages:

- Precision Agriculture is at the point to become commercially feasible.
- The market for Precision Agriculture will continue to grow every year with on average 12 per cent through 2020.
- The amount and exchange of digital farm data in the agri-food sector is increasing rapidly.
- There is not much information from farm-level studies on costs and benefits

3.1 The macro-economic background of the ICT revolution

According to Perez (2002) all technological revolutions have gone through similar long term cycles and will eventually come of age. Technological revolutions have two consecutive lives: the "installation period", one of exploration and exuberance, and the "deployment period" in which the emphasis is no longer on raw technology but on how to make it easy to use, reliable and secure (DeLong, 2003) (see Figure 1). This theory states that economic development since the first industrial revolution is driven by technological-economic cycles (waves) that take about 50-60 years to complete. These waves start with a new technology that is not necessarily a new invention (the car existed for 25 years as a toy for the rich before Henry Ford made it cheap to produce) but starts to become cheaper and cheaper (the microchip that Gordon Moore invented in 1971 still doubles in capacity / halves in price every 18 months) at such a startling speed that it has big effects on how we can organise society.

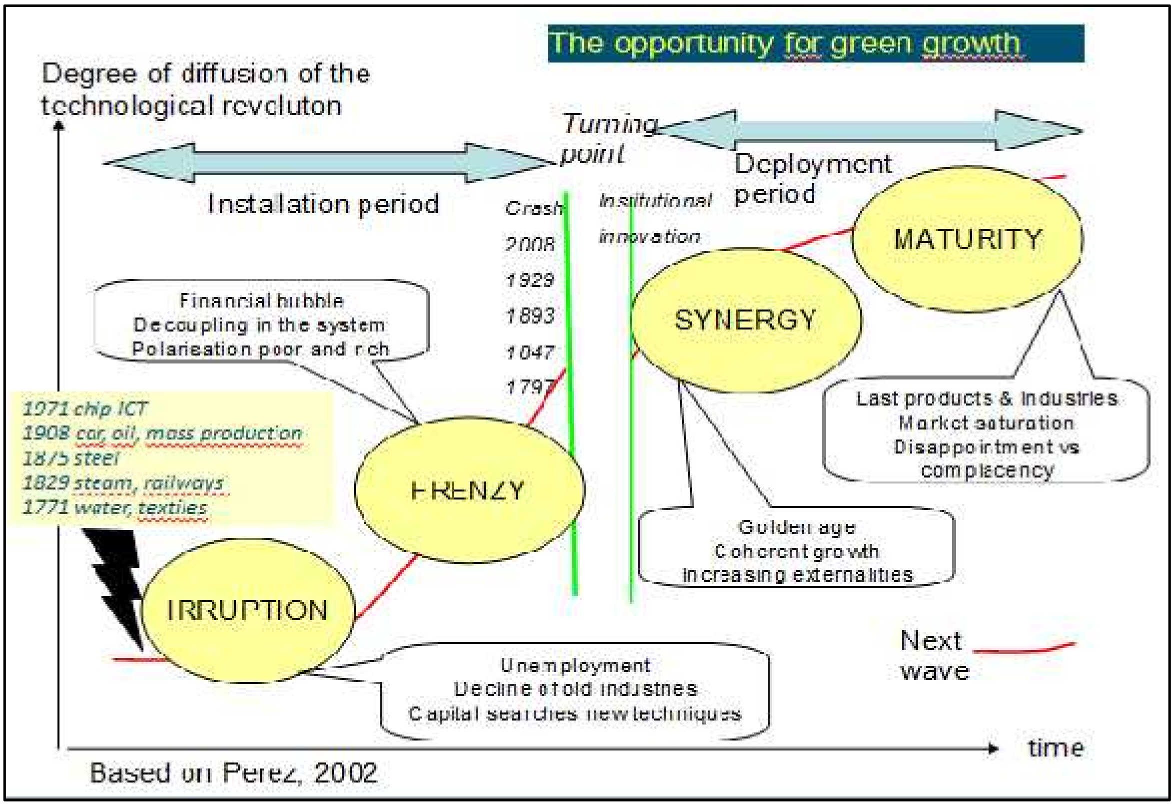
Such a breakthrough typically happens in a period of standstill and capital searching for new options. After this irruption phase in which technology is leading, investors and society become too enthusiastic. There is overinvestment ('new economy', old paradigms for prudent investment are declared non relevant as this time is considered different) resulting in a financial bubble. That leads to a crash.

According to this theory we are now in the 5th wave (or industrial revolution) with ICT as key technology and the current financial and economic crisis can be interpreted as the mid-life crisis of this ICT wave. Historically such a period is a turning point that calls for (acceptance of) institutional innovation. New ways of working are accepted. Failures of the previous period (like environmental damage) are corrected and rules are put in place to make new technologies work in situations (older industries) that until now have not been invaded with the new technology. Such a change can lead to an era of coherent growth, as for example happened in the 1950s. After that phase the technology has more and more run its course and not many profitable opportunities are left. Negative externalities (like the pollution we are confronted with from the previous wave) start to dominate and a certain level of disappointment with the technology can be sensed.

This narrative makes clear why the current economic situation is more than a normal hiccup in the economic machine, but a major crisis. It also makes clear why there are calls for institutional innovation, to renew our economic system and reduce the externalities of the previous wave. The

OECD labels this "green growth". The EU has chosen the mantra "smart, sustainable and inclusive growth" that echoes a profit-planet-people approach.

Figure 1. Longwave theory for technological revolutions



Source: adapted from Perez as in EU AKIS (2015).

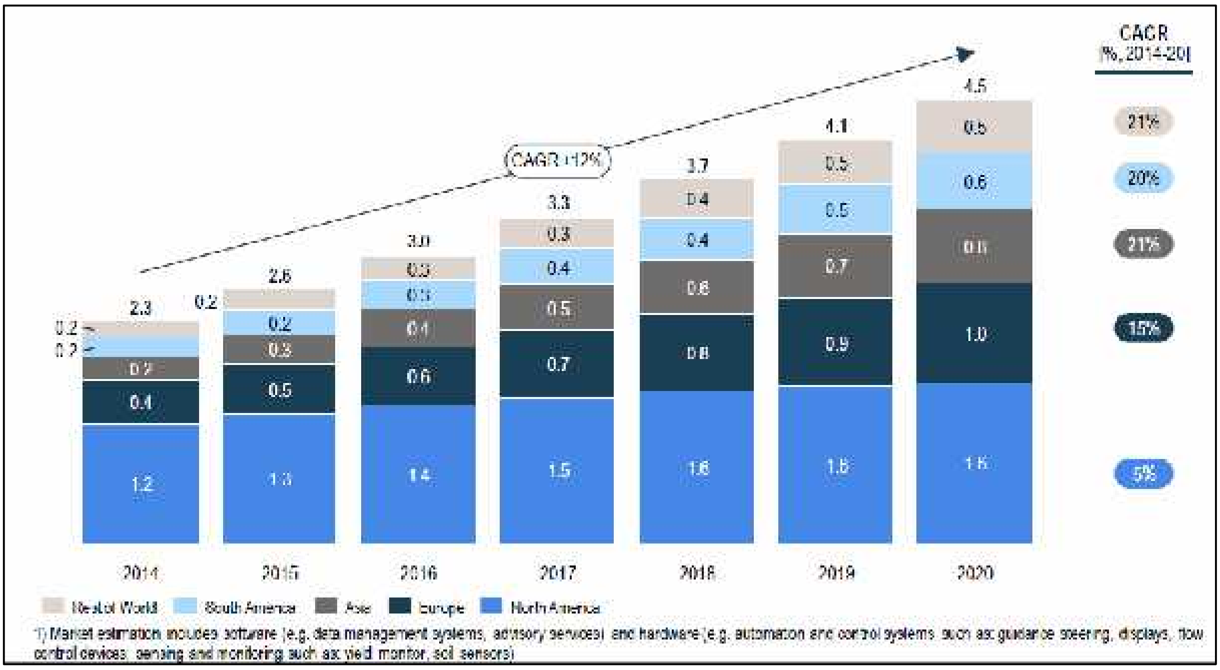
Concerning agriculture and food it also makes clear that ICT will be a major driver in the next decennia. After a turning point in the long wave cycle the technology, that in in the installation phase creates new industries (like the ICT industry, telecommunication-industry etc.) is adapted and adopted to older industries, like agriculture and food.

Precision agriculture is now becoming commercially feasible. On recent developments like drones there is still a lot of 'frenziness'. But others like milking robots and the computerisation of tractors are clearly commercially viable: according to the Deutsche Bauern Verband about 30 per cent of the costs of agricultural machinery is now for sensors, software and other ICT devices; the percentage for cars on the same is only 10 per cent (DBV, 2015). Still many choices have to be made that determine whether precision farming will deliver all its predicted promises, and to enter the "golden age" technology vendors and farmers have to leave their youthful excesses behind and further grow up.

3.2 The market for precision farming

There are no exact definitions for precision agriculture, and the recent arrival of the phenomena makes (official) statistics lacking behind. Roland Berger, a consultancy, estimates the global market for precision agriculture amounts to 2.3 billion euro at the end of 2014 and is expected to grow every year with mean 12 per cent through 2020 (see Figure 2). The precision agriculture market consists of hardware devices (automation and control systems, sensing and monitoring devices), software and services (farm management software, cloud-based, software services, etc.), technology (GPS, GIS, remote sensing, variable rate technology etc.), hardware applications (yield monitoring, field mapping, soil monitoring etc.), and software applications (crop management, financial management, farm inventory management, weather tracking and forecasting etc.).

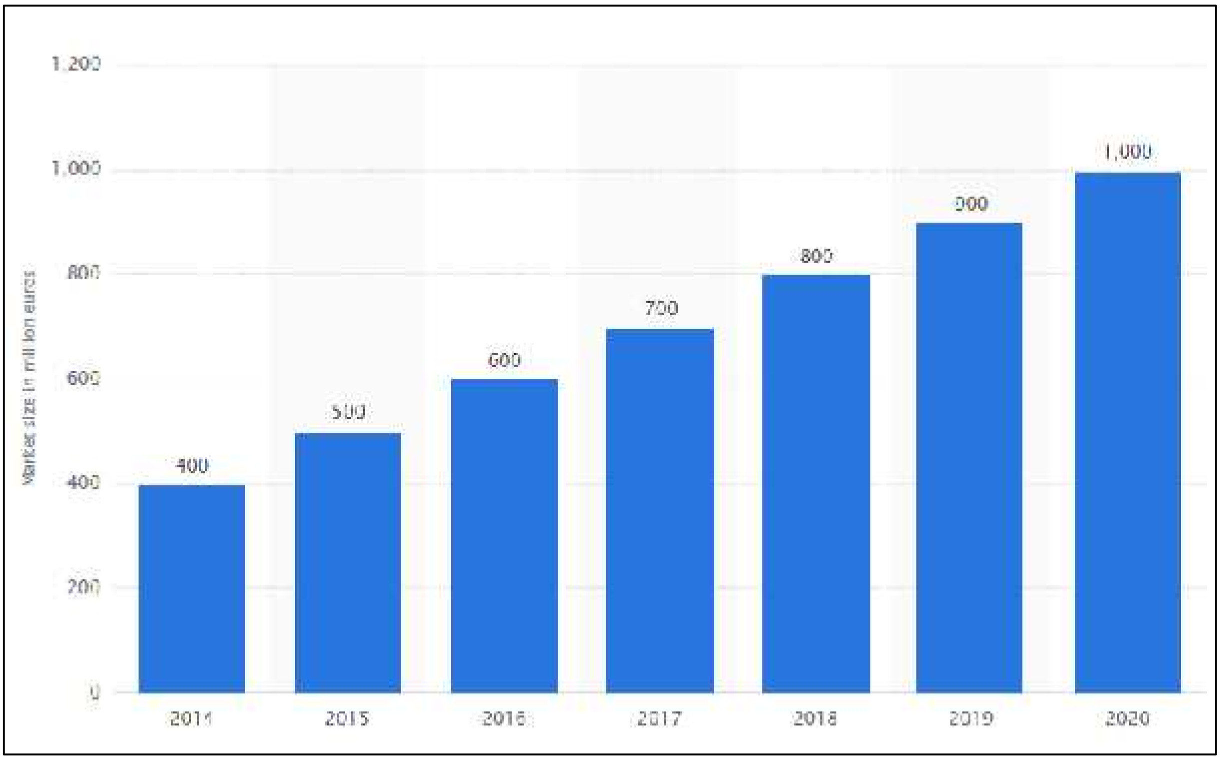
Figure 2. Market estimation of Precision Farming 2014-2020 in EUR billions



Source: Roland Berger, 2015 Reprinted with permission

The European market for precision farming is expected to be sized at around 800 million euro in 2018 (Statista, 2016) (see Figure 3 below).

Figure 3. European market for Precision Farming 2014-2020 EUR millions



Source: Statista, 2016[1]

[1] http://www.statista.com/statistics/455210/european-market-size-outlook-precision-farming/

Through the introduction of advanced sensing and monitoring technology the agrifood sector makes increasingly use of the possibilities of the Internet of Things as tool to capture digital data. Process automation in milking and crop production, site-specific application of fertilizers and crop protection based on combinations of sensors and other data sources in the chain (including market information and phenotypical data) deliver large amounts of data.

As an example we consider the growth of automatic milking systems where Northern Europe, the Netherlands, Germany and France are leading the shift towards automatic milking. 90 per cent of new equipment installations in Sweden and Finland, and 50 per cent in Germany include robotic milking (Rodriguez, 2012). According to Lely, a Holland-based international manufacturer of agricultural machines, almost half of the dairy herds in north-western Europe will be milked by robots in 2025 (Beekman and Bodde, 2015). Robotic milking generates almost 120 data variables per cow per day (Lee, 2015).

Also wireless sensor networks are quickly becoming more frequent by the agricultural industry. The majority of wireless sensor networks have been developed for research purposes. Radio-frequency identification is a booming trend with adoption by producers, food processing and handling industry, and merchants to establish "traceability system" (Caldwell, 2012). And the global market size for agricultural robots was $817 million in 2013 and is expected to reach $16.3 billion by 2020 (Eustis, 2014). Furthermore the use of Global Navigation Satellite Systems (GNSS), of which GPS is the most commonly used in piloting tractors and to track the position of livestock, is growing. It is estimated that GNSS penetration into EU tractors will rise from around 7.5 per cent in 2010 to 35 per cent in 2020 with sales rising from c. 100,000 units p.a. in 2010 to more than 500,000 in 2020 with tractor guidance and variable rate technology being the main applications (GSA, 2012). So data about products, how they are produced, processed and preserved through the entire food supply chain, via automatic identification technology, produces an important data source for tracking & tracing and early warning systems. Via smartphones, wearables and sensors an enormous amount of data about livestock is collected. Analysis of these data can lead to better insights for tailor made advice to farmers. That ensures further optimization and sustainability of business in the agrifood sector and prevents resources waste (Viool and Bogaardt, 2015).

3.3 Costs and benefits

Not much literature is available on the costs and benefits of the use of precision agriculture on farm business level. The focus group on Precision Farming of the European Innovation Partnership 'Agricultural Productivity and Sustainability' even recommended to develop a scientifically reliable Precision Agriculture Calculator tool to allow farmers (or their advisors) to make an economic cost-benefit analysis (EIP-AGRI, 2015). High costs and long return-on-investment periods have been mentioned as one of the socio-economic barriers to the adoption of technological innovation in agriculture from the perspective of the user side (Van der Wal, 2015).

So far AgEcon Search, a well-known open access repository of literature in agricultural and applied economics, includes only a few articles focusing on cost and benefits of precision agriculture on farm level. For example McCorkle et al (2016) have investigated the costs and benefits of implementing robotic technology in vineyards in the US to augment the production tasks that are labour-intensive. The net present value per acre of labour costs over ten years were calculated for production tasks that can be conducive for robotic technology. Those figures can provide insight for determining a price range to consider adoption by growers. And the study of Lencses et al (2014) showed an income growth which results from higher milk productivity due to the milking robot in the dairy farm in Hungary. Another study on the effects of milking robots in dairy farms in Finland (Heikkila et al.,

2012) showed that productivity development is heavily concentrated on those front-line farms switching to an automatic milking system. The introduction of milking robots on a farm in Finland created an average increase in productivity by 7 per cent.

The measureable benefits of precision agriculture on the farm level are often separated in three different aspects: costs reduction, yield increase and quality improvement. However, from a societal point of view, the benefits of precision agriculture serve more abstract and less measurable goals such as:

- Increase of productivity: The productivity of a farm (or a farmer), in this case not expressed as tonnes/ha but rather as the gross margin between costs and financial benefits per unit of labour, unit of equipment or unit of inputs;
- Reducing risks: Precision agriculture practices (including the application of sensors and precision equipment) help farmers to avoid risks or to respond adequately to them. Most prominent are the weather related risks (both drought and water excess) and disease related risks;
- Improving transparency: the so-called ‘license to operate’ for farmers requires more and more proof of compliance to regulations or (quality) claims. Precision agriculture technologies help farmers to automatically document their activities and as such reduce the administrative burden to get or keep their License to Operate.

And behind those farm related benefits, there are also societal benefits that align with these benefits, such as related to climate mitigation, food security, higher sustainability and lower environmental footprints. These benefits are difficult to measure but are however closely linked with the above mentioned abstract farm goals: For instance, the increase of productivity expressed as “more crop per drop” (kg crop / m3 water) has a positive effect on farm income (reduced cost per unit), hence on productivity, but also on risk reduction and therefore on climate mitigation and environmental footprint.

Studies linking these benefits are however lacking. Scholars tend to mention these aspects in a narrative way, without the qualitative support to these claims. Instead, studies on economic benefits often focus on the cost saving of applied technologies and more in particular cost savings in product used (like fertiliser, seed or crop protection agents). Swinton (2003) states that these studies often neglect the increased capital cost for equipment. Timmermann (2003) reports savings in herbicide use due to precision agriculture. In maize, winter wheat, winter barley and sugar beet, savings of respectively 42 euro/ha, 32 euro/ha, 27 euro/ha, and 20 euro/ha were realised. These savings result from less product use due to better machinery and location specific spraying, which is therefore also an ecological or environmental benefit.

Similar savings are reported in precision seeding, precision fertilizing and precision weeding. Per application these savings may not justifying investments in the equipment, but as several components (like satellite navigation, mapping costs and board computers) can be used for many applications precision agriculture can have a serious economic impact on the farm.

Adoption studies in agriculture show that precision agriculture requires capital for investments as well as substantial prospected benefits. In Europe PA adoption has been influenced at regional scale between Northern and Southern countries (Blackmore et al., 2006). PA is mainly adopted in northern countries, due to larger economic farm sizes, higher income (in some extent due to large size), ease of financing new investments (access to banking with lower interest rates), farmers-entrepreneurs and in some cases state policies. Besides economical logic, other reasons are known to apply to investments in precision agriculture, such as reduced driver fatigue, asset management and control (prevention of theft of fuel), comfort and task delegation to drivers.

4 Effects on management and business models

Messages:

- The increasing automation and digitalisation of agriculture changes farm management
- This could have implications for the family farm as a dominant organisational form
- It is creating new business models, but many data-driven initiatives are still exploring viable business models to capture the value of data.

4.1 Effects on management and the family farm

This briefing paper concentrates on smart or precision farming, adapted from the description given by JRC (Zarco-Tejada et al., 2014): Precision Agriculture (PA) is a farming management concept based upon observing, measuring and responding to inter and intra-field variability and needs in crops and to variability and needs of individual animals with the use of digital techniques. Precision Agriculture has the potential to increase yield, reduce production costs, improve sustainability of production, animal welfare and environmental stewardship. Thus, PA contributes to the wider goal concerning sustainability of agricultural production.

This description underlines a number of capabilities that Smart Farming performs. The technology leads to much more and better data capturing: nature is being digitalised. That leads to better control of the biological productions processes that take place under unpredictable influences like the weather. This makes the process better manageable. In essence this is a process of industrialisation that is not new and already strongly present in indoor agricultural sectors like glasshouse horticulture and the pigs and poultry industry. Better control can of course lead to better optimalisation, or even to self-managing of processes as the software algorithm can deal itself with variations in conditions. The self-driving machinery is the most extreme example of this. More precise this development can be sketched as:

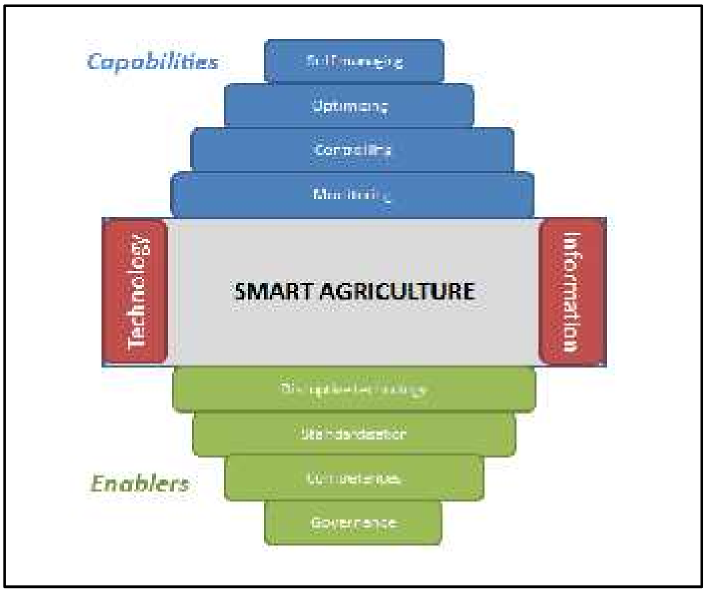
1) Monitoring: understanding the location, ownership, history, destination, quality conditions, and other functional properties of products and other objects by means of sensors and external data sources.

2) Controlling: intelligence is added in order to take corrective measures i.e. specific rules prescribe how the objects should respond to certain events. And the situation or environment of the object can be adjusted remotely by actuators.

3) Optimizing: the performances of the food supply chain are improved by applying advanced algorithms and analytics for simulation and support of the decision making based on optimisation models and predictive analytics.

4) Self-managing: through combining monitoring, control and optimization objects can operate independently (autonomous) during their way through the food supply chain without human intervention, either on the spot or remotely. Autonomous objects can also become self-adaptive systems which are able to learn about their environment, make a diagnosis of their needs, and adapt to the preferences of the users.

Figure 4. Capabilities and enablers in Smart Farming



Source: LEI, T&U Board, 2016

Figure 4 illustrates that this development is based on a number of enablers, important conditions for smart agriculture and smart food supply chains. Some of them will be discussed later in this paper, but they are:

- Disruptive technologies: hardware for mechanisation (robotics), RFID, sensors, wireless networks including broad band in rural areas, web service technology, cloud computing, big data, predictive analytics tools.
- Standardisation: fast, error-free and efficient exchange of digital data within and between companies based on information standards (see section 4.2).
- Competencies: awareness, adoption and knowledge of digital information systems and standards and the skills to use them.
- Governance: organisational implementation and business models, including agreements on ownership rights and decision rights, remuneration, risk management etc. (see section 7.1 on data ownership).

This effect of ICT on management has important consequences. It means that some forms of labour on the farm are replaced by machines and software. Farming becomes even more capital intensive and less labour intensive.

This could have implications for rural development: it implies less work in agriculture, but also that some of the work and decisions move from the farm to experts that provide their services remotely. Where in the past a farmer had a look at his cows to see which ones are in heat and can be inseminated, that is now checked by a pedometer tagged to the cow. Originally that service sent a sms to a farmer with a suggestion from the breeding organisation on the selection of the bull. As most farmers took the first choice, a breeding organisation like the Flemish-Dutch cooperative CRV has now turned that into a service where a remote computer in Arnhem takes the decision on the selection of the bull. Such services are typically provided from metropolitan regions with an attractive business environment.

Another effect on management is that the risk of *moral hazard* that exists in agriculture can be reduced or disappear. This risk of moral hazard occurs because the production process is not easy to monitor. That means that an investor or a manager (in economic theory labelled as 'the principal') cannot easily control the worker ('the agent'). How should an investor learn if his farm manager is doing his utmost best, as if he was the owner himself, and is not incorrectly blaming his mediocre results to bad luck in weather or diseases? How should the manager know that the farm labourer at a far-away field is not shirking? Such agency problems lead to transaction costs (for the principal to control the agent). ICT reduces this risk and associated costs considerably.

This could have big implications for the future of the family farm. In their seminal book *The Nature of the Farm* (referring to Ronald Coase's Nobel-prize winning study The Nature of the Firm published in 1937), Allen & Lueck (2003) argue that the choice of the organisational form of the family farm is based on the consideration between specialisation in the market and such moral hazards. If these moral hazards disappear, it would be easier for the farm manager to employ and control many labourers, and for outside investors to own large farms.

There is a rival theory that explains the fact that in Europe family farms dominate over latifundia[2] and investor-owned plantations. That is based on the observation that farm families employ their capital and own labour at relatively low incomes without much labour from outside due to other frictions in markets. Outside labour in weekends, at nights and in overtime is often expensive due to labour market regulations, where at the same time tax and social security rules are often favouring the self-employed in farming. As working outside the family farm often includes travelling or leaving the farm, and total farm income (including a capital remuneration) is more an objective for the family than the income per hour worked, the outflow of labour from agriculture is often slow and takes place at the generational transfer when potential successors vote with their feet. These low incomes makes investment in agriculture for investor-owned firms like food companies unattractive as it implies low rewards for a high risk. Also this underpinning of the family farming system is effected by ICT, as smart farming makes risks better manageable and perhaps even tradeable in insurance or capital markets

In conclusion, and in combination with other factors as the developments in the labour market (demography with less high skilled farmers and migration in Europe of low-trained labour), the capital market (with low interest rates making investment in land more attractive) and product markets (with higher prices due to global scarcity of food and biomass), ICT could have an effect on the organisation of the family farm, giving way to medium sized enterprises as we know them in other sectors of the economy.

4.2 Effects on business models

Before turning to business models, that describes with which value proposition to clients money is earned by firms and farms, it should be noted that the ICT-revolution described in section 3.1 has wider implications for farming. First of all ICT has big effects in scientific developments that also influence agriculture. Genetics, based on computer power, is a good example. Second, and probably even more important if it comes to the consequences of ICT on the organisation of the agriculture sector, developments like the Internet of Things are not only adopted in smart farming techniques, but also in the agri-food supply chain (for tracing and tracking, supply management, compliance auditing etc.) and even at consumer level (starting to link food consumption, lifestyle behaviour data like in wearable tech and health data). Such data trends have the potential to be disruptive for current food chains (e.g. more online sales in short supply chains, more prescriptive farming) and lead to new forms of organisation and new business models (Figure 5). That implies that a discussion on business models in farming should not concentrate on the current boundaries of the family farm, but look a bit broader (we discuss the data exchange in the food chain in more detail in chapter 6).

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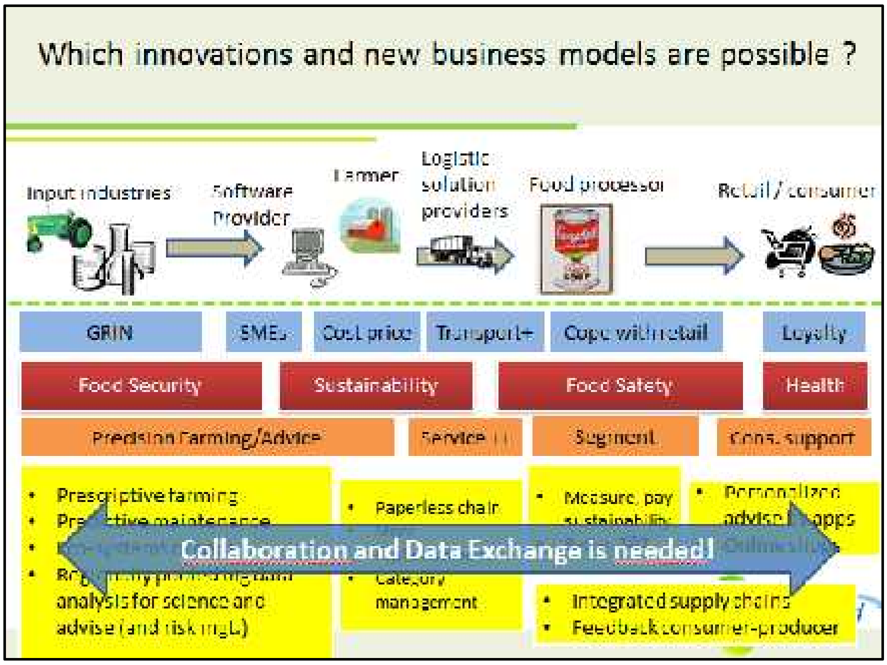
[2] Latifundia are very extensive parcels of land, historically owned by the upper class

Figure 5. Effects on ICT on business models in the food chain



Source : LEI, Wageningen UR

Digitalisation of farming processes continues to expand and intensify. The supply and demand of farming data is rapidly growing. There is a surge of data-tools in the market and even more in the making. Data-driven initiatives are steadily increasing in agrifood chains. Farming is becoming a booming data harvesting business where many players are taking bites into data generated by farming. Many data-driven initiatives are still exploring viable business models to capture the value of data. A variety of business models are being used and develop with different value propositions to different stakeholders (Ge and Bogaardt, 2015).

The variety of business models of those data-driven initiatives (e.g. data exchange platforms) present in the agrifood sector, can be illustrated by examples of the five typical business models according to Spijker (2014) in which value is created from data: by selling data, by innovating products through data, by swapping commodity offerings into value-added services, by creating interaction in the value chain, and by creating a network of value based on data exchange. Below examples are described of each of these business models.

Basic data sales

An example is Farmobile in the US that sells a simple data collection tool that centralises grower's agronomic data from multiple systems in one electronic farm record. Farmobile standardizes the data and makes it easily searchable for customers who want to purchase data. The data management system of Farmobile originates with a $1,250 annual subscription fee. If farmers opt to share their data through Farmobile, they will get 50 percent of the revenue derived from selling the data. At Farmobile the electronic farm record (ERF) is owned by the farmer. Data is stored as long as the subscription remains active. The farmer's data is housed on cloud servers of Farmobile. Farmers have the power to authorize or deny access. By the end of 2015 Farmobile has raised $5.5 million in equity financing from Anterra Capital, for developing new modules on top of its database platform. Anterra Capital is a growth capital fund, jointly funded by proprietary investment of FIL and Rabo Private Equity.

Another example is Farmers Business Network (FBN), with investment by Google Ventures. Its mission is to make data useful for farmers to select the optimal seeding grade for their variety and their field in order to reach the maximum potential. In 2015 FBN has aggregated data from 7 million acres of farm land across 17 states in the USA. FBN is able to assess the performance of 500 seeds and

16 different crops. No data is shared with other parties. Access is by payment: 500 USD per year. FBN is not linked to any company. They are a community of farmers and independent persons (Ge and Bogaardt, 2015).

Product innovation

Equipment manufacturers such as the manufacturers of tractors, combine harvesters and milking robots, collect data from the agricultural machinery of the farmer such as location of the machinery, engine hours, operational data (e.g. amount of fuel used) and diagnostic data of the machinery. This is first of all done to support smooth operation of the equipment and have feedback for further innovation of the product. In some cases there is perhaps also a strategy to develop new services based on the collected data. Examples of equipment manufacturers that collect farm data are e.g. Lely Industries (data from milking robots) and John Deere, that stores the data in the web portal MyJohnDeere.com as a service for the farmer and if so requested combines it with historical and real-time data regarding weather prediction, soil conditions, crop features etc. in order to help farmers to run and manage all their operations. The exchange of farmers' machinery data is limited to the subsidiaries of John Deere, and authorized dealers and suppliers in order to monitor safety and equipment performance and enhance customer support. The platform itself, however, is open to everyone free of charge (Ge and Bogaardt, 2015).

Commodity swap

In a commodity swap, data is exchanged between (for instance) farmers and food-manufacturers to increase the service-component of the transaction. Examples are software made available by processors.

Value chain integration

Multinational agricultural biotechnology corporations like Monsanto and Dupont have adopted the strategy of acquiring start-ups to strengthen their existing position. For example in 2013 Monsanto acquired weather and agronomic data modelling start-up Climate Corporation that provides planting advice to farmers based on data science. And Monsanto's primary software product FieldScripts helps farmers to maximize productivity, minimize risks and realize higher yields. This move into prescriptive farming originally also included an investment in a machine manufacturer, but this business has now been sold to Deere. Monsanto charges $10 per acre for FieldScripts. Monsanto states that they share farmer's business (and personal) data only with subsidiaries and business partners of FieldScripts. No data is shared, traded or sold with marketers. Monsanto may publish data related to FieldScripts but only with expressing written consent of the farmer and without disclosing the name and field location of the farmer. Furthermore the agreement between FieldScripts and the farmer states that in no event Monsanto and seed dealer agents are liable for any incidental, consequential, special or punitive damages resulting from the use of FieldScripts (Ge and Bogaardt, 2015).

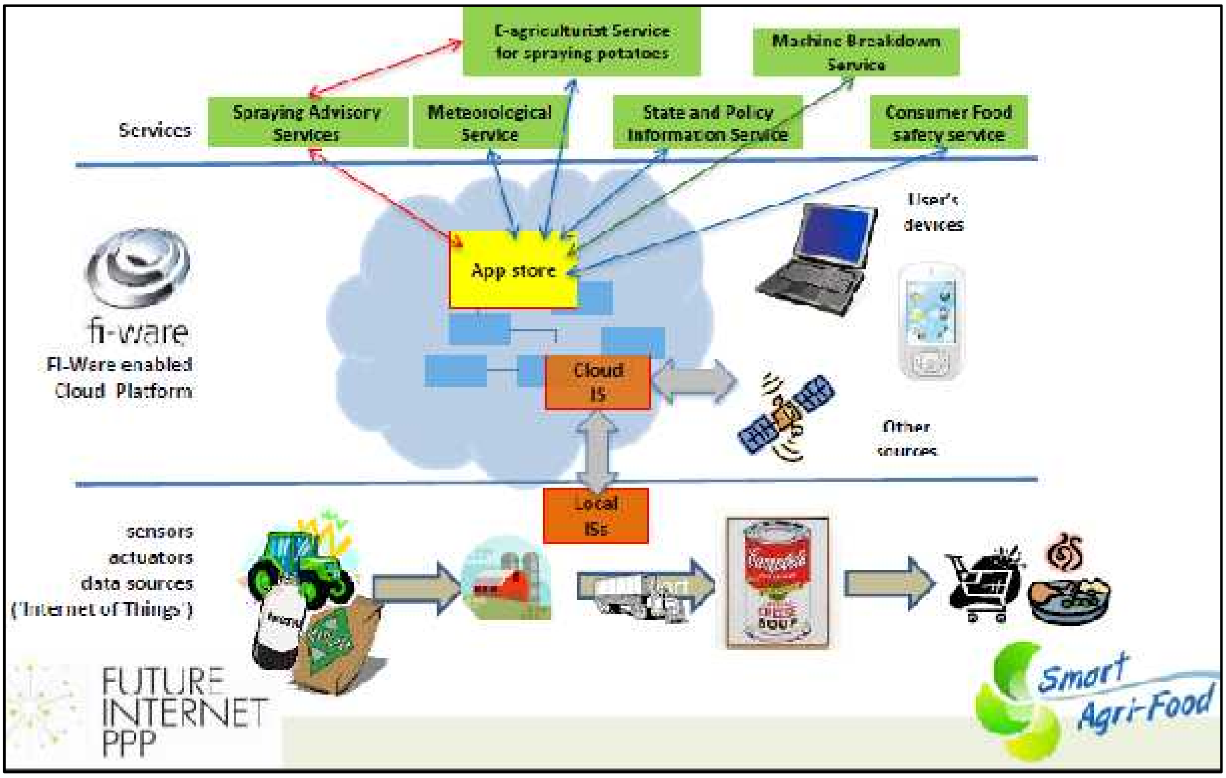
Value net creation

In the Netherlands Farm Digital, a public-private partnership programme within the Dutch top sector policy, is standardising and digitalising farm data about food safety and sustainability, and developing and implementing an independent digital platform that will enable users to freely exchange certification data. Farm Digital has set up a proof of concept with AgriPlace, a start-up by a Dutch NGO with a sustainability compliance objective, for farmers to share their certification data like GlobalGAP, with the auditing organisations and the food processors (or, in the case of farmers in developing countries, with Dutch importers).

Another example is the EU project FISpace (Future Internet Business Collaboration Network) which is now available for commercial exploiting by offering a business-to-business collaboration platform that could link platforms like MyDeere.com, 365Farmnet, Akkerweb, Agriplace and others via a Linux-like

Open Source model. Several EU FI-PPP accelerator projects are using the platform. For example SmartAgriFood (see its conceptual architecture in figure 6) which is supporting SMEs in the development of smart services and apps for the agri-food sector, and Finish which focus on projects realizing software applications for complex supply chains and networks of perishable food and flowers (see chapter 5 for more information on platforms).

Figure 6. Architecture of Smart Agri Food



Source: Wolfert et al, 2014.

5 Effects on food chain organisation

Messages:

- Organisation of food supply chains changes from markets towards vertical integration: power shifts to the food supply chains.
- It will depend on decisions taken by current actors in the food chain if a more modular or a captive governance architecture arises
- Organising data exchange in the food chain could be a good strategy to defend current structures and compete with more disruptive governance mechanisms.

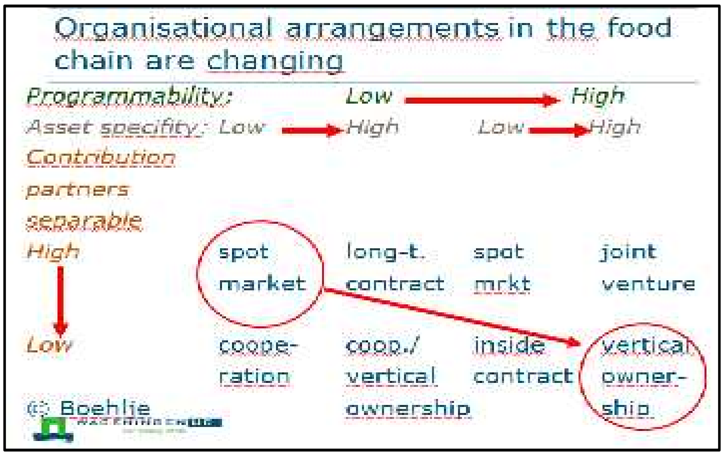
In this chapter we elaborate the point that was introduced in section 4.2, the fact that ICT influences the governance of global value chains. As in the discussion on the effect of ICT on the family farm (section 4.1), also here the fact is that ICT lowers transaction costs. It becomes cheaper to contact others (in social media as well as in Alibaba and other trading platforms). For an economist this suggests that markets will work better and that activities that are done within companies can sometimes be better outsourced to independent suppliers or even self-employed persons. This is a process that has been observed in the economy over the last decades.

When it comes to agriculture, where self-employed working in family farms are already the norm, the effect of ICT could be a contrary movement. As explained in section 4.1 ICT leads to better control of the production process, including a better planning. Production can be better programmed, and developments in genetics work in the same direction. A good example is the "plant factories" as operated by Green Sense Farms (USA: nearly 5700 m^3 of growing vegetables under red and blue LED lights 22 hours per day) or Aerofarms. This company uses similar technology and states on its website: "We disrupt traditional supply chains by building farms on major distribution routes and near population centers. We defy traditional growing seasons by enabling local farming at commercial scale all-year round. We set a new standard for traceability by managing our greens from seed to package. And we do it all while using 95 per cent less water than field farmed-food and with yields 75 times higher per square foot annually". They do this by building, owning and operating indoor vertical farms that grow safe, nutritious food with a claim of better taste as the vegetables don't have to be washed, and where the harvest moment is totally predictable from the moment of seeding.

Such programmability, in addition to other trends in the markets (like the big competition between retailers that want to differentiate themselves with specific products), can lead to asset specifity: the fact that a supplier invests in machinery, production methods or production know-how that is very specific for one buyer. This creates an interdependency in the chain, that asks for another governance mechanism, to reduce the dependency and the risk of power-play (ex-post haggling in the economic jargon). Spot markets are then replaced by contracts or even joint ventures. Competition gives way to cooperation, to maximize the value in the chain in addition to deals to share the value. Figure 7, based on (Boehlje, 1999), illustrates this, including the aspect that the optimal governance structure is also influenced by the question if the contribution to this value maximization process can be objectively shared in the market.

ICT contributes to asset specifity as it generates much more data that can be added to the transaction, as explained in section 4.2 on the data driven business models. The large array of food safety and sustainability programs in the food chains are a good example. More data on food safety and sustainability can be measured, audited and accompany the sales transaction in schemes like GlobalGap, BRC, Fair Trade, Organic production etc. Retailers, under pressure of consumers, NGOs and government ask for such schemes and link them to different segments in the consumer market. This leads to investments of farmers (and other partners in the food chain) into such schemes. Such investments are fixed costs that are easier for larger farms and contribute to an increase in farm size (although small farms can benefit because the schemes also transfer know how of desired production methods to farmers). The example of Farm Digital given in section 4.2 shows how this process is strengthened once that these data start to be exchanged by ICT in platforms like Agriplace. On one hand that lowers the effect as it becomes cheaper to exchange data, but on the other hand it makes it also easier to exchange even more data to support certification and auditing, and perhaps even establish new schemes for new market segments.

Figure 7. Drivers for changing organisational arrangements in the food chain

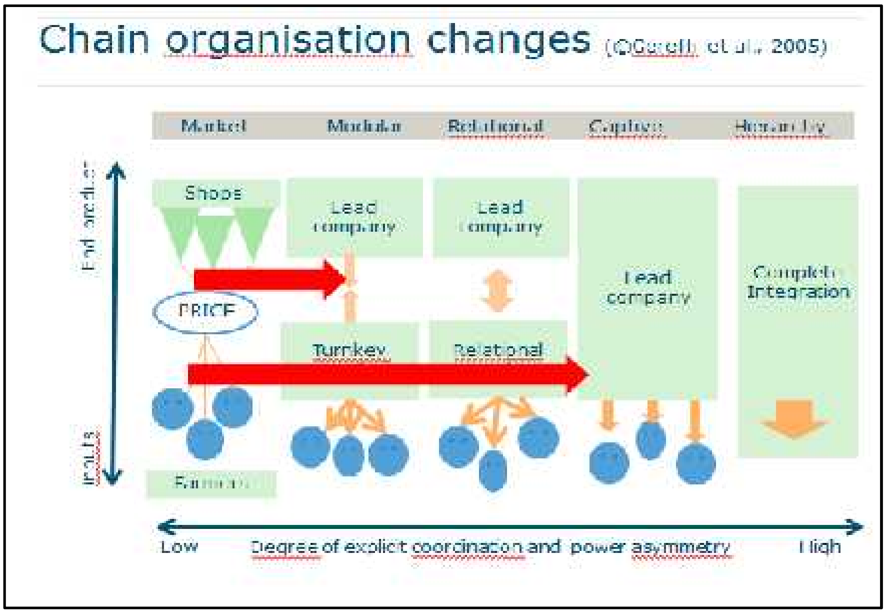


Source: adapted from Boehlje, 1999

Gereffi et al (2005) have taken the analysis above one step further. Analysing many (non-food) global value chains they came up with five arch-types for the governance of such chains (Figure 8). These 5 types are based on combinations of 4 aspects: the complexity of the transaction, the codification of the transaction, the competences of the supplier, and the extent of explicit coordination (and power balance) in the chain. Traditional markets (like an auction) are characterised by a low complexity of the transaction (in the traditional auction only the price of a standardised commodity is relevant, not other aspects as the production method or packaging and delivery information), low coordination and power balance (many buyers and many sellers), and high competences of the suppliers (the grow the produce independently from their anonymous clients) and a high options to codify the transaction.

ICT provides even more options to codify the transaction, but the improved programmability and other aspects discussed above lead to more complexity in the transaction and more coordination (as information of the consumer or retailer or food processor is needed to take on-farm decisions). That moves the governance from the Market arch type towards a Modular type in which the supplier becomes a turn key supplier that more closely work with the food processor or retailer. This is a trend that is clearly observable in for instance the growing of fresh tomatoes.

Figure 8. Governance of Global Value Chains



Source: adapted from Gereffi et al., 2005

Where the modular governance form still asks for relatively high competences of the suppliers, as they process the information (including that of their lead company clients) the Captive model arises when most of the decisions are taken centrally. Either because decisions with the supplier have been automated in algorithms, or if there is an information advantage at the central level due to e.g. the aggregation of data from the different suppliers with up to date ICT.

Contract design between farmers and food processors illustrates their position in such value chains. A nice example is the difference between a contract for canning peas and one of sugar beet (Bogetoft et al., 2002). Where in sugar beet growing there is a lot of autonomy for farmers to decide on sowing and harvesting dates, choice of variety etc., this is not the case in contracts for growing vining peas for the canning industry, where most of the decisions are taken centrally. The main reason is that in sugar beets the harvested product can be stored a few weeks, either at the farm or with the factory, without too much costs and loss of quality. Therefore decisions on harvesting moments can be left to the farmer who can take local circumstances (soil, weather forecasts, farm planning) into account. Peas have to be processed within three hours after harvesting and the factory needs a constant stream of raw material. Therefor decisions have to be made centrally. Other aspects play a role (sugar companies are often cooperatives, in the past the farmers owned a lot of the harvesting machines themselves, where viners are owned by contractors), but the point we want to make here is that the organisation of value chains is a result of drivers like the complexity of the transaction and the competences needed with the supplier. ICT changes those drivers, via better programmability, asset specifity and lower transaction cost to provide the data to partners in the chain and take decisions remotely.

Hence ICT in the form of smart farming and smart industry (Industry 4.0) will change the way the global food value chains are organised. Besides competition, that is very dominating in the current discourse on the power balance in the food chain, collaboration to create more value with new business models and new forms of governance will become more important.

Competition between organisational forms

The analysis above shows that in an economy not only products compete, but also organisational forms. For current organisations that implies that organising the data-exchange in the food chain through collaboration can help them to stay competitive. In other words, firms in the food chain (e.g. a feed company, a breeding organisation, farmers and a slaughterhouse or dairy cooperative) can choose to organise the data-exchange between their organisations to gain the advantages of a data-driven food chain and keep more or less the current delineation between the organisations, or they can give way to a more integrated value chain.

Depending on such decisions two different scenarios could become possible: the captive prescriptive farming model, or the open smart farming model. In the captive prescriptive farming model:

- The farmer becomes part of one integrated supply chain as a franchiser/contractor with limited freedom.
- Actors in the chain work on one ICT-platform for e.g. a potato breeder, a machinery company, a chemical company, farmers and French fries processors.
- Some of these actors will merge into the integrated company (compare the situation in some pigs- and poultry integrations).
- With a weak integration of data exchange with service providers like banks and accountants and with governments as a result.

In the open smart farming model:

- The current actors of the food chain stay independent, the governance of the food chain is more that of a modular than a captive arch-type
- Data is shared through common, open platforms with competition between specialised services and apps.
- That also supports data exchange with service providers and government, and thus reduces administrative burden.

Prescriptive farming in the USA is currently more organised along the first model than the open model, seen the examples given in chapter 4. Perhaps that model is easier to organise than the open smart farming model that asks for higher upfront, common investments with a business model for data exchange platforms that have a bit of an infrastructure / utility character. We come back to this issue in the next chapter 6.

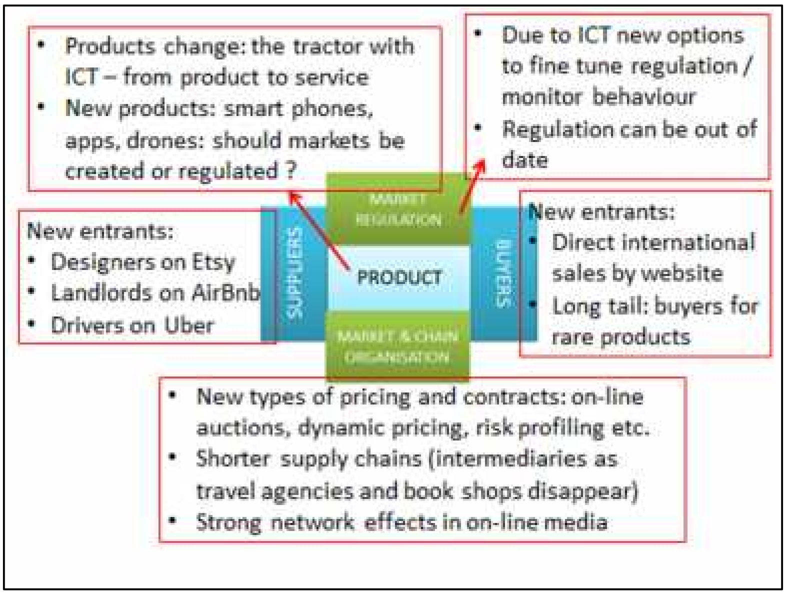
6 Effects on markets

Messages:

- ICT changes different aspects of markets: suppliers, customers, the product or service itself, the market organisation and the way the government can interfere in the market.
- This holds for (new) markets of new products and services, (new) markets for data and ict-products and for old markets of current products. In these three cases governments are confronted with different issues.
- Exchanging data between different actors is a key issue, especially if the current governance of value chains should be stabilized.
- Platforms are important solutions for such data exchange. If platforms would be connected this would promote specialisation and innovation in platforms and prevent risks of rent-seeking monopoly power due to network and lock-in effects.

Digitalisation in agriculture will affect markets. For example technology lowers the costs of storing, sharing and analysing data. Lower transaction costs mean that new suppliers could come to the market (see Airbnb that makes rooms of home owners available for tourists or Uber that makes it possible for car owners to become taxi-driver). But it could also bring new consumers to the market as a global consumer-base becomes available. We have already seen that digitalisation could differentiate products with credence attributes (e.g. by adding data like in organic farming or fair trade or PDO). Or it could add services to a product. This could also lead to very specialised products for small markets (the so-called 'long tail effect'). ICT can also change the market place itself, as in the auction example where the brick and mortar auction becomes a virtual one. Institutions in the market place can also change, like the introduction of dynamic pricing (pricing dependent on the characteristics of the buyer or the moment of buying). Last but not least the government faces changes in the way it interferes in in markets: regulation can be out of date and on the other hand ICT can provide new options to fine tune policy – parts of the current Common Agricultural Policy with its field maps to monitor greening would not be possible without ICT. Figure 9 illustrates this framework.

Figure 9. Changes in the markets due to ICT



Source: LEI, Wageningen UR

We use this framework to look into more detail to the (potential) effects of ICT on markets.

6.1 Existing product markets

The examples given in the introduction above already illustrate how markets for products change. ICT differentiates products, at least in the short time: machines with IoT sensors and machines without, dairy products where ICT and data help to substantiate a sustainability claim and those not, etc. The changes in product specification are at the moment especially strong in machines and installations bought by farmers. Sensors and other internet of things technology improve their functionality and lead to predictive maintenance. There are not yet many examples of such products that change completely into a service: e.g. by adding inventory management advice to installations (e.g. using IoT on climate control equipment to take over the management of the warehouse with potatoes from a remote control centre). Either the technology is not far enough (or already self-regulating) or such a service oriented business model is very different from the current one for a supplier from the sales of machinery, and includes new risks.

Concerning agricultural products there are at first sight not many examples of big changes in the markets due to new suppliers or new customers. An example in the entrance of new suppliers are the "plant factories" like Aerofarms discussed in chapter 5. This could be disruptive for traditional growers, and the government could then be confronted with the social effect of such a disruptive innovation on the "old" producers. Examples of new demand can be found with farmers who set up a web shop. Although the aggregate demand does not change much, such farmers can attract a large number of clients that they were not able to reach with their traditional farm shop.

As discussed in chapter 5 ICT can have important effects on the organisation of the value chain. An aspect not yet discussed is that sometimes value chains are shortened as the function of middleman disappears. Travel agencies and bookshops know this all too well. Another aspect is that new types of pricing and contracts become the standard. We mentioned already online-auctions and dynamic pricing. In the insurance market (including agricultural insurance) and banking risk profiling can be improved, even to the point that it raises ethical issues (in life insurance for instance). An example for better credit risk assessment in agricultural banking is the use of (open) data to calculate a specific benchmark for an individual farm that a credit officer can use in her decision to make an offer for a loan.

In existing markets, the government faces the question if its regulation is still up to date, given new ICT options. The fact that markets change, could lead to new policy challenges or make current regulation outdated – we discuss this in more detail in the last chapter of this paper. It could also lead to new technical options for current regulations. There are several examples in the Common Agricultural Policy. As data is recorded and produced in the frame of precision agriculture (for instance geo-referenced data such as soil characteristics, crop status at land parcel level) these data can (and are more and more often) required for policy monitoring in the Integrated Administration and Control System (IACS). This system supports different administrative and control procedures (Zarco-Tejada et al., 2014): farmers' declaration document; administrative documents; objective evidence of compliance with legislation. Making such data obligatory also stimulates precision agriculture. Such data are also used for surveys such as the Farm Structure Survey (FSS) or the Land Use and Cover Area frame statistical Survey (LUCAS).

Such data transfer also raises issues to which extent governments should also adopt industry standards (or develop them together with industry) on product coding, definitions of fields and crops and to which extent data sharing platforms should be used that are also used by the industry and its compliance or certification bodies for private standards. Arable farmers active in precision farming in the Hoekse Waard, a region south of Rotterdam (and organised in a group named H-Wodka: Hoekse Waard Op De KAart/on the map) convinced the Dutch paying agency that their maps should be used by the agency as they are more precise than those of the government.

Such questions of industry standards are not trivial as they are very much linked with the important issue of administrative burden. A lot of organisations including the government tend to use their own definitions: is a sow a sow once it is at a certain age, or once it gives birth to piglets, or already when inseminated irrespective if this leads to live piglets? – It can make sense for nutritionists, veterinaries, housing specialists or fiscal accountants to differ in such definitions. But the farmer can only use one and he seldom has a big say in such data standards. Something similar holds for websites and other forms to provide data. For all organisations it is the easiest solution to build its own website where a farmer is requested to punch in the data. But a lot of data has to be provided to different parties and farm management systems seldom serve all these destinations with a simple click.

Another issue that governments face in such situations is the property right issue: who owns this administrative data and should it be open data, at least at aggregated level (Zarco-Tejada et al., 2014). Some EU-countries like The Netherlands and United Kingdom have opened up their field data to the public, implying that everybody can see which crops have been grown on a certain field in the last five years. Like other open data this can create new services, but it can also be controversial.

6.2 Market for new products and services

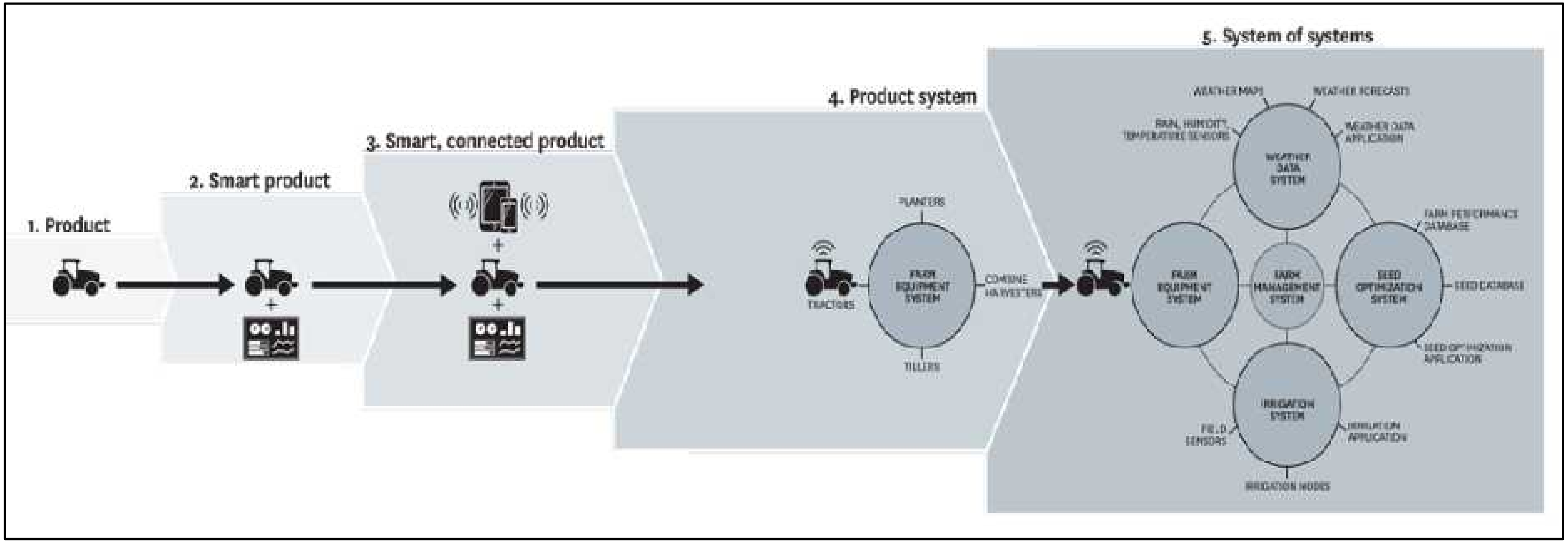
The difference between existing products and new products is a gradual one. But at a certain stage so much smart technology has been added to a product like a tractor that it becomes a new technology with new services. Porter and Heppelmann (2014) gave a nice and much quoted example in the Harvard Business Review of the tractor and how new technology make it a new product with changing industry boundaries (Figure 10). They demonstrate that smart, connected products require a new technology infrastructure, including *a network communications* to support connectivity, *a product cloud* (containing the product-data database, a platform for building software applications, a rules engine and analytics platform), and *smart product applications*. That technology enables the collection, analysis, and sharing of the large amount of data generated. The smart connected products will expand the (competitive) boundaries of an industry itself and so transforming competition. Smart connected farm equipment such as tractors, tillers and planters will enable better overall equipment performance. The tractor manufacture expands from tractor manufacturing to offering a package of connected equipment and related services that optimize results. So a tractor company finds itself competing in a broader farm automation industry. However industry boundaries are expanding even beyond product systems to systems of systems. In precision agriculture not only farm machinery but also irrigation systems, soil and nutrient sources are connected with data on weather, crop prices, and commodity futures to optimize farm performance (see figure 6.2 below).

The emergence of systems of systems raises the question whether a company should seek to provide the platform that connects the related products and data. Or a company can provide open connectivity to related products produced by others. We elaborate that point in the next section.

The ICT revolution brings not only redefined products that cross industry boundaries but also new products: smart phones, apps, drones, milking robots etc. This brings new suppliers with new products in these agricultural input markets. The current market for agricultural equipment and business solutions is still dominated by traditional companies (agricultural original equipment manufacturers and suppliers) but due to the development and adoption of information technology as data analytics and software solutions new, non-traditional players are increasingly entering the market and strengthening their market position. The main market players for precision farming technologies can be segmented into eight categories: traditional agricultural original equipment manufacturers, traditional suppliers, seed companies, large global IT infrastructure providers, high-tech solutions providers (drones, sensors, control systems etc.), start-ups developing smart devices and apps, investment funds/traders, and universities and research centres (Roland Berger, 2015). These crop protection and seed companies, equipment companies, fertilizer companies, retail distributors, and start-ups, are now competing to provide the best precision equipment and digital services. Some companies have already developed an integrated offering of equipment and services for farmers, mainly in the U.S. Corn Belt. Digital start-ups offer only a portion of the full suite of equipment and services that farmers need. The absence of integrated offerings for the overall market creates an opportunity for large companies with more financial resources, whether they are producers of seed, fertilizer, crop protection, or equipment. These companies can gradually build a compelling one-stop solution that will allow them to compete for the lion's share of the market (Corsini et al., 2015).

The government faces several questions in these markets. There can be issues on regulating the use of these products: the commercial use of drones is a clear example (Van der Wal et al., 2015), where governments are forced to rethink current aviation rules. And there is the question of such innovation should be supported and how that should be done, including the provision of infrastructure like broadband or promoting adoption by setting industry standards (as the EU did in the very different cases of GSM for mobile telephony and organic farming). This could help to create markets.

Figure 10. Redefining industry boundaries: from discrete products to systems of systems



Source: Porter and Heppelmann, 2014. Reprinted with permission

6.3 New software and data markets

Besides attention to new physical products as discussed in the previous section, there is a reason to pay special attention to markets for software and data, with apps (applications) and platforms as special categories of software. If data, apps and platforms are becoming so important, can markets for them be created and how can we value them?

Chapter 5 showed already that one of the main challenges is how to organise the data exchange, in a more integrated value chain and certainly in a more open way. Creating value out of data is based on the combination of data from different sources and on the aggregation of data. And the one that gathers the data is not always the organisation that brings out the optimal use of the data. To give some examples: data from soil analysis, crop monitoring and weather forecast have to be combined with data on pesticide recipes to generate a real time spraying advise and to instruct the spraying machine accordingly for automatic filling. The disease pressure of phytophthora in an area can be measured by aggregating the observations from individual fields of different farmers. Data from online sales of manure or fertilizers have to be shared with the accountant, the inspection services of retail standards like GlobalGap and the government for environmental legislation. Banks need access to accounting data of a farm and to benchmarks. This means that there is a need for Agri-Business Collaboration and Data Exchange Facilities (ABCDEFs) (Poppe et al., 2015).

Industry is trying to solve this bottleneck of data sharing by setting up data platforms that perform such a function. This is often done on a company basis (e.g. MyJohnDeere.com). This supports a strategy of companies to become more service oriented and earn money from the added value of data. Such platforms develop into eco-systems of applications (apps, as in smart phone apps, but here also used for machine to machine applications) that interact with each other (e.g. 365FarmNet).

As such this works fine, especially if a food chain is very integrated with one dominant company. The Dutch veal industry is probably an example: farmers are under contract with a slaughterhouse that also provides calves and feed as inputs for farmers and provides (e-)tools for administration and management. The integrating slaughterhouse can create a platform where all apps work in an integrated way based on company data standards and data event processing (pushing data from one app to another). In the machinery industry something similar applies if a company (e.g. John Deere) supplies all the machinery to a client (which is in reality not the case, farmers also buy machinery from competing companies and use contractors with machinery, making support for fleet management difficult).

However many European food chains base their strength on specialisation and are not integrated. For instance in dairy there is a need for data exchange between the machines and robots (machinery industry), breeding, feed companies and dairy companies around the farmer, as well as the service industry like veterinaries, inspection services, accountants and the government (environmental issues, agricultural policy, food safety). In this system the data management is traditionally done by the cooperatives and other organisations around the farm: it are the food processors who send an invoice to the farmer on what they bought from them, as that is more efficient than the farmer invoicing his own sales.

In some European countries the industry has until now tackled the management of these data flows in a digital world by investing in EDI-standards based on reference data models, created by industry standard organisations. For international use these standards are incorporated in the UNCEFACT system and collaboration is currently sought from Dutch and German standard organisations with the American standard organisation AgGateway to promote the use in the rest of Europe.

These EDI standards are very important and have to be enlarged to handle IoT data, but that is only the first challenge. A second challenge is to support the actual data exchange between the apps. With the multiplication of data sources and the fragmentation of software into apps (see below), the transaction costs of linking all relevant data points with each other (one to one) becomes cumbersome. A medium sized Dutch agricultural machine company (Kverneland) recently realised that it had to connect the IoT data stream from its machines with over 50 different farm management software programs that its European clients use. Just making that data available with its own or a reference standard in the cloud will not do, as the farm management software packages probably have to link to 40 different machine companies – it looks attractive to replace 50*40=2000 links by one clearing house / hub).

Even if direct links would work (which is doubtful), there is an important third challenge: the market for services in the form of apps. Some farm management software try to develop apps into complete dashboards, but in many cases there is a fragmentation into individual apps, like on the smart phone: an app for weather advise, an app for spraying sugar beet, an app for transport planning etc. Many of the data-platforms mentioned above support this development (e.g. 365 FarmNet, Akkerweb). This makes software development easier and specialists can work on a specific service in the form of an app. Many of these apps are commissioned by the platform and paid by them; however there are also apps that have a more independent business model. It could be in the interest of users (farmers) and data-platform operators to have a certain competition between apps / services on quality and price and be able to select the most appropriate app for e.g. a spraying advice on phytophthora. And in the (many) cases were a farmer uses more than one data-platform (e.g. of a machine company and of a food processor) it is certainly in his interest to pay only once for e.g. a weather advisory service that can be used in different apps on the different platforms he uses. A situation where he pays for a precise weather forecast from the Dutch meteorological institute KNMI via an app or data platform of a machinery company (directly or indirectly via the price of his machines) and a similar advice from the private weather forecast company Meteo Consult via an app of the sugar beet company to which he delivers his produce is to be prevented. In eco systems of apps, this challenge should be tackled.

A fourth challenge is in the governance of the data exchange. According to the FAIRport conditions[3] data must be findable, accessible, interoperable and reusable, but in reality this is hardly the case. In many cases the ownership of data is quite unclear. Legally ownership of data is hardly a concept, it is mainly based on privacy regulations. New concepts like the right to be forgotten, are introduced. Sometimes 'primary data' are seen as owned by the farmer, 'computed data' as being owned by the one who did the computing. There is clearly a commercial battle going on as data are seen as a strategic asset, having a value.

Most manufacturers of agricultural machines (tractors, equipment, milk robots etc.) use technological measures, such as passwords or encryption, to protect competitors and third party's from copying, tampering or pirating valuable, reliable software code that controls the vehicle, provides safe operation in accordance with safety standards, and complies with applicable emission regulations. In the U.S., the Digital Millennium Copyright Act generally prohibits circumvention of technological measures to gain access to works protected by copyright. However, the Copyright Office can grant exemptions from this prohibition pursuant to a public rule-making proceeding.

In 2015 the Copyright Office issued a two year exemption for Class 21 under 17 USC § 1201(a)(1) for the vehicle owner (acting alone) to circumvent technological measures that protect vehicle software for repair, diagnosis and lawful modification in limited circumstances. The exemption excludes the owner (or others) from circumventing security measures for: (1) computer programs for control of telematics, (2) computer programs for entertainment systems, (3) circumventions that violate Department of Transportation regulations, (4) circumventions that violate Environmental Protection Agency regulations, or (5) circumventions that violate applicable law, among other things.

[3] http://datafairport.org

The European Union issued Directive 2001/20/EC on May 22, 2001, on Harmonisation of Certain Aspects of Copyright and Related Rights in the Information Society, ("2001 EU Copyright Directive") to enable EU members to implement the WIPO Copyright Treaty with anti-circumvention provisions analogous to the Digital Millennium Copyright Act in the United States. (2001 EU Copyright Directive, available at http://www.wipo.int/wipolex/en/text.jsp?file_id=126977). In contrast to the U.S., the member states of the European Union (EU) generally do not have regular rule-making procedures on exemptions to the anti-circumvention provisions. 17 U.S.C. § 1201(a)(1)(B)-(E). Instead, most EU nations appear to have few generally static legislatively-approved exceptions to the anti-circumvention measures that were passed through each of those nation's full legislative or parliamentary process. See, e.g., Act on Copyright and Related Rights (Copyright Act), Article 69(e), Decompilation and Article 95(b) Measures in Respect of Limitations (Germany).

In the U.S. to modify legally the software under the above Class 21 exemption, the vehicle owner might pursue a fair use justification or under the section 117 exception (e.g., for machine maintenance and repair) of the Copyright Act. Under currently existing copyright law and hitherto, the sales of a computer or a vehicle does not transfer ownership of the copyright in the vehicle software to the purchaser of the computer or vehicle. For example, the purchaser of the vehicle does not generally receive the right to copy, modify or distribute the vehicle software, unless authorized under contract or applicable law. Newer equipment of some manufacturers, like John Deere, supports subscriptions to quick, convenient and professional vehicle software updates wirelessly or through a direction connection to a diagnostic port to minimize downtime of vehicles for critical agricultural tasks. Seen these technical developments of being able to update software, the need to have the rights (and be able) to change software in such complex machines like tractors, combine harvesters and milking robots, has not turned out to be a big issue, although this was suggested a few years ago by some. Farmers seem to be more concerned about the flow of data between different software (either at the same time between e.g. software from machines and farm management software, or over time when they change to another brand) than the question to which extent they own the software of their machinery.

Also for algorithms in apps IPR-rules are relevant. In these commercial battles it is not so clear what the scope of the different platforms are, and they are changing: the data platform of a machinery company tends to start with apps on its own machinery or fleet management integrating with other machines. But next is the integration with the input industry, and that brings integration with e.g. farm management software or inspection services. It is on these borders where important innovations can take place but where there is confusion on scope and commercial interests (that differ between the supplying industry, food processors and the farmers themselves).

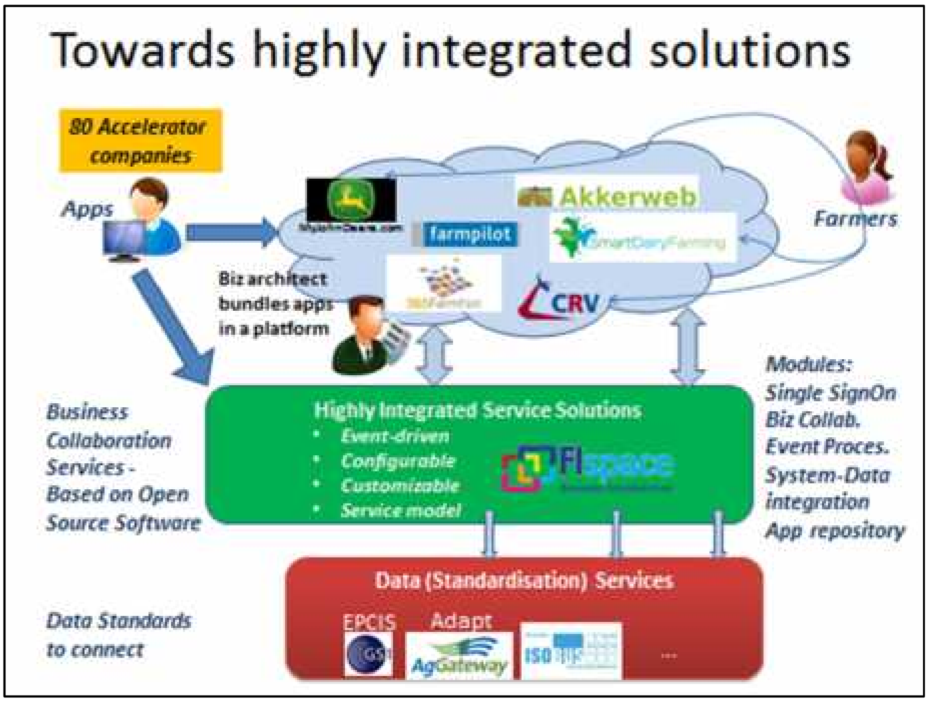
The expectations of the value of big data have also raised the idea that this value can be allocated in some way to the underlying smaller data sets that contribute to the big data insights. However it is unclear how this can be allocated, and if a reward systems or a market for data could work anyway. The unclear situation on data ownership, together with the high expectations on an unclear value of data hamper the governance of data platforms and data exchange between platforms. Should the data exchange be organised in a commercial way by an independent (ICT) company (like SAP and F4F are doing with SAP’s Hannah software: the Facebook solution), or in a non-profit way as a kind of cooperative organisation between platforms (building on experiences with e.g. standard organisations like AgroConnect, service suppliers like GS1 or EDI-circle and open source software development like LINUX) or is there even a need for a public infrastructure (similar to highways that supported the car industry to move people around). And what is the position of farmers in this game: should they or their farm organisations invest?

For the European machinery, input and food industry it is of utmost importance that this issue of agri-business data exchange is solved. It is of more importance here than in the USA, seen how we have organised our food chains with maximum specialisation between the layers instead of integration, with many specialised products in specific value chains (PDO, organic, specialized products instead of big commodities) and high demands on data for tracing and tracking, food safety and sustainability schemes. The international orientation of the machinery industry as well as the multi-national presence of many of the food processing companies (including cooperatives) are another reason of being confronted with this need to link data from different apps and platforms at a European scale.

The FI-PPP project FIspace (commissioned by DG Connect) designed a solution that could create a business collaboration service based on open source software (Figure 11) that would link the different platforms. Farmers could be users of different platforms and communicate between them and with others as e-mail can be exchanged between different mail-programs or websites can be looked at with different browsers. This solution would create a specific layer between the EDI-standards developed by standardisation organisations and certified by UNCEFACT and the commercial platforms.

Such a solution would support the market for platforms that is now an emerging business (often connected to the machinery or input industry), the market for apps, and perhaps even create a market for farmers' data. Figure 12 provides the value proposition for such a service.

Figure 11. Integrating different ICT-platforms (Eco-systems of apps) with a business collaboration service



Source: FI-PPP project FIspace

Figure 12. Value proposition for a collaboration service that would support the markets for platforms, apps and data

Value proposition

Platforms	solve the issue of connecting individually with a lot of business partners to exchange data : connect easily to apps (and data services in apps) based on EDI-standards or let farmers / end-users make the connection
App-developers	Develop one app for different platforms Reach a European / Global market
Governments (and industry organisations)	See above for your government platform (paying agency, public advisory service etc.) Promote innovation by a competitive market for apps with new services Prevent lock-inn situations for farmers and unbalanced power relations in the information exchange in food chains
Farmers	Not a direct FIspace client. Platforms using FIspace inside provide you more choice
Software writers in platforms and app-companies	Helps you to be part of an open source community that cares for sustainable food production with up to date ICT – be recognized by your peers

Platforms tend to have high network effects that could turn them into a natural monopoly. They work like a telephone network or a social media service (e.g. Facebook): people have an incentive to join the network that other persons use as this maximizes options for communication with others. Platforms can also create lock-in effects: they want to keep their clients and don't have an incentive to make it easy to leave and take your data with you. If you lose your own information when you leave, there is incentive to stay. Both effects can make platforms very profitable, and raise competition issues.

Governments are confronted with another issue concerning such platforms. Farmers do no only exchange data in the food chain with input suppliers and food processors, but also with the government, for instance in the CAP (but also in animal registration etc.). Paying agencies and other government agencies can make beneficial use of digital data for control purposes. It would help if they use the same data standards and data exchange platforms as are used in the food chains, to reduce the administrative burden ('simplification of the CAP'). Another aspect is the role of open data, to trigger innovation. For this reason some paying agencies make field data available to the public. A third aspect is that farmers and other stakeholders could share data in the European Innovation Partnership (EIP) Agri framework of interactive innovation with advisory services and researchers. E-Science implies a shift from data collection and research on one experimental farm resulting in a general advice towards using data from many farms resulting in specific advises for individual farms (EU AKIS, 2015).

7 Governance issues

Messages:

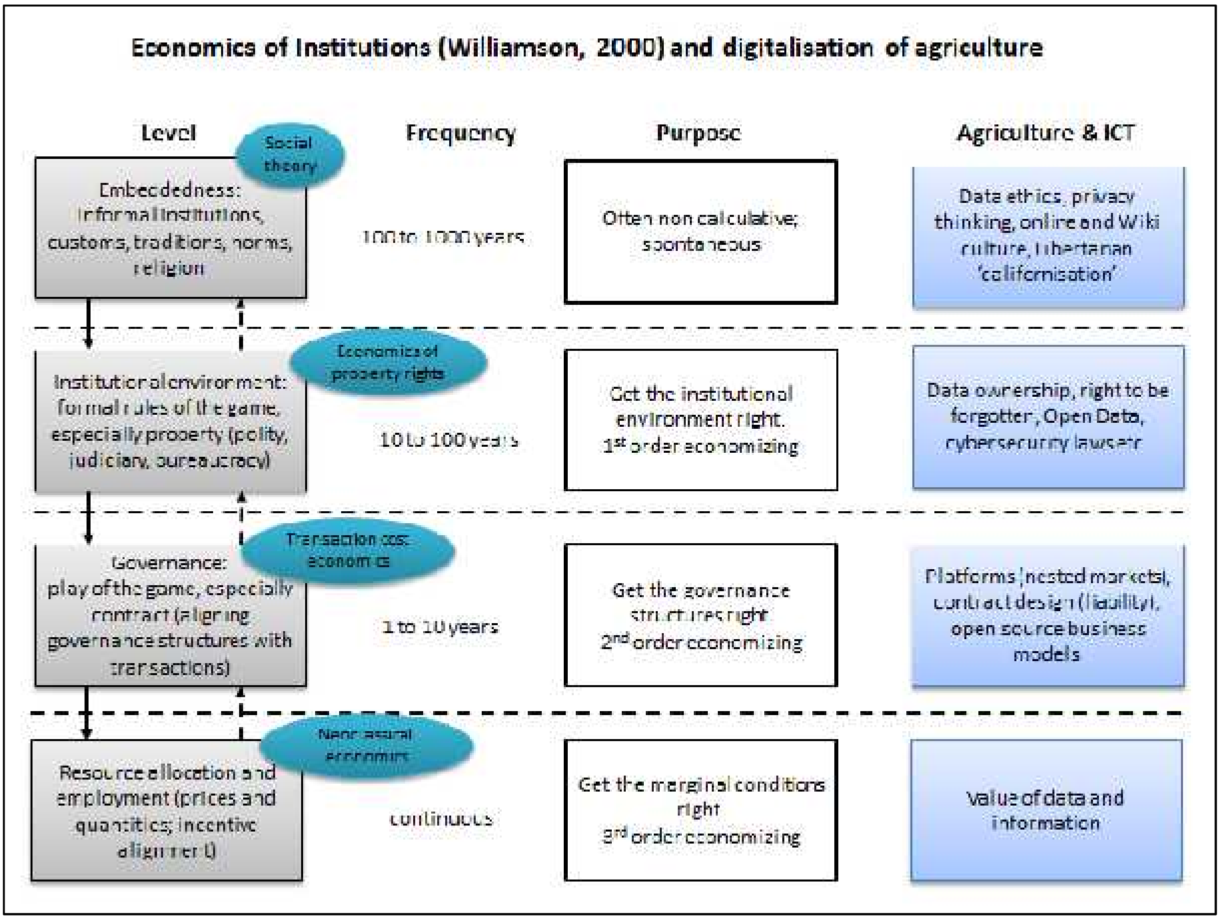
- There are issues to be explored on data ownership, privacy, data ethics and cyber security that need more attention
- The increasing role of ICT in agriculture could have implications at a more cultural level, e.g. in views of the public on the industrialisation of agriculture or lead to a more libertarian view towards the role of the government in agriculture
- It is unclear if the food system of the future will have the characteristics of a centralisation scenario or if disruptive innovation will lead to a scenario of self-organisation.

7.1 Issues at institutional levels

Digitization in agriculture and agri-food sector provides institutional changes. Williamson (2000) distinguishes four levels of institutions (see Figure 13 below). According to Williamson property rights change much slower (e.g. over a period of 10-100 years on average), but they determine contractual relations, that change faster (e.g. on average in a period between 1 and 10 years) and those contract determine daily trade. The influence is not only from culture (norms and values, e.g. regarding types of meat that can be eaten) to property rights and further down, but also the other way around: if something loses its scarcity (e.g. options to broadcast radio or television) contracts and property rights change (e.g. commercial television instead of the national public channel) .

The ICT-revolution in agriculture will continue for some time. The speed of technological developments and digitization in agriculture is much greater than the speed with which institutions change: old institutions can block uptake of ICT and ICT use can lead to new types of property rights (like the right to be forgotten). As such changes take place at different speeds, discussions and frictions are to be expected: see the examples of Airbnb and Uber are sometimes blamed to have a business model that is not legally acceptable. Through changes in property rights and transaction costs, the effects of the ICT-revolution in agriculture could be larger in the coming years than they were until now.

Figure 13. Digitalisation of agriculture on four levels of institutions



Source: Adapted from Williams (2000)

Data ownership

Data collected in precision farming offer opportunities to enhance production but it is not always clear who owns data generated through precision farming: farmers, the agronomists or service providers that create data, or machinery and software producers. Farmers in the US have already voiced concerns about the unregulated use of data from their businesses (POST, 2015).

The ownership of data sets forms another critical aspect related to the massive amount of data that is gathered from sensors that are distributed across the farm. This has implications for data-sharing schemes and privacy issues. Farmers tend to be unwilling to share data about their operations with third parties, which poses serious problems regarding efficient data integration (EIP-AGRI, 2015). There are different aspects in this "ownership" discussion. One is that farmers see some data as privacy sensitive or a business secret that they do not want to see revealed to competitors or (e.g. in case of environmental data) to the public or the government. Agri-businesses (including e.g. equipment manufacturers) sometimes state in their contracts that they treat collected data as personal, offer options to reduce the data flow and honor requests to remove data from their servers. Another aspect is if the farmer has access to the data himself now, and can combine it with other data on his farm, e.g. in his own farm management dashboard, as well as in the future when he changes suppliers.

From a legal perspective there are no rules regulating ownership of a data set. There are no property rights in data as you can only have property rights in a tangible good. Data are also not protected by intellectual property rights, like books, movies and software are protected by copyright against copying (Moerel, 2014). However there are other legal rules that can apply and determine whether data can be used for certain purposes and whether data can be transferred to another party. Non-public data can be protected: (1) under applicable privacy rules (if the data contains personal information), (2) as confidential information (e.g., trade secrets) in many jurisdictions (if the information is not publicly available), or (3) under database rights, which are applicable under EU Directive 91/250/EEC. The U.S does not have similar protection of database rights. However, if the data is disclosed (e.g., reported) to a government regulator, publicly disclosed or published, the protection as confidential information may be unavailable or lost. This all means that (at least for the moment) contract law between farms and other businesses determine if a farmer feels himself "owner" of the data gathered on his farm and can use that in other applications.

New business models for data management are needed; sharing and open-data sources should be developed to bring Precision Farming to the next level. The recognition of data ownership is crucial. Portals that can facilitate the exchange of data are a prerequisite (EIP-AGRI, 2015).

Patents

From 2010 through 2014 there were 5,337 new patent registrations worldwide relating to precision and conventional equipment for agriculture: various sensors, variable-rate/depth components, connectivity of sensors and equipment, automated applications for dairy farms, autonomous vehicles, precision harvesters and mowers, sensors and components for autonomous driving, equipment components, and tractor components. 70 per cent of those new agriculture patents are assigned to North America (the location of the filing company's main headquarters), 15 per cent in Europe, 8 per cent in China and 7 per cent in other regions in the world (Corsini et al., 2015).

One of the main restrictions for data sharing among institutions, farmers, advisers and researchers is due to non-standard software and data formatting solutions. The challenge is to enable data sets to be shared easily irrespective of the sensor model and brand used. As modern farms are increasingly loaded with all kind of sensors, data management, data storage, data sharing and interconnectivity strategies are urgently needed (EIP-AGRI, 2015).

7.2 Two scenarios

In general effects of technologies on society are being overrated on the short term and are being underrated on the long term. With this in mind we envision the possible effects of the digitalisation in agriculture and the agrifood sector on governance issues by applying two future scenarios developed by EU SCAR (2015). One is the High Tech scenario, in which the power and decision making takes place at a higher level away from farmers and the value chain is organised along a Captive model (see chapter 4). The alternative is the Self-organisation scenario, in which farmers, citizens and decentralised governments take the lead and the Modular model of chain management prevails.

High Tech Scenario

The High Tech scenario assumes a world dominated by large multinationals and advanced technology (ICT, robotics, genetics). It is characterised by globalisation, widespread use of unmanned vehicles, contract farming and outsourcing, with a large urban population. European institutions are strong, national governments are weak. In general it is a wealthy society, but inequality creates concern. Sustainability problems are largely solved through technical solutions such as precision farming and genetic modification (EU SCAR, 2015). In this scenario governments are faced with monopolies, privacy and exclusion issues.

An example is John Deere's Big Data pact with Monsanto. John Deere has granted Monsanto exclusive access to data of its systems that can be used for the Climate Field View, the management platform of Monsanto that farmers use to measure the growth of their crops and the soil conditions. Monsanto is now able to offer their customers a better link to data systems of John Deere.

Possible effects of this scenario are:

- Scaling-up: large agricultural companies arise from mergers; they are closing contracts with multinationals in supply, processing and retail. NGO's are one of the checks and balances and they force multinationals to have farmers working in a sustainable way, using such technology.
- Ownership relations: data owned by multinationals, farmers towards a franchise model, exclusion.
- The role of national governments decreases. Agreements must be made at the international level (WTO, TTIP) by international operating enterprises. The EU represents European countries.

Self-Organisation Scenario

In the Self-organisation scenario a Europe of regions exists with bottom-up democracy where new ICT technologies with disruptive business models undermine large companies, high-tech and traditional craftsmanship that leads to self-organisation, bottom-up democracy, short-supply chains, and multi-forms of agriculture. European institutions are weak, regions and cities rule and follow quite different pathways for agriculture. Products are traded between regions. There is inequality between regions, depending on endowments. In this scenario the government has to deal with the question how to arrange and guarantee public interests when facing institutional changes. Possible effects of this scenario are:

- Scale: collaboration at regional scale arises, added value is more than just money but also experience, origin of food products.
- Ownership relations: farmers remain owner of the data, farmers organize themselves in cooperatives that close contracts; new business models emerge.
- Sustainability: the availability of knowledge on high-tech systems → improves the resource efficiency and decreases the pressure on the environment of agricultural firms; agreements between companies, citizens, NGOs and regional or local government on goals, monitoring and control.

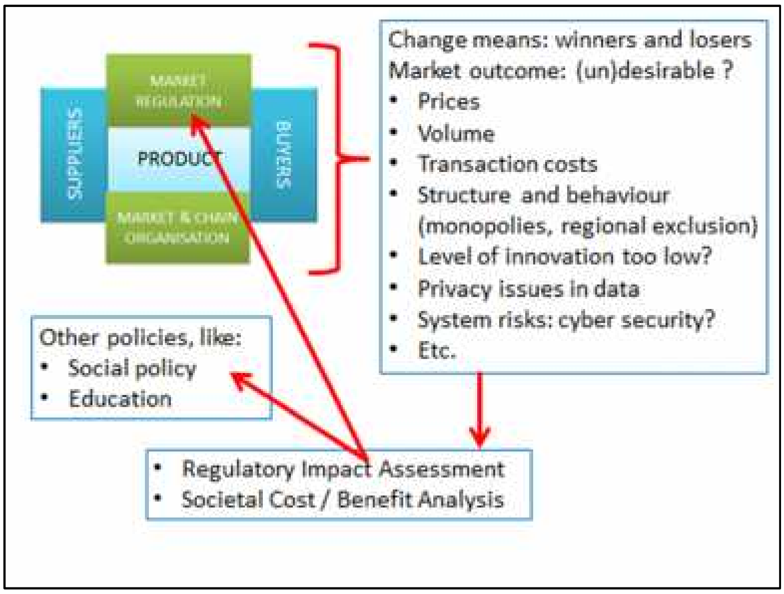
8 Key Messages - Implications for policy

Messages:

- Precision agriculture, and particularly the digitalisation of agriculture, has not only implications for the CAP but also for other EU policy domains: Environmental Policy, Regional Policy, Competition Policy, Science and Innovation Policy, Digital Policy.

As described in chapter 5 precision agriculture and the digitalisation of agriculture will have effects on the organisation and functioning of markets for products. Not only on existing markets for products, but also on markets for new products and services, and markets for new software and data. This concerns price, volume, transaction costs, market structure and behaviour (monopolies, regional exclusion), level of innovation, privacy issues in data, system risks (cyber security) etc. (see Figure 14 below). These market outcomes can be assessed with regulatory impact assessments, or societal cost/benefit analysis. Leading, if outcomes are undesirable, to market regulation or to other government interventions (e.g. training in education). This implies that all these issues could have implications for different EU policy domains.

Figure 14. Markets effects with implications for policy



Source: LEI, Wageningen UR

Agriculture serves several interests e.g. interests related to the production of crops and the provision of employment. Agriculture has various public interests which demand for a kind of government interference: production value and employment of agriculture, food security, food safety and animal health, animal welfare, environment and climate, nature and biodiversity, water management, liveable rural area (regional development). Some of these public interests are not automatically guaranteed by the market and ask for government intervention. The digitalisation of agriculture serves some interests such as food safety and less environmental pressure. The (negative) external effects in agriculture can be reduced by ICT in a way that could be more attractive than by regulation. This invites governments to take an active role in promoting ICT. However, ICT also has its negative aspects, the effect on employment. ICT could help the competitive position of the machinery industry, but it could also destroy jobs in rural areas. And there are new issues that could be put on the plate of the government like privacy of farmers, ownership of data, and shift of power balance in the chain.

Against this background we discuss the most important issues from this report for relevant EU policies.

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.

The Common Agriculture Policy relates to about ten policy objectives: Maintain market stability; Meet consumer expectation; Enhance farm income; Improve competitiveness; Foster innovation; Provide public environmental goods; Pursue climate change mitigation and adaptation; Maintain agricultural diversity; Promote socio economic development of rural areas. Digitalisation of agriculture contributes to the realisation of many those policy goals, in production as well as in environmental objectives. Therefor the fostering of innovation in the CAP (through measures as the European Innovation Partnership, Farm Advisory Services, Investment support) should certainly include the uptake and further development of ICT.

The execution of the CAP by the Management Authorities itself benefits from the use of up to date ICT and should be integrated as much as possible with ICT platforms and standards from the industry, as this reduced the administrative burden. This integration should include an option for farmers to send his data in the IACS system to other stakeholders like his accountant or food processors. The data that are in these systems could be made available to the public as open data to foster innovation. A large part of the data is linked to environmental issues in farming (crops can be a proxy for pesticide use, animals for nitrate or ammonia problems), and the Arhus Convention urges governments to make environmental data public.

Using up to date ICT databases can also make the agricultural policy more smart. A much discussed example is the greening-obligation to grow three crops. This stems from the idea that crop-rotation on the same field is a good agricultural practice but has been turned into an obligation to grow three crops in the same year. This hinders farmers who grow one specialty crop (e.g. a certain vegetable) and rent different fields every year. With modern ICT is should be possible to check the rotation at a field basis. In a similar way farm data can be linked to income tax data, so that the recent complaint of the Court of Auditors that the European Commission is in its Farm Accountancy Data Network or otherwise not aware of the total farm income, could be redressed.

The Rural Development Policy (the second Pillar of the CAP) is especially important to promote the uptake of ICT.

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 digital natives and have good access to the internet (by broadband glass fibre or 4G/5G). Our analysis in previous chapters signalled the risk that some countries or regions in Europe could face a rural exodus if unmanned tractors become a reality and some decision making will be done remotely. 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 internalized 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.

Council Directive 91/676/EEC (The Nitrates Directive) concerns the protection of water against pollution caused by nitrates from agricultural sources. The Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures.

The Water Framework Directive (Directive 2000/60/EC) commits EU members to achieve good qualitative and quantitative status of all water bodies by 2015. The purpose of the Water Framework Directive with regard to agriculture is to lower the impact of fertilizers and herbicides on surface water. The latest relevant amending act was Directive 2013/39/EU concerning priority substances..

The EU has policy limiting individual sources to limit air pollution, responsible for acidification, eutrophication and ground-level ozone pollution. Directive 2001/81/EC (the National Emission Ceilings Directive) sets upper limits for each Member State for the total emissions in 2010 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia). The NEC Directive is being reviewed as part of The Clean Air Policy Package, proposed in 2013 by the EC. It concerned a proposal for a Directive on the reduction of national emissions of certain atmospheric pollutants and also amending Directive 2003/35/EC.

Directive 96/61 on Integrated Pollution Prevention and Control (IPPC) highlights a more holistic approach to environmental protection. This Directive regulated all emissions that came from commercial sites and has only limited relevance to the agricultural industry. It only applies to specific commercial installations which include slaughter houses, food production plants, milk processing and treatment centres and those disposing of or recycling animal by-products. In terms of agriculture itself, only installations for the intensive rearing of poultry or pigs are identified. 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. But 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

What counts for environmental policy can also be applied to food safety policy. Digitalisation and exchange of data contributes to further extension and improvement of tracking and tracing systems. Making such data available to the public is especially important in times of food scares, when consumers feel uncertain and have high search costs.

The General Food Law Regulation (EC) 178/2002 provides the general principles of food safety which include the requirement on 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

ICT has effect on the organisation of the food chain: some open markets disappear and give way to collaborative contracts between farmers and food processors (see chapter 5). This should be taken into account in discussion on the organisation of the food chain and the effect on the distribution of the value added in the food chain.

Technology comes with new business models of new suppliers entering the market. In other sectors (Airbnb, Uber) we have seen cases where new players challenge/violate current market regulations. For example Uber is making car owners to become taxi-drivers. So they are competing with traditional taxi-drivers who have paid for their license and exam. This raises competition issues, however until now no clear examples are known in agriculture.

Another issue is the potential (natural) monopoly of data platforms. From a technological perspective a platform can be considered as a utility. Platforms can create lock-in effects, meaning it is becoming almost impossible for farmers to leave the platform and join another platform without losing valuable data. So the issue is to what extent does the government allows a platform to be controlled by the supplier or buyer of agricultural products because in that case there is a chance that lock-in effects will be occur. Furthermore platforms can create switching costs for farmers even without lock-in. This has to do with the portability of data. Like switching to another insurance company or energy supplier. The government can facilitate that by regulation that allows for more competition and preventing monopolies. On the other had there is a clear need for data exchange between companies and platforms. Collaboration on these aspects by competing companies in a food chain should therefore not be ruled out by competition authorities.

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 Horizon2020 research programme should further support the development of ICT-innovation for agriculture and the food sector. This should not be restricted to ICT in farming, but include the whole chain, including logistics and the consumer, including the relation between food and health. The application of a so-called multi-actor or network approach in such innovation could be very useful, as the introduction of ICT has aspects of social innovation: partners have to change their working methods at the same time for a successful introduction. Farmers and other stakeholders should be encouraged to share data with advisory services and researchers for interactive innovation and citizen science. So using big data from many farms can result in better specific advise for individual farms.

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 has also launched in agriculture, are a new approach to EU research and innovation.

Industrial Policy

To promote jobs and growth the EC could support the European machinery manufacturers by adopting Internet of Things technology and new products (e.g. unmanned tractors, drones for agriculture). In some cases a switch from a product orientation to a global service (with big data strategies that bring the data from the machines together) could create new types of employment in data science. In some cases new products asks for a renewal of the market regulation (e.g. for a safe integration of drones in the European airspace regulation).

EU Industrial policy aims to stimulate growth and competitiveness and includes a set of EU priorities such as trade, innovation and energy. The legal basis of the industrial policy is Article 173 of the TFEU. In its communication 'Preparing for our future: Developing a common strategy for key enabling technologies in the EU' (COM(2009) 0512), the Commission stated that the EU would foster the deployment of key enabling technologies (KETs).

In January 2014 the Commission launched the communication 'For a European Industrial Renaissance' (COM (2014) 0014) focusing on more coherent polices in the field of the internal market, including European infrastructure such as information networks, as well as for goods and services. For achieving its policy goals the EC manages the following support programmes: COSME (programme for the competiveness of enterprises and SMEs), Horizon 2020, and Galileo and Copernicus. EU Industrial policy also includes providing support for 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

From a legal perspective there are no rules regulating ownership of data. There are no property rights in data as you can only have property rights in a tangible good. This situation regarding data "ownership" is currently not very clear for many farmers and other food chain operations, so it needs at least explanation. A set of European rules (not necessarily in the law) that provide guidance to farmers and other stakeholders in the chain on how to deal with data governance (e.g. data from the laboratory of a food processor on the quality of the farm produce, data in the milking robot on the cows of the farmer, data with the paying agency on the farm) and obligations to make this available to the farmers would be very welcome.

Special attention is needed for establishing an open data exchange in and around the food chain, with adequate standards and platforms for data exchange that have a governance structure that prevents misuse of natural monopolies or lock-in effects. Making farmers owner of their data (although judicially speaking that is a difficult concept) and providing opportunities to control the flow of their data to stakeholders by authorisations should build trust with farmers for exchanging data and harvest the fruits of the analysis of big data.

Relevant is 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, and repealing Directive 95/46/EC (General Data Protection Regulation). 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

In order to strengthen the innovative potential in Europe, the EC is focussing on generating value through the re-use of public data (data that public bodies in the EU produce, collect, or pay for) in new products and services and for efficiency gains in administrations. In this respect the following measures have been taken: a revised Directive on the re-use of public data, financing instruments to stimulate R&D in open data, the creation of European data-portals, and facilitating coordination and experience sharing across the Member States. National and regional governments in some countries in Europe have opened up data farmers are obliged to deliver to paying agencies such as field maps, satellite data, data about nature conservation subsidies etc.

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 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.

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BRIEFING PAPER 5

ENVIRONMENTAL IMPACT OF PRECISION AGRICULTURE

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List of abbreviations

CIAA	Confederation of the Food and Drink Industries of the European Union
EAFRD	European Agricultural Fund for Rural Development
EIP	European Innovation Partnership Network
FSSCS	Food Safety System Certification standard
GAP	Good Agricultural Practices
GFSI	Global Food Safety Initiative
Ha	Hectare
HACCP	Hazard Analysis and Critical Control Points
IACS	Integrated Administration and Control System
IPM	Integrated Pest Management
IWM	Integrated Weed Management
JRC	Joint Research Centre
K	Potassium (kalium)
MRL	Maximum Residue Level
N	Nitrogen
NUE	Nitrogen Use Efficiency
NVZ	Nitrate Vulnerable Zones
P	Phosphorus
PAS	Publicly Available Specification
PPUE	Physiological Phosphorus Use Efficiency
PUE	Phosphorus Use Efficiency
QS	Qualität und Sicherheit GmbH
PA	Precision Agriculture
RD	Research and Development
SQF	Safe Quality Food institute
UAV	Unmanned Areal Vehicles (drones)
VOC	volatile organic compound
VR	Variable rate application (of fertilizers or seeds)

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1 Main policy issues

In this paper, the environmental impact of precision agriculture is assessed. In the following paragraphs the main policy issues and relevant EU legislation is presented. At the end of this Chapter a summary table of the impact of precision agriculture on environment is included.

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 European Agricultural Fund for Rural Development ("the EAFRD ") and established by Regulation (EU) No 1306/2013. It sets out the objectives to which rural development policy is to contribute and the relevant Union priorities for rural development. It outlines the strategic context for rural development policy and defines the measures to be adopted in order to implement rural development policy. In addition, it lays down rules on programming, networking, management, monitoring and evaluation on the basis of responsibilities shared between the Member States and the Commission and rules to ensure coordination of the EAFRD with other Union instruments.

On request of the European Parliament's Committee on Agriculture and Rural development, the Directorate-General for Internal Policies prepared with the Joint Research Centre (JRC) a study on 'Precision agriculture – An opportunity for EU farmers - Potential support with the CAP 2014-2020' (Zarco-Tejada el al., 2014)

Within the range of Pillar II measures available within Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013, Zarco-Tejada el al., (2014) list in the policy document several of the measures that are available for member states to support precision agriculture development through their RD programmes.

These 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 can concern commitments for both livestock and cropping systems. PA may provide agronomical and environmental justifications for that measure.
- Article 17 (Investments in physical assets)
  The measure aims at farm modernisation and intensification;
- Article 35 (Co-operation)
  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 practices 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 precision agriculture.

In addition, precision irrigation strives to make efficient use in terms of timing and location as well as water volume use. 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. and can at the same time also

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

- Articles 55, 56 and 57 (European Innovation Partnership Network EIP)
  An EIP network is be put in place to support the EIP for agricultural productivity and sustainability. It shall:
  - promote a resource efficient, economically viable, productive, competitive, low emission, climate friendly and resilient agricultural and forestry sector, working towards agro-ecological production systems and working in harmony with the essential natural resources on which farming and forestry depend;
  - help deliver a steady and sustainable supply of food, feed and biomaterials, including existing and new types;
  - improve processes to preserve the environment, adapt to climate change and mitigate it;
  - build bridges between cutting-edge research knowledge and technology and farmers, forest managers, rural communities, businesses, NGOs and advisory services.

1.1 Supporting the IACS (Integrated Administration and Control System) procedures

Objective evidence of compliance with legislation

The recording and geolocation of activities performed in each parcel (Digital farm book: date or timing, quantity of fertilizer/pesticide inputs, etc.) could be used by farmers as evidence of the respect to cross compliance rules (*e.g.* nitrogen quantity/ha, timing of application for the Nitrate Directive) (Zarco-Tejada el al., (2014).

Here we could also add the timing and quantity of manure slurry spreading in the field in accordance with respect to national or regional regulations on environmental impact.

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 fertilizer application (mineral and organic), taking into account crop needs, all nitrogen inputs and soil nitrogen supply, 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 of 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.

1.2 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 Rural development policy 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 funding streams there are nine programmes of 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. More details are available from EIP-Agri, 2016.

Below a summary table is presents the impact of the main precision agriculture processes and techniques on environment discussed in this study.

Table 1. Expected environmental gains from main PA processes and techniques

No.	Process	Technique	Expected environmental gains
1	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)
2	Leave permanent vegetation on key location and at field borders	Automatic guidance and contour cultivation on hilly terrain	Reduction of erosion (from 17 to 1 tonnes/ha/year and perhaps lower) Reduction of runoff of surface water and reduced runoff fertilizers Reduced flood risk
3	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 fertilizer runoff
4	Keep fertilizer or pesticide at recommended distances from water ways	- Automatic guidance based on geographic information - Section control of sprayers and fertilizer distribution	Avoidance/elimination of direct contamination of river water

No.	Process	Technique	Expected environmental gains
5	Avoid overlap of pesticide or fertilizer application	- Section control of sprayers and fertilizer distribution	Reduce/avoid excessive chemical input in soil and risk of water pollution
6	Variable rate manure application	On the go manure composition sensing Depth of injection adjustment	Reduced ground water pollution Reduced ammonia emissions into the air
7	Precision irrigation	Soil texture map	Avoidance of excessive water use or water logging. Reduction of fresh water use
8	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**. 24.6% average herbicide savings was achieved in tramline spraying field trials
9	Early and localized pest or disease treatment	Disease detection - 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. (Moshou et al., 2011)
10	Orchard and vineyard precision spraying	- Tree size and architecture detection - - Precision IPM	Reduction in pesticide use up to 20 – 30 % Reduction of sprayed area of 50-80%
11	Variable rate nitrogen fertilizer 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 %
12	Variable rate phosphorus fertilizer application according to crop requirements and weather conditions	Crop vegetation index Soil nutrient maps	Improvement of phosphorus recovery of 25 %
13	Crop biomass estimation	Crop vegetation index	Adjust the fungicide dose according to crop biomass (Jensen and Jørgensen 2016)
14	Mycotoxin reduction	Crop vegetation index and fungal disease risk	Optimisation of fertilizer dose and fungicide use on the basis of higher disease risk in areas with high crop density

*Gerhards and Oebel 2006
**Luck et al 2010
***Dammer and Wartenberg 2007

2 Good agricultural practices (GAP) standards

Good Agricultural Practices (GAP) in general cover a number of activities on the farm that relate to:

- food safety criteria derived from the application of generic HACCP principles;
- avoiding the inappropriate use of chemicals and reduce the level of residues found on food crops;
- environmental protection to minimise negative impacts of agricultural production on the environment;
- occupational health, safety and welfare criteria on farms, including socially related issues;
- where applicable, a global level of animal welfare criteria on farms.

Many farmers in developed and developing countries already apply GAP through sustainable agricultural methods such as integrated pest management, integrated nutrient management and conservation agriculture. GAP applies available knowledge to address the environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products. These methods are applied in a range of farming systems and scales of production units, including as a contribution to food security, facilitated by supportive government policies and programmes (FAO, 2003). A GAP approach to agriculture involves the establishment of guidelines or standards for agricultural producers and post-farm handlers, the monitoring of these standards, and the communication of these standards through credible quality signals to downstream firms, consumers and the public in general (Hobbs, 2003).

FAO (2003) also lists Good Agricultural Practices for selected agricultural components like: soil, water, crop and fodder production, crop protection, animal production, animal health and welfare, harvest and on-farm storage and processing, energy and waste management, human welfare health and safety, wildlife and landscape. Food safety is not explicit in this list, but it is of course a major overall concern.

As an example, the GLOBAL GAP (2016) standard covers the whole agricultural production process of the certified product, from before the plant is in the ground (seed and nursery control points) to non-processed end products (produce handling control points). For example the fruit and vegetables standard covers

- Food safety
- Traceability
- Quality assurance
- Workers' occupational health & safety
- Site management
- Soil management
- Fertilizer application management
- Integrated pest management
- Plant protection products management
- Water management

There are also scope modules related to livestock standards with extension to animal welfare. A general regulations document explains the structure of certification to the GAP Standard and the procedures that should be followed in order to obtain and maintain certification. The requirements for GAP certification are bundled in documents with control points and compliance criteria.

Several GAP schemes have similar requirements although the emphasis may be different depending on the country where it was initiated or applied.

Qualität und Sicherheit GmbH (QS 2016) is another scheme to support producer organizations to provide producers with support in the form of practice-oriented requirements that have been compiled in the QS guidelines and self-assessment checklists.

While these schemes may appear different, there exist possibilities to for benchmarking schemes or for mutual recognition equivalent modified checklists such that in a single audit on a farm certification for these can be the different schemes obtained.

Food safety

Closely related to good agricultural practices is food safety. government regulations and requirements, sometimes in response to accidents involving human health, as well as business and retailers expect the producers and suppliers along the whole chain to have a food safety management scheme that can be audited. SAI-Global, 2016 as well as TÜV Rheinland are private organisations that promote industry based food safety quality systems. The origin of these systems and the scheme owners may all be different, but in general they share the same concern about GAP and food safety. Key players are listed below:

SAI-Global, 2016, is specialized in certification of quality management systems.

FSSC/FS 22000 (Food Safety System Certification standard), is the latest certification scheme for food manufacturers. The scheme is based on the integration of ISO 22000:2005 Food Safety Management Systems standard and Publicly Available Specification (PAS) 220. Supported by FoodDrinkEurope[1], FS 22000 has been fully approved by the Global Food Safety Initiative (GFSI).

ISO 22000 takes a whole chain approach to food safety, providing a standard that isn't just for food processors, but goes all the way from the farm to the fork including packaging and ingredient suppliers, caterers, storage & distribution facilities, chemical and machinery manufacturers and can be applied to primary producers such as farms.

BRC Global Standards, the world's first GFSI-recognized standard, is one of the choices for retailers worldwide looking for confidence from food suppliers.

SQF (Safe Quality Food institute) is one of the world's leading food safety and quality management systems, designed to meet the needs of retailers and suppliers worldwide. The programme provides independent certification that a supplier's food safety and quality management system complies with international and domestic food safety regulations.

HACCP (Hazard Analysis and Critical Control Points) is a risk management system that identifies, evaluates, and controls hazards related to food safety throughout the food supply chain.

IFS International Food Standard is a quality and food safety standard for retailer (and wholesaler) branded food products, which is intended to assess suppliers' food safety and quality systems, with a uniform approach that harmonizes the elements of each.

GFSI: Under the umbrella of the Global Food Safety Initiative (GFSI), 7 major retailers have come to a common acceptance of four GFSI benchmarked food safety schemes.

PACsecure is a HACCP-based standard for the packaging industry.

Global GAP was introduced by FoodPLUS GmbH, derivative of GLOBALGAP, to raise standards in the production of fresh fruit and vegetables. Certification to the standard ensures a level playing field in terms of food safety and quality, and proves that growers are prepared to constantly improve systems to raise standards. Additional lists with regional implementation specifics of GAP schemes can be found in FAO,2016.

[1] Before 2011: Confederation of the Food and Drink Industries of the European Union (CIAA)

Chemical residues

The use of pesticides is very much regulated in terms of which molecules are allowed on which crops and also on what the minimum waiting time is between treatment and harvest. This is in addition to the maximum residue level (MRL) on the product. Furthermore, there is no good MRL regulation when cocktails or mixtures of pesticides have been used on the same crop. The question is if there is an additive effect, or can there be an MRL separately for each molecule in the cocktail. Of course, no residues should be found of molecules that are not registered for use. Within Europe, the Commission evaluates every active component against pests/plant diseases (the "active substance") for safety before it reaches the market in a product. Substances must be proven safe for people's health, including their residues in food and effects on animal health and the environment. The MRL of this active substance applies then EU wide. However, there are differences between countries in authorized products (containing active substance). Within Europe, the free trade of crops is between countries is not hindered by these differences since the MRL's are valid for the entire EU. However, for trade with countries outside the EU it is more difficult for farmers and exporters, since a molecule allowed in the country of destination may not be allowed in the country of production or vice-versa and also the MRL's may be differently defined

In response to the challenges posed by fast changing crop protection product legislation, the GLOBALG.A.P. organization developed guidance notes to help producers to become fully aware of the maximum residue limits (MRLs) in operation in the markets where the product will be sold. Minimum waiting times are also in the check lists of most GAP schemes.

Microbial safety

The Community microbiological criteria for foodstuffs have been revised and certain important new criteria have also been set down. Commission Regulation (EC) No 2073/2005 on microbiological criteria for foodstuffs, applicable from 1 January 2006, lays down food safety criteria for certain important foodborne bacteria, their toxins and metabolites. The regulation contains the rules to be complied with by food business operators when implementing the general and specific hygiene measures. The microbiological criteria have been developed in accordance with internationally recognised principles, such as those of Codex Alimentarius.

In the USA, the FDA and USDA issued in 1998 a "Guidance for industry – Guide to minimize microbial food safety hazards for fresh fruits and vegetables." This guidance document ("the guide") addresses microbial food safety hazards and good agricultural and management practices common to the growing, harvesting, washing, sorting, packing, and transporting of most fruits and vegetables sold to consumers for reducing the risk of microbial contamination in fresh produce or minimally processed (raw) form (USDA, 1998, 2015). The guide identifies 8 basic principles of microbial food safety related to growing, harvesting, packing, and transporting fresh produce. They form the basis for good agricultural management practices to avoid microbial food safety problems.

Consumers perceive very often fresh leafy vegetables and other raw or minimally processed vegetables or fruit as very healthy. However, recent outbreaks of food based illnesses could be traced back to fresh products-associated contamination (FDA 2007). Retailers selling leafy vegetables are risk averse and are targeting zero-risk production systems. There is also an increasing evidence of contamination of products from irrigation water, but scarce information on the microbial quality of agricultural water is available. It is likely that a combination of different approaches like chemical or physical treatment and drip irrigation water placement will be needed to meet the microbial requirements of leafy vegetables and ensure safe food for consumers (Allende and Monaghan, 2015). A study by Van Der Linden et al. (2014) confirms that the survival of Salmonella and E. coli O157:H7 may vary between different irrigation water samples.

Toxin safety

Microbial and toxin contamination can occur during the field stage and at harvest and postharvest. In GAP regulations this is mainly linked to worker hygiene and to systems to enforce hygiene of workers and repeated cleaning of harvesting and transport equipment.

Other aspects of microbial and mycotoxin risks are related to fungi developing on crops growing in the field. In the following we use edited excerpts from the review articles of Piotrowska et al. (2013) and Klabak et al. (2006) to summarize the main agricultural practices related to mycotoxin risks

Due to their chemical composition, cereals and soybean are particularly susceptible to microbial contamination, especially by filamentous fungi. Cereals, soybean, and other raw materials can be contaminated with fungi, either during vegetation in the field or during storage, as well as during the processing. Fungi associated with cereal grains and oilseeds are important in assessing the potential risk of mycotoxin contamination. Mycotoxins are fungal secondary metabolites which are toxic to vertebrate animals even in small amounts when introduced orally or by inhalation. Cereals in the field are exposed to fungi from the soil, birds, animals, insects, organic fertilizers, and from other plants in the field. Fungal growth is influenced by complex interaction of different environmental factors such as temperature, pH, humidity, water activity, ventilation, availability of nutrients, mechanical damage, microbial interaction or the presence of antimicrobial compounds. Poor hygiene, inappropriate temperature and moisture during harvesting, storage, processing and handling may contribute to increased contamination extent. Appropriate field management practices include crop rotation, soil cultivation, irrigation, and fertilization approaches are known to influence mycotoxin formation in the field. Crop rotation is important and focuses on breaking the chain of production of infectious material, for example by using wheat/legume rotations. The use of maize in a rotation is to be avoided however, as maize is also susceptible to *Fusarium* infection and can lead to carry-over onto wheat via stubble/crop residues. It is generally accepted that wheat that follows an alternative host for *Fusarium* pathogens is at greater risk of subsequent contamination of grain. The soil must be tested to determine if there is need to apply fertilizer and/or soil conditioners to assure adequate soil pH and plant nutrition to avoid plant stress, especially during seed development. Fertilizer regimes may affect *Fusarium* incidence and severity either by altering the rate of residue decomposition, by creating a physiological stress on the host plant or by altering the crop canopy structure. In some instances it was reported that increasing the nitrogen-rate significantly increased the incidence of *Fusarium* infection of grain in wheat, barley, and triticale. Environmental conditions such as relative humidity and temperature are known to have an important effect. There is evidence that drought-damaged plants are more susceptible to infection, so crop planting should be timed to avoid both high temperature and drought stress during the period of seed development and maturation. Another factor which is known to increase the susceptibility of agricultural commodities to toxigenic mould invasion is injury due to insect, bird, or rodent damage. Insect damage and fungal infection must be controlled in the vicinity of the crop by proper use of registered insecticides, fungicides, and other appropriate practices within an integrated pest management control.

We can conclude that adherence to good agricultural practices will reduce the risks for mycotoxin contamination. Also, considering time slots for infection, the site specific variability of field conditions require appropriate site-specific management practices. These must also rely on appropriate information collection before and during plant growth as well as on the history of the field and of the growing conditions to either make decisions on site specific treatments or harvest practices.

The early detection and removal or separation of infected items implies that process design and equipment engineering must also have a strong emphasis on design for food safety using suitable cleaning procedures. Additional microbial or toxin sensing technology should be installed harvesting, handling, sorting and packing equipment to warn the user of a potential problem and to take appropriate measures All detections and subsequent cleaning actions should be registered as part of the traceability system.

2.1 Proper use of chemicals, especially plant protection products

Fertilizer use

Addition of nitrogen (N) to agricultural cropping systems is one of the major reasons that crop production has kept pace with human population growth. The benefits of nitrogen added to cropping systems come at well-documented environmental costs because of the relatively low nitrogen-use efficiency in many crops. Nitrogen is mobile, hard to contain, and even nitrogen that is efficiently conserved and taken away in crop harvest eventually makes its way back to the environment (Robertson and Vitousek, 2009). Despite the complexity of the challenge, however, these authors see that a number of technologies are available today to reduce nitrogen loss. These include adding rotational complexity to cropping systems to improve nitrogen capture by crops, providing farmers with decision support tools for better predicting crop fertilizer nitrogen requirements, improving methods for optimizing fertilizer timing and placement. Solutions to the problem of agricultural nitrogen loss will require a portfolio approach in which different technologies are used in different combinations to address site-specific challenges. Moreover, the nitrogen management practices for improving nitrogen-use efficiency while maintaining an economical yield of acceptable quality may be different for the different crops that a farmer grows. Grains crops have been mostly studied in this respect, while pulse crops or root crops seem to require more complex strategies. Also, calcium, potassium and phosphorus are other minerals that must be incorporated in an efficient fertilizer management strategy.

Weed control

Historically and up to this date the core technologies for weed control are detection, identification and a decision followed by a control action. This was certainly the case in manual weed control. The developments of automated mechanical weed control required that technologies for the above actions had to be developed and preferably also combined with automatic guidance and location techniques.

In chemical weed control the initial approach was full field coverage with herbicides either prophylactic or curative. This then also required herbicides that are selective and do not damage the cultured crop. In a further step, the crops were made resistant to broad spectrum herbicides. This in turn has caused the emergence of herbicide resistant weed. For combatting these either higher doses are required which is mostly not effective and causes a higher chemical input in the environment. Such phenomena then required that constantly new molecules for chemical weed control must be made available. In the curative approach, detection systems were developed that can discriminate between the crop and the weeds and then a decision system directs the chemical treatment to the individual weeds or to the weed infested locations in a field. Alternatively, more attention goes again to have more efficient and versatile mechanical weed control systems. This also brings attention to a multilevel approach where cropping systems are re-examined in combination with chemical and mechanical (or thermal) methods as a basis for integrated weed management (IWM). Organic crop production has of course a great need for non-chemical weed control based on mechanical control in combination with cropping system. And so IWM can draw from a lot of experience and developments that were done in organic agriculture.

GAP certification requirements also involve the minimal use of herbicides as well as a registration of the time, location and doses of chemical application. It appears that the automation as described above can limit the chemical use and also allows for automatically register place and time of weed populations and the applied treatments in the GAP database as well as in the field data base

The recent developments in weed control technology has been summarized in a number of review publications (for example: Young and Pierce, 2014: Zijlstra et al., 2011; Shanner and Beckie, 2014; Bajwa et al., 2015).

As a summary we can state the following:

- Various methods have been developed to discriminate between weeds and the crop based on spectral characteristics and/or image based shape recognition (Vrindts et al., 2002; Slaughter et al., 2008). However, for operations in uncontrolled outdoor environmental conditions there remain some major challenges like mutual covering of the leaves of crops and weeds, the growth stage of crops and weeds and the changing light conditions during the day, unless artificial lighting can be used;
- Current weed control practices lack the precision needed to effectively and safely control weeds without harmful side effects. The problems of current mechanized agricultural systems have set the stage for the introduction and adoption of more advanced technology to meet the needs of growers and satisfy the desires of consumers (Young et al., 2014);
- No single strategy is perfect, and therefore an integrated approach may provide better results. Future research is needed to explore the potential of these strategies and to optimize them on technological and cultural bases. The adoption of such methods may improve the efficiency of cropping systems under sustainable and conservation practices (Bajwa et al., 2015);
- Uptake by most growers of non-herbicidal weed management strategies as well as strategies that integrate other weed management systems with herbicide use has been poor. In the future, weed management by growers will require more knowledge, planning, time, cost and risk than in the past, in spite of ever-increasing farm size (Shanner and Beckie, 2014);
- The potential should be explored in precision agriculture of a weed dynamics model. Such a model predicts weed flora dynamics over the years, depending on cropping system and pedoclimate[2] and can help to determine management rules for reconciling weed-related biodiversity (weed species richness and equitability, weed-based trophic offer for birds, insects and pollinators) and weed harmfulness (crop yield loss, harvest contamination, harvesting difficulty, field infestation, additional crop disease due to weeds) (Meziere et al., 2015). They are the basis for future model based weed management systems and decision making.

Pest and Disease Management

Good agriculture practices reduce the incidence and intensity of pests and diseases (for example using crop rotations, hygienic measures for workers and equipment, water and soil management,…) and also reduces the use of chemical control methods.

Integrated pest management (IPM) is a key component of the strategy towards sustainable pesticide use. According to the definition by FAO (2016), IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. Harmful organisms must be monitored with adequate methods and tools, where available. Such adequate tools should include observations in the field and where feasible warning, forecasting and early diagnosis systems (e.g. traps). Based on these observations it should then be decided if a pest control measure is used and which one is the most appropriate. Where possible, biological control, physical methods or use of predators are favoured and

[2] Pedoclimate: microclimate within soil

chemical control are then the last resort. Spatial information can have a potential value in IPM decisions. Ferguson et al. (2003) discuss the spatial ecology of pests in terms of the roles of environmental factors, behavioural responses and the implications of spatial patterns for yield loss and for developing sustainable integrated crop protection. Their data with insect traps indicate that decision support systems should use sampling strategies which incorporate spatial information to model crop loss more accurately and that there may be potential for spatially targeted applications of insecticide to optimise the influence of biocontrol agents in oilseed rape

In pest and disease management attention should be given to spatial and temporal effects which can be based on observations integrated in epidemiological models. These models can help in evaluating the potential economic impact of the disease and of control measures. Collins and Duffy (2016) used models for a qualitative analysis, including the treatment cost, and concluded that a control measure at the outset of the outbreak of maize foliar disease can reduce the spread of the disease at a minimum cost.

The above findings imply that reliable techniques are available for detecting the outbreaks or onset of pests and diseases and that this should be done frequently in time and at a sufficient spatial resolution. Sankaran et al. (2010) reviewed advanced techniques for detecting plant diseases. Some of the challenges in these techniques are: (i) the effect of background data in the resulting profile or data, (ii) optimization of the technique for a specific plant/tree and disease, and (iii) automation of the technique for continuous automated monitoring of plant diseases under real world field conditions. In a review on plant disease detection by optical sensors (Mahlein (2016) finds that sensors that can be used to specifically detect plant diseases are still not available on the market. The full potential of sensor based disease detection has still not been exploited. Instruments and technological solutions for field, greenhouse, and for phenotyping are available. However, these are highly specific and tailored prototypes and cannot be used on a broad scale (Mahlein, 2016).

A growing body of evidence indicates that volatile organic compounds (VOCs) are important signaling molecules, and the deciphering of this chemical information will be of enormous relevance for the early detection of plant responses to biotic and abiotic stress, facilitating the search for new sustainable methods for pest and environmental control (Maffei et al., 2011). However for rapid deployment as basis of site specific disease detection there is a need for affordable field usable detection systems (artificial nose?) combined with localization tools.

The decision-support tools for IPM in the context of precision agriculture can be based on many different sources of information like on-site devices, mobile equipment or airborne or satellite observations if these are of sufficient spatial resolution. These tools can be part of a crop management system that has two main parts: (i) an integrated system for real-time monitoring of the components (air, soil, plants, pests, and diseases) of vineyard or part thereof, and (ii) a web-based tool that analyses these data by using advanced modelling techniques and then provides up-to-date information for managing the vineyard in the form of alerts and decision supports for the vineyard part under consideration (Rossi et al., 2014). There are emerging commercial services offered to farmers for scouting and decision support, but the spatial or temporal resolution are at this moment not explicitly available (Precision Farming Dealer, 2015).

2.2 Environmental protection

In this section we will deal with data and observations that are used in long cycles for GAP decision making related to environmental impact.

- Geographic information about the field location:
    - Slope of the terrain determines the sensitivity to erosion and in precision agriculture that translates into the direction of soil cultivation and contour planting. Digital elevation maps

in combination GPS offer a technology basis for the most effective cultivation that facilitates conservation measures. Strip cropping or other measures to reduce or slow down the water runoff must be placed at suitable locations across the field. These can include perennial vegetation, in-row soil walls, microdams in furrows or mulches. It also implies perennial vegetation or even fruit trees on field borders for reduction of both water induced erosion in rainy periods as wind erosion in dry periods. Precision agriculture implies that chemical or mechanical treatments against weed must not damage or destroy these erosion barriers. Note that in reduced or no tillage farming preserving these erosion barriers is facilitated by field maps and GPS.

By decreasing soil and nutrient loss, suitable conservation technologies preserve the soil's fertility and may lead to higher yields. Pimentel et al., (1995) indicate that conservation tillage can reduce erosion rates in US crop land from 17 tonnes/ha/year to a more sustainable 1 tonne/ha/year.

Figure 1. Micro-dams in between furrows (left) and green field borders (right) to slow down water run-off and to reduce erosion

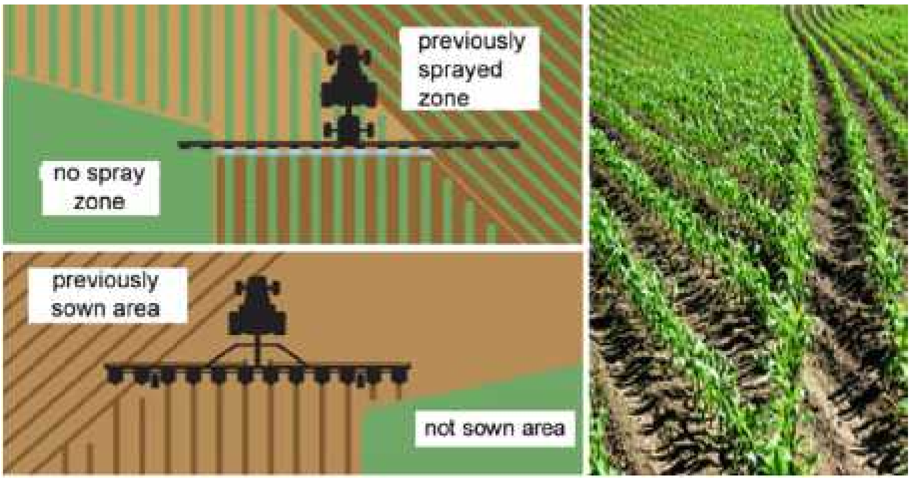
Source: J. De Baerdemaeker adapted from Shutterstock

- When digital information of the location of waterways with respect to cultivated land is available and combined with GPS based actual location of sprayers or fertilizer spreaders, then regulations to avoid waterways contamination can be easily implemented in real time. The Pesticide Application Manager is a decision support system for crop protection based on terrain, machine, business and public data (Scheiber 2016). It creates machine-readable application maps that include legal buffer zones where spraying is prohibited. It is the basis for automation to keep the machine at a prescribed distance from the waterways or to automatically close certain sections of the sprayer. In this case long cycles for decision making (field and crop location with respect to streams) are connected with short cycles in crop protection or fertilizer application.
- Soil maps are in GAP standards required as part of decision making for cultivation of certain crops, fertilizer application or irrigation decisions. However, at a larger scale soil maps can help in deciding which land is suitable for agriculture or crop production and which areas are for example wetlands or moorland that should not be cultivated and where

contamination with fertilizers or pesticides and herbicides should be avoided. Also here, GPS based automation in combination with digital maps can have a significant contribution for sustainable protection of these fragile sites.

- Soil degradation is a slow process that is affected by land management. These management decisions then must take into consideration the spatial and temporal dynamics of soil nutrient fluxes and pools. Monitoring soils organic matter evolution and defining soil degradation thresholds based on the SOC content is considered essential to develop conservation strategies and for implementing differential management strategies (Serrano et al., 2015). The results of a study by Veum et al. (2016), show that on claypan soils, conservation cropping systems with no-till and reduced chemical inputs or with no-till, extended rotations, cover crops, and integrative chemical inputs can sustain grain yield compared to a conventional system with more inputs. Furthermore, conservation systems often can increase yield on the backslope and can increase crop yield stability and reduce crop yield variability. According to the authors, these results will aid in the further acceptance, targeting, and use of conservation practices across claypan landscapes experiencing variable and changing climate. Of course the implementation of precision agriculture technologies for monitoring and conservation practices can enhance the environmental benefits
- Note that for erosion protection and also for the protection of waterways there are requirements of perennial vegetation. These vegetation strips hosts wildlife but also a lot of insects that at a certain moment feed on grain crops by puncturing the seed coat. This in turn ay favour fungal growth in the seed and the production of mycotoxins. Here a careful consideration about production conditions and food safety is required.

Figure 2. Schematics of section control for sowing and spraying in irregular fields



Source: Left: adapted from Raven Industries Inc.). Right: result with maize (John Deere & Co) (Heege, 2013, reprinted with permission)

2.3 Occupational health, safety and welfare

The European Commission, Directorate-General for Employment, Social Affairs and Inclusion, Unit B.3 published in 2012 'A non–binding guide to best practice with a view to improving the application of related directives on protecting health and safety of workers in agriculture, livestock farming, horticulture and forestry' (EU-Progress-2012).

The guide states that "at present, there is no single European-level directive that specifically deals with the protection of the health and safety of workers in all aspects of agriculture, including livestock farming, horticulture and forestry. The Framework Directive (89/391/EEC), however, and several individual directives are applicable in these sectors of activity. It should also be stressed that the particular features of these sectors—such as working in the open air, greenhouses, with heavy machinery, animals, isolation at the place of work, low levels of training, use of chemical and plant-protection products — increase the risks facing the workers, as reflected in an accident rate that is higher than the average for other sectors."

The guide wants to raise awareness about the risks farm workers are facing and also makes suggestions as to reduce or eliminate these risks. The guide is more exhaustive than national codes of practice, for example from the Health and Safety Authority (HSA) in Ireland (Hsa.ie, 2006)

GAP standards include a number of checkpoints and requirements covering the workers' rights and improves the working conditions of on-farm permanent employees, seasonal workers, piece-rate workers and day laborers.

Furthermore, in response to growing concerns regarding specific aspects of the agricultural production process and supply chain, GLOBALG.A.P. has developed made-to-measure add-on modules to upgrade the status of a producer that uses these and offers buyers specific assurances tailored to their interests and preferences. One such module is the GLOBALG.A.P. Risk Assessment on Social Practice (GRASP), which covers workers' health safety and welfare. GRASP also covers everyone on the farm: permanent employees, seasonal workers, piece-rate workers and day laborers.

2.4 Animal welfare

Animal welfare is an important part of EFSA's remit. The safety of the food chain is indirectly affected by the welfare of animals, particularly those farmed for food production, due to the close links between animal welfare, animal health and food-borne diseases. The welfare of food producing animals depends largely on how they are managed by humans. A range of factors can impact on their welfare including housing and bedding, space and crowding, transport conditions, stunning and slaughter methods, castration of males and tail docking. Stress factors and poor welfare can lead to increased susceptibility to disease among animals. This can pose risks to consumers, for example through common food-borne infections like salmonella, campylobacter and *E.coli* (EFSA, 2016).

Animal welfare can relate to individual animals (for example dairy or beef), and also to flocks (poultry).

The GLOBALG.A.P**.** dairy standard covers: legal registration, feed, housing and facilities, dairy health, milking, milking facilities, hygiene, cleaning agents and other chemicals. (http://www.globalgap.org/uk_en/for-producers/livestock/DY/)

The GLOBALG.A.P. poultry standard covers: stock sourcing, breeding (parent) flock, hatchery, feed and water, housed poultry, outdoor poultry, mechanical equipment, poultry health, hygiene and pest control, handling, residue monitoring, emergency procedures, inspection, workers, humane slaughter of casualty poultry, dispatch and transportation. (id.)

3 Precision Agriculture, GAP and 'license to operate'

Changes in society and attitude of consumers are such that agricultural practices will be questioned more in the future. This is even more the case, when the products on the market are not locally produced by a well-respected farmer from the local community.

This will go further than 'say what you do' and 'do what you say', but will also imply that communities will give a 'license to operate' only when stringent production requirements are met and documented. It is not only that global consumers require GAP when buying products, but that local consumer action groups will only allow production when certain conditions are met and documented. This license to operate implies that a farm may be forced to stop operations, or change is production plan, or not get permission for expansion. The conditions or regulations described in chapter 2 will increasingly be questioned or used by consumers and action groups.

Good agricultural practices as supported by precision agriculture technology require operators that are well trained both in agronomy and in the use of tools and equipment. This implies that continuous training of operators and managers is provided for the use of crop protection products, fertilizers and for operation of the equipment. While this is a general requirement for sound agricultural production, in benchmarking schemes for GAP, it is a 'must' in case of operators of pesticide sprayers or fertilizer applicators. It can be considered that environmentally friendly results in agricultural production can be achieved using precision agriculture concepts and tools, but it may require that operators and managers are certified.

4 Management cycles in Precision Agriculture

The agricultural production systems involve processes and process conditions are that *very variable* (natural variability of biological processes, soils, climate). Some external conditions like short term weather change have already a degree of predictability that makes them reliable enough for short term management decisions. Unpredictable disturbances or external conditions complicate the design and control of equipment, the decision making as well as the evaluation of the impact of these decisions and tools on the outcome, in terms of profit as well as environmental effects.

In many industrial activities process management and process control can be explored designed and tested by making use of process models. The accuracy and detail of these models affect the management and control performance in simulations involving that should be as close as possible tot real conditions.

agricultural production complexity also arises from the fact that processes occur on different spatial and temporal scales, from molecular or sub-cellular processes to organs, fruits or seeds, and to fields or regions. Processes on the different spatial scales have a dynamic behaviour involving different time constants that must be taken into account in modelling and managing these systems.

In crop models the existing knowledge of the physics, physiology and ecology of crop responses to the environment are used to study some phenomena like crop response to water or nutrient availability. The time scales in are often chosen on the basis of the time horizon and the final use of the simulations and can be short (month) or several seasons. Simulation results of Semenov and Porter (1995) indicated that changes in climatic variability can have a more profound effect on yield and its associated risk than changes in mean climate. Most of the time the spatial variability of soils is not incorporated, but it should be possible at the cost of simulation time. Indeed, few studies are available in the literature on how to account for the effects of spatial variability of measured soil properties and local micro-climatic conditions on simulated crop growth and (growth limiting factors) yield variability.

Ma et al., (2016) concluded that the variability in yield and biomass as simulated by their model due to spatial distribution in soil water field capacity (FC) was less than observed variability in the field. Other soil properties, such as bulk density, nutrient level, and uneven distribution of irrigation water, might have contributed to the larger variation in measured yield and biomass.

The time variable of potential disease development adds to the difficulty to model the systems as a step to control them or to design suitable equipment.

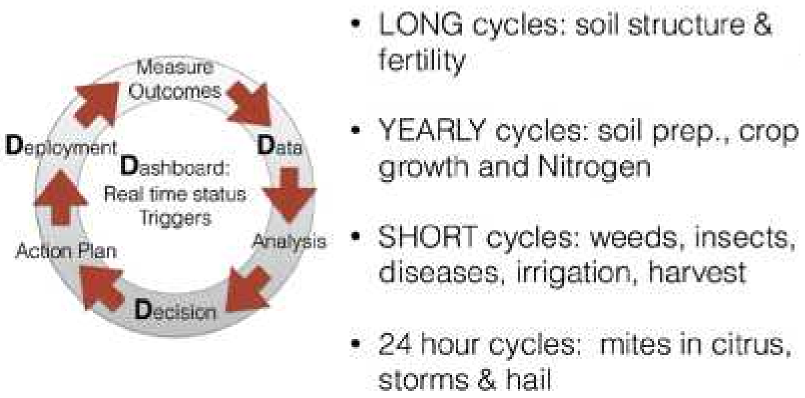
Hoogenboom et al. (2004) integrated genomics into models as a promising avenue for reducing uncertainty relating to differences in physiological responses of cultivars and for strengthening the fundamental physiological assumptions underlying model equations. However, the crop response or crop productivity characters linked to the genomics requires additional field trials, perhaps for each cultivar. This in turn can build a basis for decision making by farmers for selecting the appropriate varieties or genotype depending on the soil variability and the historical microclimatic conditions in the field. It thereby links genetics to precision agriculture.

Precision agriculture can be seen as a summary of good agricultural practices that rely on (De Baerdemaeker, 2013a):

- Correct observation
- Correct analysis
- Correct information (soil, previous crops and treatment…)
- Correct genotype
- Correct dose
- Correct chemical/biological compound
- Correct place
- Correct time
- Correct (climatic) conditions
- Correct (use of) equipment

The environmental impact cannot be studied separately for all of these points since there are many interactions. Moreover, the activities in precision agriculture an also be considered as management cycles. In these cycles the analysis of available data leads to decisions which in turn have to be executed. The results of these lead in turn to data that can be analysed as basis for next or other decisions and actions. These management cycles can be long term (spanning more than one season), yearly cycles, short term cycles or even very short, within one day (Figure 3, Vanacht, 2014).

Figure 3. Management cycles in precision agriculture



Source: Vanacht, 2014 (reprinted with permission)

This means that the environmental effects also can have different cycles or time constants, but these do not necessarily coincide with the management cycles that have contributed to the environmental effect.

Climate Corporation, a US-based commercial company, launched in 2013 the products CLIMATE Basic and CLIMAT Pro to optimize a farmer's daily decision making by providing up-to-the-minute, field-level current and future weather, soil, and crop growth stage information. The service also gives recommendations to planting date will optimize yield; where, when and how much to side-dress nitrogen; what integrated pest management mitigates yield loss; where variable rate application will be beneficial; and what harvest date optimizes dry down costs, grain moisture and yield. Farmers will also have access to up-to-the-minute, field-specific weather, forecasts, and crop conditions as well as farm-level yield projections (Grassi, 2013). The service is based on big data computing and analysis of many years of local crop yield information from the USDA linked with detailed local weather scans also available from the US government.

When the term 'correct use' in precision agriculture also implies complying with the governmental or private regulations on health and environment then it helps to strengthen the underlying ideas of good agricultural practice (GAP). Furthermore, the technology developed for precision agriculture may offer important tools for documentation of the production conditions as a proof of compliance.

5 Environmental impact of Precision Agriculture

5.1 Deviations and possible economic effects

5.1.1 Fertilizer use

Nitrogen

Diacono et al., 2013, analyzed the literature of the last 10-15 years about precision nitrogen management of wheat. Their summary included different tools and approaches like treatment maps, in season nitrogen management decisions and sensor based nitrogen rate recommendations. An overview of the literature with the benefits as compared to conventional treatments is given in Annex 2. The main conclusions from the review can be summarized as (Diacono et al.,2013):

- sensor-based nitrogen management systems when compared with common farmer practices showed high increases in the nitrogen use efficiency of up to 368 per cent;
- these systems saved nitrogen fertilizers, from 10 per cent to about 80 per cent less nitrogen, and reduced residual nitrogen in the soil by 30–50 per cent, without either reducing yields or influencing grain quality;
- precision nitrogen management based on real-time sensing and fertilization had the highest profitability of about $5–$60 per hectare compared to undifferentiated applications.

Bongiovanni and Lowenberg-Deboer (2004) gave an example where variable rate nitrogen application maintains farm profitability even when nitrogen is restricted to less than half of the profit-maximizing uniform rate.

Miller et al., (2015) suggest that from a disease management perspective the impacts of nitrogen fertilization on Wheat Streak Mosaic Virus (WSMV) spread may be large because nitrogen addition increased wheat susceptibility to WSMV infection. The vector for WSMV is the wheat curl mite (WCM). In addition, the increase in vector population growth rate associated with nitrogen resulted in many more mites containing the virus which, in turn, may result in large differences in number of vectors. Exploiting the positive relationship between nitrogen fertilization and disease management poses difficulties to maximize crop yield. In the WSMV-WCM system, modifying the timing and amount of fertilization may provide effective disease management. It follows that correct timing of the split nitrogen fertilizer application should also take disease management into account. This in turn can reduce the amount of pesticides required. Spatially variable split fertilizer application based on crop observations that include nitrogen stress as well as disease risks can be a major precision agriculture practice.

Vos (1999) states that nitrogen fertilizer recommendation at the beginning of the season should use a limited horizon of prediction to only a part of the growing season. Subsequently, during the growing season an assessment of the nitrogen status of the crop is made and based on this nitrogen status a follow-up recommendation for additional nitrogen supply should be made. The observation of nitrogen status of a potato crop must take into account that plant biomass is responsive to nitrogen whilst nitrogen concentration in leaves is conservative. It follows that direct assessing the leave nitrogen (or chlorophyll content) is less sensitive or less useful than assessing nitrate-nitrogen of stems (Vos, 2009). This makes that technology as used in corn cannot directly be used for potato production.

Nevertheless, development of effective diagnostic systems to spatially and timely distinguish nitrogen deficiency from other causes of altered crop conditions can be a good contribution to limit the environmental impact of excessive nitrogen input in potato production. Excessive nitrogen input, at the wrong moment is not efficient for production and creates risk of degrading water quality.

Figure 4. Sensing of crop Nitrogen stress for precision fertilizer application

Source: CEMA

The above results do not resolve the potential contradictions between maximizing the yield, optimizing the profit or nitrogen management towards minimizing the environmental impact of wheat production. The environmental concern is that the incremental recovery for the last unit of nitrogen fertilizer applied (i.e., nitrogen use efficiency, NUE) near the point of maximum economic yield is <10 per cent (Schepers, 2008). According to Robertson and Vitousek (2009), deployable solutions exist that would achieve high yields, use less nitrogen, and decrease nitrogen-losses to the environment. Social mechanisms that can encourage the adoption of these techniques exist as well, but what remains most uncertain is society's willingness to pay for their implementation.

Phosphorus (P), Potassium (K)

Single year P use efficiency (PUE) is reported to be as low as near zero per cent to as high as 35 per cent. Potatoes are especially challenging with regard to P nutrition in that it has a shallow, inefficient root system with very high late season demand. Options for increasing PUE include: modification of soil pH (particularly on acid soil), incorporation of P fertilizer into the root zone, use of concentrated bands of P fertilizer, slow release P fertilizer, and use of fertilizers with enhanced P solubility. In addition, mycorrhizal inoculation may be an option for increasing P efficiency in certain circumstances (Hopkins et al., 2014).

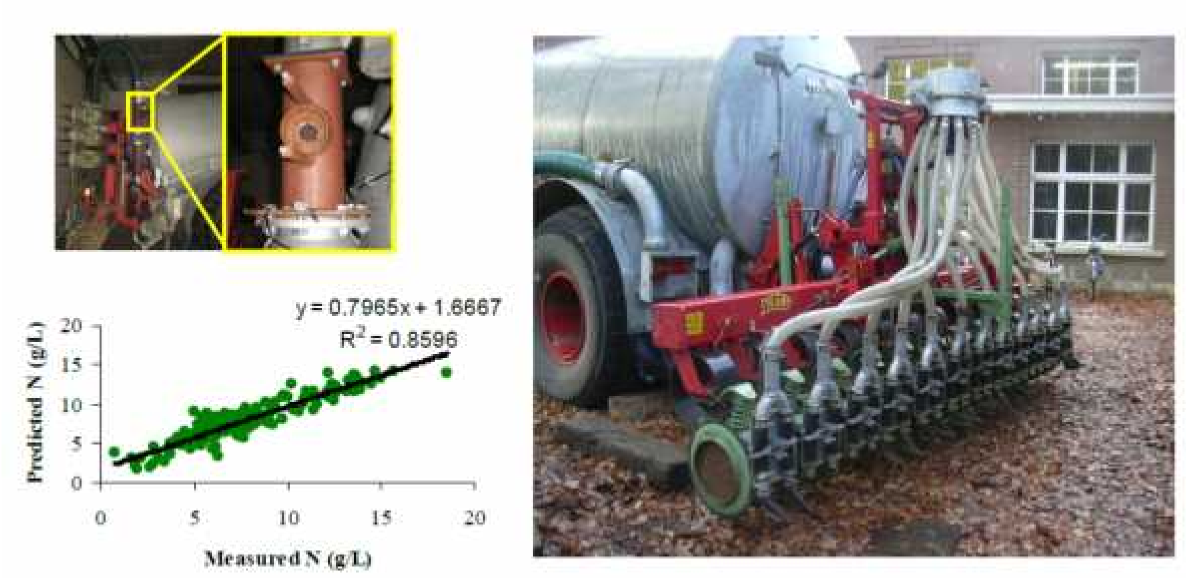
Ruark et al. (2014) found in a review on environmental aspects of P fertilizer in potatoes that potato production systems are at risk for dissolved P losses in surface runoff, particulate P losses with eroding soil particles, and even leaching losses of P, although high risk may only occur on specific management practices and soil types. Management to minimize risk of P loss from potato fields should strive for balancing P inputs from all sources with the P removed with the crop harvest. Cambouris et al., (2014) reported that in one year out of three, variable rate application of P and K significantly increased the total and marketable tuber yield compared with the uniform application of P and K. They learned from their experiments that P and K recommendations should take soil texture groups into account. Such recommendations for P to reflect the soil texture groups have been implemented in Quebec, Canada, and research is carried out on potato K response for various soil texture groups.

Ekelöf (2014) studied potato P requirements as regards optimizing P application strategies, use efficiency and potato tuber yield. The results show that split P applications can improve P recovery by 25 per cent, particularly on soils with low content and low buffering capacity, and can improve physiological P use efficiency (PPUE) where P availability is limiting yield. The author also concluded that many Swedish soils contain sufficient amounts of P to support optimal growth and are no longer responsive to P fertilization. As long as yield effects from P fertilization cannot be predicted, excessive P fertilization will probably continue, resulting in waste of a non-renewable resource, eutrophication of the aquatic environment and reduced farm profits. Therefore there is an urgent need for a new fertilizer product for potato which contains lower amounts of P in relation to N (nitrogen) and K (potassium) (Ekelöf, 2014). This then would allow for adjusting fertilizer application according to the N requirements without the (excessive) waste of P. It appears that affordable tools, either online or off line, for detecting locations in the field where P availability and solubility is the limiting factor can be the basis for avoiding the excessive use of P fertilizer. It should also take into account the P derived from manure. This implies that there is a correct assessment of the true P requirement of the crops, the availability in the soils and of the P-supplying ability of the various types of inputs.

Schröder et al. (2009) state that in more general terms P utilization can be improved if uniform blanket dressings would be replaced by differentiated applications, tuned to specific needs of individual crops and fields, of patches within fields, of particular positions within the bulk soil, and of periods within seasons. Farming practices characterized by fixed 'insurance' shots of P, should hence be replaced by more reasoned 'precision farming' applications of P. Furthermore, also the vertical placement of the sources of P is important since for uptake by the roots it should be placed close to them and also below surface placement can reduce P runoff. The Nitrate directive of the EU states the annual amount of manure based N-fertilizer (170kg/ha/year) that can be applied. This manure also includes P and the depth of vertical placement of the manure may then be a compromise between reducing the volatilization losses of ammonia and the uptake by roots or surface runoff of P. Precision agriculture using GPS based technology for site specific balancing the P inputs and the P removed with the crop can contribute to reducing environmental effects.

Note that developments are underway to continuously monitor the composition of animal manure as it is being applied in the field. The application rate as well as the depth of injection is the adjusted according to the local soil composition and fertilizer requirements and the manure composition (Saeys et al., 2008). In some cases, the manure can be supplemented by chemical fertilizers to achieved a well-balanced nutrient supply for crops and at the same time reduce the risk of ground water pollution or even emissions in to the air.

Figure 5. Manure composition measurement for precision injection in combination with mineral fertilizers

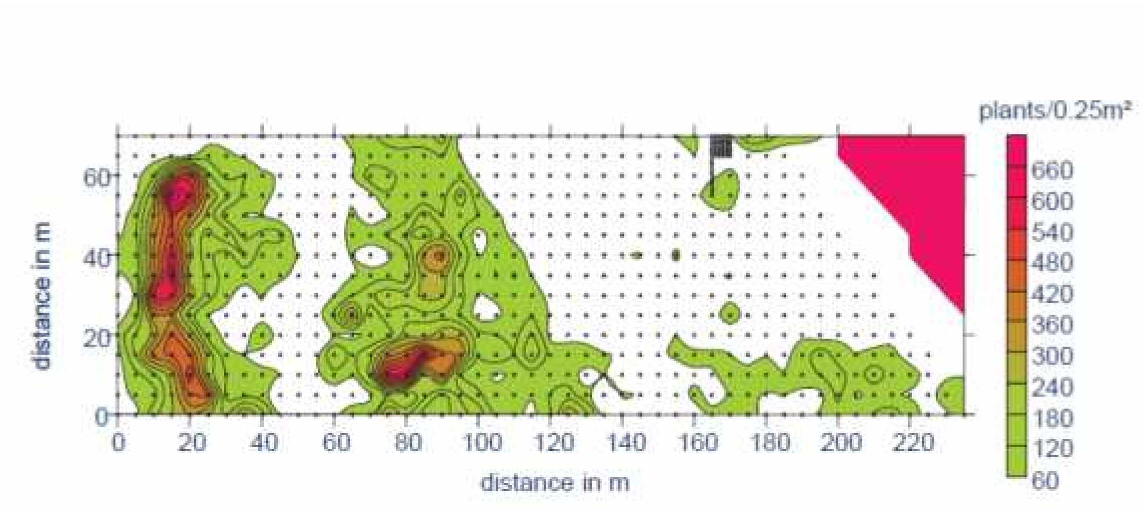


Source: W. Saeys (with permission)

5.1.2 Weed control

Chemical weed control and mechanical weed control can both have many applications in precision agriculture. Besides the effects on crop damage and subsequent crop yield, the environmental effects of the two approaches are different. In patch spraying only those area's in a field are treated where the weed density and size may impair the crop yield or crop quality. This can be applied before planting or after emergence. An estimate of potential herbicide savings from patch spraying (Perry et al., 2001 referenced by Miller, 2003) ranges from 9 to 42 per cent when the infested area covers between 65 and 27 per cent of the field. In precision spraying one would aim at an early growth stage to distinguish between the crop and the weed, evaluate the potential effect on crop development and then use micro-spraying nozzles to deposit herbicide on (parts of) the weeds. Gerhards and Oebel (2006) did experiments with a system that includes on-line weed detection using digital image analysis, computer-based decision making and global positioning system-controlled patch spraying. In a 2-year study they concluded that such a map based approach can reduce herbicide use in winter cereals by about 6 to 81 per cent (see also Annex 2). It can be expected that combining inline weed detection with immediate herbicide spraying can lead to similar savings in herbicide use.

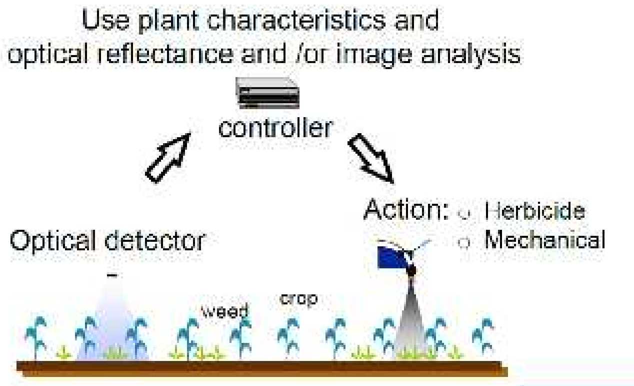
Figure 6. Weed map for selective herbicide application related to weed density `



Source: J De Baerdemaeker

Mechanical weed control techniques that cover the full field like harrowing where it is assumed that the weeds are more susceptible to the mechanical disturbance than the crop. Hoeing is possible for a uniform planting in rows, especially when row distances are larger. In precision mechanical weed control within rows weed and crop discrimination is also used followed by near robotic weeding action. Thermal weed control uses either steam or direct flaming to kill the weeds. Working width of sprayers are larger than those of mechanical weeders which gives the former an advantage in terms of area covered by one operator. Chemical weed control can leave residues in the soil or cause (harmful?) chemical drift. Herbicide resistant weeds have appeared forcing farmers to either use higher doses or switch to yet different molecules as herbicides. Mechanical weed control usually requires a higher level of mechanical energy and hence of fossil fuel. Thermal weed control mostly burns the above ground part of the weed, causing regrowth and perhaps more frequent treatments leading to high energy requirements. It should be noted that some form of resistance development to mechanical weed control should not be excluded. Intense and continuous barnyard grass [Echinochloa crus-galli (L.) Beauv.] hand-weeding in rice (Oryza sativa L.) allowed the selection of rice-mimic biotypes that ''resisted'' hand-weeding efforts (Barrett 1983, cited by Harker and O'Donovan, 2013).

Figure 7. Online discrimination of weeds and crops for precision spraying or mechanical weeding



Source: J De Baerdemaeker

An experiment in Canada compared broadcast treatment with banded treatment[3] where herbicide was sprayed 30 cm wide over the top of carrot rows and then followed by mechanical cultivation between rows. The demonstration showed that herbicide use in banded treatments was reduced by approximately 50 per cent, compared to the broadcast application. However, the cost benefit analysis showed that in this demonstration the banded treatment was more expensive than the broadcast application method (Crawford, 2015). In an evaluation of band spraying supplemented by inter-row cultivation, it was shown that spraying herbicide on only the maize rows can save up to 70 per cent of the amount of herbicides normally applied by broadcast spraying (ENDURE,2008). One could consider that precision row spraying and row following for mechanical cultivation can even further reduce the herbicide use. However, depending on the weed pressure and of course on the weather several mechanical treatments are required in a season, for example in organically growing of sugar beets where slow growth and late canopying are typical**.**

Deytieux et al. (2012) studied Integrated weed management (IWM) in arable crops. IWM relies on the combination of various measures for preventing, avoiding and suppressing weeds, with the aim of reducing the reliance on herbicides and their environmental impacts. IWM requires changes in the cropping systems like modifying e.g. the crop sequence, the strategies for soil tillage and eventually introducing mechanical weeding. In the study, a Life cycle assessment method was used to compute several environmental impacts for four variants of IWM-based cropping system tested over a multi-annual experiment, and compared with a standard reference. For crops common to all the cropping systems (winter cereals and oilseed rape), biodiversity scores were better for IWM cropping systems due to less intensive soil tillage (mouldboard ploughing), and lower use of pesticides and fertilizers. However, in-crop mechanical weeding (used in 2 of the cropping systems) was considered harmful for most of the indicator organisms. Many environmental issues investigated in this multi-sector evaluation were favourable to IWM-based systems when assessed for the 'Land management' function, namely the energy demand, the global warming potential, the eutrophication and acidification, the aquatic and terrestrial ecotoxicity. However, the ranking of the cropping systems changed significantly with the two other functions (both 'production' and 'income' functions) (Deytieux et al., 2012).

The increased system complexity of IWM can hamper the adoption by farmers (Bastiaans et al., 2008). IWM might introduce bottlenecks in the labour organisation at the farm level, because both mechanical weeding and the false seedbed preparation are time-consuming techniques, and delaying the sowing of winter cereals on large areas at the farm scale may be a poor decision because the weather might become less favourable for sowing in the late autumn, leaving only few days (if any) available for field operations (Chikowo et al., 2009).

There have been efforts to promote the use of small field robots for automatic and unsupervised mechanical weeding or chemical weeding using micro-nozzles for herbicide delivery (Slaughter et al., 2008). It is an appealing technology but no extensive field testing on the technical reliability nor on the effectiveness in environmentally friendly weed control were published thus far.

Perhaps a combination of precision weed control, either mechanical or chemical with adapted cropping systems can lead to an effective Integrated Weed Management approach of the second generation that overcomes some of the farmers resistance to IWM and still achieves considerable environmental benefits. Indeed, IWM reduces overall the reliance on herbicides while precision spraying spatially reduces the use of herbicides. Adoption of herbicide reduction practices in combination with precision agriculture technology to account for the variability can be seen as an evolutionary process that also has to take into account the heterogeneity among farmers (and their willingness to change) as well as

[3] In broadcast treatment a spray solution is applied uniformly over the entire treated area. In banded treatment the spray solution is applied over a portion of the total treatable area (for example, in strips on top of a seedling row).

government or EU policies that either favour the implementation or indirectly makes it economically less favourable.

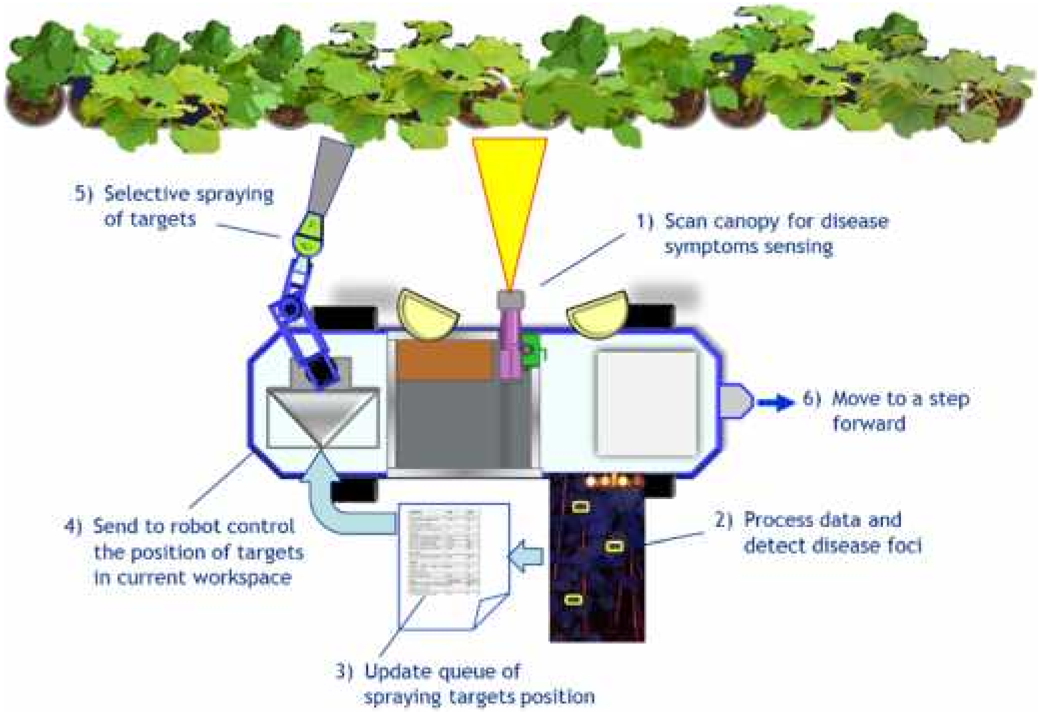
5.1.3 Disease and Pest control

Early observation of the outbreak of a disease followed by early treatment is most likely the most economical way for disease control. As state earlier, this implies an early detection. One approach could be based on different spatial and temporal scales of monitoring.

At those different scales information is required for correct identification or classification of diseases or of plants or crops. In many cases this identification can rely on optical information taken at a high spatial resolution, but it can just as well happen that this identification is only possible through the use of high temporal frequency information. Also, in case one wants to use information for statistical process control in order to detect abnormal deviations, then it is required to have high temporal frequency information. Then there is usually a trade-off to be made between fine (or coarse) spatial resolution and low (or high) temporal frequency information since it may be impossible to have a high spatial and temporal resolution. For example, in vegetation observation satellite with a high spatial resolution are not usually available for measurements at very short time intervals. Moreover, at the moment that they are doing the observation on the site of interest, there can be cloud covers that renders the images almost useless. Under those conditions, a benefit can be derived from high frequency passes of satellites or other airborne observations , even if the spatial observations are more coarse. It is then a challenge to combine the data obtained at different temporal scales and different spatial scales such that useful information is obtained (Robin et al., 2005). The patterns in spectra or hyperspectral images changes can be observed using time-lapse acquisition. Obtaining the information from subtle changes may require advanced image processing. Hao-Yu Wu et al. (2013) describe a method to reveal temporal variations in videos that are difficult or impossible to see with the naked eye and display them in an indicative manner. On an image sequence as input, spatial decomposition is applied, followed by temporal filtering. The resulting signal is then amplified to reveal hidden information. The technique can run in real time to show phenomena occurring at temporal frequencies selected by the user. Such techniques may be able to reveal spatio-temporal responses of crops to treatments (fertilizer application, pest control, disease spreading…)

There remains the difficulty that sometimes the first signals of a disease can only be observed at a very small scale as discussed by Mahlein et al. (2012) in the case of sugar beet. They reported that the sugar beet diseases differed in their temporal and spatial development as well as in their effects on plant tissue associated to reflectance characteristics. The size of the first fungal symptoms can be very small in the range of a millimetre. For reliable image inspection then the pixel size of the observation should be 3 to 5 times smaller. This restricts the early observation to proximal sensing rather than remote sensing. Repetitive inspection of all the leaves in a field for potential infection creates a problem an extremely large dataset that should be processed in near-real time. The development of patterns in time and space, recorded by hyperspectral imaging may help to identify disease or stress influencing crops on the tissue level and on the canopy level.

Figure 8. Disease detection for selective pesticide application in vineyards



Source: Oberti et al., 2016; with permission

Bavo et al., (2003) used a combination of different optical sensing techniques on a small carriage in the field. The results look promising but at this time they have not been further developed for either ground based or airborne systems for very early disease detection. It is not clear at this moment at which stage of disease development a detection system in combination with population dynamics models can lead to an optimal treatment decision. Mewes et al. (2011) reported on detection of a fungal infection in wheat using airborne hyperspectral remote sensing where the pixel size corresponded on the ground with an area of 4m x 4m.

Moshou et al. (2011) describe a system in which the disease pattern in the field was optically detected and mapped based on sensor data fusion of multi-spectral imaging (providing a reliable idea of necrotic spot concentration of yellow rust on wheat leaves) and a the spectrophotometer (providing reflectance spectra at canopy level). The resulting disease map was used, together with relevant information (e.g., growth stage and uppermost-infected leaf) and epidemiological models to make a spray decision using a decision support system. If the decision to spray was made, then the disease map was transformed into a spray map that corrected for undetected disease and, if necessary, incubating disease. The disease map, based on automated optical sensing and intelligent prediction, provided a spatially variable recommendation for spraying that could lead to substantial savings of up to 84.5 per cent in pesticides, with financial and environmental benefits. (Moshou et al., 2011)

Mankin et al. (2000) did experiments using vibration and acoustic sensors for their potential to detect hidden insect infestations in soil and interior structures of plants. Their results indicate that such sensor systems have considerable potential as activity monitors in the laboratory and as field tools for rapid, nondestructive scouting and mapping of soil insect populations. This approach may form the basis for diagnostic tools for spatial and temporal changes in soil insect populations in order to make decisions for variable treatment. A similar approach already exists in industry (Langone et al., 2015)

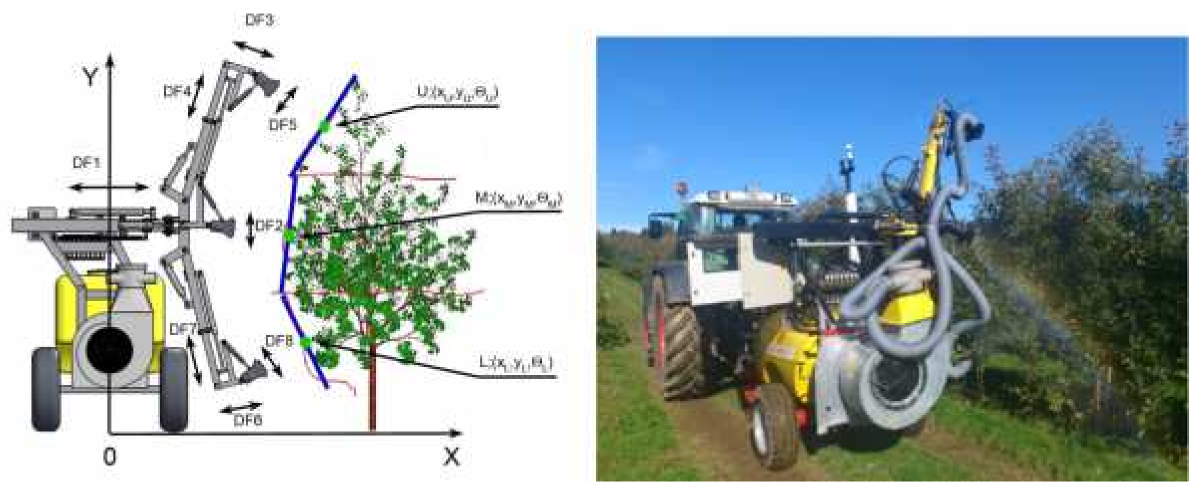
In orchards and vineyards traps are frequently used to observe the presence and density of pest insects. The read out of these traps requires a lot of field travel because the traps must be spread out over a large area. In case this can be automated, then a larger density of traps can be used and they can also be spread out over a larger area so that the temporal and spatial evolution of the pest population is monitored as a basis for treatment decision.

Sciarretta et al. (2011) report on site-specific IPM strategies to decrease as much as possible the quantity of utilized insecticides and the total treated area, compared to uniform IPM protocols. To achieve this purpose, the strategy was to direct curative efforts towards the areas of vineyards with the highest level of oviposition, excluding areas with low egg density. The site specific control, i.e. treating only egg hot spots with *Bacillus thuringensis var. kurstaki*, allowed for a decrease in the surface of the treated vineyard and, consequently, the quantity of insecticide utilised. In 2008, no significant differences between uniform and site-specific IPM in vineyards were observed in the number of damaged berries and the percentage of infested bunches. Following precision targeting control, they obtained a reduction of between 80 per cent and 50 per cent of the covered surface compared to uniform IPM. These results varied between years. They concluded that the site-specific approach was economically advantageous with higher damage up to 1 per cent of infested berries per bunch. A major limitation however is the higher sampling cost for precision IPM. However, there are indications that it may be possible to identify insects and the population density for example through optical detection of the wing beat characteristics (Van Roy et al., 2014). Similar methods should be studied for detecting hot spot with high densities of insect eggs.

When spray target information obtained from an ultrasonic measurement system is used to control spray manifolds of orchard sprayers, then the achieved spray volume savings ranged from 28 to 52 per cent and were strongly related to the target architecture (Giles et al., 1989).

There have been several experiments on the reduction both of pesticide use and pesticide drift in orchards (Gil et al., 2007, Llorens et al., 2013). Sensing the canopy and real time adjustment of the liquid flow can reduce the applied volume by 22.7 per cent (Llorens et al., 2013). Oberti et al. (2016) explored selective targeting such that pesticides are deposited only where and when they are needed and at the correct dose using the example of powdery mildew on grape vines. A new precision-spraying end-effector with an integrated disease-sensing system based on R-G-NIR multispectral imaging was tested in a greenhouse setting. They claim that the robot was able to automatically detect and spray from 85 per cent to 100 per cent of the diseased area within the canopy and to reduce the pesticide use from 65 per cent to 85 per cent when compared to a conventional homogeneous spraying of the canopy.

Figure 9. Spraying arms with eight degrees of freedom positioned according to the shape of a tree canopy



Source: left: the design; right: the implementation (Osterman et al., 2013; with permission)

DF: degrees of freedom

To avoid overdose or under-dose of a crop protection treatment the application rates of plant-protection products need to be adapted to the plant mass present in the greenhouse when the spray is applied. Adjusting the volume application rate based on the Plant Row Volume has resulted in a reduction of more than 30 per cent of the quantity of plant protection product sprayed, without decreasing yield (Sánchez-Hermosilla et al., 2013).

Precision mapping of tree structure or tree architecture and the leaf area may then be an important criterion to adjust spray volume such that the efficacious treatment is maintained and spray drift or soil and water contamination are reduced as much as possible. A risk is to under-dose as this might induce pesticide resistance development. Similar observations can be made for field crops. Since the leaf area and leaf area index changes during the growing season it is advisable that an accurate model based estimation is available supported by on-the-go measurements to account for spatial variability.

5.1.4 Economic effects

Schieffer and Dillon (2015) used a whole-farm model to investigate the interacting effects of precision agriculture technology and agro-environmental policy on the production choices of a representative grain farm. Although some precision agriculture technologies did increase efficiency of resource use, they also decreased the effectiveness of policy, especially policies that rely on economic incentives (e.g., emission taxes) and policies that were designed for traditional production methods (not using PA). Bongiovanni and Lowenberg-Deboer (2004) did a sensitivity analysis and came to the conclusion that PA is a modestly more profitable alternative than whole field management for a wide range of (government) restrictions on nitrogen application levels.

Figure 10. Use of GPS leads to reduction in fuel consumption and improved timeliness of operations

Source: CEMA

Bora et al., (2012) in a survey of large farms in North Dakota, US, found that 34 per cent of farms used GPS guidance systems, reducing machine time and fuel consumption by 6.04 per cent and 6.32 per cent, respectively. Twenty-seven percent of the farms used auto-steering systems, which further reduced machine time by 5.75 per cent and fuel consumption by 5.33 per cent. Here cost savings in terms of fuel consumption as well as a reduced carbon footprint are achieved.

5.2 Advances with the greatest environmental effects

The following PA techniques are considered to have the greatest positive environmental effects or potential:

- Patch spraying with herbicides in field crops, based on economic and crop yield considerations of weed infestation;
- In orchards and vineyards: mechanical and thermal weed control within and between rows;
- Use of PA technologies in combination with digital elevation maps and soil erosion measures to reduce erosion risks;
- Introduction of equipment for pest and disease control in orchards that include tree architecture, tree volume and shape. In the near future this could be complimented with disease detection;
- Use of unmanned aerial vehicles (UAV) detection of diseases and weeds as a more flexible and versatile management support system. If suitable image treatments become available then this technology can be a good support for frequent crop monitoring and early warning of impending problems;
- Using less pesticides by better risk-based spatial and temporal interventions;
- Detect insects that may damage grain kernels crops which in turn can lead to fungal growth and toxin production. When the insect population is large then insecticide may be needed. Alternatively, spatially fungicide application may be required on areas where insects are active in order to reduce the incidence of mycotoxins;
- Use the relation between nitrogen-fertilizer rate, time of use, crop and environmental condition and the risk for fungal development for site specific variable rate (VR) application of fertilizers;
- Look in more detail and apply a more versatile detection of variability and availability of phosphorus in the soils, in connection with the crop requirements;
- Use of monitoring systems for nitrogen and phosphorus in ground water and the relation with timing and rate of fertilizer application as well as weather conditions and soil maps (or soil variability). Analyze this information over time in season and over several season) to draw conclusions for better management;
- Avoid contamination through irrigation by precise placement of drip irrigation, monitoring the system such that water does not get in contact with leafy vegetables;
- Use GPS, climatic conditions and wind direction to avoid spray drift that can damage neighboring crops or make them unfit for consumption. Similar approach is needed for spreading of liquid and solid manure on fields;
- Use PA for reducing risks from microbial contamination or toxin contamination that could affect human health;
- Look at potential diverging effects of different local, national or European policies that may have adverse environmental impact when applying PA;
- Low cost environmental monitoring tools for nitrates, or other chemical is the drainage or runoff water from fields can be a stimulus as these may show the environmental effects of PA and be a basis for rewards. At this moment, the regional nitrate monitoring combined with management measures is showing its effect on drinking water quality.
- Information technology in agriculture can support and enhance the environmental impacts of precision agriculture in many different ways;

- Modern farm equipment relies on electronics and software for controls (‘fly by wire concept’). On board machinery, these can make use of GPS and databases for continuously changing operations like flow rate of fertilizers or adjusting machine components. These systems can also record position and time in the field as well as the applied quantities at that moment. A comparison with prescribed doses is then possible. IT enable these data to be transferred to a farm computer or even to a traceability system. A unique identifier of the chemical compound is required to facilitate the traceability and reduce administrative burdens.

  Continuous improvement of harvesting equipment has reduced crop losses. However, such machines not only harvest a crop, they also ‘harvest data’. In a similar way, data are collected by sensors on all the equipment used by farmers. Sometimes these data are for immediate use during an operation (like for example crop stress for fertilizer application), but these data also are important for information extraction towards improved future management and decision making. In this way the environmental effects of precision agriculture can be continuously evaluated by farmers for improved future management. The data can also serve automatically to certify that a farmer is operating in the framework of environmentally friendly good agricultural practices. The farmer say what he does.

Precision agriculture should not only be technology (equipment) driven. Long term and alternative agronomic practices should be included to come to an economic and environmentally stable situation. This also includes operator safety and consumer safety: consumer safety in PA is affected by chemical fertilizers (like nitrate) in the drinking water, chemical residues in the edible plants that exceed MRL as well as fungal toxins that arise form crop diseases that have not been adequately dealt with in the field.

Precision agriculture tools allow a an efficient and optimized crop production depending on the site and other conditions. It may also imply that farmers and managers now become aware of those sites that do not yield economic benefits and hence should not be cultivated. When these tools lead to a more efficient higher yield in some locations, then other sites or areas can be better taken out of production and returned to nature.

This also implies that agricultural policies and supporting measures should not only consider areas in cultivation or quantities of production, but can also now consider (environmental) efficiency of production. Investments are required to widely adapt precision agriculture technologies and to document the efficiency of production, while earnings of farmers may not recover these costs. Supporting measures to innovate the agricultural production methods and tools that also benefit the environment are needed, especially since the technology tools allow for continuous/yearly monitoring of progress in environmentally friendly production.

From this overview it follows that technology development in precision agriculture will have benefits for consumers in terms of a more efficient healthy production with lower chemical inputs and reduced environmental risks. The benefits for the environment are the reduced used of potentially harmful pesticides, the reduction of fertilizer efflux to the groundwater, the reduction of soil erosion, the scope for preservation or re-establishing of vulnerable nature areas. The uptake of the technology by farmers requires encouragement from society as well as univocal supporting measures to be incorporated in the national and European agricultural policy.

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Annex 1 - Ground water quality standards

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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 I

GROUNDWATER QUALITY STANDARDS

1. For the purposes of assessing groundwater chemical status in accordance with Article 4, the following groundwater quality standards will be the quality standards referred to in Table 2.3.2 in Annex V to Directive 2000/60/EC and established in accordance with Article 17 of that Directive.

Pollutant	Quality standards
Nitrates	50 mg/l
Active substances in pesticides, including their relevant metabolites, degradation and reaction products (1)	0,1 μg/l 0,5 μg/l (total) (2)

2. The results of the application of the quality standards for pesticides in the manner specified for the purposes of this Directive will be without prejudice to the results of the risk assessment procedures required by Directive 91/414/EEC or Directive 98/8/EC.

3. Where, for a given body of groundwater, it is considered that the groundwater quality standards could result in failure to achieve the environmental objectives specified in Article 4 of Directive 2000/60/EC for associated bodies of surface water, or in any significant diminution of the ecological or chemical quality of such bodies, or in any significant damage to terrestrial ecosystems which depend directly on the body of groundwater, more stringent threshold values will be established in accordance with Article 3 and Annex II to this Directive. Programmes and measures required in relation to such a threshold value will also apply to activities falling within the scope of Directive 91/676/EEC.

(1) 'Pesticides' means plant protection products and biocidal products as defined in Article 2 of Directive 91/414/EEC and in Article 2 of Directive 98/8/EC, respectively.

(2) 'Total' means the sum of all individual pesticides detected and quantified in the monitoring procedure, including their relevant metabolites, degradation and reaction products.

Annex 2 - Herbicide savings by PA

Savings (%) for herbicides using site-specific weed control in 2004 and 2005

Crop/field size (ha)	Savings for herbicides against broad-leaved species	Savings for herbicides against grass weeds
Spring barley, Hurtz 2004 (17.5)	18	42
Winter rape, Hurtz 2004 (11.5)	20	22
Winter barley, Hurtz 2004 (8.1)	38	34
Maize, Dikopshof 2004 (4.6)	6	46
Winter wheat, Dikopshof 2004 (5.3)	77	69
Sugar beet, Dikopshof 2004 (5.8)	57*	46
Winter barley, Dikopshof 2004 (8.5)	39	56
Spring barley, Hurtz 2005 (8.4)	26	71
Winter rape, Hurtz 2005 (6.6)	19	20
Winter wheat, Hurtz 2005 (20.0)	58	65
Spring barley, Dikopshof 2005 (2.4)	40	76
Winter wheat, Dikopshof 2005 (5.3)	81	79

*Only for *Galium aparine*.

From: Gerhards, R. & Oebel, H. 2006. Practical experiences with a system for site-specific weed control in arable crops using real-time image analysis and GPS-controlled patch spraying, Weed Research 46(3): 185–193 (reprinted with permission)

BRIEFING PAPER 6

SKILLED WORKFORCES AND PRECISION AGRICULTURE

Table of contents

List of abbreviations

AIC	Agricultural Industries Confederation
AB	Agri Associated British Agriculture
ASDAN	Award Scheme Development and Accreditation Network (UK)
BIS	Department for Business, Innovation & Skills
CAP	Common Agricultural Policy
Cedefop	European Centre for the Development of Vocational Training
CoP's	Communities of Practice
CoPE	Certificate of Personal Effectiveness
COSA	Committee on Sustainability Assessment
DEFRA	Department for Environment Food and Rural Affairs
DGIP	Directorate-General for Internal Policies
DNA	Deoxyribonucleic Acid
EC	European Commission
EAFRD	European Agricultural Fund for Rural Development
EAGF	European Agricultural Guarantee Fund
ECVET	European Credit system for Vocational Education and Training
EEA	European Environment Agency
EISA	European Initiative for Sustainable Development in Agriculture
ENRD	European Network for Rural Development
EU	European Union
EUSBR	European Strategy for the Baltic Sea Region
E2C	European Association of Cities, Institutions and Second Chance Schools
FACE	Farming and Countryside Education
FAS	Farm Advisory Service
GHG	Greenhouse Gas
GLEAN	Growing Levels of Employability/Entrepreneurship in Agriculture for NEETs
GRAB	Groupe de Recherche en Agriculture Biologique (France)
HESA	Higher Education Statistics Agency
ICT	Information Communication Technology
IT	Information Technology
IMPROFARM	Improvement of Production and Management Processes in Agriculture through Transfer of Innovations
INRN	Italian National Rural Network
JWT	Jobs without Training
LEAF	Linking Environment and Farming (UK)
LEISA	Low External Input Sustainable Agriculture
LLP	Lifelong Learning Programme
MOOCS	Massive Online Open Courses
NAJK	Nederlands Agrarisch Jongeren Kontakt (Dutch Agricultural Youth Contact)
NAGREF	National Agricultural Research Foundation (Greece)
NEET	Not in Education, Employment, or Training
NFU	National Farmers' Union of England and Wales
Norad	The Norwegian Agency for Development Cooperation
OECD	Organisation for the Economic Co-operation and Development
RASE	Royal Agricultural Society of England

RDPW	Rural Development Plan for Wales
SAWS	Seasonal Agricultural Workers Scheme
SEGIRA	Study on Employment, Growth and Innovation in Rural Areas
SFEDI	UK Sector Skills Body for Enterprise
SFYN	Slow Food Youth Network
SME	Small and Medium Enterprises
UK	United Kingdom
VALERIE	VALorising European Research for Innovation in agriculturE and forestry
VET	Vocational Education and Training
VNIL	Validation of Non-formal and Informal Learning
WIRE	Water and Irrigated agriculture Resilient Europe
WFD	Water Framework Directive
YPADR	Young Professionals for Agricultural Development

1 Main issues and concerns

This paper will focus on ways in which a skilled workforce can be developed within 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 many 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 per cent of EU-27 holdings are owned by farmers under 35 (around 5 per cent in the EU-15 and 7 per cent 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, 2012). Young people have become distanced form the way that our food is produced and with more and more of our populations 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 or 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 per cent supplement to the direct aid allocated to their farm, for a period of five years. Some initiatives depend on what Members include in their national Rural Development Programmes, so it seems that coverage across the EU is not uniform. The Council and the Parliament have called for stronger support to help young people overcome economic and market barriers to enter farming. However, there is much evidence to suggest that this is a deep-rooted problem that cannot be easily resolved.

In a report published in 2010, Mark Shucksmith identified one of the most pressing issues for the future sustainably of rural communities as 'the exodus of young people.' Shucksmith discusses the complex nature of youth transition and recognises that despite several EU policies focusing on young people and employment there is no emphasis on specifically addressing rural issues. He made several key recommendations for policy reform to include; funding to support the promotion of the role of youth in rural areas, the provision of guidance and support for young people entering farming to develop their own strategies for diversification, the provision of lifelong training and finally the employment of innovative ways to involve young people in local rural development action. In response to these findings this report will focus on researching progress on these recommendations and seek to present examples of the development of successful strategies aimed at supporting these recommendations.

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. Consequently the Employment Committee and the Indicators Group devised their own definition and methodology for a standardized indicator in order to analyse the situation further, among member states. The NEET definition recognised by the European Commission is thus 'young people who are neither in employment nor in any education nor training' who are aged between 15-24 years (European Commission 2011). Their status as unemployed or inactive fits the terms laid out by the International Labour Organization.

Forming a central role in European Policy debate NEET has recently been mentioned in both the Europe 2020 agenda and the 2012 Employment Package ' Towards a job-rich recovery' (European Commission, 2012). The Youth on the Move and the 2012-2013 Youth Opportunities initiatives have resulted from these, putting pressure on "Member State authorities, businesses, social partners and the EU to tackle the youth challenge" (Mascherini et al., 2012). In order to tackle the NEET problem, the aim is to provide pathways back into education or training and facilitating integration into the job market, especially for young people with health problems or disabilities. Furthermore, by using NEET as an indicator, one of the European Commission's key actions will be to 'establish a systematic monitoring of the situation of young people not in employment, education or training on the basis of EU wide comparable data, as a support to policy development in this field' (Mascherini, et al, 2012:37).

A good example of recent research into the issues specifically facing rural youth is a project undertaken in the UK by Merchant, Waite and Quinn (2012) which sought to further understand the positive and negative influences which contribute to young rural residents' educational and vocational choices. Focusing on one particular rural area in the UK, Exmoor National Park, the research gathered evidence about the educational and vocational pathways followed by young people living in and around this area. The research found that there were several key issues: close proximity to the natural environment seemed to positively influence the educational and vocational aspirations of young people often influencing their choices in favour of animal and land-based courses. However transport, low pay, high housing costs and old-fashioned views restricted these choices for some young people. In addition to formal schooling, many young people had acquired useful skills and knowledge informally through their everyday involvement with traditional and family-based practices involving the land. Responses to living in a rural area were gendered. Young women were more likely to envisage themselves staying locally because of caring and family commitments, whereas young men anticipated that they might choose to leave in search of employment. This female attachment to rural areas is not something that has been widely explored when considering the future of framing and bears more consideration. The rural environment was viewed both positively and negatively with a love of the environment often being prevalent but with an acknowledgement that this environment often failed to provide infrastructure to meet young residents' needs. For more information and recommendations from the report see Annex 1.

Across the EU there have been efforts to address the sort of issues identified in the above report. One such was 'Sustainability through youth participation, entrepreneurship and innovation' project supported by the European Network for Rural Development within the European Strategy for the Baltic Sea Region (EUSBR). The short term objectives of this project were to connect rural youth organisations and innovation support organisations in 'a strong and active partnership and through participation in each other's activities within the partnership, good models and methods would be gathered to create joint learning and knowledge transfer'. At the end of the project it was anticipated that these methods and best practice would be presented and discussed with politicians and decision makers at regional and local level in all the Baltic Sea states. The main findings from the project were firstly that it is not possible to have sustainable development in rural areas, if young people don't want to commit their future and secondly that to be willing to commit your future to a place, you need 'to feel welcome now'. Thirdly the project found that there is a natural link between being involved and participating in society, receiving training in entrepreneurship and being innovative and finally that there are no general support systems/programmes targeting rural youth, only those targeting young farmers.

The issues outlined in the introduction to this report form the basis for this briefing paper. A review of the international literature relating to these issues across the European Union has been conducted. Although acknowledging that different countries have problems specific to the landscape and culture of their individual region, the paper will present current effective methods aimed at encouraging and retaining young farmers and strategies that have been proven to address the challenges they face.

This briefing paper will specifically focus on the following issues:

2 An attractive farming profession for young people

The section of the paper identifies successful strategies aimed at encouraging young people into farming. The focus will be research that engages with young people directly in order to explore their attitudes and aspirations in relation to farming.

2.1 Overview

To put the farming industry and the age of its current farmers into context, in 2013, 31 per cent of individual EU-based farmers were aged over 65 and only 6 per cent of the total was made up of farmers under the age of 35. Most farmers are not formally trained, 70 per cent have only practical experience, 20 per cent have basic training and only 8 per cent have attended a full time agricultural course (Eurostat 2013). Following the publication of a report by Royal Agricultural Society of England that stated more than 60,000 new entrants are needed in the farming industry over the next 10 years, much international press coverage has focused on the urgent need to get more young people interested in starting a career in farming (Piggot, 2012; Burton, 2012; Fursdon, 2013).

2.2 Barriers preventing young people from becoming farmers

It is useful to consider a project carried out by the Italian National Rural Network (INRN) in 2012 which was aimed at looking at young people's perceptions both of agriculture and the rural areas in which it takes place. This European survey, included eight Member States and the resulting report was published in October 2012. A total of 1,563 interviews were carried out across the Netherlands, France, Italy, Finland, Belgium, Poland, Latvia and Malta (and Sweden which was added in a preliminary phase). Interviewees were predominantly students in their last two years of secondary school but also included first year university students, the average age of respondents was 19 years of age. The research incorporated representatives living in both rural areas (53 per cent) and urban centres (47 per cent) and a very clear result of this difference in the location of respondents homes, revealed that 'the more young people know about and live in rural areas the more they love them' (INRN Report, 2012).

The overall conclusions from this report summarise that young people in Europe identify rural areas 'as a place where man and nature are in harmony' and presented a fairly positive opinion of the agricultural sector in relation to the environment and nature. Unlike many of those questioned in the CHILDWISE report a large number of the young people interviewed for the INRN 2012 report had considered the possibility of becoming farmers; however the perceived main barriers were remarkably similar. Three main difficulties were presented as barriers to getting into the industry

- a lack of resources for investments;
- inadequate income to meet the family needs;
- land availability.

In summary the report revealed that the more time young people spent in rural areas, the more positive their response to living in these areas and therefore the more open they are to the option of agriculture as a possible career choice. In order to facilitate this:

- Provide more adequate services in these areas.
- Establish concrete opportunities to access to land and funding in order to begin a new agricultural businesses or improve an existing one.
- Give them responsibility 'this responsibility puts them in the front line as far as the future of these areas is concerned: their choice to live in a rural area and to become farm manager turns into a challenge that young people want to tackle' (INRN Report, 2012).

In 2006, a series of research reports were published by CHILDWISE (a leading specialist in research with children and young people) aimed at exploring young people's opinions and ambitions in relation to farming. Conducted on behalf of Farming and Countryside Education (FACE) the research aimed to establish and monitor the views and opinions of 11-16 year olds in the UK towards food, farming and the countryside. It found that many young adults have an 'outdated' view of the countryside which means that they often fail to appreciate the scope of careers available to them. Many of those interviewed felt the image of the countryside as a calm and relaxed environment could also imply 'boredom and backwardness' (CHILDWISE, 2006). Farming was, in general 'rarely perceived as an accessible occupation, with many young people recognising that responsibility and ownership are usually passed down through the generations of one family. Children also thought that the amounts of money needed to acquire land, livestock and machinery, were prohibitive. (CHILDWISE, 2006)

This research was repeated in 2007, using the same methodology but focusing on children aged 7 to 15. These children were asked a similar range of questions regarding their attitudes to food, farming and the countryside, in all 2500 children from 65 schools completed online questionnaires. In comparison with young adults children in this age range seemed 'reasonably well informed about farms and mainstream farming practices' and this was thought to be because recent visits to local farms remained 'relatively fresh within their minds'. (CHILDWISE, 2007: 18)

This research suggested that young adults in the UK see farming 'as old fashioned and dated, with farmers often working alone in undesirable conditions for very little recompense'. Most presented an image of farming as somewhere where skills are learnt on the job with little or no academic support or input. 'Only a few sophisticated images were mentioned, mainly referring to machinery.' (CHILDWISE, 2007)

Finally, in 2011 a further report was published also commissioned by Farming and Countryside Education (FACE) in association with the recently launched 'Careers in Agriculture' campaign. The report presented data gathered from secondary school aged students (12-18) and included the views of teachers and careers advisers. It explored the current perception of careers in farming amongst young people, questioning what young people find interesting or attractive about farming and whether they were made aware of any farming career options. The findings of this report broadly supported the previous two reports suggesting that most children in the UK have 'a limited knowledge of agriculture, and what they do know is partial and based on stereotypes'. The obvious problem with these fairly entrenched views is it limits their interest in 'agriculture as a career area.' (Ehren, Duff & Leggett, 2011)

One of the key recommendations from this report was:

- the agricultural industry needs to improve 'the accuracy and scope of the image of agriculture that emerges from schools' through the provision of appropriate, up-to-date and exciting teaching materials and/or case studies for schools to use.

- These lessons should aim to 'reflect agriculture in a wider and more progressive way' and to ensure the provision of farm visits to 'include the bigger picture, via pre visit / post visit resources / exercises, and as part of the visit itself.' (Ehren, Duff & Leggett, 2011)

Furthermore the report stated that it was clear that some of the careers advisers and teachers are already aware of the vast number of varied opportunities available in agriculture, but that they 'lack the resources or persuasive power to encourage their students to consider these'. It was also noted that local colleges played an important role in supporting and advising those who had already expressed an interest in agriculture, but that 'outside help is needed to address the wider student community.' (Ehren, Duff & Leggett, 2011)

There are several key reasons why young people do not engage seriously with farming as a career option. For example AgriSkills Forum in a report published in 2010 entitled 'Towards a New Professionalism' developed a strategy in consultation with industry organisations and the Department for Environment Food and Rural Affairs (Defra) with one of the key aims being to promote the industry as being a professional and progressive place to work. This report highlighted that key challenges to implementing this strategy are that young people are not clear on the career structure or prospects available to them in farming; that there is of lack of funding or available places in initial training establishments such as the land-based colleges and that there is a lack of understanding of agricultural opportunities within the minds of, and literature available to, those who provide information, advice, and guidance to potential new entrants such as teachers and finally that the impression gained of industry within mainstream media is/continues to be unrepresentatively negative.

Further to this the 'Future of Farming Review Report' published in 2013 by Defra launched a 'Call for Views' in a bid to find information, views and evidence about the issues new entrants to the farming industry face, with a focus on concerns particular to the UK. The questions focused on what challenges and opportunities faced young people and new entrants when selecting and beginning their careers in the agriculture sector and reflected on how they thought these challenged could be overcome. A second question looked at the key challenges that the farming industry itself faces in attracting and keeping the enough skilled young people to work, manage and own agribusinesses in the future. Overall the research finding suggested that

- it is crucial that the farming industry itself takes more responsibility for the education and skills development of the next generation of farmers and farm workers.
- Business training is crucial both to farming and to new entrants and should be delivered by mentors who already have an in depth knowledge of this sector.
- Ways of demonstrating professionalism in agriculture must be developed,
- Keeping agriculture embedded within the National Curriculum so that both pupils, teachers and careers advisors understand what it means to be a farmer today.
- Provide an image of agriculture and farming that acknowledges the breath and exciting nature of possible careers in farming, whilst teaching schoolchildren about how food is grown and re-establishing a link between the farmer and the consumer.

2.3 Initiatives to get young people into farming

There are currently several key initiatives aimed at getting young people more interested in farming as a possible career choice and also at getting relevant information out to schools and colleges. Further information can be found in Annex 2.

The European Council of Young Farmers (CEJA) is an important forum in this arena. CEJA represents two million Young Farmers in Europe and provides a dialogue between young farmers and European decision makers. Their main objective is to promote a younger and innovative agricultural sector across the EU 28 and to create good working and living conditions for young people setting up in farming. According to CEJA figures just 4.1 per cent of famers in the UK are under 35 years of age, with only 6.5 per cent being the EU average. CEJA supports a number of successful projects:

- CEJA in collaboration with Groupe de Bruges and the Slow Food Youth Network (SFYN) aimed at demystifying the Common Agricultural Policy (CAP) for the general public and therefore helping people, especially young urbanites, to learn and talk about the CAP. CEJA organised a one-day event at a farm aiming to look at how through an interest in food, and food production urban dwellers could be encouraged to be part of the solution. For more details about this and other projects see Annex 3
- AgriMultifunctionality is supported and developed by CEJA and funded by the Lifelong Learning Programme of the European Union is II which aimed to address the problems of an ageing farm workforce and the flight of young people out of the countryside. The main outcomes of the Agri-Multifunctionality II project which was disseminated through the subsequent MULTIFARM_EU project was the development of a training system for young European Farmers who would like to start different activities on their farms. The training system was considered innovative because it combined e-learning and self-learning based courses which are often the most suitable training methodology for young farmers who may not be able to attend traditional face to face training courses.
- The Nutri project developed a computerized corporate platform to enable farmers and advisors to settle a business plan, to update, change and improve specific farms. In Italy this approach has been developed with further applications for business management, environmental management and conditionality, quality management, safety at work, e- commerce, work intermediation, human resource management, accountancy and business plan, and fiscal support. The subsequent Agri-YOUTH project funded with the support of the European Union aims at updating, adapting, transferring those teaching materials with specific focus on new established young farmers and female entrepreneurs, also bridging experiences and best practices between the European countries and Turkey.
- Bright Crop is a further successful project developed in 2012 in the UK by a cross-industry working group. This project is the first sector-wide initiative focused on attracting the best and brightest into the food supply sector, from farm to processor. The key outcome of the project was a website aimed at inspiring and informing young people to explore career opportunities across the entire sector. This site includes resources and careers-related activities for new recruits, their schools and their career advisors to make sure that everyone is informed about the scope of possible employment in the agricultural industry.

2.4 An alternative perspective: is there really a young farming problem?

Contrary to much of the evidence presented above, there are a growing number of academics who are questioning the very premise of a shortage of young farmers across Europe at all. In an article published in the Journal of Rural Studies in 2015 Lukas Zagata (Czech Republic) and Lee-Ann Sutherland (UK) state that there is vast inconsistency between European Policy documents, which 'conflate new farm holders with new entrants; Eurostat numbers which concentrate on young sole holders; and the academic literature which consistently demonstrates the importance of farming successors to farm business development' (Zagata & Sutherland, 2015). Their analysis of the current statistics and literature suggests is that instead of there being a significant 'gap' in the age of farming recruits, what these statistics reflect is 'a broader reaching small-scale farming problem', with a particular issue being limited opportunities for young farmers to acquire land. The paper concludes that the difficulties with Eurostat classifications in which 'young famers' must also be the 'sole holder' is problematic, especially given the fact that succession is such a prevalent method for entry into farming in Europe but that this clearly happens later in life. The paper also asserts that there is confusion over the classification of a 'new entrant' who could be of any age and a 'young famer' who is described as under 35. Given these issues with new farmer classification and comparison the paper recommends further research into these issues including the definition of young farmer which 'needs to be conceptually refined and made consistent and institutionalised within the Eurostat figures' (Zagata & Sutherland, 2015). In defining the role of a young famer more consideration is required on how farms are operated and who decisions are made by as currently 'the assumption that decisions are made primarily by one individual glosses over the number of possible farm management set-ups.' (Zagata & Sutherland, 2015)

There is also growing evidence to suggest that young people are taking matters into their own hands and due to a renewed interest in where food comes from and the popularity of farmers markets and the organic food movement there is considerable evidence to suggest that young urban dwellers may now be interested in entering the agricultural industry on a small scale farming basis. In an article published in Farming Matter in June 2015 Sidney Ortun Flament and Bruno Macias state that a growing number of urban youth, often with a university degree, are deciding to become farmers, many choosing agroecology as an alternative way to enter the food system, promoting both social and environmental sustainability. Describing them as 'new peasants' Flament and Macias describe this as a 'new urban–rural link' and one that counters the dominant trend of rural outmigration. Based on a series of interviews conducted in France they found that 'new peasants' have little prior agricultural knowledge, and certainly no 'family land' to inherit, meaning that they often have to learn how to farm without the support of their rural neighbours who consider them 'outsiders'. However, they also found that as these new entrants connect fluidly between both rural and the urban contexts they often use these mixed skills in new and innovative ways. Put to use and working alongside existing farmers, they 'become a driving force for change based on sustainable, agro-ecological production'. Furthermore 'new peasants' are increasingly seen as a crucial response to the issue of succession. As many retiring farmers do not necessarily have a family member willing to take over the business, these new peasants are looking for land to start a new farm meaning more support is required to bring the two together. In response to this perceived need Flament and Macias founded the Neo-Agri Association to facilitate such crucial knowledge sharing and networking among new peasants and between them and established farmers.

The idea of young farmers being 'innovative' and turning away from traditionally intensive industrial farming models was also promoted by Sabine de Rooij in 2004 AgriCultures Network's LEISA Magazine. The article states that young farmers are now looking for 'low input, economical and multifunctional ways of managing their farms'. In the article the author describes how some recent research carried out in in Western Europe (to include the UK, the Netherland, Italy, Germany, Spain and Ireland) shows that more farmers are opting for "multi-functional farming". In doing so they use farm resources to create new products and services, which they generally sell on the local market. 'Many of these farmers are young and relatively highly educated. In developing their farms along multi-functional lines they deepen, broaden and re-ground farm activities' (de Rooij, 2004 22).

Recent reports in the UK also support this trend for growing numbers of young graduates entering the agriculture industry with a growing number of individuals undertaking postgraduate study in agriculture. In 2016 postgraduate-level agricultural degree courses were surging in popularity, according to figures released by the Higher Education Statistics Agency. Courses throughout the UK categorised as "agriculture and related subjects" saw the biggest growth in new student numbers at both undergraduate (4 per cent) and postgraduate (29 per cent) levels from 2013-14 to 2014-15. The 29 per cent increase in postgraduate agriculture students was the largest of any other subject, the closest being a 10 per cent increase in the uptake of medicine-related courses.

A pay and careers survey undertaken by Farmers Weekly in 2015 and carried out online in association with recruitment consultancy De Lacy Executive, was completed by over 1, 300 farm-based workers and by those working in agriculture-related businesses. The results of the survey 'explode many of the myths about working in the agricultural sector with findings that show a workforce that is increasingly educated, ambitious and motivated by the interesting work that it undertakes' (Davies, 2015). The evidence suggests that there are still several challenges to be addressed, such as a long-hours culture and issues relating to whether pay reflects the level of responsibility in some areas but overall it suggests that most of those questioned would be happy to recommend agriculture as a career choice.

2.5 Agricultural migration and seasonal work

The satisfaction with agricultural work expressed above, tends to represent those in more stable positions but it is vital to remember that most people working in farming are part time and seasonal. Continued work in farming can be high skilled and relatively well-paid. Seasonal work is low paid and low skilled and involves both home and migrant workers. According to figures published by agri-info about two million workers are employed full-time in the agricultural and forestry sector in rural areas across the European Union. However, more than four million are in temporary employment and according to estimates two thirds of these seasonal workers are migrant workers who move nationally and internationally from their place of residence to their place of work. These numbers ca n only grow with the current wave of migration to Europe. These unstable and often very poorly paid jobs classed as seasonal work, often employ unskilled labour to assist with the harvest in roles such as fruit picking. These jobs are often done in Western Europe by workers who come from Eastern Europe and the majority of these migrant workers migrate within the European Union itself. For example seasonal work described by agri-info as 'precarious' meaning those who are employed for periods less than 8 months includes an estimated 180,000 migrant workers in Spain, 270,000 in Germany and 125,000 in Italy. Many of those migrating to Western European to countries such as Spain, Portugal, England or Germany are Romanian people who often don't speak the language of the country they are going to, making them vulnerable to unfair working and living conditions.

There appear to be few initiatives to protect and support such workers. Until January 1st 2014, England had a scheme called the Seasonal Agricultural Workers Scheme (SAWS) specifically for workers from Romania and Bulgaria who were coming to work in the horticulture and agricultural sector. Historically around 21,250 such workers were allowed to come to the UK every year. However, the British government did not renew the SAWS in 2014, arguing that there were enough unemployed people within the UK itself to meet the needs of the seasonal agricultural sector.

This can be seen as a capitulation to stereotypes of migrant workers as 'stealing 'farming jobs. In 2014 Eco Ruralis (an association of peasants, organic farmers and gardeners, academics and agricultural activists based in Romania) argued convincingly that instead of blaming migrants for stealing seasonal jobs in agriculture, energy should be put into preventing such precarious employment in the first place not only for migrant workers but also for domestic workers as well. 'The greening of the CAP introduces cross compliance with environmental criteria for the first pillar, but the aid should also be conditioned to respect labour laws and good working conditions on farms. And let's not forget that the easiest way to limit unstable jobs is to help and support smallholders and to recognize their economic and social importance in rural areas' (Eco Ruralis, 2014).

Precarious labour conditions and low pay are one of the key problems that need to be addressed across EU countries, not only in farming but in many other sectors such as retail, care and hospitality.

3 Alternative education systems for compensating school dropouts

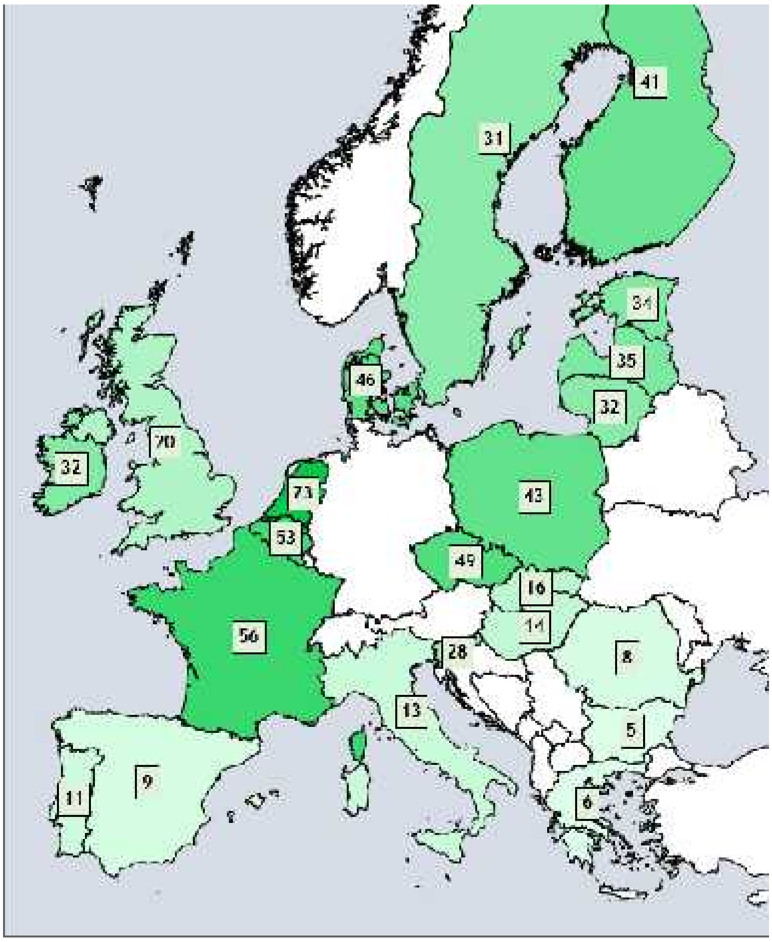
According to recent Eurostat figures at age 15, nearly 100 per cent of the population in the European Union are still at school. 'Not all leave education at the same age, so there is a gradual change for the young population as a whole. Its pace is determined by national systems of education and training, as well as other factors' (Eurostat, 2015 Participation of young people in education and the labour market, 2015)

All young people across Europe reach the end of their compulsory schooling aged 18 and an average of 80.4 per cent still participates in education and training at this stage, but this participation rate drops to 29.2 per cent for 24 year-olds. Additionally, despite the different structures of education and training systems across Europe, 60.5 per cent of 18 to 24 year-olds attain an upper secondary education or post-secondary education, and 12.7 per cent attain a degree at the tertiary level, however as much as 26.8 per cent of this age group has attained no more than lower secondary education. (Directorate-General for Education and Culture (European Commission) Education and Training Monitor 2015 Report, 2015)

Across Europe countries differ enormously in the extent to which there is an institutional linkage between the education/training system and the labour market. Some countries offer mainly general education and in this context there is often only a notional link to the workplace and vocational training is primarily obtained on the job. In other countries, occupation-specific skills are taught and embedded within the education system and it is here that the link between education, training and employment is strong. The way the link between education and employment is institutionalized differs enormously and in some cases, the teaching of vocational skills is shared between vocational schools and the workplace, such as in the apprenticeship system of the German-speaking countries and in other cases, the provision of vocational skills is primarily school-based for instance in The Netherlands (Wolbers, 2007). For more information see Annex 3.

According to figures published in 2012 in a European Commission staff working document entitled 'A View on Employment, Growth and Innovation in Rural Areas' in 2007 more than 80 per cent of the labour force came from the farm holder's family and 12 per cent of the labour force was made up of regularly employed workers. In addition, only 15 per cent of family farm managers in the EU had a working time in agriculture equivalent to a full-time job. The diversification of farmers' income is typical for about one third of all EU farms. Seasonal employment remains an area where more research is need to provide an accurate picture of its impact on the farming sector. Poland, the Czech Republic, Finland, Belgium and France have the youngest farming societies. In 2005 the percentage of EU farm managers that had basic or full agricultural training varied between 5 per cent in Bulgaria to 73 per cent in The Netherlands (see Figure 1).

Figure 1: Percentage of managers with basic or full agricultural training (2005)



Source: Study on Employment, Growth and Innovation in Rural Areas (SEGIRA, 2010). No data available for AT, CY, DE, LU, or MT (adapted)

In terms of unemployment young people (aged between 15 and 25) are the most vulnerable group as they are entering the labour market for the first time. Previously employment rates for young people in rural regions had improved but since 2004, the situation for young people has become less favourable. There are many reasons for this including the impacts of recession on available jobs, and the decline in those public services such as transport which support access to jobs for young people in rural areas.

Population growth is also an issue in rural regions with only 15.6 per cent settling in rural regions over the period 2000-2008, amounting to just 3.3 million people. The negative net migration in EU12 rural regions is a particular concern as about 1.2 million people have left in just eight years, however in EU15 rural regions newcomers reached 4.5 million in 2008 accounting for a population increase of 6.4 per cent compared to 2000. These figures are from 2012 so it is very likely that new migration patterns across the EU will change them dramatically.

This section of the paper will explore the current international literature on alternative strategies for those who have not succeeded in formal education. Current research shows these young people may still be active in informal learning and that strategies aimed at building on these existing skills should be prioritised. The paper will research and present innovative examples of alternative provision including vocational training, community based learning programmes, individual mentoring and digital learning initiatives.

The current unemployment figures in Europe for young people have seen an increase in all Member states apart from Luxembourg. According to Eurostat figures, in 2010, 12.8 per cent of young people (which is about 7.5 million) were classified as NEET (Not in Education, Employment, or Training). Figures vary between countries, ranging from 4.4 per cent in the Netherlands to 21.8 per cent in Bulgaria, but overall, between 2008 and 2010, young people accounted for nearly one-fifth (17.5 per cent) of the increase in the unemployment figures. It is estimated NEET's lack of participation in the labour force costs approximately 2 billion euro per week, with some countries such as Ireland and Bulgaria paying as much as 2 per cent of their GDP (Eurofound Report, 2012)

In 2014 11.1 per cent of 18–24 year-olds in Europe left education and training early, down 0.8 per cent from 2013. The share of 18–24 year-olds in Europe with at most a lower secondary level of educational attainment who were no longer in education or training fell for 12 consecutive years from 17.0 per cent in 2002 (Eurostat statistics, 2015).

3.1 NEET gender gaps

The gender gap in NEET levels decreased between 2008 and 2011. However, for those aged 15-19 years the NEET rate is higher among men and for those aged 20-24 the NEET rate is higher among women. It has also been observed that males are less likely than females to be NEET in Italy, Portugal and the UK (Robson, 2008). Aside from in Italy, Greece and Spain, individuals who live with a partner and at least one child are additionally more likely to be NEET (especially in France, Germany, the UK and Portugal). Robson (2008) explains that in the UK, reasons for men to be NEET tend to be due to poor labour market experience, yet for women they are often due to teenage pregnancy, and more commonly lead to mental health problems such as depression and low self-esteem.

3.2 Policy responses to the needs of NEET young people

Hawley, Nevala and Weber (2012) acknowledge that while there has been some action to challenge the current NEET phenomenon at both EU and national levels there is clearly room for improvement in a number of areas. The report suggested a mixture of measures should be adopted in each country depending on the context and the profile of young people who are NEET . However, there is the need to recognise the diversity within the NEET group, which means that the policy response must be both comprehensive and multifaceted.

The report recognised that

- In the context of globalisation and the shift towards a knowledge economy, young people need to be equipped with the right mix of both job-specific and cross-cutting core skills to be able to access the labour market. Skilled ICT competencies are an extremely important part of these cross-cutting skills and the ability to adapt and progress these skills is crucial.
- NEET-relevant policies based on a coordinated, partnership approach that ensures stakeholders from outside the public sector, including social partners and employers, are consulted and involved will be most effective
- Working life familiarisation opportunities and the availability of comprehensive information, advice and guidance are other key ingredients in supporting young people in finding employment

Finally, the report stated that due to the lack of data and long-term follow-up of young people who are NEET, it can be difficult to decide what type of interventions work better than others. There is a lack of systematic evaluation of the adopted measures, and more evaluations of NEET-relevant measures should be carried out. This is particularly important in the current economic context, when evidence is required to identify and implement those measures which are most efficient and cost-effective. (Hawley, Nevala and Weber, 2012)

Being NEET is not a stable category, many young people are intermittently NEET and also move in and out of low status, low paid jobs without training. Research untaken by Lawy, Quinn and Diment in 2009 based on a series of interviews with such young people found that there was a need to 'reconceptualise or at least question many of the underlying assumptions' about them (Lawy, Quinn and Diment, 2009). The young people were not 'inadequate' and under-achieving; there was a huge diversity in their range of activities and informal learning experiences. They were 'active co-constructors of their lives, asserting degrees of agency and control over different aspects of their lives including their self-identifications and presentations'. Overall the research highlighted the fact that 'young people have been misunderstood and misrepresented, and that what is needed is research to uncover more about the lives and interests of this socially disadvantaged and excluded group'(Lawy, Quinn and Diment, 2009).

Such research has now increased. For example (Maguire et al., 2012) found that young people who leave school without pursuing education post sixteen are 'diverse in terms of the motivations and aspirations of young people who enter the labour market at the age of 16 or 17, their commitment to employment, and their ability and willingness to access training'. Other studies have provided a more detailed breakdown of the 'types' of young people who are NEET or in a job without training, the structural and personal issues they face and the likely routes into participation in learning for each of them. (Spielhofer et al. , 2009; Spielhofer et al., 2010).

Further and more recent research presenting an overview of the situation of youth in OECD countries concludes: 'NEETs are far from a homogeneous group both within and across countries: younger NEETs do not have the same needs and expectations as older ones; NEETs from low-educated families face specific educational challenges; young parents often need additional child care; those with health problems need specific interventions that combine medical and employment support; those living alone do not have the same motivations as those living with their parents.' (Carcillo et al., 2015).

3.3 Young people who are NEET accessing careers in agriculture

Since the economic crisis in 2008, vocational education and training have become an important focus in the EU and a key strategy in the process of lowering NEET numbers. A paper published in 2012 identified and examined the various types of training measures introduced by EU Member states in response to this crisis. It concluded that despite governments in Europe advising that their policies for tackling unemployment were focused on 'training-first' rather than 'work-first' measures 'levels of participation in training activity by employed and unemployed workers have fallen or stagnated in Europe since 2007'. (Heyes, 2010) This lack of provision in relevant industry linked training is further complicated, certainly in the UK, by the findings of a recent review of technical education commissioned by the National Foundation for Educational Research that found that there is a 'lack of universal understanding of what is meant by 'vocational', 'technical' and 'professional' education' (McCrone et al., 2015).

There are currently several schemes aimed specifically at those wishing to undertake a career in agriculture. Further information on these projects can be found in Annex 4.

- The EU-funded GLEAN project aspires to open up career paths in agriculture for young disadvantaged people, promoting development and growth. GLEAN introduces an innovative, engaging approach for learning the job in the agricultural field. The approach is based on the design and implementation of a blended course, combining classroom and online/self-learning with an emphasis on hands-on experience.

3.4 Mentoring in agriculture

Apart from such training schemes, mentoring by experienced farmers is also a valuable approach 'Where opportunities occur for existing farmers to bring in new entrants from outside the family, it gives them a way to pass on their knowledge and expertise to someone who can be an effective successor or progress on in the sector.' (Future of Farming Review Report, 2013)

In 'Mentoring in Agriculture' in the Journal of Farm Management Richard Turner and Martyn Warren (2008) attempt to define mentoring and establish its prevalence, value, and potential problems that might inhibit mentoring for farm managers in the UK. The data was acquired through the use of a structured questionnaire and a series of semi-structured interviews and fund that the majority of respondents 'had experienced mentoring relationships at different career stages, and had found them to be rewarding both in terms of career and personal development'(Turner & Warren, 2008: 21). A large number of these mentors were the employers or line-managers of their protégés and this arrangement 'seemed to be an accepted feature – an almost unremarked tradition - of the industry'. 'Mentoring is not a general panacea for the problems and challenges in a farm manager's professional life, but it emerges from this study as a critical development process that can assist a person's development both professionally and personally, and as such should be considered as much part of a manager's portfolio as skills development' (Turner & Warren, 2008).

The paper recommended

- that these existing, 'informal' arrangements were built on and enhanced to enable further facilitation of what was already functioning effectively
- to improve the knowledge transfer of mentoring and to provide opportunities for mentoring relationships to occur, new structures should be created to enhance this already effective measure.

In March 2016 the European Mentoring Summit in Leeuwarden in the Netherlands: 'Mentoring, a powerful tool for 21st century skills in an economic vital region' brought together professionals, practitioners, researchers, corporate partners, government and civic leaders who represent the mentoring movement in Europe. The summit incorporated three major themes: Mentoring in an economic vital region, Developing research lines for Evidence-Based Mentoring and Mentoring, a powerful 21st century tool'.

Currently there are several initiatives aimed at promoting mentoring in agriculture. Further details can be found in Annex 5.

- An international example of mentoring is YPARD. YPARD describes itself as a global organisation 'by Young Professionals FOR Young Professionals for Agricultural Development' and operates as a network, not a formalized institution. It encourages its members, to become active in their area, spreading the news about YPARD to other young professionals, and encouraging a stronger voice of youth in their own organizations and to share their views and ideas with other young professionals in the network. This global on-line and off-line communication and discussion platform is meant to enable young professionals all over the world to realize their full potential and contribute towards innovative agricultural development. The central role that digital media plays in this network demonstrates in action the need for, and the value of, ICT competencies in the future development of farming.
- Research carried out by SEGIRA (Study on Employment, Growth and Innovation in Rural Areas) and presented in the European Commission Staff Working Document 'A View on Employment, Growth and Innovation in Rural Areas' looked at a range of current local actions across the EU aimed at supporting young people in rural areas. Projects included the LEADER Young Entrepreneur Programme, which has been running since 2007 in Ireland and focusses on the importance of getting infrastructure in place to attract young people back to the region and enabling semiskilled labour to develop (in the agricultural sector) via training programmes.

In Scotland investment in broadband in rural schools has opened up new opportunities for growing entrepreneurship amongst young people and investment in start-up businesses amongst school leavers has also been supported resulting in the business start-up rate for the region being higher here than in the rest of Scotland as a whole.

- In Oberkärnten young people have been involved in regional development in an original way by working on the question 'What should rural areas look like if they are to be attractive to young people?' The aim of this project was to provide input for future policies to prevent youth unemployment and to create an image to enable young people to identify themselves with the region. The output is a computer game that simulates such areas.
- In Spain, the PRODER projects and initiatives had a strong focus on the employment of women and young people. They aimed at improving the integration of women in the labour market in sectors such as agricultural production, the agri-food industry, childcare services and services for other dependent people (the elderly, people with disabilities, etc)
- The 'Grogrund' project which took place in Sweden distinguished between four stages in the professional business development of women and offered the following: idea seminars (for women interested in starting a business, but still at a conceptual level); mentoring (for women already running a business or for those who need business plan development in order to make their ideas a reality); education within the field of business knowledge (for women who wish to expand their business); and individual follow-up of participants in mentoring groups and individual counselling.
- 'Get Mentoring in Farming' was established following the 2013 Future of Farming Review which highlighted the crucial role played by mentoring in developing business and management skills in the sector. Funded by BIS (the Department for Business, Innovation & Skills), led by SFEDI (UK Sector Skills Body for Enterprise) it involves many partners and has been developed to help those working in the farming and agriculture sector across the country to mentor each other. Research suggests that seventy per cent of small business owners that receive mentoring survive for five years or more, double the rate of non-mentored entrepreneurs (Lantra, 2016).
- In the UK the Cywain Agriculture Project (based in Wales) is an agri-food support scheme looking to develop innovative ideas in adding value to Welsh producers through dedicated development managers and one to one mentoring and access to market intelligence. The project has been available over the whole of Wales and is delivered by Menter a Busnes, an independent economic development company that operates in Wales.

3.5 Digital initiatives

There are several current digital initiatives aimed at encouraging young people back into employment through online networking and learning opportunities.

- The 'FIWARE accelerator project', SmartAgriFood2 has been allotted 5 million in EU funding, 4 million of which is going directly to SMEs with innovative ideas on how apps can make farmers lives easier and lead to more efficient, high-quality agricultural production. The idea must target large-scale arable farming, horticulture or livestock farming. Technology-wise, it must also use the open-source platform FIWARE. This was developed within the Future Internet Public-Private-Partnership launched by the European Commission in 2011.

3.6 Vocational training

Initiatives exist which help to link those who may drop out of education with farming. For further information see Annex 6.

- Future Roots, Dorset UK is an excellent example of an organisation working with those young people who have traditionally been hardest to reach or those who are struggling with transitions in life. The Future Roots programme is an opportunity to gain an accredited qualification for the hardest to reach young people who are at risk of permanent exclusion from the education system (pre-NEET) due behavioural, emotional and social difficulties as well as those with special educational needs

Some projects will benefit young people more indirectly by improving agricultural practice and saving money in the sector, which could then, theoretically, supplement wages or improve training.

- 'Promoting Energy Efficiency on the Farm ("Eco-Driving in Agriculture) was aimed at existing and experienced farmers in Sweden between 2008 and 2009. It was a vocational training project supported by EAFRD funding to promote the energy efficient "eco-driving" of farm machinery in order to improve profitability and encouraging climate action at farm-level. Improving driving style, can save between 10-15per cent of fuel which has benefits for both the environment and farm profitability. For further information see Annex 7. The overall aim for the project is that it will contribute to the agricultural industry reducing emissions by 10-15 percent in 15 years. Agriculture in Sweden would thus be able to save 60-70 million euro per year.

3.7 Apprenticeships

- The 'Horticulture and Agriculture Apprenticeship Scheme' launched by the supermarket chain Sainsbury's in September 2015 in UK is open to any grower or farmer that supplies Sainsbury's, who are able or willing to take on an apprentice . Once selected the apprentice will work towards a Level 2 city and guilds work based diploma in either Agriculture or Horticulture with the aim of introducing both Level 3 and higher level apprenticeships in future. Sainsbury's has teamed up with Staffline Agriculture to support employers throughout the apprenticeship from recruitment through to on the job advice.

3.8 Alternative provision

'SecondChance' School (E2C) has been developed by the Auvergne regional Council. It accepts young people with serious social or professional problems, aged between 18 and 30 years and without diplomas or qualifications. The major objectives are to: (i) allow the acquisition of basic knowledge and skills necessary for integration of the person in the workplace; (ii) develop participants' social, behavioural, and cultural skills; and (iii) support to young people in defining their personal career plan, based on alternating school/company; (iv) assist in the professional integration into employment and/or training and follow this integration out of the school.

4 Advisory systems and services to farmers

This section of the paper will examine ways in which farmers can receive ongoing training and advice to develop their skills base and importantly the ability to teach and transfer these skills to other people. Further details of initiatives can be found in Annex 7.

The Lifelong Learning Programme (LLP) was designed to enable people, at any stage of their life, to take part in stimulating learning experiences, as well as developing education and training across Europe. With a budget of nearly 7 billion, the programme, which ran from 2007-2013, funded a range of exchanges, study visits, and networking activities. The activities of LLP continue under the new Erasmus+ programme link to another EC website from 2014-2020.

Recent successful projects supported by the Erasmus+ programme include:

- IMPROFARM (Improvement of Production and Management Processes in Agriculture Through Transfer of Innovations) a project with partners in Poland, Italy, Slovakia, Bulgaria and Cyprus which ran between 2013 - 2015. The project partnership consists of a university, research institute, professional agriculture body, training, research and consultancy organisations. The main aim of IMPROFARM project was to support transfer of innovations and knowledge between the partner countries to support development of skills and competencies of farmers and employees in the agriculture sector and related services, to support effectiveness of services and production related to agriculture, to support development of rural areas and employment in rural areas in partner countries. The project outputs consist of training resources and ICT assisted training utilising e-learning, blended learning and software training tools. The training resources consist of text books, case studies and assessment tools.

4.1 The European credit system for vocational education and training

On a systematic level, accreditation for vocational and experiential learning is very beneficial for farmers. The aim of the European Credit system for Vocational Education and Training (ECVET) is to make it easier for people to get validation and recognition of work-related skills and knowledge acquired in different systems and countries – so that they can count towards vocational qualifications; to make it more attractive to move between different countries and learning environments; to increase the compatibility between the different vocational education and training (VET) systems in place across Europe, and the qualifications they offer; to increase the employability of VET graduates and the confidence of employers that each VET qualification requires specific skills and knowledge.

4.2 Online advice and knowledge exchange

The European Network for Rural Development (ENRD) is the hub that connects rural development stakeholders throughout the European Union (EU). ENRD aims to contribute to the effective implementation of Member States' Rural Development Programmes by generating and sharing knowledge, as well as through facilitating information exchange and cooperation across rural Europe.

Following the changes to the CAP in 2003 a Farm Advisory Service (FAS) was set up with the explicit aim of helping farmers to better understand and meet the EU rules for environment, public and animal health, animal welfare and good agricultural and environmental conditions. However, in November 2010 the Commission published a report on the Farm Advisory System suggests

- ensuring that knowledge exchange is a priority and that advice, training, information, extension services and research are all improved.
- 'The FAS should therefore pro-actively develop and encompass issues that go beyond legal requirements under cross compliance'. (European Commission Report on the application of the FAS, 2010: 11)
- Future Farmers in the Spotlight is an initiative that aims to inspire and encourage the next generation of sustainable farmers. Currently based in Wageningen, the Netherlands, the groups aim is to show and share inspiring stories about young farmers who have, despite many difficulties, managed to set up farming initiatives which are innovative, viable and sustainable. So far the website contains thirteen films showcasing inspiring farming initiatives from throughout Europe to include examples from The Netherlands, Ireland, Germany, Denmark, France and Greece. The project is currently focusing on including inspiring stories from farmers in Southern and Eastern Europe.

4.3 Lifelong and informal learning

Lifelong learning has become an increasingly important aspect in the agricultural sector due to the rapidly changing environmental conditions, the introduction of more technology based farming techniques and the ability to remain competitive in a global market place. Being able to respond to this changing environment requires both innovation and learning and a certain degree of entrepreneurial spirit. A paper published by the Commission of the European Communities in 2000 looked at lifelong learning categories and came up with 'three basic categories of purposeful learning activity' to include formal learning (in educational and training institutions), non-formal learning (takes place alongside formal learning perhaps in the workplace) and informal learning (ideas and experiences gained in everyday life) (Commission of the European Communities, 2000). In a study untaken on lifelong learning in the agri-sector, learning needs, preferences and motivations were investigated using random sample of representatives from within the primary production sector (arable farming, livestock production, horticulture and forestry) with the aim of providing support for them in lifelong learning in the future. (Lans, Wesselink & Biemans, 2004). The results from the study indicated that technology, the use of IT and 'enterprising competencies' will become of increasing importance in the future.

In February 2016 the Lifelong Learning Platform (an umbrella association that gathers 39 European organisations active in the field of education and training, coming from all EU Member States and beyond) proposed five key success factors that would help take VNIL one step further. Firstly, implementing long-term and sustainable strategies for validation (this requires a shift of approach towards learning outcomes), secondly overcoming resistance (changing mind-sets is a prerequisite in making progress in this area), thirdly reaching out to disadvantaged groups (reaching out to a wider population by offering an alternative path and to integrate disadvantaged groups socially and economically), fourth guidance, counselling and information (presenting validation as a means to social inclusion, personal development, empowerment and employability), and finally the EU has had a leading role in the policy shift (the EU should take advantage of its position to secure a successful implementation of VNIL across the continent).

Implementing this approach would clearly be highly beneficial in attracting more young people to farming and creating pathways for those who have dropped out of education. However, moving from 'success factors' to successful actions requires many structural and economic changes.

Current projects based on the validation of non-formal and informal learning (VNIL) within agriculture include:

- AGROSKILL Transferring methods for validation of informal learning to VET institutions in the field of sustainable agriculture'. This project based in France, supported by the European Commission and funded by the Leonardo da Vinci programme aims to transfer innovative training methods, to exchange results and to agree best available methodologies in the field of non-formal and "informal" training in sustainable agriculture. Therefore, the aim is to achieve common frameworks for recognition at the European level. The main foreseen activities of the project include the transfer of best practices in sustainable agriculture and skills validation, the development of pilot training courses involving more experts and teachers of vocational training, and to establish an European network of experts, comprising at least 65 skilled and 100 vocational training centres; to broadcast online training programmes.

4.4 Communities of practice

One important way in which farmers can share good practice and innovation techniques is through their own informal networks and peer groups. Communities of Practice (CoP's) are 'informal learning communities characterized by a shared practice of its members, their voluntary engagement and a shared repertoire of communal resources' (Dolinska et al., 2016). In an interesting paper published in

2013, the idea of CoP's in agriculture is explored with the aim of documenting the activity of sharing and knowledge production within particular communities 'focusing specifically on how farmers who are geographically distant but linked by a common technical practice, manage to share their personal and particular experiments' (Goulet, 2013). The paper discusses the formation of specialized 'groups' within specific areas of the agricultural sector stating it is only when these participants come together that the 'story of each person's experiences becomes an essential part of the meeting' and through the creation of a personal narrative that 'private and situated experience is made available to other' (Goulet, 2013).

In a more recent publication the question of the role of communities of practice in the innovation process is explored. The author investigates the notion that by exploring the discursive space of CoP's it is possible to identify narratives and stories that may stop farmers innovating (Dolinska et al., 2016: 129). The paper concludes that the creation of innovation platforms should be 'turning towards learning communities of farmers spaces where norms shaping individual behaviour are collectively constructed and new narratives can be produced which empowers participating farmers as agents of change in agricultural practice' (Dolinska et al., 2016).

- A good example of this is the VALERIE research project consisting of 16 European partners including representatives from France, Italy, UK the Netherlands and Poland, Portugal, Spain, and Greece. The main aim of the project is to improve the accessibility and availability of new knowledge for innovation in agriculture and forestry. The ultimate goal is for a better flow of information to drive innovation in agriculture and forestry around six VALERIE themes. Key activities include working with practitioners in 10 case studies to identify current challenges for sustainability in agriculture and forestry, the extraction of knowledge from European research projects to help meet these challenges and the development of the "ask-Valerie.eu" search engine to improve access to information and knowledge. For further information see Annex 7.
- Another example of this type of network has recently been set up in Newcastle (UK). Landbridge is a knowledge exchange network for rural professionals. Its aims are to provide a platform for inter-professional learning and debate among advisors from across the professions and to provide opportunities for exchange with research communities. Through contributions to advisor learning, networking and training, landbridge aims to enhance advice to farming and land-focused businesses. Landbridge involves rural professionals from the public, private and third sectors. They include, for example, land agents, veterinarians, agronomists, ecologists and environmental advisers, renewable energy consultants, agricultural lawyers, planners, forestry advisers, archaeologists, game advisers, rural finance specialists, business advisers, feed advisers and nutritionists, solicitors, water engineers etc. The network is supported by the Economic and Social Research Council, the Rural Economy and Land Use Programme and the Living with Environmental Change Partnership.

5 Environmental management

This section of the paper will focus on farmers' awareness of and views on environmental issues (whilst BP5 focuses on more technical information). It will suggest ways in which farmers can manage their farms more efficiently taking into account factors such as sustainable use of water, efficient use of land, yield optimization and uses of alternative energy. Environmental management of farms is becoming increasingly important not only as a way to reduce chemicals and greenhouse gas emissions but also as way of making farming more cost effective and shortening the food chain which also makes locally grown food part of the solution to the global problem of food security.

In 2002 Defra produced a document entitled 'The Strategy for Sustainable Farming and Food: Facing the Future' which reviewed the long-term problems faced by the sector in terms of the food chain's under-performance across all three elements of sustainability: economically, environmentally and socially. The report concluded that 'the whole of the food chain has to reconnect with its customers, the world economy, the countryside and the environment. (Defra, 2002). Ten years later a report produced with the support of the European Union and the Committee on Sustainability Assessment (COSA) and developed as part of the Sustainability in the 21st Century Project implement by the Division of Sustainable Development of the United Nations Department of Economic and Social affairs aimed 'to stimulate – not end – a healthy discussion that integrates and respects diverse "world views" on food and agriculture.' As a result of the research commissioned in respect of this report, leading thinkers and experts from around the world were consulted about their views on the most significant trends and important priorities in the next twenty years to ensure sustainable food and agricultural systems. Nine key areas were identified as key actions; primary focus of investment should be small and medium farms; definition of the goal in terms of human nutrition rather than simply more production; high yield production within the parameters of a healthy ecology; innovation and the exploration of diverse technologies; a significant reduction of waste; avoid food production crops and productive land being diverted into producing bio-fuels; intelligent and transparent measurement of results; develop and adapt public and private organisations that can effectively respond to new goals and finally motivate and reward investments and business systems that result in measurable improvements.

There are currently several organisations aimed at promoting effective environmental management in farming.

- The overall aim of the Sustainable Food Trust is to develop a global network of individuals and organisations in positions to influence change; to build consensus around strategies to enable the transition to more sustainable food systems and finally to bring together groups of individuals to communicate across sectors about the challenges faced and potential solutions. They believe that the key principles for sustainable food systems should optimise the production of high quality safe food; minimise the use of non-renewable external inputs; maintain and build soil fertility; enhance food security and a high degree of resilience against external shocks; support plant and animal diversity and animal welfare; minimise environmental pollution and promote public health. Current key projects include 'Story Bank' which is a project aimed at building a bank of stories and information about building healthy food communities. The premise of the project is that by informing everyone about the principles of sustainable food systems into practice from farmers to eaters that we can all learn about overcoming challenges and solutions inspiring everyone to take individual action to improve our health and the production of the food that we eat.
- 'True Cost' is a project investigating the present systems of food production which are based on the notion that it is more economically profitable to farm unsustainably than it is to farm sustainably. This project aims to promote a system whereby monetary value is placed on the benefits and impacts of alternative food production systems enabling the introduction of policy mechanisms to penalise damaging practices and reward the development of systems that deliver positive environmental and public-health outcomes.
- A good European example of an organisation aimed at promoting sustainable agriculture is the European Initiative for Sustainable Development in Agriculture (EISA) which was founded in May 2001 with the common aim of developing and promoting sustainable farming systems, which are an essential element of sustainable development. EISA has members from agricultural associations in seven European countries and promotes 'Integrated Farming' practices which are based on a holistic 'whole farm' approach to sustainable development in agriculture. For further information see Annex 8.

5.1 Young farmers and climate change

Based on the premise that existing knowledge and experience from farmers play an important part in defining best-practices that are cost-efficient and effective the Climate Farmers project was aimed at European farmers willing to tackle the reduction of GHG emissions on their farms. Organised and supported by NAJK (a Dutch based collective defending the interests of young Dutch farmers) and CEJA the project gathered practices which were already being implemented by young farmers in the dairy and arable farming sector. As dairy and arable farming are the largest in Europe and are also carried out in all EU-member states measures taken within these sectors could have the largest impact on the decrease in GHG emissions. The outcome of this project includes the publication of a booklet showing that young farmers all across Europe are developing a wide range of methods in order to reduce the greenhouse gas emissions from their farms. The farmers that have been showcased in this publication have successfully achieved innovative ways to make food production more sustainable and produced with fewer emissions of greenhouse gases, like carbon dioxide, nitrous oxide and methane that we know are responsible in part for changes to our climate. What is fundamental about this project is that it is young farmers that are being presented as are part of the solution through the provision of the next generations more "climate friendly" food. For further information see Annex 8

5.2 Sustainable farming

AGRICULTURAL Transition is organised, managed and administered by the More and Better Network (an international network for support of food, agriculture, and rural development to eradicate hunger and poverty) and supported by The Norwegian Agency for Development Cooperation (Norad), The Development Fund (Norway) and Heidehof Stiftung (Germany) this web-based strategy aims to showcase a wide range of sustainable agricultural practices, and promote the notion that peasants and other small scale food producers and providers can nourish a growing population, preserve the environment and contribute substantially to stop the climate change. For further information see Annex 8.

5.3 Organic farming

The EU-funded EUPHOROS project was completed in August 2012. The project was a four-year study, that took place in the Netherlands, with participants in Hungary, Spain, Italy, Latvia, United Kingdom, and Switzerland. The project focused on increasing the efficient use of inputs such as fertilisers and pesticides in protected horticulture and developed a sustainable greenhouse system that was not completely reliant on fossil fuels for energy thus minimising its carbon footprint. Overall the project achieved a 50per cent reduction in the amount of energy used as well as a sizeable saving on chemical inputs. For more information see Annex 8

The "Smiling Sun" Organic Farm Product Collection and Marketing Network project. Was Supported by EAFRD funding. Sonnentor (a large-scale organic food retail company) developed an organic food production network, marketed both nationally and internationally, whilst conserving small farm structures and traditions. Sonnentor's aim was to develop a method in which specialist organic farm products were sourced directly from farmers but sold and marketed internationally. Farmers in the Waldviertel region of Austria were keen to cooperate and support the initiative but wanted to conserve their small farm structures and traditions.

5.4 Grasslands

'Reviving Europe's grassland farming' worked with collaborators in the Netherlands, the United Kingdom, Switzerland, Germany, Ireland, Belgium, Norway, Poland, and Italy looking at the cultivation of grasslands for biodiversity and productivity and to the benefit both farmers and consumers. 'MultiSward' was a project aimed at establishing the optimal acreage and use of European grassland and to communicate the environmental benefits of grassland-based animal production to politicians, farmers and industry. MultiSward set out to develop grassland production systems suited to the diversity of Europe's farming, soil and climate. Working closely with farmers and industry, the project investigated various economic and political scenarios including farm commodity prices and various Common Agricultural Policy (CAP) instruments such as milk quotas that could affect grassland areas. They then used these findings to propose grazing and animal management innovations for use by farmers. For more information see Annex 8.

5.5 Water sustainability

'A third of water use in Europe goes to the agricultural sector. Agriculture affects both the quantity and the quality of water available for other uses. In some parts of Europe, pollution from pesticides and fertilisers used in agriculture alone remain a major cause of poor water quality' (EEA 2012).

The sustainable management of water in agriculture has its own particular set of complex issues and challenges. 'Agricultural pollution, abstraction and morphological pressure have been identified as the main threats to the water environment in western Europe' (Blackstock et al, 2010). With reference to the range of difficulties faced by farmers in relation to sustainable water use and management recommendations from the 'Sustainable Management of Water Resources in Agriculture' published by the Organisation for the Economic Co-operation and Development (OECD) in 2010 include; a recognition of the complexity and diversity of managing water resources in agriculture; strengthening of institutions and property rights for water management in agriculture; ensuring charges for water supplied to agriculture at least reflect full supply costs; improving policy integration between agriculture, water, energy and environment policies; enhancing agriculture's resilience to climate change and climate variability impacts; addressing knowledge and information deficiencies to better guide water resource management.

Within Europe, the Water Framework Directive (WFD) provides legislation aimed at maintaining and improving water quality. The WFD covers not just what happens within water bodies, but also crucially addresses the land use around them and considers how this may be affecting water quality.

In a paper published in 2009 concerning the specific problem of diffuse pollution from agriculture, the authors investigate possible methods of influencing famer behaviour in a bid to improve water quality. The authors state from the outset that they consider the farmer 'an important decision maker to influence' when managing agricultural diffuse pollution and that by aiming to influence farmer behaviour through legal instruments, economic rewards, the provision of advice and voluntary collective actions water sources are more likely to be effectively protected. The paper concludes by suggesting that the farmer is interacting with a range of advisors and that no single strategy is likely to prove effective in influencing behaviour alone, rather that 'attempts to influence farmer behaviour need to take into account of good practice in communicating and developing consistent and salient messages that the famer feels willing and able to respond to.'

In a report published by the Woodland Trust (UK) in 2012 it was stated that the use of trees and woodland integrated into farming systems 'can help to reduce the risk of harm to water quality, and contribute to mitigation of flood risk, while also helping to support agricultural production'. (Woodland Trust, 2012). The report suggested a number of successful strategies for famers to adapt to their own particular environment to include field margins and riparian buffers where planting trees can reduce soil and water movement by increasing water infiltration rates and slowing the flow of transported soils and sediments. More specifically, in riparian areas trees and woodland can aid sediment removal and erosion control, and protect water quality by buffering the water source from pollutants and nutrients. In addition tree planting and woodland can assist to reduce aerial pollution. Where fields are subject to application of manures or fertilisers, trees can allow for capture of ammonia, and the woodland edge is especially effective at capturing air borne pollutants. Finally the report suggested that even buildings and yards could benefit from the existence of small areas of woodland as they represent a potential source of both air borne and surface pollution. Buffers of trees around livestock housing, or next to slurry and manure storage, can reduce the amount of ammonia in the air and tree belts can also act as buffers against smaller accidental spills from manure or slurry storage areas or runoff from farmyards. In addition to any benefits to pollutant capture, planting around livestock housing can lower wind speed, reducing the chill factor for livestock, and lowering heating costs to other buildings.

- The WIRE Action Group (Water and Irrigated agriculture Resilient Europe) is committed to unlocking the potential and accelerating uptake of innovative irrigation technology and improving agricultural water. An example of a recent successful project supported by the group includes one in Spain called which aimed to optimise the use of irrigation water resources for cherry orchards in the Valle Del Jerte region. The project involved the development of irrigation strategies specifically adapted to the cherry crop in mountain regions, where resources are limited by the difficulty in the water regulation. The project worked with different cherry farms in varying climatic conditions where irrigation strategies were established and adjusted to suit the specific climatic conditions in each area. Results achieved so far include an improvement final fruit size, longer harvest periods, and a saving of 75per cent of the water applied during the post-harvest period. The information generated from this project should be transferable to other farms within the region, benefiting more than 3,500 cooperative members, local farmers and irrigation communities.
- In 2013 the UK based LEAF (Linking Environment and Farming) group produced a guide with six simple steps for managing water quality and case study examples of how to achieve the best results. The recommended check list of improvement measures included: Water Saving; Protecting Your Water Sources; Soil Management; Drainage; Tracking Your Water Use; Water Availability and Sunshine Hours. The guide also used examples of successful improvement measures from farms around the UK. For more information see Annex 9.

6 Managerial skills for competing on global markets

This section of the paper explores how farmers can develop their skills to compete more effectively in a global market. ‘Farmers, agricultural business, researchers and governments have recognized the need for a more entrepreneurial culture in the farming business (Mcelwee, 2006). In the Future of Farming Report published by Defra in 2013 the authors concluded that ‘if we are to deliver a competitive and sustainable farming sector, we concluded that we need the right people, including farming entrepreneurs, managers and workers, to ride to that challenge’ (Defra, 2013).

The EU-funded research project ‘Developing Entrepreneurial Skills of Farmers’ aimed to increase understanding about the nature and relevance of entrepreneurial skills in farm business using a qualitative, interview-based methodology conducted in the UK, Finland, Italy, the Netherlands, Poland and Switzerland. A general conclusion from the study was that most farmers who were interviewed agreed that entrepreneurial skills are important and relevant for their own business activities, however there were found to be clear differences among individual farmers concerning their degree of skilfulness in this area. ‘These differences, together with the notion that entrepreneurial skills can be learned, imply that to develop and improve these skills among farmers is a feasible option and objective’ (Vesala and Pyysiäinen, 2008).

In a paper published in 2013 entitled 'Moving Beyond Entrepreneurial Skills' the authors set out to focus on the learning processes leading to the development of entrepreneurial skills in the specific context of multifunctional agriculture. Through the study of farmers who had started new non-farming businesses on their existing farms the research focused on the learning processes that occurred within this context. In conclusion the study found three major factors motivating this learning process: firstly the redevelopment of an entrepreneurial identity, the study found that farmers developed their new identities slowly through exploration and experimental learning which helped them to develop new skills, confidence and a belief in multi-functionality. Secondly crossing the boundaries of agriculture new social interactions broadened perspectives and operating outside farming domains was often found to be easier for women of the farming community. Thirdly opening up a family farm, there was a significant level of new skills, experiences, knowledge and networks associated with introduction of external labour to the farm. This study is useful in its potential to assist farmers to employ these learning techniques.

More recently, a report launched in January 2016 at the Oxford Farming Conference entitled 'Entrepreneurship: A kiss of life for the UK farming sector' argues that entrepreneurialism is 'a necessary management philosophy to harness the winds of change, to control the creative destruction and to succeed in a tougher farming environment'. It concludes by recommending a six-point plan towards an ongoing process of renewal and growth.

Their recommendations are rather evangelical in tone and need to be combined with a realistic understanding of the structural and economic factors which constrain the development of farming activities.

7 Farmers' Education

It is surprisingly difficult to find information about farmers' education apart from some historical outlines of national developments. See Annex 9 for an illustration. In 2005 Martin Mulder produced a series of papers on agricultural education for Cedefop (Mulder, 2005a, Mulder, 2005b, Mulder and Gaspari, 2005) He argued that whilst some might consider it dull, agricultural education is a 'red hot' topic (Mulder, 2005a) because of population growth and food security. Farmers play a crucial role in both feeding and protecting us.

He argued that, as learners, farmers are a special group: 'They learn a lot from others such as suppliers (of animal food, seeds, fertilizers, protection materials, health care), customers (traders, whole sale agents, buyers from the processing industry, large retails chains), financing organisations (banks, investment agents), insurance agents(for property, livestock, machinery), colleagues-competitors (in the same niche or in other sectors), research and good practices (through professional journals, information days or evenings), networks (such as growers associations) and specific reports (of research organizations such as benchmark reports that give specific information about the performance of the farmer – like characteristics of milk production – compared with a given reference group), regulating authorities (that require for instance mineral management documentation) (Mudler, 2005a).

The diversity and informality of these learning inputs is surely a key reason why it has been difficult to formalise farmers' education

With Olimpia Gaspari (2005) Mulder argued that dialogues across sectors including professions and policy makers were essential to progress the development of effective farmers' education. However, he also cautioned against believing that the farming sector itself held all the knowledge necessary to stimulate such change. In reflecting on the case of the Netherlands he concludes: "More attention should be given to the knowledge infrastructure to stimulate effective, co-operative, knowledge production and learning" (Mulder and Kupper, 2006)

However, despite such strong recommendations, by 2016 Mulder recognises that:

"Regarding the question of Farmers' education there are hardly any publications with an overview of this. At various levels, like EQF levels 4 and up there are all kinds of programmes which are relevant for farming, but there are no dedicated educational programmes to become a farmer. This has several reasons:

1. Farming as a profession is very diverse.
2. Knowledge and capital intensive farming, such as precision farming, is an economic sector in which it is difficult to start.
3. In practice, many farms are inherited, and complex financing/ownership arrangements exist. Farming itself is a matter of intergenerational learning, although education plays an important role. Many young farmers have higher education (BSc or MSc).
4. It is more and more difficult to get loans of banks for farming."[1]

It seems that as yet there has been little success in organising systematic farmers' education, although, as we have seen in earlier sections of the briefing paper farmers have taken up many learning opportunities at the level of projects and specific initiatives. Any future farmers' educational development would need to be flexible and experiential and respectful of informal learning.

8 Future trends

This section of the report will describe different roles and skills for future farmers. It will focus on the main future trends in agriculture, their origin, and their expected development towards 2050.

The following trends have been identified as having an impact on future developments in farming and employment: demographic trends, economic trends, sociological trends, technological trends, ecological trends, political trends, and spatial (planning) trends. Whilst it is difficult to predict what will actually happen, many in the farming community have creative visions of what might be possible.

8.1 Creative visions of future farming

A useful place to start is with a piece of work co-created by Farming Futures and Forum for the Future in 2010/2011. Farming Futures is a multi-award winning climate change communications and behaviour change project in the agricultural and land management sector. The research aimed to stretch current thinking on skills and roles in the agricultural industry, highlight a positive future with an essential role for farmers and agriculture, promote debate between incumbent farmers and the next generation and use 'futures thinking' to help farmers take action to adapt to and mitigate climate change. The object of the work was to assist in preparing the farming community for the changes the future could bring in terms of climate change, resource depletion and the loss of global biodiversity. New ways of farming need to be developed to be low carbon, resilient, environmentally restorative and sustainable in social and economic terms. This project aimed to promote renewed investment and interest in skills and help develop a climate in which farmers are excited about the future possibilities offered by their profession.

The project outcome was the development of six possible roles that farmers could be doing by 2030 with a summary of the skills that they would need in order to succeed. The roles were; Geoengineer, Energy Farmer, Web farm host, Animal therapist, Insect farmer and Pharmer. Many of these roles appear at first glance to be rather futuristic but they are based on trends already present in our food and agricultural systems. The roles and skills required are as follows:

[1] Mulder, personal communication; 30.03.2016

- The Geoengineer would specialise in carbon sequestration, alongside a food production business by using a combination of techniques such as land use management, soil management, the production of biochar, and forestry to capture and bury carbon.
- The Energy Famer would specialise in renewable energy production and management for the local area, perhaps being part of a smart grid or a hub provider of mobility-on-demand services for the local rural community.
- The Web Farm Host would work on the farm but their main job is to give a constant, positive commentary to the outside world, explaining what's going on and often giving virtual tours to school children as well as dealing with the concerns and curiosities of customers in the supermarket or the people who buy direct online.
- The Animal Therapist would act as a welfare manager for the farm animals working closely with the local and on-site vet, and also with the farm brand manager, making sure that the consumers buying the meat or dairy products from the farm are able to access information about animal wellbeing, often right down to the webcam in the field or barn.
- The Pharmer would use biotechnology expertise to grow and harvest plants that have been genetically engineered with foreign DNA to make them produce medicine - or proteins which can be purified to produce medicine - at a fraction of the price of conventional manufacture.
- The Insect Farmer would farm large quantities of insects for use as natural predators to control the new species of insect that has been brought to farming because of climate. The insects are grown in large controlled environments, and monitoring their progress is a highly skilled job. Insect farmers also produce crickets and beetles for food outlets for people to eat.

The development of these potential roles, some of which are already very much a part of the farming environment, is a useful way to inform potential new, young farmers about the exciting new opportunities available to them and also as a means of informing potential training and educational colleges about new ways in which to support young farmers to gain the support and training they may require to undertake these new types of occupation.

There are many projects that are exploring such new territory in agriculture, including

- Nemo's Garden a project developed by a Geneva-based scuba diving company (the Ocean Reef Group). Launched in 2012 in collaboration with a group of agricultural experts the aim of the project is to utilize the properties of the large bodies of water (constant temperature, united with the natural evaporation of a surface of liquid in contact with an air space) to try and create an underwater greenhouse. Based on the principle of hydroponics, the project uses 'biospheres' to generate fresh water through desalination. Seawater evaporates and condensates at the top of the biospheres and then trickles back down as fresh water. This water is then used to feed plants.

8.2 Implications for education and training

New developments in agriculture will have important implications for education. Freija Van Duijne (Futurista, 2014) describes the trends and developments of future food systems using the Three Horizon approach, developed by Bill Sharpe. Through the use of this systematic approach she attempts to visualize different visions for the future of agriculture that can be recognized in the present. Firstly, a sustainable agricultural sector in the bio economy, secondly emerging, transformative technologies and thirdly a local, connected, value based food system.

Van Duijne concludes by questioning how schools and colleges can prepare students for their future careers: 'The traditional learning method of spending days in your chairs at school rooms may also be over sooner than we think. Already MOOCS, massive online open courses, are used by students all over the world to absorb learning materials. As developments go fast, it is key to pick up new things fast and translate this into learning materials. In addition, internships, practice in startups, entrepreneurship is the way to get experience with a new way of doing business. Creativity and a keen eye on new opportunities will be essential. These are great challenges for education.'

It is probable that educational institutions themselves will survive more fully than Van Duijne envisages here. However, it is certainly true that they will need to be much more adaptive, flexible and creative to prepare students for careers in farming or in any other sector. Learning outside formal education will become more recognised and more important in the future with synchronisation between what happens within institutions and the learning that takes place in the home, in communities, in work, in creative activities, in on-line environments and in nature. Finally, new ways of understanding relationships between humans, animals and nature, inspired by posthuman thinking (see Braidotti, 2012), will reconfigure our understanding of what farming is and how it should be undertaken.

8.3 New points of interest for policy-makers

Mentoring

Mentoring is an effective, bottom-up way to encourage young people into farming. Systems where established farmers mentor emerging farmers already exist and should be supported and developed further.

Communities of Practice

New educational initiatives for those who are NEET should build on existing informal communities of practice amongst farmers.

Migration

New patterns of migration will have a profound impact on farming. Systems need to be developed which draw on the new skills they bring and also promote better conditions and pay for all working in farming.

Female farmers

Farming has traditionally been considered male, yet it is women who most seem to anticipate staying in rural areas and women also graduate in equal numbers to men in agricultural studies degrees across Europe. Women should be supported into farming and flexible working encouraged so farming and caring responsibilities can be combined, both for women and men farmers.

An overview of relevant initiatives and projects is presented in Annex 10.

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Annex 1: Research on rural youth

Further information about Merchant, Waite and Quinn, 2012

Key recommendations from the report were to explore alternative transport facilities enabling more flexible access to potential educational opportunities. The development of distance learning options and of potential affordable housing initiatives to support young people in their decision to stay living locally. It was also recommended that children and young people were involved from an early age in natural environment activities, and to consider ways that the skills that young people acquire through informal learning can be better recognised and rewarded. Finally to consider how on-going support could be given that provides guidance to young people in negotiating ways to realise their aspirations.

Annex 2: encouraging young urbanites into farming

Further information about initiatives to encourage young urbanites into farming

CEJA initiatives:

One day events to listen to talks and workshops, accompanied by delicious, local and seasonal food. The project also included a one day event in Scotland which focused on new farmers and the recruitment of new young and inspired individuals into Scottish farming

The Agri Multifunctionality training system is based on a 'Learning from Good Practices' model in which learners acquire knowledge from real experiences, often case studies, which cover many different European contexts and include almost all the aspects of multifunctional agriculture. The benefits of this training tool are that young farmers will gain knowledge of what other European "colleagues" are doing successfully and tailor this new activity on his or her own farm.

The Naturaliter project was a successful project based on different levels of education and training tools: the 1st level for a basic self-evaluation on farming; the 2nd level for a training-gym from a library of case studies; the 3rd level for farmers with skills on farm planning and managing. A variety of farms were selected and used as case studies for multifunctional activities such as agro-tourism, organic products, traditional food products, gardening, nursery and landscaping, renewable energy sources.

Annex 3: Educational statistics in europe

Further data on educational statistics in Europe

According to recent Eurostat statistics the twenty eight countries in Europe had just over 20 million tertiary education students in 2012. Five of those (namely Germany, the United Kingdom, France, Poland and Spain) quoted 2.0 million tertiary education students or more in 2012. The overall figures state that, one third (32.8 per cent) of the students in tertiary education were studying social sciences, business or law in 2012. The second largest number of students by field of education was in engineering, manufacturing and construction-related studies which accounted for 15.0 per cent of all students in tertiary education and the third largest field of study was health and welfare, with 14.3 per cent of all tertiary education students.

Close to three fifths of graduates were women; this share exceeded three fifths for social sciences, business and law, exceeded two thirds for humanities and arts, and exceeded three quarters for health and welfare fields. Male graduates accounted for three fifths of the total number of graduates for science, mathematics and computing fields, and close to three quarters of the total for engineering, manufacturing and construction-related fields. In the two smaller fields —agriculture and veterinary fields, and services — the number of graduates was balanced between men and women

Annex 4: Attracting NEET young people into farming

Further information about projects to attract NEET young people into farming

GLEAN: addresses disadvantaged youth, such as young people Not in Education, Employment or Training, so-called NEETs, long-term unemployed and young graduates in agriculture motivated to improve their skills through work experience guided by experts in the field exploits the registered huge potential of agriculture for employability promotes the social role of agriculture for inclusion proposes the design, development and implementation of a training programme, based on learning the job in the agricultural field.

The Pre-VENT 14-19 scheme aims to tackle the underlying reasons why young people in rural Wales find it difficult to learn and are at risk of leaving school without qualifications or the skills to find a job. Backed with over £8m from the European Social Fund through the Welsh Government, the project is targeted at 14-19 year olds and will provide a package of support and training for around 8,000 young people both in schools and outreach settings. Led by Bridgend County Borough Council, the project will collaborate with Blaenau Gwent, Caerphilly, Merthyr Tydfil and Torfaen councils, alongside further education colleges in the area, to raise aspirations and tackle the barriers to learning faced by some young people. The scheme will offer alternative curricula and innovative training approaches to motivate and boost the confidence of students who are experiencing problems with learning. Tailored to the needs of each individual, a range of techniques will be used such as vocational training, one-to-one intensive support and activities to raise self-esteem will encourage young people to remain in education and improve their skills.

Annex 5: mentoring

Further information about mentoring projects

The original Cywain Agriculture project was launched in August 2008. The support provided by Cywain is targeted at addressing an identified gap between other previous agri-food support schemes that were run in Wales. These schemes work with farmers to generate and identify innovative ideas to add value to Welsh primary produce; however there was no follow-on support to help farmers translate these ideas into viable and profitable businesses. Cywain Agriculture was also developed to encourage and aid cooperation within the farming industry. This was done by supporting innovative individuals with the potential to see a growth in successful collaborative initiatives and thereby achievement of the vision for Wales set out by the Welsh Government in 'One Wales' (2007).

Annex 6: the future roots project

Further information about future roots

The organisation, based in Dorset (UK) runs a range of programmes for all ages and specialise in working with young people who have an interest in farming, but who find school challenging. Future Roots runs several vocational training course for young people for example Future Farmers (aimed at 14-21 year olds) is based on a City & Guilds Award in Land-based Operations, and is a one or two year training course that provides all the basics for a career in agriculture, horticulture or animal care.

A hands-on programme, Future Farmers is delivered around the seasonal demands of farming life. Young people build employability skills (teamwork, communication, problem solving and planning) and life skills (healthy living and nutrition) by feeding and caring for livestock, cleaning and maintaining the farm, and tending and harvesting fruits and vegetables.

Another programme run by Future Roots is 'Field 2 Fork' an outdoor education and enrichment for 8-21 year olds with complex learning needs. Structured around one-to-one and small group sessions as well as after school and holiday clubs, this is ideal for young people with more complex needs who require enriching activities and is often used to supplement formal schooling,

Annex 7: education and training

Further Information about education and training

Energy efficiency

The overall aim of the promoting energy efficiency project was to create the motivation and knowledge for most farmers using tractors and other diesel vehicles to drive in a more "eco" way was promoted through the implementation of a training package for trainers in the Swedish county of Jönköping. Activities began with the collection and documentation of available knowledge and experience on the theme of eco-driving in agriculture. This was then applied to development of a professional "training-of-trainers" course in the "economical driving" of agricultural machinery. At least ten instructors (including two women) were trained and now lead farm level training courses throughout Sweden. The project concluded with some local pilot training activities for tractor drivers.

Entrepreneurship

The IMPROFARM project also wants to contribute to the transparency of skills of farmers and targeted types of professions in agriculture and agriculture related services. The project focuses on these areas of training: agritourism, business related skills in agriculture establishments (management, marketing, financial management, planning, production management), organic production, nursery, innovations in animal production and farm production. The project will also contribute to "fostering dynamic entrepreneurship, taking advantage of the opportunities provided by the recent reforms, which have created a market-oriented environment for European farming" through innovative training resources and exchange of relevant experience between the partner countries and from Transferring project through cases studies of real farm enterprises. Through involving the nursery module the project also contributes to "Improving the environment and countryside, (preservation and development of high-nature value farming and forestry systems and traditional agricultural landscapes) priority of the community guidelines.

Communities of practice

A further key aim of VALERIE is to develop an advanced search engine and repository of structured information that will interactively provide information to farmers, agricultural organisations and researchers. It will do so by providing easy access to knowledge created in EU-research projects and other research. The "ask-VALERIE.eu" search tool will allow users to retrieve relevant and useful information using all available and reliable sources. VALERIE will explore new methods to support question formulation (query articulation), to retrieve information and present meaningful answers.

Annex 8: environmental management

Further information about environmental management

Integrated farming

The key principle of the Integrated Farming system includes good soil husbandry, crop nutrition awareness and optimisation, crop protection based on as little chemical use as possible and use of biological methods where possible. Animal husbandry, health and welfare should aim for maintenance of good health of livestock in comfortable, low stress conditions which mirror natural behaviour patterns. Key factors in the management of the environment itself include a focus on water use and protection of ground and surface resources with management systems designed to protect wildlife and bio-diversity and making effective use of re-using strategies where possible. Strategies aimed at reducing climate changing practices include maintenance of carbon stores in the soil and use of cover crops to increase carbon sequestration of soil thus improving air quality. Finally, energy efficiency such as re-cycling and re-use of products and the use of renewable energy and fuel is a crucial aspect of the Integrated Farming method and is key to the effective sustainable management of natural resources.

Farmers and climate change

Innovations under the Climate Farmers project include improvements in effective grassland management and efficient energy use in an Irish farm owned by John, Bryan and Philip Daniels. The 132 hectares of based on a compact spring calving farming system aims to convert as much grazed grass into milk solids as possible. Grass growth is now measured as to optimize demand and reduce the use of artificial nitrogen. Stitching red and white clover into grassland silage swards has also reduced the protein content in the grass silage crop thus reducing the need to either grow arable protein crops or buy in protein for winter feeding. This also reduces the fertilizer requirements to grow the silage. GHG reduction is achieved through reducing the need for fossil fuel to produce fertilizer but also because of lower nitrous oxide emissions when fertilizer is replaced by a nitrogen fixating crop like clover and by having a spring calving herd Bryan is able to reduce his diesel use for harvesting grass. The farmer intends to implement and develop the measures further with the aim of achieving an overall 60per cent energy reduction.

Other successful models include a farm in the Spanish province of Zamora in the Castile and Leon region which started to run their farm organically using as little as fossil energy as possible, growing all the feed for the sheep themselves, not ploughing the land and not using any fertilizer or pesticides. Furthermore, they try to sell their products on the local market. The Santos's focus on reducing GHG emission is to use as little as possible fossil fuel to produce high quality food. Fariza de Sayago lies in a remote area. By not using concentrates and fertilizers a lot of energy spent on the production and transport of these products is being saved. The wasteland consists of trees and bushes. A lot of organic matter is stored in these parts. The way the Santos's are running their farm means they increase the organic matter content of the soil. They also apply direct seeding for their arable crops. The higher organic matter content is very positive with respect to GHG emissions.

Sustainable farming

AGRICULTURAL transition. Current projects championed by the network include one in Greece called 'Designing and Disseminating Ecological Production Systems for Perennials: Organic Olive Production in Crete' a project run by the Agricultural Research Foundation (NAGREF) aimed at exploring organic olive production which offers agroecological and socioeconomic advantages. A prototyping design methodology was used to design, introduce, test and disseminate ecological olive production systems. In France, La Durette a project run by GRAB (Groupe de Recherche en Agriculture Biologique) based on a pilot farm in agroecology located in Avignon, France. Its aim is to set up innovative Mediterranean agricultural systems, mixing crops under agroforestry in various designs - mainly fruits and vegetables, and integrating animals into the systems. The 5-hectares farm will be managed by 2 farmers from 2015 on, in order to see if such innovative complex systems are easy to manage, and still competitive. And finally in The Netherlands a project initiated by the World Society for the Protection of Animals that following the disappearance of battery cages, began developing alternative, more humane and sustainable methods of egg production. Roundel, a concept in The Netherlands that became operational in 2010 and is success-fully expanding is shown in this case how it's social, environmental and economic benefits are flourishing due to a unique partnership between business, scientists and civil society that lay the foundation to its success.

Organic farming

The main objectives of the Sonnentor project were to increase the income of local organic farms, to conserve traditions and farm structures in the region and to develop a marketable brand and set of products that could be collected and distributed by the specialist food retailer Sonnentor, building a franchise system that could potentially extend organic product sales further in new, non-traditional markets. For further information see Annex 9

The project has created one of the largest organic food retailing companies in Austria, with approximately 50per cent share of the national market, as well as significant sales in Switzerland, the Czech Republic and Germany, with products sold in 35 countries worldwide and 20 or more new products brought to market each year. The company has established over 150 Austrian contractual partners, supplying both high quality organic raw materials and finished products. The project showcases the notion that with well-developed producer networks, good quality assurance systems and well targeted branding and marketing, organic food production and sales can be both highly profitable and sustainable.

EUPHOROS project

The result of the project was the development of a number of structured components that can be used by farmers across the EU, three of which contain innovative tools and systems to reduce energy, water, fertiliser, pesticide consumption and waste. Another intervention optimises the growing environment, developing innovative and robust monitoring tools. The project collaborated with a German company Groglass, which specialises in large-area, thin-film coatings the project developed different types of glass coatings and structures for optimum light and climate controls.

Reusing water was also one of the projects team's key aims, especially effective in one of the project's test locations, Hungary, where the use of fertilisers accounts for 19 per cent of their total production costs. This method also reduces the demand on the water supply, which is particularly critical in the Mediterranean region. The system had to be adaptable to the diversity of climatic, economic and environmental constraints across Europe. In order to be locally relevant the scientists installed, fine-tuned and evaluated crop combinations, equipment and techniques in sites across the Netherlands, Spain and Hungary. The participation of commercial partners and local stakeholders meant the most promising results were implemented swiftly and the researchers received prompt feedback from dissemination activities such as workshops and training courses. The results of the EUPHOROS project, could be adopted by greenhouse farmers across the EU, not only reducing their dependence on resources but also enabling them to remain competitive in an ever-changing global market place

Grasslands

Reviving Europe's Grasslands Farming. The project team carried out tests and experiments on various plots of land across the EU and results showed that multi-species swards or meadows containing legumes and grasses are just as productive as highly fertilised grasses, however these swards not only produce high quality feed for livestock, resulting in healthy and productive animals, but also preserve the ecosystem. MultiSward also proposed several innovations to manage grazing. For example, in Ireland scientists found that despite their initial fears over high rainfall and higher amounts of dung in paddocks during the rainy period, the length of the grazing season could be extended with little or no nitrates finding their way into drainage water – a process known as leaching. They also showed that the numbers of bumblebees and butterflies increased by removing cattle and sheep from the grassland during the summer flowering period. This increase in insects is vital for pollination and biodiversity.

As part of the project, a survey of over 2,000 farmers, politicians and industry representatives showed that grasslands are considered as more than just a valuable resource, they are essential for the economy and environment. The project's results have also been presented at meetings of national grassland societies, and to decision-makers in Brussels. MultiSward was recognised as one of the best scientific projects of 2014 by the French Ministry of research and it is hoped that the project's findings will help politicians take the necessary decisions to make sustainable grassland systems a viable option for farmers.

Water purity

Measures such as those untaken on a mixed arable and sheep farm in Gloucestershire where the creation of a silt trap and reed bed in a ditch line aimed at slowing down the water flow so that any particles would stay in the silt which later could be dug out and returned to the fields. It is anticipated that over time, as this reed bed will become more established, acting as a natural water filter removing nitrates, phosphates, thus improving water quality before the water continues back on the ditch line and into the stream. Another mixed dairy, arable and potato farm just outside Great Yarmouth in Norfolk was keen to work on the efficiency of their water use, both as drinking water for the cows and for washing down and cleaning out in the parlour. With each cow drinking between 90 and 190 litres of water per day, depending on their stage of lactation, water use is a key contributor to business costs. By adding rainwater harvesting facilities to the roof of one of the farm building it is estimated that 1,188 m3 of rainwater will be collected annually to be used for parlour and yard washing, and saving on mains water usage and costs.

Annex 9: a history of traditional farmers' education in the UK

A history of traditional farmers' education in the UK

- The late eighteenth century saw the start of formal education and research with the first Chair of Agriculture being established at the University of Edinburgh (1790) with the support of the Highland Society of Edinburgh.
- Although not formalised until the mid-twentieth century, the pattern of agricultural education was set fairly early on. Universities were delivering higher level teaching and research, although not always at degree level, with agriculture and related subjects such as forestry and estate management being considered to be less than academic by some of the institutions which delivered early courses. Oxford gained a professor of agriculture in 1907, pass degrees were not awarded until 1919 with honours degrees not conferred until 1945.

- There were then a small number of colleges delivering extended courses, normally referred to as diplomas. These started with the Royal Agricultural College in 1845.
- There were then two colleges which, although relatively short lived, enjoyed considerable educational prestige at the time: Aspatria, established in Cumberland in 1874 (closing in 1914) and Downton, established in Wiltshire in 1880 (closing in 1906). Their closures were a product of the combination of increasing state provision for agricultural education, the death/ retirement of extraordinary principals and, with Aspatria, the outbreak of war.
- For an even shorter period (1887-1903), Hollesley Bay in Suffolk was also considered to be of a similar type. Harper Adams in Shropshire (established 1901) and Seale Hayne in Devon (established 1919) were later and long-standing colleges in this category. In addition to studies in agriculture, these colleges prepared students for the Surveyors' Institution (now the Royal Institution of Chartered Surveyors) land agency qualification, which Harper Adams and what is now the Royal Agricultural University, still do. In the nineteenth century, the Royal Agricultural College, Aspatria and Downton also prepared students for Royal Agricultural Society examinations.

Then came what have been variously termed farm institutes, county colleges and, latterly, simply agricultural colleges. Some of these still concentrate on courses for 16 year old school leavers but a growing number are offering a higher education degree or foundation degree provision for post A-level students. Whilst many of these bodies, some dating back to the nineteenth century, are thriving (independently or as an agricultural department of a larger college), it is sadly apparent that there are no institutions in the UK with the words 'Agricultural College' in their title since the Royal Agricultural College became the Royal Agricultural University in April 2013

Annex 10: Relevant projects for skilled workforces and sustainable farming

Initiatives	Coverage	Country (lead/initiator)
Attractive farming profession for young people		
Slow Food Youth Network (SFYN)	Demystifying the Common Agricultural Policy (CAP) for the general public and therefore helping people, especially young urbanites, to learn and talk about the CAP	Global
Neo-Agri Association	Building an international network of new-peasants and established farmers in agroecology in order to help aspiring new-farmers, by compiling and disseminating resources and testimonies	Global(FR)
'Sustainability through youth participation, entrepreneurship and innovation' (EUSBR)	Connect rural youth organisations and innovation support organisations in 'a strong and active partnership and through participation in each other's activities within the partnership, good models and methods would be gathered to create joint learning and knowledge transfer	EU
Nutri project	Computerized corporate platform to enable farmers and advisors to settle a business plan, to update, change and improve specific farms	EU; IT
Agri-YOUTH project	Updating, adapting, transferring those teaching materials with specific focus on new established young farmers and female entrepreneurs, also bridging experiences and best practices between the European countries and Turkey	EU
CHILDWISE	Exploring young people's opinions and ambitions in relation to farming	UK
Bright Crop	Sector-wide initiative focused on attracting the best and brightest into the food supply sector, from farm to processor. The key outcome of the project was a website aimed at inspiring and informing young people to explore career opportunities across the entire sector.	UK
Agricultural Migration and Seasonal Work		
Seasonal Agricultural Workers Scheme (SAWS)	Protect and support seasonal workers specifically for Romania and Bulgaria for work in the horticulture and agricultural sector	UK
Alternative education systems for compensating school dropouts		
YPARD	Mentoring network of young professionals for Young Professionals for AgRicultural Development' and operates as a network, not a formalized institution	Global
GLEAN project	To open up career paths in agriculture for young disadvantaged people, promoting development and growth	EU
Get Mentoring in Farming	Help those working in the farming and agriculture sector across the country to mentor each other	EU (UK)

Initiatives	Coverage	Country (lead/initiator)
FIWARE accelerator project	Supprot SMEs with innovative ideas on how apps can make farmers lives easier and lead to more efficient, high-quality agricultural production	EU
PRODER	Improving the integration of women in the labour market in sectors such as agricultural production, the agri-food industry, childcare services and services for other dependent people	ES
'SecondChance' School (E2C)	Accepts young people with serious social or professional problems, aged between 18 and 30 years and without diplomas or qualifications	FR
Grogrund	Offers professional business development for women as idea seminars; mentoring; education within the field of business knowledge; and individual follow-up	SE
Promoting Energy Efficiency on the Farm ('Eco-Driving in Agriculture)	Vocational training project supported by EAFRD funding to promote the energy efficient "eco-driving" of farm machinery	SE
Cywain Agriculture Project	Agri-food support scheme looking to develop innovative ideas in adding value to Welsh producers	UK
Horticulture and Agriculture Apprenticeship Scheme	Apprentices support developed by and available for growers or farmers that supply to Sainsbury	UK
Advisory systems and services to farmers		
Lifelong Learning Programme (LLP)	Enable people, at any stage of their life, to take part in stimulating learning experiences, as well as developing education and training across Europe.	EU
European Credit system for Vocational Education and Training (ECVET)	Make it easier for people to get validation and recognition of work-related skills and knowledge acquired in different systems and countries	EU
European Network for Rural Development (ENRD)	Connect rural development stakeholders throughout the European Union by digital hub	EU
Lifelong Learning Platform	Gathers 39 European organisations active in the field of education and training, coming from all EU Member States and beyond) proposed five key success factors that would help take Validation of Non-formal and Informal Learning (VNIL) one step further	EU
IMPROFARM	Improve production and management processes in agriculture through transfer of innovations	BG, CY, IT, PL, SK
AGROSKILL	Transferring methods for validation of informal learning to VET institutions in the field of sustainable agriculture	FR
Future Farmers in the Spotlight	Inspire and encourage the next generation of sustainable farmers	NL
VALERIE research project	Improve the accessibility and availability of new knowledge for innovation in agriculture and forestry consisting of 16 European partners	ES, FR, GR, IT, NL, PL, PT, UK

Initiatives	Coverage	Country (lead/initiator)
Environmental Management		
Sustainable Food Trust	Develop a global network of individuals and organisations in positions to influence change to more sustainable food systems	Global
True Cost	Promote a system whereby monetary value is placed on the benefits and impacts of alternative food production systems enabling the introduction of policy mechanisms to penalise damaging practices	EU
European Initiative for Sustainable Development in Agriculture (EISA)	Promoting sustainable agriculture	EU
Climate Farmers project	Tackle the reduction of GHG emissions on farms	EU (NL)
WIRE Action Group (Water and Irrigated agriculture Resilient Europe)	Unlocking the potential and accelerating uptake of innovative irrigation technology and improving agricultural water	EU
MultiCHard	Establishing the optimal acreage and use of European grassland and to communicate the environmental benefits of grassland-based animal production to politicians, farmers and industry	EU
''Smiling Sun'' Organic Farm Product Collection and Marketing Network project	Develop a method in which specialist organic farm products were sourced directly from farmers but sold and marketed internationally	AT
EUPHOROS	increasing the efficient use of inputs such as fertilisers and pesticides in protected horticulture and developed a sustainable greenhouse system	ES, HU, IT, LV, UK, CH (NL)
Reviving Europe's grassland farming	Cultivation of grasslands for biodiversity and productivity and to the benefit both farmers and consumers	BE, DE, IE, NL, NO, PL, UK, CH
AGRICULTURAL Transition	Showcase a wide range of sustainable agricultural practices	NO
LEAF (Linking Environment and Farming)	Guide with six simple steps for managing water quality and case study examples of how to achieve the best results	UK
Managerial skills for competing on global markets		
Developing Entrepreneurial Skills of Farmers	Increase understanding about the nature and relevance of entrepreneurial skills in farm business using a qualitative, interview-based methodology	FI, IT, NL, PL, CH, UK,
New territory in agriculture		
Nemo's Garden	Utilize the properties of the large bodies of water (constant temperature, united with the natural evaporation of a surface of liquid in contact with an air space) to try and create an underwater greenhouse	EU (CH)

The aim of the project "Precision Agriculture and the Future of Farming in Europe" is to identify implications for legislative pathways for precision agriculture in Europe by mapping areas of concern around future developments. The project has three phases:

1. Analyse underlying technologies and existing insights from the field, as well as the anticipated future developments
2. Identify possible development paths to 2050, construct scenarios, and map the related concerns around precision agriculture, adopting a stance of "What if..?"
3. Identify the legal instruments that may need to be modified or reviewed, including — where appropriate — areas identified for anticipative parliamentary work, in accordance to the conclusions reached within the project.

This publication is the outcome of the first phase of the foresight study and consists of six background briefing papers.

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