SCENARIOS OF PRECISION FARMING IMPLICIATIONS IN INDUSTRIAL & AGRICULTURAL FRAMEWORK

D.T3.1.2 –	Version 1
SCENARIOS OF PRECISION FARMING	06 2022

Content

1. Development of the agricultural innovations

1.1. General introduction of the World's agriculture

The six-fold increase of the world's population in the last two centuries has triggered an immense growth in global agricultural production (Federico, 2004). With global numbers currently standing at 7.9 billion (World Population Clock: 7.9 Billion People (2022) - Worldometer, 2022), estimations show that feeding a world population of 9.1 billion in 2050 would require an increase in overall food production by 70 percent. Hence the challenge that 21st century producers face, is how to produce more food to feed a growing population with a smaller rural labour force, by adapting more efficient and sustainable production methods to adapt to the upcoming outcomes of climate change (FAO, 2009).

According to FAO (2021), current figures indicate that the agricultural land comprised 4.8 billion hectares (ha) in 2019, which is 3 percent down, or 0.13 billion hectares less than 2000. About two-thirds of agricultural land were used for permanent meadows and pastures (3.2 billion hectares) in 2019, which marked a 6-percent, or a 0.19-billion-hectare decrease from 2000. In contrast, one third or 1.6 billion hectares of the overall agricultural land was under crops in 2019, which in comparison to the beginning of the millennia is 4 percent (0.06 billion hectares) more.

Europe has the largest forest land share (46 percent), followed by North and South America (41 percent), while the rest of the world covers around 20 percent. In terms of main cropland share, FAO (2021) listed Asia as the highest-producing continent, adding up to 38 percent of the global cropland area in 2019, right before North and South America (24 percent), Europe (19 percent), Africa (18 percent) and Oceania. Additionally, about 30 percent of the global cropland and permanent meadows and pastures are in China, Australia, and the United States of America.

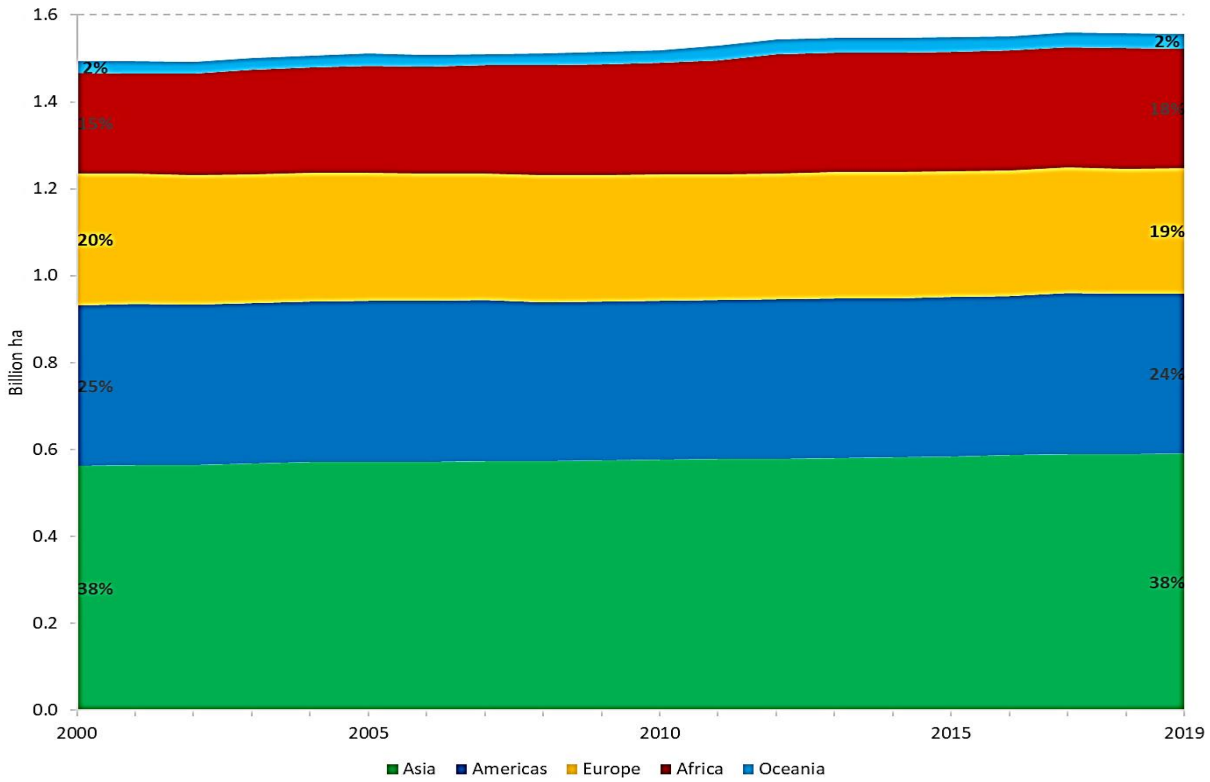


Figure 1. Cropland area by region

Source: FAOSTAT (https://doi.org/10.4060/cb4477en-fig05)

The largest share of global cropland between countries is split between India (169 million ha), the United States of America (160 million ha) and China (134 million ha). These are followed by Russia (123 million ha), Brazil (63 million ha), Indonesia (51 million ha), Nigeria (40 million ha), Argentina (40 million ha), Canada (38 million ha), and Ukraine (33 million ha) (Cropland Area by Country - Worldometer, 2022).

Primary crop production (cereals, sugar crops, vegetables, oil crops, fruit, roots and tubers, and others) reached 9.4 billion tonnes in 2019, with cereal being the main group of cultivated crops with over one third of the total production globally, followed by sugar crops (24 percent) and vegetable and oil crops (12 percent each). Fruit and roots and tubers production was estimated at 9 percent of the total production for each of the two groups (FAO, 2021).

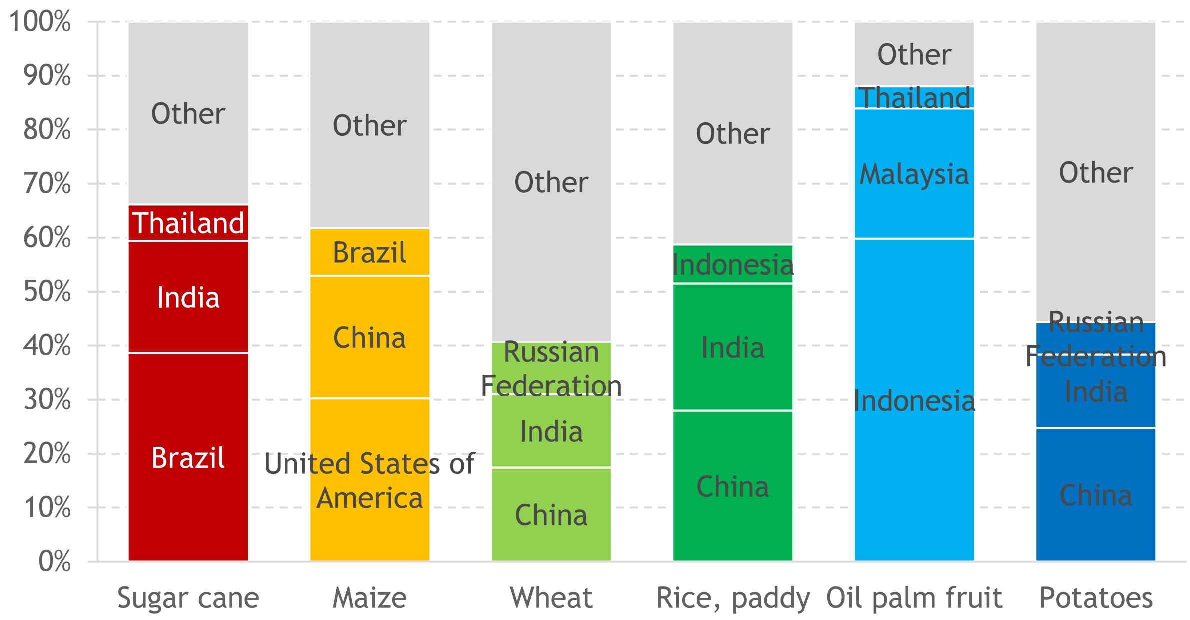


Figure 2. World production of main primary crops by main producers (2019)

Source: FAOSTAT (https://doi.org/10.4060/cb4477en-fig22)

The global fruit production is estimated at 883 million tonnes, with five fruit species accounted for 57 percent of the total production. At 18 percent bananas and plantains are produced the most, and are followed by watermelons (11 percent), apples (10 percent) and oranges and grapes (9 percent each). On the other hand, the world vegetable production was 1,128 million tonnes on a global scale, with five main vegetables that comprise up to 45 percent of the total production in the world, these being: tomatoes (16 percent), onions (9 percent), cucumbers and gherkins (8 percent), cabbages (6 percent) and eggplants (5 percent).

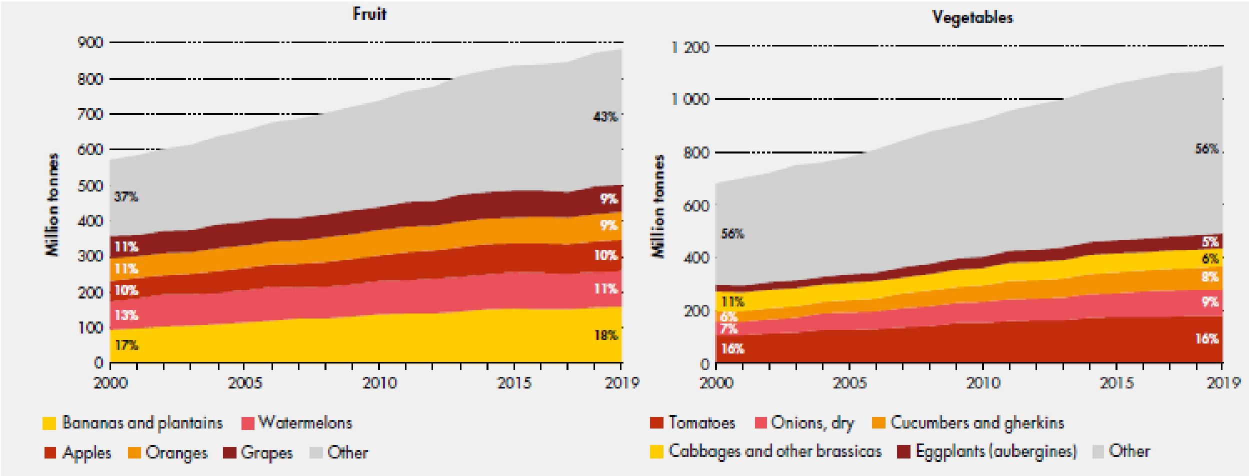


Figure 3. World production of fruit and vegetables, main commodities (2019) Source: FAOSTAT (https://doi.org/10.4060/cb4477en-figb1)

Irrigation, as one of today's main aspects of agricultural intensification, has reached an 18 percent increase since 2000, starting at 289 million ha, and getting as far as 342 million ha in 2019, according to FAO (2021). About 70 percent of the global area equipped for irrigation is located in Asia (led by China with 75 million ha and India with 70 million ha) mostly due to irrigation-intensive rice cultivation, while North and South America account for 16 percent and Europe for 8 percent. Africa, on the other hand, has the fastest growing area equipped for irrigation with a 25 percent increase since 2000.

Rising labour productivity and falling food prices are critical for agricultural development (Dorward, 2013). However, despite labour importance the number of people working in agriculture has gone down for 17 percent in the past two decades (874 million in 2020). The biggest decrease among continents has been observed in Europe (50 percent), due to people leaving or replacing the agricultural sector for another, while agricultural employment has increased in Africa with over 224 million people working for the sector today which equals to approximately 49.5 percent of the total employed population. Additionally, the percentage of women employed in agriculture on a global scale was 36.7 in 2019 (FAO, 2021).

The agricultural sector has been a driver of innovation and developments regarding mechanization, which is a primary feature of modern agriculture. Mechanization is used to enhance overall productivity and production with the lowest cost of production, many times even together with irrigation, fertilizers, pesticides, etc (Verma, 2006). Moreover, sustainable agriculture is important for increasing land productivity and quality of cultivation, supporting labour shortages and enabling households to withstand shocks better, reduction of poverty and improvement of food security and people's safety. Countries with highest usage of mechanization involve the United States of America, India, Japan, Italy, Poland, France, Spain, Germany, and China (Countries ranked by Agricultural machinery, tractors, 2022). In addition, plant protection includes over 4.2 million tonnes of pesticides per year, with the highest contributions coming from Asia, followed by North and South America, Europe, Africa and Oceania (FAO, 2021).

1.2. Drivers of agriculture and agricultural innovations:

Agriculture and agricultural innovation is present from the very beginning of history. Many authors link agricultural development to the industrial development. Accordingly, agriculture is divided to several periods: from agriculture 1.0 to agriculture 5.0. Agriculture1.0 means the period which lasts in the XIX. century and was a labor intensive agricultural era based on manpower and animal forces. Productivity was at a low level even if a large rate of the population were involved. Agriculture 2.0 refers to agricultural development included machinery and chemicals resulting in increased productivity and efficiency of the farms. In the same time ecological impact and footprint increased too. While agriculture 3.0 means the help of the agricultural machinery, and computer science, data management environmental impact and the use of chemical were reduced. Agriculture 4.0 also called digital farming and smart farming. This period of agriculture is based on the already existing concept of PA combined with telematics, data management of those data generated by the growers in their farms for proper strategic and operational decisions. Agriculture 5.0 is the era which is usually linked to robotics and artificial intelligence (AI). A.5. is following the precision agricultural concepts included with autonomous equipment, unmanned operations and decision support systems.

Paloma et al. (2013 and citations therein) summarizing those studies provided by for example: FAO, OECD-FAO, USDA, SCENAR2020, SENSOR, EURURALIS, MEASCOPE, SCAR which details the main drivers of the agricultural development. Among the main factors demography, macro-economic growth, agri-technology, world agricultural markets, trade and agricultural policies, environmental policies, enlargement, international agreements are considered.

Sands et al. (2014) reported that the effect of the changing population, the change in per capita income, the change in agricultural productivity are main demand drivers.

The report published by the FAO The future of food and agriculture – Alternative pathways to 2050 investigates the drivers: income growth and distribution, population, growth, technical progress and climate change.

According to Hazell and Wood (2008) there are more concerns related to the agricultural development for example hunger, health, environment in more particular deforestation and forest degradation, water depletion and degradation of irrigated land, soil degradation, biodiversity losses, global and regional climate change. The authors emphasized that drivers of the change in agriculture and land use could be grouped as global-scale drivers, country-scale drivers and local-scale drivers. A global-scale driver is the international trade and globalization of markets and low world prices, high energy prices, OECD agricultural policies. While the country-scale drivers are per capita income and urbanization, changing market chains and shift in public policy. On the local-scale poverty, population pressure, health, technology design and property rights and infrastructure and market access with non-farm opportunities influence agricultural development.

1.3. Development of precision farming innovations

Latest agricultural innovations for example provide optimal conditions to the pollination by bees as a key in the production. There are efforts to increase the sustainable farming while other innovations aims to replace bees with mechanical pollination methods. Indoor vertical farming is also a promising innovation with regulated light conditions improving yield and ingredients. Farm management according to DDS and automation are important innovation purpose. Caused by the climate change, drought stress is a risk in the production, in this way water management technology is also a key element of innovations. Drone technology is also promising for both plant protection and remote sensing, where various service providers and manufacturers are present in the market.

In many cases companies, private or governmental research institutions and universities perform innovations and research to solve a specific problem raised by for example the farmers according to a practical need.

2. Austria

Approximately 90 percent of the Upper Austrian surface area is used for agriculture and forestry. About 32.000 agricultural holdings are employing 45.000 people directly and provide for another 55.000 jobs in agriculture-related industries. The Upper Austrian agriculture, in addition to feed 2.3 Million people, forms the background of the rural regions, in economical, but also cultural and social terms. (source: https://ooe.lko.at/)

Agricultural production

With a yearly turn over of € 1.823 Billion, Upper Austria is the second strongest agricultural province in Austria. The diverse landscape structure results in different production focuses like cropping farms, pork production and vegetable cultivation in the centre, strong cattle and milk farming in the west and north of the province as well as alpine farming in the south. Upper Austria is the leading province in animal husbandry, producing approximately a third of Austria`s milk (0,97 Million tonnes) and about 39 percent of Austria`s pork.

About half of the agricultural grounds in Upper Austria are used as green land (215.000 ha). The main crops on arable grounds are cereals (127.000 ha), maize (80.000 ha) and soy bean (13.000 ha). Sugar beets, vegetables and potatoes are also of importance.

Organic Farming

Upper Austria is the home of 4.129 organic farmers. The geographic distribution is skewed – about half of them are located in the hilly landscape of the Mühlviertel. Nearly every culture is grown also organically – Austria has a leading position in organic farming because of the strong consumer demand (more than 10 percent of all food-expenditure).

Forestry

30.021 holdings are cultivating 498.000 ha of forest, covering 42 percent of Upper Austria. Every year, 4.7 million cubic metres are growing, but only 3 million cubic metres of wood are cut. Still, wood is imported for the strong timber and paper industry with about 5.000 employees. The forests also produce the biomass to heat 27 and power 35 percent of all Upper Austrian households.

Alternative agricultural income

A big part of Upper Austrian farmers have an additional income besides the production of unprocessed food. Direct marketing, holidays/school on farm and leasing work enable farmers to generate enough income without the pressure to enlarge their holdings. In addition, these activities strengthen the connection between farmers and consumers and the reputation of the farming sector.

2.1.1. Existing Scenarios of Precision Farming in Austria

The following information is based on a master thesis [Title: Smart Farming; submitted by: Philipp Brandstetter; submitted at: Johannes Kepler University Linz, submitted at: February 2022].

Precision Lifestock Farming

By means of modern data acquisition systems, farmers are able to record specific data of the animals. Based on this, the individual animal can often be monitored without further work. The following list describes the possible specific parameters to be recorded and clarifies the individual measurable physical quantities:

- **Animal specific parameters: Body condition including animal weight, lying time, exercise time, chewing time, quantity & ingredients of milk, etc.**
- **Feeding specific parameters: Ingredients, quantity and components of the feed, etc.**
- **Environmental parameters: Stable humidity, temperature, light intensity, gases, etc.**

[source: Digitalisierung in der Tierhaltung, https://info.bmlrt.gv.at/themen/landwirtschaft/digitalisierung/praxis/tierhaltung.html]

Using the generated data, it is possible to monitor animals better or more easily. Automate monotonous or physically demanding work processes for farmers and thus improve the productivity and quality of the products produced by the farmer. Other areas in which digitization is opening up new opportunities are briefly listed below.

In Upper Austria, a System for Precision Lifestock Farming was developed by “Smartbow” (https://www.smartbow.com/en/home.aspx). This system allows for rumination monitoring, rut detection, and real-time localization of cows

Digitization in arable farming

Digitization in arable farming offers enormous potential to revolutionize arable farming and grassland management. Machines such as tractors, combine harvesters or drones can automatically collect data from other devices and thus fertilize, weed, map and carry out other diverse work steps on the areas to be cultivated more precisely. The data on which this automatic management is based may already be available, or may be generated automatically by new systems during the familiarization phase. The following list gives an insight into the diverse fields of application of intelligent technology in arable farming.

[source: Digitalisierung in Ackerbau und Grünlandwirtschaft. https://www.ingenieur.de/technik/fachbereiche/landtechnik/bilder-all-landwirtschaft-erde-verbessern/]

In Upper Austria, several companies develop systems for digitization in arable farming. An overview about such systems or system providers is given in Section 2.1.3.

2.1.2. Key Findings to the topic of Precision Farming in Austria

The following findings are based on a master thesis [Title: Smart Farming; submitted by: Philipp Brandstetter; submitted at: Johannes Kepler University Linz, submitted at: February 2022].

The use of smart technology in modern everyday agriculture can generate added value in many different ways. Today's technology offers a wide variety of possible applications, although the legal situation clearly lags behind the technological achievements of the last 10 years. Nevertheless, the soon conventional use of Smart Farming technologies seems inevitable, as they bring much more advantages than disadvantages when used correctly. In arable farming, for example, this means saving soil, greenhouse gases, time, labor, pesticides and fertilizers while maintaining or increasing yields. In animal husbandry, feed can be saved, animal health improved and yields increased. Likewise, the steadily increasing global demand for food should not be ignored in this context.

But for smart farming to be used by a broad range of farmers, the most important thing is to have uniform legal regulations, ideally at EU level, that adequately protect third parties and are not too complex for farmers. In the area of autonomous and data protection, the European Union has already taken important steps with the European drone regulations toward standardization. The current laws primarily protect third parties who may be negatively affected by drone use, thereby making the agricultural use of drones more difficult. Farmers who want to use autonomous drones must fulfill a variety of training and conditions to be allowed to use the drone, and therefore before the use of drones adds value for them. Privacy concerns can still be added.

The use of autonomously driving tractors that cultivate fields, plow or apply fertilizer independently and without human intervention still seems to be a long way off from a legal perspective. The legal dilemma here is what happens in the event of an accident involving property damage or personal injury caused by an autonomously driving machine. In the relevant legal regulations, neither the term autonomous nor liability issues have been conclusively clarified. There is also a lack of uniform regulation at EU level. Although there are regulations concerning the testing of autonomous or highly automated vehicles, these differ significantly from the regulations currently in force in other countries.

Further problems arise from the personal data recorded and possibly stored during operation. Finally, the life-versus-life issue should be legally addressed, so that manufacturers and consumers can assume that such autonomous vehicles will behave in a predictable manner.

From an environmental and legal point of view, there would be nothing to be said against the automated application of crop protection products, since the great advantage is that they can be used as needed. Depending on soil health, plant growth and pest infestation, different amounts of pesticides are used. Although there are different environmental legislation, requirements and conditions that often contain exemption clauses for ordinary agriculture and forestry (agricultural clauses), for farmers the legal situation is often opaque.

In addition to the data privacy concerns of operating an autonomous drone or tractor, there is no getting around data privacy regulations when it comes to smart farming. The unauthorized disclosure of data within an app on the smartphone for analysis purposes can have legal consequences for the respective farmer. Furthermore, if personal data of employees is recorded, the question of the farmer's responsibility as an employer must always be answered in the affirmative. This also applies if the farmer uses an external service provider for data processing in individual cases. In this case, further data protection problems may arise if the external data processor has its registered office outside the territory of the Union. The outdated agricultural and forestry business information system LFBIS also urgently needs to be amended, so that it is brought into line with the new regulations of the GDPR.

In any case, farmers are advised to inform themselves about the legal regulations or to consult legal counsel before using smart farming technologies. When using external providers of smart farming technologies, particular attention should be paid to the location (geographical) of the data storage and, if possible, that all personal data is anonymized or that the consent of the data subjects has been obtained.

2.1.3. Examples for stakeholders in Precision Farming in Austria

In the region of Upper Austria, there are several institutions that conduct research and development in the field of precision agriculture. In particular, the development of innovative machinery is in the spotlight in this region.

The companies, service providers, and research institutions listed here provide an overview of precision agriculture in Upper Austria, but it is certainly not a complete listing of all institutions.

2.1.3.1. Farming Associations, Networks, and Service Providers

Landwirtschaftskammer OÖ:

The "Landwirtschaftskammer OÖ" (https://ooe.lko.at) is the legal representation of farmers and foresters in Upper Austria. This institution provides farmers with information, consulting, and all kinds of events.

Maschinenring:

The "Maschinenring" (https://www.maschinenring.at/oberoesterreich) is an association that includes agricultural entities with jointly use of agricultural and forestry machines, and that arranges for agricultural manpower when needed.

Agricultural services of Maschinenring that are relevant to the topic of precision farming include:

- "farming.software" (https://www.maschinenring-farming.software): A digital platform designed to strengthen the member farms for crop farming, livestock, and mixed farms
- "Maschinenring Teamwork" (https://maschinenring-teamwork.at/): A mobile solution (as app or web version) to easily search, book, offer, rent, or invoice agricultural machinery, machinery services, and agricultural and forestry business assistance.

- “Real Time Kinematic” (https://www.maschinenring.at/leistungen/agrar/rtk): A method for precise determination of a geographic position using multiple GPS satellite signals. A correction signal, which corrects the GPS signal received at the tractor, is transmitted via the mobile network (mobile RTK). The companies own base stations serve as reference stations for calculating the correction data.
- “Grundfutterbörse” (https://www.maschinenring.at/leistungen/agrar/grundfutterboerse): A platform where farmers can publish an offer for animal feed or ask for it
- “Maschinendatenbank” (https://www.maschinenring.at/leistungen/agrar/maschinendatenbank): A database through which farmers can offer or borrow machinery.

OÖ Bauernbund:

The OÖ Bauernbund (https://ooe.bauernbund.at/) offers agricultural networks, where all persons can become members. Aim of the networks is to provide amongst others the following services:

- **Exchange of experience and information**
- **Interface to politics, business and stakeholders**
- **Lectures, excursions, and events**

Bauernnetzwerk:

The Bauernnetzwerk (https://www.bauernnetzwerk.at/) is a service platform for farmers and consumers. Aim of the network is to provide amongst others the following services:

- **networking**
- **provide services to farmers and consumers**

2.1.3.2. Manufacturers of Machinery

Pöttinger:

The „Pöttinger Landtechnik GmbH“ (https://www.poettinger.at/en_us) is one of the leading agricultural machinery manufacturers in Europe. They offer products for grassland cultivation and arable farming, and various digital services like data management solutions, machinery management systems, and harvest assistants.

Steyr Traktoren:

The S-Tech System of “Steyr Traktoren” (https://www.steyr-traktoren.com/de-at/landwirtschaft) provides high precision steering with an accuracy of up to 2,5 cm (RTK+). Functions: Automatic turn-around at the end of the track, Vehicle settings logging, Power monitoring, Intuitive Touchscreen Monitor and ISOBUS interface.

WINTERSTEIGER:

The “WINTERSTEIGER AG” (https://www.wintersteiger.com/en/Group) is an international machinery and plant engineering group. It has gradually established itself as a leading provider of innovative solutions for customers in technically sophisticated niche markets. The Division SEEDMECH is specialized on harvesting technology, sowing & laboratory technology, and data management.

Smartbow:

“Smartbow” (https://www.smartbow.com/en/home.aspx) developed a comprehensive system for dairy cow monitoring including Industry-leading rumination monitoring, unparalleled heat detection, truly real-time localization and Animal Pattern Recognition IntelLigence (APRIL).

***Regent*:**

The company “Regent” (https://www.regent.at/en/) produces equipment for tilling such as ploughs, power harrows, seed drill gear and cultivators.

***Göweil*:**

The company “Göweil” (https://www.goeweil.com/en/) produces various agricultural machinery like wrappers, transport devices and lift buckets.

Einböck:

The portfolio of Einböck (https://www.einboeck.at) includes machines for crop-care, tillage, grassland care and seeding & fertilizing.

2.1.3.3. Agricultural Research Institutions

The University of Applied Sciences Upper Austria (https://www.fh-ooe.at/campus-wels/studiengaenge/bachelor/agrartechnologie-und-management/alle-infos-zum-studium/schwerpunkte/) offers a bachelor study in agricultural technology and management

Focal points:

- **agricultural sciences**
- **agricultural technology**
- **agricultural management**

Topics:

- **technology (amongst others: electrical engineering, sensor technology, digitization)**
- **plants (amongst others: tillage, greenhouses, precision farming)**
- **animals (amongst others: anatomy, breeding, precision livestock farming)**
- **management (amongst others: business administration, agricultural markets, digital marketing)**

Certificates:

- **agricultural skilled worker**
- **crop protection expert**
- **drone pilot**

2.1.4. Conclusion

Austria has a strong focus on agriculture, since approximately 90 percent of the Upper Austrian surface area is used for agriculture and forestry. The diverse landscape structure results in different production focuses like cropping farms, pork production and vegetable cultivation in the centre, strong cattle and milk farming in the west and north of the province as well as alpine farming in the south.

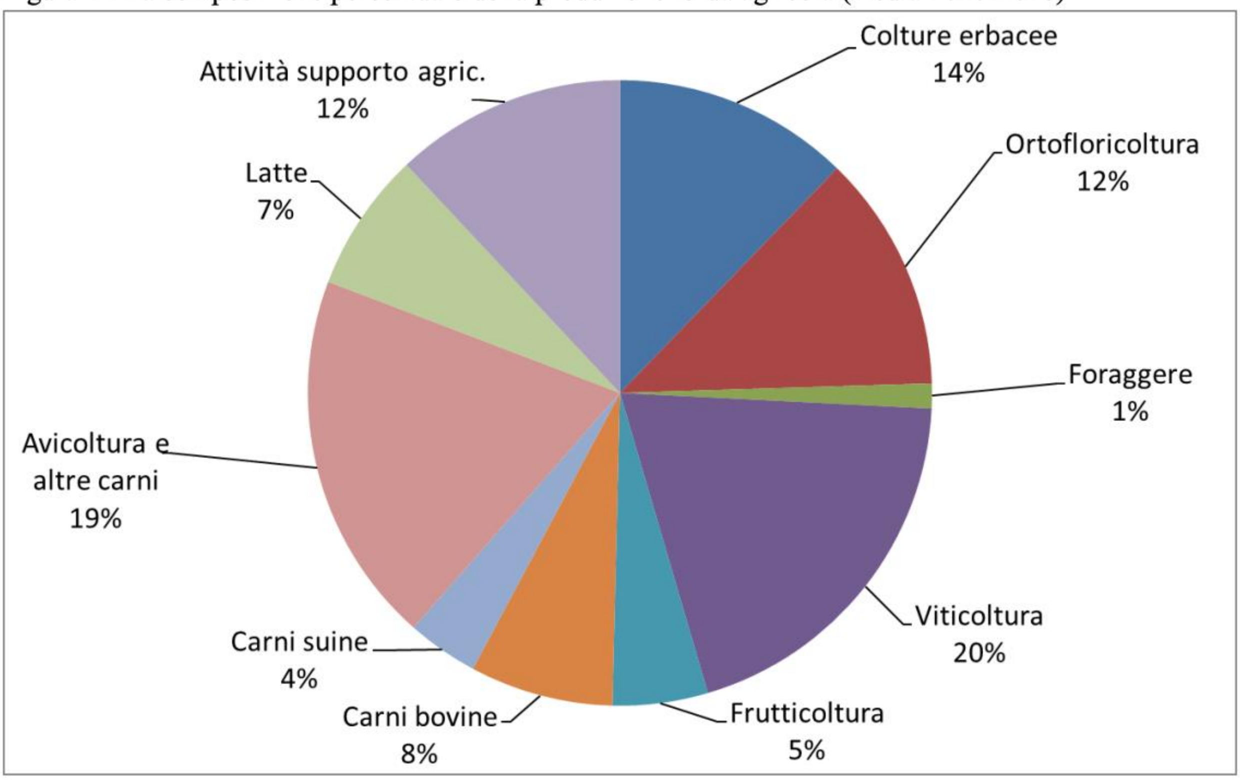
In Upper Austria there are several institutions that conduct research and development in the field of precision agriculture. However, since Upper Austrians industry and also its school education has a strong focus on mechanical engineering, in particular the development of innovative machinery is in the spotlight in this region.

3. Italy

3.1. Agriculture in Veneto Region, land use and main crops

Veneto region in north east of Italy is located in a strategic area for agricultural production, due to the presence of flatlands, hills and mountains the region has a strong agricultural background with a wide range of specialization that space from cereals to vineyard. As well the agrifood industry behind the agricultural sector carryout a strategic role for some of the wolrdwide known Italian food brands. Farms cultivate around 782.000 hectars with different specialization, the average size of the farm in the region is less than 10 hectars.

Figura 1 - La composizione percentuale della produzione lorda agricola (media 2016-2018)



Fonte: ISTAT, Conti della branca agricoltura, silvicoltura e pesca.

Figure 4 Percentage of gross agriculutral production in Veneto region

Cereals and soybean grown mainly in the flatlands cover around 400.000 hectars, the yield for these crops is high thank to the possibility of mechanization and the specialization of the sector. Sunflower and rapeseed are a marginal crop compared to cereals covering respectively 5.300 hectars and 3.200 hectars. Vegetables are grown in 22.200 hectars, main crops are radicchio, potato, tomatoes, asparagus, green beans. Fruit trees covers around 116.550 hectar of which 92.800 hectars belongs to vineyard, followed by apple and olive trees 5.000 hectars each. Wine sector is one of the core businesses for the region in the agricultural sector, vineyards produces around 1,41 million of tonnes of grapes. Grapes are mostly used for wine production in 2020 has been produced 11 mllions of hectolitres. In the region livestock farms are present as well with around 3.000 companies active for milk with a production of around 1,2 millions of tonnes, beef productions stands around 166.178 tonnes of meat. Similar production is obtained with livestock of pigs (141.183) while pultry reached 564.500 tonnes in 2020. Veneto region results a key player in Italian agriculture: for the cereals it is the second region for wheat, rapeseed, sugarbeet and soybean production and first for corn. The region is also an important player for horticulture being one of the five regions most productive for zucchini, leeks, radicchio, peas,garlic, beans and green beans. Fruit tree are also well represented, Veneto is one of the bigger producers of apples, pears, kiwi, cherries and of course vineyards especially for wine production.

3.2. Driving forces of the Veneto Agriculture and Precision Farming

European agriculture covers around 40% of EU's land and it is an important factor on the natural environment. Agricultural practices have a profound impact on the natural resources as like the pollution of soil, water and air, fragmentation of habitats and loss of wildlife. To better undestand the state of art and the evolution of regional farming system three key indicators can be taken into consideration:

Input use: Mineral fertiliser, pesticides, irrigation, energy use:

In Veneto region the use of fertiliser is regulated by specific rules that take into consideration the pedoclimatic condition and allow the use of fertiliser only during a part of the year in certain amounts. Pestcides selling is regulated by the PAN (National action plan for the sustainable use of the plant protection products). Different initiatives are promoted by the region to move the population toward the Agenda 203 sustainable development goals. Rural development fund, in particular EIP support and test opportunities for inputs reduction. At the same time the market demand has been received from the industry that is renewing its tools offer updating to the sustainability demand.

Land use and Farm management: Land use change, crops grown, tillage practices:

Land use is an important factor to monitor over time to understand the changes in the region. The region presents a fragmented environment with a dispersed urbanisation along the overall central part of the region, Belluno and Rovigo districts are an exeption, the first due to the location in mountain area and the second vocated for the cereals and deflected from main . As mentioned in the above paraghraph, Veneto agriculture has different focuses: viticulture, cereals, livestock, horticulure and fruit growing and a complex environment. This is reflected in the agricultural practices: more traditional in mountains and remote areas and more efficient and industrial in the districts of Venice, Padova, Vicenza, Verona and Rovigo. Beside farm production food industry and logistics are well developed to trasnform products enhancing primary sector performance.

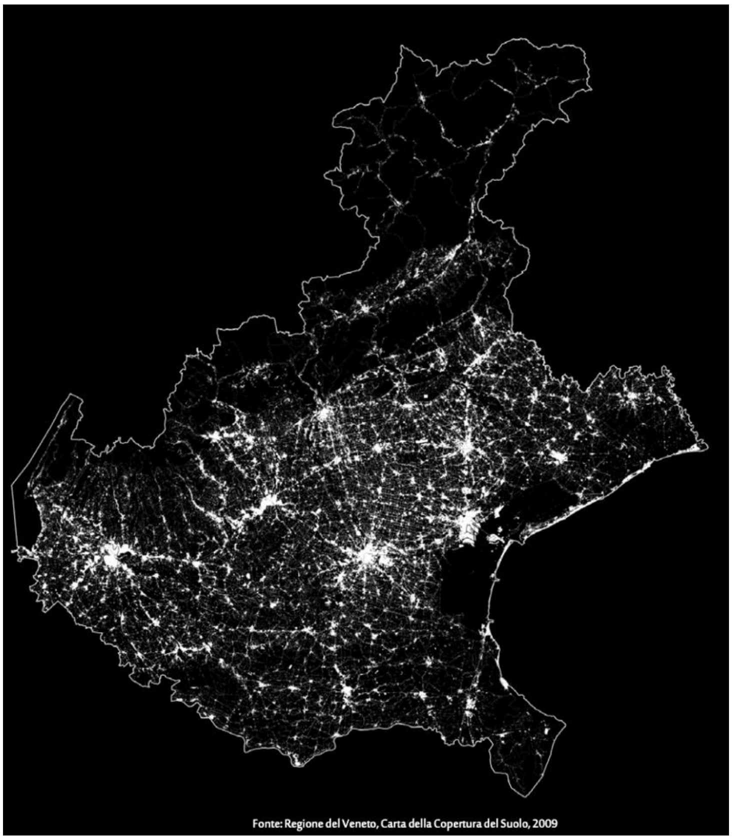


Figure 5 Soil coverage in Veneto region 2009

Trends: Intensification, specialization, risk of land abandonment:

The agriculture in the region has different specialisations some of which are worldwide recognised excellences.The sector is facing a strong intensification and specialisation, small farms are decreasing in favour of bigger more profitable ones. Due to the climate changes many initiatives to mitigate the impact of the sector on the environment and natural resources are rising: fertiliser and plant protection products reduction. According to the statistical report of Veneto region (2019) the primary sector is facing a growing period: higher exportations, investments, digitalisation. Green economy and sustainability are key factors for the region aiming to reach Agenda 2030 sustainable development goals. Digitalisation is a increasing within the region even though there is a gap between small and medium large enterprises according to the Digital Intensity indicator. Main technology priorities emerging in the statistical report of Veneto region (2019) are Predictive Maintenance, Automation of Industrial Processes and Integration in Value Chains typically of products. The result of the survey and the action undertaken in the project Transfarm 4.0 overlap and show similar results. Precision farming is developing and new tools are adopted by farmers and consultant. The use of technology supports the end users to increase farm efficiency, reducing inputs, forecast diseases, improving specialisation and farm practices. Other innovative applications, adopted especially from bigger companies, are e-commerce, marketing and value chains/quality certification. The PF sector is divided in two categories, big farm that import technology from the industrial sector and smaller farms that require more personalised,low cost and modular techologies to adopt in their organisation as evidenced by Mizik (2022). Regional and National institutions are supporting PF development through rural development funds and other funding opportunities as shown in the regional action plan D.T3.1.5. The competences of the workforce are another topic that deserves to be explored in depth: according to Federico Butera, senior professor in Sociology of economic and labour processes, in particular there is the need of a comprehensive participative design processes of technology, organisation and people growth. In this perspective, companies demand trained IT/ICT workforce and the education are respondig to the demand.

3.3. Precision Farming and technology providers

Precision farming is an expanding sector and relatively new, according to the survey developed in the portal www.precisionfarm.it not all the respondents know the topic in-depth and most of them would know more about it. PF is considered a strategic area for the agricultural sector that could improve farm efficiency, reduce costs and inputs as well an opportunity for new business development. According to David Cleary, Director of Agriculture, The Nature Conservancy, Precision farming main limitation is its applicability only in a few environments that are supported by strong supply network and adopt intensive farming tecniques. Roger Nkoa Ondoua in his article Precision agriculture advances and limitations: Lessons to the stakeholders, presents the complexity of PA adoption, cost, extra work, ease of use, credibility of the techology, all these factors limit a straight adoption of PA and slow down the process. But even though the actual limits of the sector the innovation is driving the agriculture toward digitalisation and a change. According to this vision, most probably unmanned aerial vehicles mounted with cameras and sensoristics will support farmers in its every day activities: measure crop growth, prescribe variable rate fertilisation, weeding and irrigation, weed identification, spot spraying, herd monitoring. The sector potential is wide, other potential application according Gusev et al. 2021 are: development of tools for farm management, solutions to optimize production and processing activity according the variability in the field, automation of activities through the use of computers, sensors, AI and robots. Micheal Boehlje and Michael Langemeier in their article in farm doc daily analise the potential payoffs of PF:

Potential Payoffs for the Producer

- Cost Reduction/Efficiency Improvement Increases
- Value Enhanced Differentiated Products
- Span of Control and Crop monitoring
- Reduced Downtime and Better Capacity Utilization
- Risk Reduction
- Landlord/Supplier and Buyer Relationships

Potential Payoffs for the Value Chain

- Food Safety
- Sustainability
- Traceability

Potential Payoffs for the Environment

- Reduced Fertilizer and Chemical Leaching and Runoff
- Conserving Irrigation Water
- Comprehensive Nutrient Management

Beside technology potential and knowhow, technology provider and manifacturers network covers a fundamental role in the development of the sector: spare parts, education, innovative solutions are available in the Veneto region. As emerged in D.T 1.2.1 and D.T1.4.1 central Europe regions host a vast and dense environment of organisation engaged in PF.

The region with its policies and funding opportunities should keep promoting collaboration between the actors of the production chain, research centres and end users. The interactions between actors is a strategic factor for innovation with a bottom-up approach not always easy in the primary sector due to its constrains. As well, pilots and demo days initiatives are supporting the development of the sector and the approach of PF by the workforce presenting new tools for their farm.

4. Hungary

4.1. Agriculture of Hungary

Hungary's agricultural potential can be considered above average, as there are many favourable factors at our disposal. In European terms, Hungary's topography is optimal for agriculture, and the exposure of the lowlands is also very high, which further enhances Hungary's agricultural value. Hungary is situated on the edge of a dry and humid continental climate, which means that it is often subject to periods of drought, with a very unfavourable rainfall distribution in many years. The number of sunshine hours is relatively high, which is very favourable for many agricultural crops. Hungary is suitable for the cultivation of many important temperate zone crops. The main crops grown on Hungarian soil are cereals. Wheat and maize occupy half of the arable land and are important exports. Vegetable and fruit production is also known beyond our borders. Our vegetables are popular for their uniqueness and special flavour, for example spicy peppers (Kalocsa, Szeged) and red onions (Makó). Historic wine-growing areas, based on centuries-old production traditions, have developed on the sunny southern slopes of the low hills and hillsides. About one fifth of the wine produced is exported. Some specific products (e.g. poultry meat, foie gras) are also successful on international markets. In livestock production, the 20th century saw a change of breed, with the spread of breeds with higher meat or milk yields. Today, traditional Hungarian breeds are coming to the fore again because of their healthier meat and fat.

In Hungary, the proportion of people employed in agriculture is currently still on a downward trend. While in 1990, a total of 693 thousand people were employed in this sector, the latest figures for 2021 show that only 203 thousand people are engaged in agricultural activities. Year on year, the number of people employed is falling drastically.

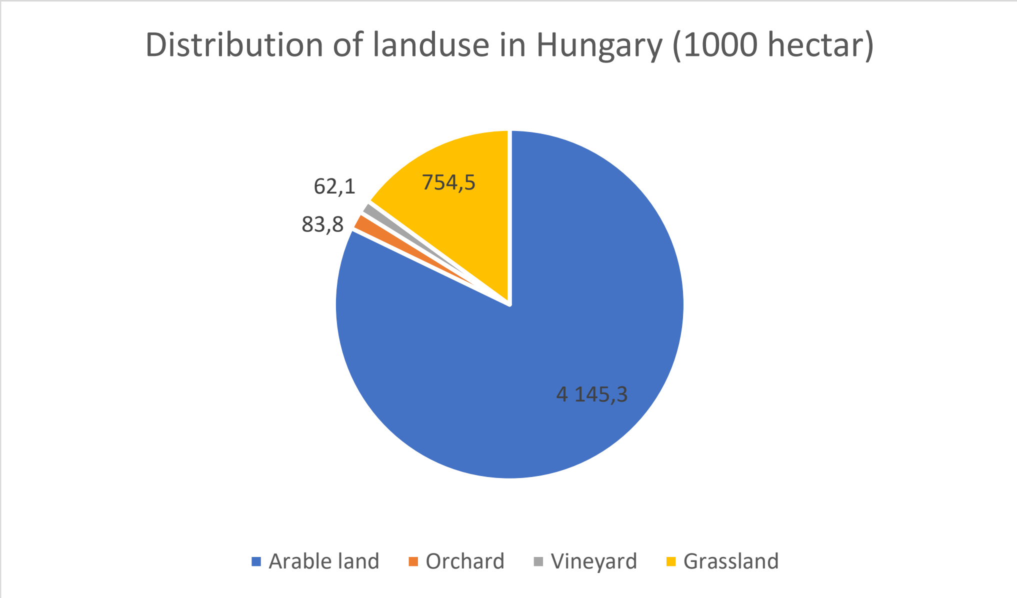


Figure 6. Distribution of landuse in Hungary (Source: Hungarian Central Statistic Office https://www.ksh.hu/stadat_files/mez/hu/mez0008.html)

4.2. Land use, main crops

More than half of Hungary's land is arable land, the most important of which are the various cereals, wheat, maize, barley, rye, oats, triticale, sunflower, rape, soya, sugar beet and lucerne. The size of arable land in 2021 is 4 145.3 thousand hectares, compared with 3 452.8 thousand hectares in 1853, which shows that for almost 200 years the various arable crops have been the dominant crop in Hungary. The total area of orchards in Hungary is 83.8 thousand hectares, the area under vines 62.1 thousand hectares and the area under grassland 754.5 thousand hectares. The remaining agricultural areas are forests, reedbeds, fish ponds and set-aside. The size of the orchards reached 180 000 ha in the 1960s and 1980s, but has been in drastic decline since the change of regime and this trend is still visible today. This may be due to the low purchase price of fruit and the increasing imports. The size of vineyards has undergone similar trends. After the Second World War and until the change of regime, the area under vines reached 250 000 ha, but since the 2000s there has been a drastic decline, which is still visible today.

Among arable crops, maize is the largest crop in Hungary, with a total area of 1 043 thousand hectares in 2021. This size has changed very little since the 1990s. The second largest area under wheat is currently 891,000 hectares in 2021. The third largest arable crop is sunflower, with a total area of 653 thousand hectares. Sunflower cultivation is on an upward trend compared to 1990, with almost doubling in the last 30 years. The fourth most important domestic crop is rapeseed, which is currently grown on 256 thousand hectares. This figure has almost tripled in the last 30 years. The quantities harvested in 2021 were as follows: wheat 5 970 kg/ha, maize 6 040 kg/ha, sunflower 2 700 kg/ha and rapeseed 2 810 kg/ha.

Of the orchards, apples are the most widely grown, with a total area of 25 973 ha. This figure has been decreasing over the last almost 15 years, with a total of 43 240 ha under apple production in 2004. Cherries are grown on 13 460 hectares, 5 939 hectares are under apricots, 7 058 hectares are under plums, 3 162 hectares are under cherries and 2 618 hectares are under pears.

Sweetcorn is the most widely grown vegetable crop in Hungary, with a total area of 38 195 hectares in 2021. The second largest crop is green peas, currently grown on 18 012 hectares. Tomatoes are in third place with a total of 1 821 ha. The land use data broken down by county in Hungary are presented below.

Table: Figure Land by type of farming and by county and region in Hungary (thousand hectar) Source: Hungarian Central Statistical Office

https://www.ksh.hu/stadat_files/mez/hu/mez0068.html

Name of the Hungarian county	**Arable land (ha)**	**Orchards (ha)**	**Vineyard (ha)**	**Grassland (ha)**
Pest	**247,1**	**7,4**	**1,5**	**52,2**
Fejér	251,4	3,1	2,3	22,5
Komárom-Esztergom	101,5	0,6	1,0	8,4
Veszprém	156,0	1,1	2,9	44,2
Győr-Moson-Sopron	198,7	2,2	1,6	20,0
Vas	151,7	1,2	0,4	9,9
Zala	99,2	1,8	0,4	23,9
Baranya	197,5	1,1	3,0	21,2
Somogy	204,7	2,9	3,8	21,5

Tolna	208,6	1,9	4,3	13,3
Borsod-Abaúj-Zemplén	227,9	6,9	5,5	60,7
Heves	140,9	4,6	11,6	31,9
Nógrád	53,2	1,4	0,2	29,2
Hajdú-Bihar	334,1	1,3	0,0	122,1
Jász-Nagykun-Szolnok	377,0	1,3	0,7	49,8
Szabolcs-Szatmár-Bereg	238,6	31,7	0,0	36,6
Bács-Kiskun	324,7	9,4	22,1	98,1
Békés	389,8	1,1	0,0	48,6
Csongrád-Csanád	238,2	2,5	1,0	39,6

Based on the Hungarian Central Statistical Office there is 4% share of agriculture, forestry and fishing section as a share of gross value added. In 2021 the output of agriculture reached 3.378 billion HUF. In 2020 the numbers of the agricultural farms were 241.000 which is 31% less than those in 2010. These more than 240.000 farmers are working on more than 4.9 million hectares, which is the 53% of the Hungarian territory. Within this 82% was arable crop, 15% field, and 3% vineyards and orchards.

Average size of farm in Hungary is 23 hectares. The farmers in Jász-Nagykun-Szolnok county have the largest average size of land (40 hectares) while those in Budapest the average size is the smallest, 5 hectares.

Owners used the 45% of the agricultural land, while 50% by tenants and 5% by other purposes (partial cultivation, favor land use). In the case of arable land, the proportion of leased areas was the highest (53%). The orchards and vineyards mainly cared by the owners, and 68% of the land used by individual farms cultivating 61% of the land was self-owned.

According to the evaluations, 61% of the farmers (139.168) have practical experience while 30% (67.979) have elementary or intermediate qualification and 9% (20.498) have higher education graduation. Among these the highest rate of the those who have practical experience are working in the field of viticulture (32%), while the highest rate of those who have higher education graduation are working in the field of arable crop production.

Age of the leaders of the farms (companies) is variable, mostly (55%) are between 40 and 64 years old, while 35% is older than 65 years old and only 10 is younger than 40. Among these the highest rate of the young generation (younger than 40 years old) are fruit growers, while the lowest percent (11%) of the young farmers are in grapevine growing. Highest rate (27%) of the older generation (older than 65 years old) are working in the field of arable crop growing, while the lowest percent (23%) are cultivating grasslands.

4.3. Driving forces of the Hungarian agriculture and land use

According to Li et al. (2018) there are several factors influencing the European agriculture and land use, such as climate change, changing consumption patterns, international trading patterns, increasing population density and new farming technologies with new crops.

According to Bartholy et al. (2014) influenced by the emission there are several climate change scenarios, which would modify weather conditions in Hungary. Based on the scenarios certain land use changing would be possible in the future and new innovations to solve for example lower precipitation or higher radiation would be essential. There is also a need for innovative hardware (meteorological stations, computer hardware) and software (e.g. data management) solutions to monitor the changing climate. Based to the report published by the Ministry of Foreign Affairs and Trade and Hungarian National Trading House[1] we could define the key areas of the agricultural information in Hungary as crop production, animal husbandry, wildlife management, food safety, food processing and monitoring the environmental impacts. Corporate management systems and robotics and decision support systems are valuable solutions. Beside these process management systems, image recognition devices, drones and sensors would assist agricultural production.

Among the technology competences beside others animal husbandry, pisciculture technology, turnkey dairy processing plant / dairy processing technology, agricultural machinery, grain technology are the most relevant. Caused by the climate change, irrigation is a key factor of the agricultural production, for this reason irrigation technology related to both equipment and regulation innovation has strategic importance.

[1] Hungarian Agriculture: The potential of tradition & innovation

4.4. Precision farming in Hungary

According to the Agrárcenzus[2], 38% of the farms were using some type of digital device in 2020. Farmers mainly managed the banking and E-government tasks electronically. Precision farming tools were applied by 12% of the farmers, mainly (5.6%) for phenotyping and evaluation of the plant vigor. The 15% of the farmers hired consultant, in most cases for plant protection.

National survey and those carried out within the Transfarm4.0 project showed that the percent of the digital tool users decreased with the age of the famers, while increased with the educational level. In the same time, National survey by the Hungarian Central Statistical Office showed that only 75% of the farmers with higher agricultural graduation use digital solutions. HCS found that rate of the digital tools is the highest between the age 14-39 (56%).

Survey showed that if a farm have higher standard production than 100.000 € digital tools are essential, and rate of the digital tools are increasing with the higher standard production. More than 90% of the farms which have higher standard production than 500.000 € are using digital tools.

Among the most important PF tools phenotyping and vigor mapping are the most widespread among the growers: 3.5% are using own devisec while 2.3% hire service providers. Steering tools are the second most widespread where 2.8% of the farmers are using own equipment and 1.2% hire the service. More than 3% of the farmers are using variable rate treatments, while more than 2% applies environmental sensors, yield mapping or decision support systems.

Those who applies fleet management, drones or robotics. In geographical point of view the highest rate of PF solutions are in Fejér county (15%) in Komárom-Esztergom, Győr-Moson-Sopron and Baranya (14%), while the lowest in Pest (9.9%).

Beside the current situation of the PA solutions in Hungary Takácsné György et al. (2018) evaluated those barriers which makes the spreading of the new solutions more difficult. More than 50% of the respondents considering PF as excessive investment cost, while

[2] https://www.ksh.hu/docs/hun/xftp/ac2020/agrardigitalizacio/index.html

almost 20% consider that PF is not suited to their farm size. Also almost 20% answered that lack of appropriate financing is the barrier, while less than 10% consider the lack of knowledge, lack of experience of using PA, distrust of new technologies, lack of services, lack of time to adopt PA and lack of advisory services are the barriers.

Later Balogh et al. (2021 and citation therein) found similar results including that the lack of trust and transparency of the data ownership would be also a barrier of spreading PF.

Takácsné György et al. (2018) showed that the main factors influencing the adoption of the PF solutions are:

- higher profitability,
- more and/or more detailed information,
- would be part of an area-based subsidy,
- would be a measure in a RDP,
- compatibility among technologies
- higher market price (e.g. by certification)
- support of machinery used by farmers' group
- would be part of a 'greening' payment
- would be part of an AEP subsidy
- availability of data recording mobile apps

Moreover Balogh et al. (2021) found that the main factors contributing to the willingness to apply PF technologies are:

- higher profitability
- investment support in the Rural Development Program
- more and/or more detailed information

while the following factors are also important:

- income supplement support for technology users
- higher buy-in price

SWOT analysis (D.T1.3.2) within the Transfarm4.0 showed the main factors (strengths, weaknesses, opportunities and threats) in precision farming uptake in Hungary is detailed in follows.

STRENGTHS	WEAKNESSES
• several agricultural equipment manufacturers and dealers are present • latest technologies are available to the farms • high occurrence of stakeholders could generate a good competition in favour to the development and spread of new technologies • largest farmers generally are interested in new technologies due to their high affinity towards innovations to increase their farm's sustainability and improve its management (e.g. simplifying bureaucracy, lowering pesticide use, etc.) • educational system teaching PF practices • reduction of environmental footprint • rising of start-up companies dealing with PF services • agricultural fairs, exhibitions and workshops on precision farming	• overall size of farms is generally small • high average age of farmers • cost of PF technologies is too high for small-medium enterprises, not favouring the spread of PF • limited availability of PF sensors' data for the farmers • high GPRS prices • in hilly zones, with high hand labour demand, mechanization is limited • restricted availability and high price of satellite and GIS data, maps for farmers • farmers are linked to their traditional methods • low salaries, weak education level and missing skilled manpower • missing competence in response to EU calls
OPPORTUNITIES	**THREATS**
• increase of young farmers with higher education level • rising of start-up companies dealing with PF • research projects conducted by universities and research centres • reduction of environmental footprint • mitigation of negative agronomic effects of climate change • lower use of input materials • less work consuming processes • demand from the consumers of more safety food with a certain origin • support of free availability of satellite and GIS data, maps for farmers • marketing advances of higher food safety (inland and abroad) • water saving irrigation technologies • developments and innovation in IT • rising of start-up companies dealing with PF services	• resistance to PF innovation • uncontrolled failure of field sensors • critical security level of field equipment (sensors, data loggers, solar panels, cables, etc.) • low GPRS performance, communication failures • unexpected data losses • internet attacks • enhancement and extremes of climate change • uncertainty of the market • unwanted spread of sensible data linked to the farmers • crucial changes in policy • missing competence in response to EU calls • cutback in EU sources and diminution of project calls

Among the main findings, main barriers to the adoption of PA are excessive investment cost, farm size, lack of appropriate financing, lack of appropriate knowledge, lack of experience of using PA, distrust of new technology, lack of services, lack of time to adopt PA, lack of advisory services.

4.5. Hungarian precision farming technology providers and manufacturers

There several PF service providers and manufacturers in Hungary in different sectors. Precision farming is a requires complex solutions, in this way PF service providers have multiple services for example environmental data collection, data management, and decision support.

Agricultural machinery manufacturers: KITE, Axiál Kft., Agrárin Kft., Bartifarm, Sióagrár Kft., ODISYS , SZEGÁNA, DORKER, SZALAGRO, Agroker Alkatrész Kft., Agro Nova Kft., Alfa-Gép Kft., CGP Zrt., Inter-Plant Kft., Pap-Agro Kft., AGROTEC Magyarország, VEKTOR Mezőgép, Invest Gépkereskedelmi Kft., SASFORM, Agricultural sensors and remote sensing: Sys-Control Informatikai Kft., Envirosense, AGRON Analytics,

Environmental sensors and Irrigation systems: SmartGreen, Netafin, Sencrop

Farm management and DSS: Okosfarm, Axial Ltd., Xarvio, ESRI, Agrovir, PlantCT Europe Zrt., Winery Datamanagement Kft.

Drone manufacturers, technology providers and education organizations: AgriDron Mezőgazdasági Szolgáltató és Kereskedelmi Kft., ABZ Drone, Detectology, DroneOne, DrónaAkadémia, Légtér.hu, Drone Hungary, DroneHub, DroneSys, Agron, ABZdrone.

5. Slovenia

5.1. Socio-economic description of Slovenia

Slovenia is one of Europe's smaller countries, both in terms of land area and population. According to the OECD typology, Slovenia has intermediate (27.2%) and rural regions (72.8%). More than half of Slovenia's land territory is covered by forests, and 34% of its land area is predominantly agricultural. Slovenia is characterized by a dispersed and sparse population and a large number of small settlements. In Slovenia, agriculture with hunting, forestry and fishing contributes 2.3% (2019) to total value-added and 6.9% (2019) to full employment. The share of employment in agriculture is a declining trend and thus decreases year on year.

In Slovenia, decreasing the number of agricultural holdings continues, while the average size of a farming holding increases yearly. On average, a large agricultural holding in Slovenia cultivates 7.0 ha of agricultural land and rears 6.0 LU, and manages an average of 5.6 ha of forest. Compared to the EU-28, Slovenia still has a very unfavorable size structure of agricultural holdings. The average age of farm owner (manager agricultural holding) in Slovenia amounted to 57 years (2016), which indicates a markedly unfavorable age structure in agriculture. In 2019, 745 companies were operating in the food processing industry, employing 14,627 people. Value-added was EUR 604 million and value-added per employee was EUR 41,270 EUR. Grassland is the most predominant area (84%). Then arable (9%), orchards (intensive and extensive - 4%), vineyards (1.4%), and vegetables (0.7%).

Income in Slovenian agriculture is among the lowest in the EU and represents only around 20% of comparable income in the whole economy. Non-agricultural sources of income are decisive for farming on low-income farms, which can represent a significant part of the income on small farms. Such a poor income situation is the unfavorable structure of Slovenian agriculture with an average of small farms, a large share of land in LFAs, a large percentage of absolute grassland, a large share of non-specialized and self-sufficient farms. Existing processes of Slovenian restructuring agriculture in the direction of increasing income are too slow. Subsidies (direct and LFA payments) are a significant factor in Slovenia, at least partly improving the lower-income situation. Specific agricultural sectors (arable crops, other permanent crops, mixed farming, other grazing livestock), economic farm size (up to EUR 50,000 standard income), and farm location (in

LFAs) would generate negative value-added if they did not receive subsidies. Uncertainty about incomes and low productivity leads farms to stagnate investment and, in the long term, to lose competitiveness. Instability is a significant problem in Slovenian agriculture. Fluctuations in prices and/or agricultural volumes can cause liquidity problems for farmers. Uncertainty about incomes and low productivity leads farms to stagnate investment and, in the long term, to lose competitiveness. Uncertainty also causes stagnation or even contraction of agricultural production.

5.2. Strengthening market orientation and increasing competitiveness (emphasis on research, technology and digitalization)

Multiple factors affect the competitiveness and productivity of Slovenian farms; 73.7 % of farms are located in less-favored areas (of which 73.3% - are mountain areas, 10.8% - are areas with natural handicaps, 15.9% - specific constraints), climate change (storms, frost, drought, floods, strong wind,...) and role of technology (state of machinery/equipment, digitalization, knowledge and innovations in relation to precision farming technologies).

There is a strong divide between productivity indicators between EU-27 countries and Slovenia; on average, the divide in EU countries is caused by the introduction of new technologies that substitute the workload. In Slovenia majority of the work is done by manual labour (avg. size 7 ha), and lacking new technology. Farms located in mountain areas face special challenges, shorter vegetation periods and lower income per farmland. Due to the limitations, these farms primarily focus on animal production. An additional factor that limits the possibilities on these farms are the inclinations of farmland that require expensive special-purpose machinery.

5.3. Promoting knowledge, innovation and digitalisation in agriculture in Slovenia

There are a number of research and training institutions working in the field of Slovenian agriculture and forestry institutions. Public services have been working for decades for the advancement of agriculture and forestry, for better performance of professional tasks in agriculture (livestock farming, crop production, forestry, genetic).

Access to formal as well as non-formal education is good. Identified needs and necessary actions in this area:

- *Strengthening capacity building and knowledge transfer.*
- *Strengthening cooperation between the research sphere, consultants and end-users.*
- *Strengthening research and development, innovation in agriculture, forestry and food.*
- *Retrieved from agricultural advice.*
- *Digitalisation in agriculture, food, forestry and rural areas.*
- *Strengthening digital competences.*

5.4. Resolution, action, programs and an overview of the state of Slovenian agriculture politics

- **The strategic plan (2023-2027) in Slovenia:** contains the key strategic guidelines for the implementation of the Common Agricultural Policy in the Republic of Slovenia. Among the CAP 2014-2020 objectives, the following were important for the precision agriculture: improving agricultural competitiveness, promoting innovation, delivering environmental public goods, and mitigating and adapting to climate change. The studies highlight the current gap in the modernization of farms, innovative approaches, and the use of new technologies for the precision agriculture. They conclude that the use of new technologies remains below expectations and is unevenly spread across the EU. More effective CAP measures in this area are key for the future and balanced funding from both pillars is important for new technologies in agriculture. The CAP objectives are implemented in two ways in a given country for the 2014-2020 period: as direct payments to farmers and through market measures (Pillar I), or under the Rural Development Programme through various forms of subsidies (Pillar II), both supported by an agricultural advisory service, which includes agricultural advisory systems. The CAP has been financed at European level as part of the EU budget since 1999, through two funds, the European Agricultural Fund (EAFRD) and the European Agricultural Fund for Rural Development (EAFRD)

    - Pillar I: Appropriate rural development measures in this pillar play an important role in promoting the development of precision agriculture. The determination of measures and financing depends on the individual country or the decision-makers. It is therefore essential to carefully identify the needs for priorities and measures based on the specific local conditions and farming systems that each country wants to achieve in the field of precision agriculture.

- Pillar II: The priorities here are the following: promoting the competitiveness of agriculture, ensuring sustainable management of natural resources and measures in the field of climate change, and achieving balanced territorial development of rural economies or communities by creating / maintaining jobs. Most measures are met through the Rural Development Program (RDP)

To the extent of measures II. pillars available in Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013, the main precise support can be defined in the following articles:

- Article 17 (investments in fixed assets),
- Article 28 (agri-environmental-climate payments),
- Article 35 (participation),
- Article 14 (transfer of knowledge and innovation),
- Article 15 (advisory services, farm management assistance, support services).

The CAP therefore plays an important role in the development of the precision agriculture and thus in providing farmers with the appropriate technology and equipment. It is well known that the CAP faces specific challenges in terms of precision, mainly due to the size and diversity of agricultural structures across the EU

- **Smart specialisation strategy (Slovenian s3 or s4)** is an operational plan facilitating the shift to a high-productivity economy. To achieve a high-productivity economy, nine priority domains with corresponding focus areas and technologies are defined. The implementation of S4 represents one of the key tools for strengthening and upgrading the Slovenian innovation ecosystem. The implementation S4 is base on a new model of development cooperation, which emphasizes closer, between the state, the economy, knowledge institutions and other relevant stakeholders in the field of research, development and innovation.

- Industry 4.0: Factories of the future - Robotics (advanced robotic systems, advanced robotic vision and sensing, HPC and big data, advanced robotic technologies)

- Circular: Networks for the transition to a economy, sustainable food (a) Raw materials and sustainable use of resources (reducing environmental impact, risk management, quality management of raw materials, implementing the principles of the circular economy), (b) Smart process design and process control (optimisation, automation and robotics, digitalization), (c) Sustainable energy (optimising energy and material efficiency), (d) Processes and technologies

- Digital: Smart cities and communities; (a) Quality of urban living, (b) Digital transformation, (c) GIS-T (advanced applications and location services, advanced platforms for data products, integrated data capture systems)

- **Resolution: "Our food, rural areas and natural resources after 2021"** (Resolucija o nacionalnem programu o strateških usmeritvah razvoja slovenskega kmetijstva in živilstva »Naša hrana, podeželje in naravni viri od leta 2021« (Uradni list RS, št. 8/20): the essence of the new approach is targeted strategic planning of public support to food production and processing and rural development, taking into account the natural features of the Slovenian countryside and actual needs. Emphasis is placed on the protection of the environment and nature and on the conservation of agricultural areas, whose goals can only be successfully achieved through knowledge, innovation, entrepreneurship, and networking. In all this, an appropriate level of digitalization and more intensive use of various modern technologies is indispensable.

- **Rural development program:** The Rural Development Program of the Republic of Slovenia is a joint programming document of the Republic of Slovenia and the European Commission. The Rural Development Program highlighted six priority areas for action, of which measures, sub-measures and operations for the development of precision agriculture in Slovenia can be indirectly included in the set of three given areas, namely:

- accelerating the processes of structural adjustment in agriculture and thus creating conditions for increasing the productivity of Slovenian agriculture,
- promoting agricultural practices that have a positive impact on the conservation of natural resources and adaptation to climate change,
- transfer of knowledge and innovation and care for the environment and climate change (horizontal objectives of all five priority areas for action in the RDP).

5.5. Slovenian providers and manufacturers of precision farming technologies

One of the important factors for the mass introduction and practical exploitation of precision agricultural technologies is the bridging of the gap between the producers of precision agricultural technologies and all the stakeholders already described. In recent years, the production of agricultural equipment in Europe with precision agriculture components has increased. According to the JRC and MARS (2014), there are 4,500 companies in Europe that produce different types of agricultural equipment. However, there is a lack of general information on producers and traders (suppliers) of precision agricultural technologies in the EU and Slovenia. A list of companies (services and providers) of precision agriculture technologies can be found in one of the previous deliverable in this project.

5.6. SWOT analysis of precision agriculture in Slovenia

With the help of the strategic tool SWOT analysis, we summarized the current situation and guidelines for the development of precision agriculture in Slovenia in four aspects (advantages, opportunities, dangers, shortcomings). The purpose of the analysis is primarily to assist decision-makers in strategic decisions regarding precision agriculture in the future and to assist in further research in this area. The SWOT analysis included summaries of the state of EU and Slovenian policy measures, characteristics, and structure of Slovenian agriculture, as well as the results of a survey obtained in this project (Transfarm 4.0) on the topic of precision agriculture.

Strengths	Weaknesses
Farm owners are aware of the potential of PATs (precision agriculture technologies). More than three-quarters of farm owners are already educated about PATs. There is more and more research development and talk about PATs.	PATs require a high initial investment. Complex and unreliable PATs.
Opportunities	**Threats**
Accelerate sustainable agriculture through technological development. Interaction of farm owners with ideas / solutions. Optimization of agricultural work, processes, reduction of environmental impact, management of uncontrolled changes and support decision-making.	Questionable willingness and maturity of farm owners for the implementation of PATs. Complex quantification of PATs advantages. Questionable knowledge about open opportunities or fear of farm owners' interactions. Prejudices of farm owners about the maintenance costs of PATs.

6. Poland

6.1. Agriculture in Poland

6.1.1. Significance for the national economy

Over the last thirty years, Polish agriculture has undergone a profound transformation. After 1989, the principles of market economy were extended to the agricultural sector, which resulted, inter alia, in the appearance of foreign products on the market, the liquidation of state-owned farms previously occupying around 18% of the agricultural land and a three-fold reduction in employment in agriculture. Another turning point was the accession to the European Union and the adoption of the principles of the Common Agricultural Policy. After accession to the EU, financial support for Polish agriculture increased significantly. Productivity in the agricultural sector increased by 2.3 times between 2004 and 2020 (Miniszewski 2021).

In 2021, the value of agri-food exports reached a record high of €37.4 billion, with a positive trade balance of €12.7 billion. Poland is an important exporter of rye (2nd place in the world) and apples (3rd place in the world), as well as eggs and poultry, beef, oats, potatoes, sugar and confectionery, tobacco and tobacco products.
The share of gross value added of agriculture, forestry, hunting and fishing in total gross value added in 2020 was 2.7%, 0.8% lower than in 2000 (Central Statistical Office 2022).

Agriculture, through the provision of biomass energy crops, plays an important role in ensuring the country's energy security. The combustion of solid biofuels and biogas accounts for 8% of green energy capacity in Poland. Given the need to increase the share of renewables from 13 to 23% of final energy consumption by 2030, investment in this industry is expected to increase.

6.1.2. Characteristics of farmers and holdings

Polish farmers, along with Austrians, are the youngest in Europe - every fifth farmer is under 40. Young farmers usually farm 20-50 ha of land. As many as 44.7% of the farm managers have an agricultural educational background, although on the other hand half of the farm managers do not have any educational qualifications. The highest percentage of people with higher agricultural education is recorded in the age group below 35 years and among owners of farms > 50 ha. Agricultural activity is the main source of livelihood for only one in three farmers. Other sources of income in holdings include hired work, pensions, non-agricultural activities, other unearned sources of income.

Poland is a lowland country (75% of the area). Light, medium quality soils, often acidic, predominate. Compared to other EU countries, they are characterised by relatively low production potential but negligible heavy metal and PAH pollution. In Poland, 60% of the country's area is used for agriculture, of which 73% is under sown crops, 19% is grassland, 2.8% is pasture and 2.2% is orchards.

The agricultural area in farms in 2020 was 14.6 million hectares, 91% of which was used by individual farms. Cereals have invariably dominated the sowing structure for many years. Specialisation is advancing in Polish agriculture. Over the last 10 years, the land under sugar beet (up by 19%) and pulses (up by 91%) cultivation has increased significantly. There was a significant reduction in the area under potato cultivation (by 40%). Since 2010, the poultry population has increased by almost 30% and the number of beef cattle by almost 10%, while there has been a large decrease in the number of pigs (by 26.85%).

The number of farms in Poland has decreased by 13% over the last decade. In 2020, there were 1 317 000. More than half of them have an area of less than 5 hectares, but it is farms with an area of more than 15 hectares that control more than 60% of the agricultural area. The average size of agricultural land on a farm is 11.20 ha. This value is on an upward trend, although it is no longer as dynamic as in 2000-2010. Farm size varies considerably from region to region: the largest dominate in the north and west of the country, while the smallest are in the south.

The number of organic farms in the country has not changed much (about 20,000), but their area has been increasing.

The trade in agricultural equipment has been on the increase in Poland for several years. This is a different trend from that observed in other EU countries.

6.1.3. Poland's forest resources

In 2020, the share of forest land represented 30.9% of the national area, i.e. 9,464.2 thousand hectares, and 80.3% of this area is in public ownership. It is estimated that the timber resources in Polish forests amount to 2.59 billion m^3, with an annual harvest of 39.7 million m^3. The average abundance per hectare of forest (286 m^3/ha) is almost twice the European average. Wood is used for heating nearly 29% of homes in Poland.

6.1.4. Cooperation between science and agriculture

Knowledge transfer, alongside financial resources, is essential to ensure agricultural development. In Poland, the exchange of knowledge and innovation between administration, science and agricultural practice is based on the Agricultural Knowledge and Innovation System (**AKIS**).

The AKIS system partners are members of the National Rural Network (NRN), as well as other entities supporting the development of innovation and entrepreneurship. The system consists of:

- administration (ministries and subordinate services),
- scientific entities (universities, research institutes, the National Academy of Sciences, The Łukasiewicz Research Network, centres for technology transfer, academic business incubators),
- educational institutions,
- agricultural advisory (Innovation Network in Agriculture and Rural Areas (**SIR**) including public advisory: Agricultural Advisory Centre in Brwinów and 16 Regional Agricultural Advisory Centres; private advisory, chambers of agriculture),
- industry associations and organisations, NGOs, EIP-AGRI operational groups,
- agri-entrepreneurs,
- media
- consumers.

Agricultural education in Poland includes:

- 59 secondary schools training in 27 professions, approximately 2,000 graduates per year. One of the most popular field of study is agriculture engineering and agrotronics technician.

- 6 agricultural higher education institutions and several other universities with agricultural faculties, 22.8 thousand students, 60% of them in first degree engineering studies.

6.1.5. Investment in agricultural areas

Poland is gradually increasing expenditure on research and development (R&D). In 2020, the level of R&D expenditure as a proportion of GDP (GERD/GDP) was 1.4% (EUR 7.3 billion), an increase of 58.6% over the last 5 years. A similar trend is noted in the private sector. In the total expenditure on R&D, the share of expenditure in the area of agricultural and veterinary sciences decreased by over 4%. The most innovative companies in the agri-food sector are those operating in the form of commercial companies and cooperatives.
In 2019, total investment in agriculture was around €1.2 billion. Over the past 20 years, farms have increased their investments by nearly 2 times. The value of fixed assets on farms has also doubled. Young farmers invest the most, often using investment loans. The investments mainly concern the purchase of land, agricultural machinery and equipment, the renovation of livestock buildings and irrigation installations.

6.2. Driving forces of the Polish agriculture and land use

According to Stolarska et al. (2020) the main challenges to be faced by Polish agriculture by 2030 include: climate change, land concentration and consolidation, specialisation of farms, development of organic farming, implementation of the principles of sustainable agriculture, achievement of strategic objectives related to the use of pesticides, fertilisers and antibiotic management, implementation of modern technologies (especially by farms with a smaller scale of production), reduction of greenhouse gas emissions, changes in global trade, development of producer groups. The analysis of climate change carried out by The Institute of Environmental Protection - National Research Institute (2020) indicates inevitable changes in thermal and precipitation conditions in Poland. The average annual temperature by 2060 is projected to increase by 1-1.2 ^{o}C, the number of hot days will increase and the number of frosty and freezing days will decrease. An increase in annual precipitation is also to be expected, which is mainly due to an increase in the number of days with extreme precipitation. The effects of these changes will include droughts and extreme weather events.

In order to improve the competitiveness and productivity of Polish farms it is necessary to concentrate land. The fragmentation of farms results in both low profitability, inefficient use of labour resources (approx. 500 000 so-called hidden unemployed) and of the machinery stock (1 tractor in Poland works on 9 ha, while in Germany it is 20.7 ha, in Spain 27.7 ha and in France 24.7 ha). Small farms account for 52.5% of all farms and are responsible for only 20% of agricultural production in the country. It is mainly large farms that invest the most in, for example, land purchase or modern technologies, and also implement innovations.

Another factor determining the development of Polish agriculture is the need to focus on the implementation of modern technologies and digitisation. Low innovation and technological advancement undermine the enormous potential of domestic agricultural production. The innovativeness of farms depends, among other things, on the state of the farmer's knowledge, his/her education and professional experience, access to information and the current economic situation of the farm and prospects for its development in the context of trends in the supply of agricultural products.

6.3. Precision farming in Poland

The sustainability of agricultural development depends largely on technological advances that increase productivity. Precision agriculture has great potential to increase resource utilisation efficiency in agriculture, reduce time-consuming work, stabilise yields and increase adaptation to climate change, thereby increasing productivity.

6.3.1. Farmers and PF

The results of a survey conducted by the Polish Foundation of The Space Industry (2021) show that 34.3% of Polish farmers know what precision farming is, and one in three of this group uses it on their farm. As many as 90% of farmers using PF believe that it has been profitable for them to implement these technologies. The group of farmers who do not use PF, but have knowledge about it, indicate the following as obstacles to its implementation: lack of profitability of these technologies for their farms and lack of knowledge how to start. Importantly, nearly 3/4 of the farmers in the group declaring current lack of knowledge about PF (65.7% of all respondents), want to obtain such

information. The greatest use of PF was recorded among owners of farms over 20 ha - 38.4% of all respondents respectively. In farms of 2-20 ha, PF is used by 7.6% of respondents, while in farms of less than 2 ha, it is used by only 3.6%.
According to a study conducted by the University of Agriculture in Krakow in cooperation with Microsoft (Startup Poland 2020), Polish farmers are interested in solutions improving the efficiency of fertilisation (72% of them), modern equipment for mechanical weed control (54%), systems supporting soil cultivation (48%), automatic machine guidance (54%) and telemetry (48%).

6.3.2. Agricultural policy and precision agriculture

The Polish **Strategic Plan for the Common Agricultural Policy for 2023-2027** (Plan Strategiczny… 2022) takes into account the growing demand for new technologies in agriculture and provides for a number of instruments and actions to accelerate their implementation. Developing precision farming services for environmental and climate protection is an intervention that aims to implement new business models and market organisation in rural areas, through investment support to providers of agricultural services for environmental protection.
The basic document defining objectives, lines of intervention and actions for the Polish agricultural policy and rural development in the perspective until 2030 is the **2030 Sustainable Rural Development, Agriculture and Fisheries Strategy** (Ministry of Agriculture and Rural Development 2019). Precision agriculture fits in with the lines of intervention: I.3. Development of innovation, digitalisation and Industry 4.0. in the agri-food sector and II. 4. Sustainable management and protection of environmental resources. Actions to maintain and strengthen the competitiveness of the agri-food sector (direction I.3.) include the implementation of innovation, digitalisation, satellite technologies, IoT and Industry 4.0. Another important line of action is the implementation of research projects (national and international) aimed at innovative solutions in the agri-food sector. In turn, for sustainable management and protection of environmental resources (direction II.4.), precision farming is applicable by

increasing productivity with lower use of yield-forming agents, pesticides and mineral fertilisers.

Precision farming is supported under the **Rural Development Programme 2014-2020**. The objectives of the RDP are to improve the competitiveness of agriculture, sustainable management of natural resources and climate measures, and balanced territorial development of rural areas.

The **National Smart Specialisation** are industries the development of which will ensure: the creation of innovative socio-economic solutions, increasing the added value of the economy and increasing its competitiveness in the international arena. The National Smart Specialisation indicates preferences for providing support for the development of research, development and innovation (R&D&I) under the new financial perspective 2014-2020. Smart farming fits in with the specialisations:

- Innovative technologies, processes and products of the agriculture and food and forest based sector (NSS 2),
- Electronics and photonics (NSS 9),
- Smart networks, information and communication technologies and geoinformation technologies (NSS 10),
- Automation and robotics of technological processes (NSS 11).

6.3.3. Agricultural machinery manufacturers, precision farming technology providers

The key players in the precision farming and Smart Farming market are global corporations with a wide range of machinery and tools for agriculture, but the Polish market is developing rapidly. There is a lack of large companies developing comprehensive solutions to compete with the concerns.

Agricultural machinery manufacturers: Unia Group, Expom Krośniewice, Meprozet Metaltech, KFMR Krukowiak, Akpil, Pracowniczy Ośrodek Maszynowy w Augustowie, Sipma, Samasz

Remote sensing: Agrocom, SatAgro

Irrigation systems: CaseLogics, Inventia, Łukomet

Herd health control systems, farm management: Smart Soft Solutions, e-stado, AgriSolutions

Production of nano-satellites: SatRevolution

Specialist LED lighting: PlantaLux

The unmanned aerial vehicle industry (UAV)

UAV flight coordination platform: DroneRadar - the world's first implemented nationwide UTM system. It is a cloud-based system platform for recording, monitoring and managing drone operations.

Drone manufacturers: Novelty RPAS, FlyTech UAV, uAvionics Technologies, BZB UAS

In addition to UAV manufacturers, the drone market is also formed by, among others: start-ups, spin-offs of companies developing technologies, manufacturers of components: microprocessors, sensors, software, scientific institutes developing platforms, as well as companies offering a service for the analysis of acquired data (Darowska and Kutwa 2019).

6.4. Future scenarios of precision farming in Poland

The 2030 Sustainable Rural Development, Agriculture and Fisheries Strategy (Ministry of Agriculture and Rural Development 2019) outlines the development trends and challenges for the digitisation of the sector. Horizontal opportunities (affecting all holdings) include:

- reducing production costs through the use of modern technologies,
- the spread of IoT solutions in society forcing the creation of digital solutions for agriculture,
- introduction of digital solutions for agricultural consultancy to promote the use of modern solutions and support for agriculture,
- the increasing use of digital solutions by those managing and monitoring public aid in agriculture,
- development of high-speed broadband Internet infrastructure to enable access to e-services and agricultural know-how.

Factors negatively affecting the development potential of this trend (threats, barriers, weaknesses) include:

- slow uptake of “complex” solutions,
- wide variation in the digitisation of farms,
- low level of use of digitalisation in national strategic and crisis management,
- insufficient public funding for the digitalisation of agriculture and fisheries.

The implementation of elements of Agriculture 4.0 is an opportunity for smaller and medium-sized producers to increase farm potential. The main barriers to progress in the digitisation of limited-potential farms are the small range of solutions dedicated to smaller producers and their relatively high cost, and often still insufficient infrastructure at farm level. For this group of farmers, the use of simple digital functions is most beneficial.

The scenario for developed or developing farms is different. For them, digitisation progress is an opportunity to transform from a subject of public intervention to an entity actively shaping the PF market in Poland. Increased accessibility and new PF solutions will allow digital solutions to be better suited to the farm. Their growing needs will also stimulate the development of advisory services to support agriculture in the choice of digital solutions. The popularisation and affordability of digital solutions for Polish holdings is still lower than in the “old EU” countries. It is necessary to implement appropriate instruments to protect the interests and rights of producers with regard to their data. The small amount of R&D collaboration with manufacturers on digital needs is also a barrier.

The development potential of Smart Farming in Poland is supported by the high standard of technical facilities, the high competence of research units, the extensive support for this industry through R&D programmes and the growing market of customers (The Polish Agency for Enterprise Development 2019).

The three areas of Smart Farming that have the best prognosis on the Polish market are:

- contact sensors, bio-sensors and optical sensors in plant production, animal production, aquaculture and food quality assessment,
- farm management systems and agricultural production processes (comprehensive monitoring based on data processing using Big Data and AI technologies, integrating data and information from various sources),
- robotics, cobotics and automation control engineering (agricultural machines and subassemblies for autonomous platforms).

In addition, due to the high potential of specialists and low barriers to entering the technology, the IoT sector in Poland is expected to grow strongly. In line with global trends, consumers want food of known origin and verified quality (food tracing), and organic products are increasingly being chosen. This direction of development will require a reduction in the use of fertilisers and pesticides for conventional farming, and Smart Farming tools are helping with this. In the case of organic farming, Smart Farming can realise advanced consultancy and automation control.

Innovation in agriculture should support the desired strategic directions and be mission-oriented. Agriculture 4.0 is a relatively new technology that is beginning to interact with existing agricultural and food systems concepts. Coevolution, selection and transformation of this technology can be expected to occur in certain areas (Klerkx and Rose 2020).

7. References

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Figures

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Figure 2. World production of main primary crops by main producers (2019). (2021). FAO Statistical Yearbook 2021 Datasets. doi: 10.4060/cb4477en-fig22

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